Final Economic Analysis and Final Regulatory Flexibility Analysis

Supporting Document for the Final Rule
for Occupational Exposure to Respirable Crystalline Silica

Occupational Safety and Health Administration
U.S. Department of Labor

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CHAPTER I: INTRODUCTION

OSHA's Final Economic Analysis and Final Regulatory Flexibility Analysis (FEA) addresses issues related to the costs, benefits, technological and economic feasibility, and the economic impacts (including impacts on small entities) of the respirable crystalline silica final rule and evaluates regulatory alternatives to the rule. When OSHA identifies a significant risk to workers, section 6(b)(5) of the Occupational Safety and Health Act (OSH Act) directs OSHA to select a standard that, based on the best available evidence and to the extent feasible, ensures that "no employee will suffer material impairment of health or functional capacity, even if such employee has regular exposure to the hazard dealt with by such standard for the period of his working life." 29 U.S.C. 655(b)(5).

While drafting its final standard to fulfill its statutory directive, OSHA also acknowledges applicable executive orders pertinent to rulemaking. Executive Orders 13563 and 12866 direct agencies to assess all costs and benefits of available regulatory alternatives and, if regulation is necessary, to select regulatory approaches that maximize net benefits (including potential economic, environmental, public health and safety effects, distributive impacts, and equity). Executive Order 13563 emphasizes the importance of quantifying both costs and benefits, of reducing costs, of harmonizing rules and of promoting flexibility. Section 3(f)(1) of Executive Order 12866 requires the Office of Information and Regulatory Affairs (OIRA) in the Office of Management and Budget (OMB) to review the Agency's assessment in these areas if the rule is economically significant. OSHA has determined that this final rule governing occupational exposure to respirable crystalline silica ("silica") is an economically significant regulatory action under section 3(f)(1) of Executive Order 12866. Accordingly, the Office of Regulatory Analysis and the Office of Technological Feasibility within OSHA have prepared this FEA for the rule, and it has been reviewed by OIRA. In producing this FEA, OSHA acknowledges the requirements of OMB's Circular A-4 (OMB, 2003, Document ID 1493), a guidance document for regulatory agencies preparing economic analyses under Executive Order 12866.[1]

The purpose of this FEA is to:

- Identify the establishments and industries affected by the rule;

[1] Cost-benefit analysis is a standard economics topic. However, "technological feasibility," which is discussed in Chapter IV, and "economic feasibility," which is discussed throughout the document, are key concepts for the OSH Act, but do not have standard economic definitions, and are not required by Executive Orders 12866 or 13563 or by OMB Circular A-4.

- Determine current silica exposures, compile exposure profiles for the affected industries and construction tasks, and identify the technologically feasible methods of controlling these exposures;
- Estimate the benefits resulting from employers coming into compliance with the rule in terms of the reduction in fatal cases of lung cancer, fatal cases of non-malignant respiratory disease, fatal cases of end-stage renal disease, and cases of silicosis morbidity;
- Estimate and evaluate the costs and economic impacts that establishments in the regulated community will incur to achieve compliance with the rule;
- Evaluate the economic feasibility of the rule for affected industries;
- Evaluate the principal regulatory alternatives to the final rule that OSHA has considered; and
- Evaluate the impacts of the rule on small entities as defined by the Small Business Administration (in accordance with the Regulatory Flexibility Act, as amended in 1996).

To develop this FEA, OSHA relied considerably on the support of OSHA's contractor Eastern Research Group (ERG).

SUMMARY OF THE STANDARDS FOR RESPIRABLE CRYSTALLINE SILICA

OSHA has developed a comprehensive standard to protect employees from exposure to respirable crystalline silica in general industry and maritime and has developed a separate standard for the construction industry. The text below summarizes the requirements contained in the standards, which are explained in more detail in the preamble to the final rule, especially the sections on Summary and Explanation.

Scope and application

New 29 CFR §1910.1053 applies to all workplaces in general industry and maritime where there is occupational exposure to respirable crystalline silica. New 29 CFR §1926.1153 applies to all workplaces in construction where there is occupational exposure to respirable crystalline silica. Neither standard applies to agriculture. Both standards exempt workplaces where the employer can demonstrate, based on objective data (as defined in the standards), that exposures in their workplace will remain below an 8-hour time weighted average (TWA) of 25 micrograms per cubic meter ($\mu g/m^3$) under any foreseeable conditions.

Control Methods

Employers are required to fully and properly implement the engineering controls, work practices, and respiratory protection necessary to ensure that employees are protected from respirable crystalline silica exposures above the permissible exposure limit (PEL). The construction standard includes a table (Table 1) setting out controls for a specified list of tasks, and specifying which of those tasks require respiratory protection to complement the controls in order to maintain exposures at or below the PEL.

The two standards generally require that the employer follow OSHA's "hierarchy of controls," using engineering and work practice controls to maintain exposures to levels at or below the PEL, unless the employer can demonstrate that such controls are not feasible. Wherever feasible engineering and work practice controls are not sufficient to reduce employee exposure to the PEL, the employer must use them to reduce employee exposure to the lowest level achievable and then supplement them with respiratory protection. As an alternative to that performance standard, compliance with the construction standard's Table 1 specified methods of control for a listed task will meet a construction employer's obligation under the standard to control respirable crystalline silica, but that obligation can also be met by following the traditional hierarchy-of-controls, a performance-standard approach to ensure that employees are not exposed to levels above the PEL. In construction, exposure assessment (sampling employee exposure) is not required if an employer fully and properly implements the controls on Table 1; otherwise, exposure assessment is required as under the general industry and maritime rule.

Permissible Exposure Limit (PEL) and Action Level

For each silica standard, OSHA has established a PEL of 50 $\mu g/m^3$ as an 8-hour time weighted average (TWA) for respirable crystalline silica in the form of quartz, cristobalite, or tridymite.

In this rule, OSHA also has set an action level of 25 $\mu g/m^3$ as an 8-hour TWA. In these standards, as in previous OSHA standards, the provision for exposure assessment is only triggered once the action level is exceeded. Thus, employers may be able to considerably reduce the burden of complying with the standards by reducing employee exposures to below the action level. However, other ancillary requirements like medical surveillance for employees in general industry and maritime, and training for all employees covered by the standards, are triggered by the action level.

Exposure Assessment

With the exception of employers engaged in construction work and complying with Table 1 of the silica construction standard, each employer subject to a silica standard is required to conduct an assessment for each employee who is, or may reasonably be expected to be, exposed to levels of respirable crystalline silica at or above the action level. Each standard provides options for the assessment (performance-oriented assessments based on relevant objective data or scheduled monitoring through the employer's own air sampling of affected employees) and specifies when a reassessment of exposures must be performed, the methods of sample analysis, employee notification of assessment results, and observation of monitoring.

Regulated Areas (general industry and maritime standard)

To minimize any unnecessary employee exposures, the standard for general industry and maritime requires employers to establish a regulated area wherever an employee's exposure to airborne concentrations of respirable crystalline silica is, or can reasonably be expected to be, in excess of the PEL.

The standard requires that employers demarcate the boundaries of the regulated area (as separate from the rest of the workplace), post signs at the entrances to the regulated area, limit access to the regulated area, and provide an appropriate respirator to each employee or employee representative entering the regulated area.

This requirement does not apply to the standard for construction, which provides for restricting access to areas of significant silica exposure only through the requirement to maintain a written exposure control plan (including designation of a competent person to implement it).

Respiratory Protection

For all three affected major sectors (general industry, maritime, and construction), the standards reference OSHA's respiratory protection standard for general industry (29 CFR 1910.134), which must be complied with when employees are required to use respirators for protection against respirable crystalline silica exposure. The respiratory protection standard requires written procedures for the proper selection, use, cleaning, storage, and maintenance of respirators. The standards for respirable crystalline silica require the use of respirators in five situations: (1) during periods necessary to install or implement feasible engineering and work practice controls to meet the PEL; (2) during tasks where meeting the PEL with engineering and work practice controls is not feasible; (3) during tasks in which an employer has implemented all feasible engineering and work practice controls and these controls do not reduce exposures to the PEL; (4) for general industry and maritime, during periods when the employee/employee representative is in a regulated area; and (5) for construction, as required by Table 1 when employers are relying on Table 1 to satisfy the dust control requirements of the standard.

Housekeeping

The construction standard generally prohibits dry sweeping and the use of compressed air for cleaning clothing or surfaces where such activity could contribute to employee exposure to respirable crystalline silica.

Written Exposure Control Plan and Competent Person (construction standard)

For all three affected major sectors (general industry, maritime, and construction), the standard requires that each employer establish and implement a written exposure control plan to describe how it plans to limit employee exposure to silica. Each standard details when the plan must be evaluated, updated, and made available. The construction standard (which does not have a separate regulated areas requirement) requires that the written exposure control plan contain procedures to restrict access to work areas to minimize the number of employees exposed and their level of exposure, including exposures generated by other employers or sole proprietors.

The provision for a written exposure control plan requires that construction employers designate a competent person to make frequent and regular inspections of job sites, materials, and equipment to implement the written exposure control plan.

Medical Surveillance

The standards require employers to make medical surveillance, including specified initial and periodic medical exams (including follow-up referrals to a specialist), available at no cost to the employee, and at a reasonable time and place, for those employees in general industry and maritime who will be exposed at or above the action level for 30 or more days a year and for employees in construction who will be required to use a respirator for 30 or more days a year to limit exposure to respirable crystalline silica. All medical examinations are to be performed by a physician or other licensed health care professional (PLHCP).

Communication of Respirable Crystalline Silica Hazards to Employees

The standards include a cross-reference to OSHA's Hazard Communication Standard (HCS) (29 CFR 1910.1200) and requires that employers include respirable crystalline silica in their hazard communication program, implementation of which must include labels, safety data sheets, information and training. This is not a new requirement, as the existing hazard communication standard already requires that hazardous chemicals such as respirable crystalline silica be included in the employer's hazard communication program.

Recordkeeping

The employer is responsible for maintaining a record of air monitoring data, objective data and the basis on which that data is relevant to its work, and employee medical surveillance information. Exposure and medical records must be maintained in accordance with 29 CFR 1910.1020.

Significant Changes Between the Proposed Standards and the Final Standards

As noted above, OSHA added new limitations to the scope of the final standard to exclude activities with predictably low levels of silica exposure, i.e. below the action level (as a time-weighted average over eight hours) under any foreseeable condition. OSHA also clarified in the scope of the final rule that employers engaged in certain general industry activities identified on Table 1 of the construction standard may choose to comply with the construction standard instead of the general industry standard. A specific exemption for exposures that result from the processing of sorptive clays has been added.

For the final construction standard, OSHA expanded Table 1, from 13 construction operations to 18 common construction equipment/tasks known to generate high exposures to respirable crystalline silica, in order to address the common equipment and tasks that are overwhelmingly the common sources of exposure to respirable crystalline silica; however, neither abrasive blasting nor underground construction (tunnel boring) has been added to Table 1, and they remain subject to the traditional, performance-based methods of compliance. OSHA also transformed compliance with Table 1 from mere evidence of compliance with the PEL into a full alternative means of complying with the silica control requirements of the construction standard. Employers complying with Table 1 need not conduct exposure monitoring to determine whether their employees are exposed above the PEL.

As explained in more detail in the preamble discussion of Table 1, the final standard for construction clarifies that employers following Table 1 must protect all employees “engaged in a task identified on Table 1,” including not only the equipment operator, but also laborers and other employees who are assisting with the task. The revisions to Table 1 reduced the number of construction workers who would be required to wear respirators, which, in turn, reduced the number of workers who would receive medical surveillance since that requirement is triggered by the number of days (30 or more in the ensuing year) a worker will be wearing a respirator. In the final standard for general industry and maritime, the medical surveillance requirements are triggered by the action level rather than the PEL (provided exposure is for 30 or more days per year), which increased the number of workers who will be required to receive medical surveillance. This change accounts for a large portion of the increased costs for medical surveillance compared to the estimates in the preliminary economic analysis.

The final standards include a new requirement for a written exposure control plan and clarify that employers must protect their employees from silica exposures generated by the activities of other employers or sole proprietors. This requirement eliminated the need for a "written access control plan," which is not included in the final standards. In the construction standard, the requirement for a written exposure control plan includes a requirement for a “competent person” to implement that plan. In both the general industry and construction standards OSHA removed the proposed requirement that would have required workers to wear protective clothing in regulated areas to prevent silica contamination.

Finally, the final standards extend many compliance deadlines beyond the dates proposed in the NPRM.

OSHA revised its technological and economic analysis in response to these changes and to comments received on the NPRM. This FEA contains some costs that were not included in the PEA and updates data to use more recent data sources and, in some cases, revised methodologies. Detailed discussions of these changes are included in the relevant sections throughout this FEA.

FEA CONTENTS

Following this Introduction, the FEA contains the following chapters:

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- Chapter VIII: Regulatory Alternatives
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CHAPTER II: MARKET FAILURE AND THE NEED FOR REGULATION

INTRODUCTION

Executive Order 12866 (58 FR 51735, September 30, 1993) and Executive Order 13563 (76 FR 3821, January 18, 2011) direct regulatory agencies to assess whether, from a legal or an economic view, a Federal regulation is needed to the extent it is not "required by law." Executive Order 12866 states:

> Section 1. Statement of Regulatory Philosophy and Principles.
> (a) The Regulatory Philosophy. Federal agencies should promulgate only such regulations as are required by law, are necessary to interpret the law, or are made necessary by compelling public need, such as material failures of private markets to protect or improve the health and safety of the public, the environment, or the well-being of the American people.

OSHA is revising the existing rule setting one permissible exposure limit for general industry and another, higher one for the construction and maritime industries regarding occupational exposure to respirable crystalline silica because, based on the evidence in the record, there is a compelling public need for a stricter, comprehensive standard under OSH Act legal standards. OSHA presents the legal standards governing this rule and its full findings and conclusions supporting promulgation of the revised rule in Section II of the Preamble, Pertinent Legal Authority, and throughout other sections of the Preamble (e.g., Section V, Health Effects and Quantitative Risk Assessment and Section VI, Significance of Risk).

Even a perfectly functioning market maximizes efficient allocation of goods and services at the expense of other important social values to which the market (as reflected in the collective actions of its participants) is indifferent or undervalues. In such cases, government intervention might be justified to address a compelling public need (Document ID 1493, p. 4). The history and enactment of the OSH Act indicate that Congress recognized that American markets undervalued occupational safety and health when it set forth the Act's protective purposes and authorized the Secretary of Labor to promulgate occupational safety and health standards.

Section 6(b)(5) of the OSH Act requires the Secretary of Labor, when promulgating health standards, to set the standard at the level "which most adequately assures, to the extent feasible, on the basis of the best available evidence, that no employee will suffer material impairment of health or functional capacity . . . ." (29 U.S.C. 655(b)(5)). As discussed more fully in the Pertinent Legal Authority section of the Preamble, the Supreme Court has interpreted this language to mean that OSHA's health standards must reduce a "significant risk" of material impairment of health, subject to other regulatory constraints such as economic and technological feasibility (*Indus. Union Dep't, AFL-CIO v. Am. Petroleum Inst.*, 448 U.S. 607, 639-40 (1980) (*Benzene*)).

OSHA has determined that employees across a range of industries are exposed to levels of airborne silica that result in the development of lung cancer, silicosis, end-stage renal disease, and premature death. The Agency's final standard will reduce these occupational risks of lung cancer, silicosis, other lung diseases and end-stage renal disease. Protecting employees from a significant risk of these diseases establishes the compelling public need for the Agency's remedy: to increase worker protection from exposure to silica.

OSHA discusses, in this chapter, the possibility that this rule corrects a market failure in which private markets fail to adequately protect human health.

OSHA concludes there is a failure of private markets to protect workers from exposure to unnecessarily high levels of respirable crystalline silica. In making this statement, the Agency recognizes that many firms have responded to the risks posed by exposure to silica by implementing control programs for their workers. In fact, some existing control programs go beyond the requirements of the final rule, and information that OSHA has collected suggests that a significant percentage of all employees in workplaces where silica is present are currently receiving at least some level of protection against the risks posed by silica that is similar to the protection provided by this standard. For these firms and these workers, the economic incentives provided by private markets appear to be working effectively. Nevertheless, the effectiveness of private markets in providing the level of worker health and safety required by the OSH Act is not universal as many other employers in the same sectors fail to provide their workers with equivalent levels of protections against respirable silica. Accordingly, the general availability of adequate controls speaks to the feasibility of the standard, not to any supposed lack of need.

In this case, OSHA is addressing a situation in which there is an existing OSHA regulation that the Agency wishes to make more stringent. If markets work efficiently there would be no need for either the existing regulation or a new one. This section is devoted to showing that markets fail with respect to optimal risk for occupational exposure to silica. Other sections address whether, given that markets fail, a new regulation is needed to replace the existing regulation.

The discussion below considers why private markets, as well as information dissemination programs, workers' compensation systems, and tort liability options, each may fail to protect workers from silica exposure, resulting in the need for a more protective OSHA silica rule. That is followed by OSHA's discussion of public comments on the preliminary analysis of the need for regulation—presented in the Preliminary Economic Analysis in support of the proposed silica rule (Document ID 1720)—and the Agency's response to those comments. Finally, OSHA briefly summarizes this chapter.

PRIVATE MARKETS

Under suitable conditions, a market system is economically efficient in the following sense: resources are allocated where they are most highly valued; the appropriate mix of goods and services, embodying the desired bundle of characteristics, is produced; and further improvements in the welfare of any member of society cannot be attained without making at least one other member worse off.

Economic theory, supported by empirical data, argues that, in the job market, employers and workers bargain over the conditions of employment, including not only salary and other worker benefits, but also occupational risks to worker safety and health. Employers compete among themselves to attract workers. In order to induce workers to accept hazardous jobs, employers must offer a higher salary—termed a "wage premium for risk" or "risk premium" for short—to compensate for the additional job risk.[1] Because employers must pay higher wages for more hazardous work, they have an incentive to make the workplace safer by making safety-related investments in equipment and training or by using more costly but safer work practices. According to economic theory, the operation of the private job market will provide the optimal level of occupational risk when each employer's additional cost for job safety just equals the avoided payout in risk premiums to workers. The theory assumes that each employer is indifferent to whether it pays the higher wage or pays for a safer or more healthful workplace, but will opt for whichever costs less or improves productivity more.

For the job market to function in a way that leads to optimal levels of occupational risk, three conditions must be satisfied. First, workers and employers must have the same, perfect information—that is, they must be fully informed about their workplace options, including job hazards, or be able to costlessly acquire such information. Second, participants in the job market must directly bear all of the costs and obtain all of the

[1] The concept of compensating wage differentials for undesirable job characteristics, including occupational hazards, goes back to Adam Smith's ***The Wealth of Nations***, which was originally published in 1776.

benefits of their actions. In other words, none of the direct impacts of job market transactions can be externalized to outside parties. Third, the relevant job market must be perfectly competitive, which means it must contain such a large number of employers and such a large number of workers that no individual economic agent is able to influence the risk-adjusted wage.

The discussion below examines (1) imperfect information, (2) externalities, and (3) imperfect competition in the job market in more detail, with particular emphasis on worker exposure to silica, as appropriate.[2]

(1) Imperfect Information

As described below, imperfect information about job hazards is present at several levels that reinforce each other: employers frequently lack knowledge about workplace hazards and how to reduce them; workers are often unaware of the workplace health and safety risks to which they are exposed; and workers typically have difficulty in understanding the risk information they are able to obtain. Imperfect information at these various levels has likely impeded the efficient operation of the job market regarding workplace risk because workers--unaware of job hazards--do not seek, or receive, full compensation for the risks they bear. As a result, even if employers have full knowledge about the risk, their employees do not. If employees do not have full knowledge about the risk, employers have less incentive to invest in safer working conditions than they would in the presence of full information since wages are suppressed below what full knowledge by the workers would yield. In contrast, see Casillas-Pabellón testimony at 2452-2453 (workers who received full training about silica risks refused to work without the protections that had not been previously provided).

Lack of Employer Information

In the absence of regulation, employers may lack economic incentives to optimally identify the health risks that their workers face.[3] Furthermore, employers have an economic incentive to withhold the information they do possess about job hazards from their workers, whose response would be to demand safe working conditions or higher wages to compensate for the risk. Similarly, employers who develop cost-effective methods of reducing workplace risk have little incentive to share information with their

[2] The section on workers' compensation insurance later in this chapter identifies and discusses other related market imperfections.

[3] Other private parties may lack sufficient incentives to invest resources to collect and analyze occupational risk data due to the public-good nature of the information. See Ashford and Caldart (1996), Document ID 0538, p. 234.

competitors about such methods (unless they are patentable.) Relatedly, in the absence of regulation, employers, as well as third parties, may have fewer incentives to develop new technological solutions to protect workers on the job. For evidence of regulatory stimuli inducing innovations to improve worker health and safety, see, for example, Ashford, Ayers, and Stone (1985) Document ID 0536, as well as more recent evidence from OSHA's regulatory reviews under section 610 of the Regulatory Flexibility Act (5 U.S.C. 610).

As a result, without regulation, many employers are unlikely to make themselves aware of the magnitude of silica-related health risks in the workplace or of the availability of effective ways of ameliorating or eliminating these risks.

Lack of Worker Information about Health Hazards

Even without information from their employers, workers might reasonably be cognizant, at least at some basic qualitative level, of many occupational *safety* hazards. Many safety hazards are obvious to the eye, such as holes in floors, ice and snow covered work surfaces, and work near electrical power lines. Likewise, workers can understand that activities involving explosive materials or working at heights are inherently dangerous. Furthermore, workers can develop some, admittedly limited, knowledge of safety hazards in their workplace from their own and their coworkers' on-the-job accident and injury experience.

Occupational *health* hazards are generally less obvious and well known to employers and employees alike than occupational *safety* hazards. Whereas the relationship between a workplace accident and the resultant injury is usually both immediate and visible, the connection between exposure to an occupational health hazard and the resultant disease may not be. Even though falls and physical trauma occur in everyday life, it is easier to know when the injuries occurred on the job than to know the cause of a particular lung disease long associated with occupational exposure to a toxic substance. Some diseases have multiple potential causes and may be the result of synergistic effects, thus creating difficulties in ascertaining whether, in some specific situations, a worker's disease is job-related rather than an "ordinary disease of life" resulting from genetic, physiological, lifestyle, or non-occupational environmental factors.[4]

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[4] It is true that, in rare circumstances, the cause of a disease is unique or nearly so. Examples of such "signature" diseases include mesothelioma and angiosarcoma, which are caused by exposure to asbestos and vinyl chloride, respectively. In some cases, silica can be uniquely identified as the dust causing a worker's pneumoconiosis, a restrictive lung disease due to inhalation of dust; in such cases, the disease is classified as silicosis. OSHA is not aware of evidence that silica can be uniquely identified, in

Compounding this causation problem is the fact that there is frequently a long latency period—sometimes 20 years or more—between exposure to the occupational health hazard and the manifestation of the resultant disease. Consequently, without specialized knowledge, the connection between work conditions and a chronic disease is more easily missed than an acute injury and more easily attributed to non-occupational exposures. Furthermore, by the time that signs and symptoms of occupational health problems arise, it is often too late for workers to make use of that information. For example, lung cancer does not surface until many years after the exposures that contributed to causing it, and preventive action can no longer be taken. Therefore, any incentive an employer has to invest in occupational disease prevention is diluted by the lengthy passage of time between exposure and disease manifestation (by which time the employees may be working elsewhere or retired) and the various uncertainties regarding causation in any specific case. Markets cannot adequately address this risk of latent occupational disease if employees and employers are unaware of the changes in risk brought about by an employer's actions. Even if employees and employers are aware of a risk, the employer may have limited economic motivation to install controls unless the employees are able to accurately assess the effects of those controls on their occupational risks. Accordingly, even if workers have general knowledge that they are at increased risk of disease from occupational exposure, it is unrealistic to expect, absent mandatory regulatory requirements, that they know the calculated risks associated with different exposure levels or the exposures they are experiencing or accumulated in the past, much less that they can use that knowledge to negotiate a significant reduction in exposures and other protections or (if more desirable) trade it for greater hazard pay. And without any way to enforce standards agreed to by an employer, employees would have no way to check that they are getting the benefit of their bargain or hold the employer to it. Another reason that imperfect information impairs a worker's decision-making ability is that workers are unlikely to know the workplace risks associated with their particular employer, or with one potential employer versus another, even if the types of work assignments are the same. More specifically, on tasks involving silica exposure, workers may not know whether adequate engineering controls are being applied or that the respirators the employer provides have adequate protection factors and have been properly fit-tested and maintained. In fact, even the assumption that the employer is using engineering controls and supplying respirators may not be warranted in the absence of regulation.

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individual cases, as the cause of other diseases arising from worker exposure to silica, such as lung cancer, tuberculosis, and renal failure.

Both experimental studies and observed market behavior suggest that individuals have considerable difficulty rationally processing information about low-probability, high-consequence events such as occupational fatalities and long-term disabilities.[5] For example, many individuals may not be able to comprehend or rationally act on risk information when it is presented, as risk analysis often is, in mathematical terms—a 1/1,000 versus a 1/10,000 versus a 1/100,000 annual risk of death from occupational causes. See, e.g., Guth testimony (Document ID 3585, Tr. 3007-3008).

Of course, in the abstract, many of the problems that employers and workers face in obtaining and processing occupational risk can lead workers to overestimate as well as underestimate the risk. However, in the case of silica exposure, the related diseases—including silicosis and end-stage renal disease—may be sufficiently unfamiliar and unobvious that many workers may be completely unaware of the risk, and therefore will underestimate it. See, e.g., testimony of bricklayer Tommy Todd:

> I just took it as a grain of salt, the dust. I never thought it was harmful or anything. . . . If I'd known it was hurting me, you know, or killing me, shoot, I'd have done things a lot different, and I had no idea back then (Document ID 3585, Tr. pp. 3030-3035).

In addition, for markets to optimally address this risk, employees need to be aware of the changes in risk brought about by an employer's actions. Even if employees are aware of a risk, the employer may have limited economic motivation to install controls unless the employees are able to accurately assess the effects of those controls on their occupational risks. Furthermore, there is substantial evidence that most individuals are unrealistically optimistic, even in high-stakes, high-risk situations and even if they are aware of the statistical risks (Thaler and Sunstein, 2009, Document ID 1697, pp. 31-33). Although the Agency lacks specific evidence on the effect of these attitudes on assessing occupational safety and health risks, this suggests that some workers underestimate their own risk of work-related injury, disease, or fatality and, therefore, fail to demand adequate compensation for bearing those risks. Finally, the difficulty that workers have in distinguishing marginal differences in risk in alternative worksites, both within an industry and across industries, creates a disincentive for employers to incur the costs of reducing workplace risk.

(2) Externalities

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[5] The literature documenting risk perception problems is extensive. See, in particular, the classic work of Tversky and Kahneman (1974), Document ID 1675. For a recent summary of risk perception problems and their causes, see Thaler and Sunstein (2008), Document ID 1697, pp. 17-37.

Externalities arise when an economic transaction generates direct positive or negative spillover effects on third parties not involved in the transaction. The resulting spillover effect, which leads to a divergence between private and social costs, undermines the efficient allocation of resources in the market because the market is imparting inaccurate cost and price signals to the transacting parties. Applied to the job market, when costs are externalized, they are not reflected in the decisions that employers and workers make—leading to allocative distortions in that market.

Negative externalities exist in the job market because many of the costs of occupational injury and illness are borne by parties other than individual employers or workers. The major source of these negative externalities, for chronic occupational diseases, is the occupational illness cost that workers' compensation does not cover.[6] Workers and their employers often bear only a portion of these costs. Outside of workers' compensation, workers incapacitated by an occupational injury or illness and their families often receive health care, rehabilitation, retraining, direct income maintenance, or life insurance benefits, most of which are paid for by society through Social Security and other social insurance and social welfare programs.[7] Furthermore, substantial portions of the medical care system in the United States are heavily subsidized by the government so that part of the medical cost of treating injured or ill workers is paid for by the rest of society (Nichols and Zeckhauser, 1977, Document ID 0834, pp. 44-45). To the extent that employers and workers do not bear the full costs of occupational injury and illness, they will ignore these externalized costs in their job-market negotiations. The result may be an inefficiently high level of occupational risk. It should be noted, however, that OSHA expects that the effect of these externalities on the market-determined level of occupational risk would be relatively minor in comparison to the other types of market failure described here.

(3) Imperfect Competition

[6] Workers' compensation is discussed separately later in this chapter. As described there, in many cases (particularly for smaller firms), the premiums that an individual employer pays for workers' compensation are only loosely related, or unrelated, to the occupational risks that that employer's workers bear. However, workers' compensation does not cover chronic occupational diseases in most instances. For that reason, negative externalities tend to be a more significant issue in the case of occupational exposures that result in diseases.

[7] In addition, many occupational injuries and most occupational illnesses, other than musculoskeletal disorders, are not processed through the workers' compensation system at all. In these instances, workers receive care from their own private physician rather than from their employer's physician.

In the idealized job market, the actions of large numbers of buyers and sellers of labor services establish the market-clearing, risk-compensated wage, so that individual employers and workers effectively take that wage as given. In reality, however, the job market is not one market but many markets differentiated by location, occupation, and other factors; entrants in the labor market face search frictions because of limited information on employment options; and, furthermore, in wage negotiations with their own workers, employers are typically in an advantageous position relative to all other potential employers. In these situations, discussed below, employers may have sufficient power to influence or to determine the wage their workers receive. This may undermine the conditions necessary for perfect competition and can result in inadequate compensation for workers exposed to workplace hazards. Significant unemployment levels, local or national, may also undermine the conditions necessary for adequate compensation for exposure to workplace hazards.

Beyond the classic—but relatively rare—example of a town dominated by a single company, there is significant evidence that some employers throughout the economy are not wage-takers but, rather, face upward-sloping labor supply curves and enjoy some market power in setting wages and other conditions of employment.[8] An important source of this phenomenon is the cost of a job search and the employer's relative advantage, from size and economies of scale, in acquiring job market information.[9] Another potentially noteworthy problem in the job market is that, contrary to the model of perfect competition, workers with jobs cannot costlessly quit and obtain a similar job at the same wage with another employer. Workers leaving their current job may be confronted with the expense and time requirements of a job search, the expense associated with relocating to take advantage of better employment opportunities, the loss of firm-specific human capital (i.e. firm-specific skills and knowledge that the worker possesses), the cost and difficulty of upgrading job skills, and the risk of a prolonged period of unemployment. In addition, employers derive market power from the fact that a portion of the compensation their workers receive is not transferable to other jobs. Examples include job-specific training and associated compensation, seniority rights and associated benefits, and investments in a pension plan.

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[8] See, for example, Borjas (2000) Document ID 0565. See also Ashenfelter, Farber, and Ransom (2010) and Boal and Ransom (1997), providing supplemental evidence. The term "monopsony" power is sometimes applied to this situation, but it does not necessarily require a single employer.

[9] See Borjas (2000) Document ID 0565. As supplemental authorities, Weil (2014) presents theory and evidence both in support of this proposition and to show that, in many situations, larger firms have more monopsony power than smaller firms, while Boal and Ransom (1997, p. 97) note that the persistent wage dispersion observed in labor markets is a central feature of equilibrium search models.

Under the conditions described above, employers would not have to take the market-clearing wage as given, but could offer a lower wage than would be observed in a perfectly competitive market,[10] including less than full compensation for workplace health and safety risks. As a result, relative to the idealized competitive job market, employers would have less incentive to invest in workplace safety. Several hearing participants testified that their workplace experiences are far different from those described in the idealized competitive job market, and described the difficulty in obtaining jobs and the resulting inability to bargain for, or even request, protection from silica exposure. See, e.g., testimony of New Labor Director Ms. Casillas-Pabellon (Document ID 3583, Tr. 2449-2450); construction worker Mr. Armendariz (Document ID 3583, Tr. 2484; and construction worker Mr. Granados (Document ID 3583, Tr. 2485).

NON-MARKET AND QUASI-MARKET ALTERNATIVES TO REGULATION

The discussion in this section considers whether non-market and quasi-market alternatives to the final rule would be capable of protecting workers from the hazards of silica exposure. The alternatives under consideration are information dissemination programs, workers' compensation systems, and tort liability options.

Information Dissemination Programs

An alternative to OSHA's final silica rule would be the dissemination of information, either voluntarily or through compliance with OSHA's hazard communication standard (HCS) (29 CFR 1910.1200), about the health risks associated with workplace exposure to silica. Better informed workers could more accurately assess the occupational risks associated with different jobs, thereby facilitating, through labor market transactions, higher risk premiums for more hazardous work and inducing employers to make the workplace less hazardous. The final rule recognizes the link between the dissemination of information and workplace risks by requiring that workers engaged in jobs involving exposure to silica be provided with information and training about silica-related illnesses and ways to prevent them. There are several reasons, however, why reliance on information dissemination programs alone would not yield the level of worker protection achievable through the final silica rule, which incorporates hazard communication as part of a comprehensive approach designed to control the hazard in addition to providing for the disclosure of information about it.

[10] For a graphical demonstration that an employer with monopsony power will pay less than the competitive market wage, see Borjas (2000), Document ID 0565, pp. 187-189.

First, in the context of HCS, which requires employers to transmit information about the inherently hazardous properties of hazardous substances, that standard alone does not require that sufficient information be provided to identify risks in specific workplaces. Silica-related risks, for instance, are highly specific to individual tasks and work environments.

Second, in the case of voluntary information dissemination programs, absent a regulation, there may be significant economic incentives, for all the reasons discussed in the Private Markets section above, for the employer *not* to gather relevant exposure data or distribute occupational risk information so that the workers would not change jobs or demand higher wages to compensate for their newly identified occupational risks.

Third, even if workers were better informed about workplace risks and hazards, all of the defects in the functioning of the private job market previously discussed—the limited ability of workers to evaluate risk information, externalities, and imperfect competition—would still apply. Because of the existence of these defects, better information alone would not lead to wage premiums for risk in accordance with efficient market theory.

Thus, while improved access to information about silica-related hazards can provide for more rational decision-making in the private job market, OSHA concludes that information dissemination programs will not, by themselves, produce an adequate level of worker protection.

Workers' Compensation Systems

Another theoretical alternative to OSHA regulation could be to determine that no rule is needed because State workers' compensation programs augment the workings of the private job market to limit occupational risks to worker safety and health. After all, one of the objectives of the workers' compensation system is to shift the costs of occupational injury and disease from workers to employers in order to induce employers to improve working conditions. Two other objectives relevant to this discussion are to provide fair and prompt compensation to workers for medical costs and lost wages resulting from workplace injury and disease and, through the risk-spreading features of the workers' compensation insurance pool, to prevent individual employers from suffering a catastrophic financial loss (Ashford, 2007, Document ID 1702, p. 1712).

OSHA identifies three primary reasons, discussed below, why the workers' compensation system has fallen short of the goal of shifting to employers the costs of workplace injury and disease—including, in particular, the costs of worker exposure to silica. As a result, OSHA concludes that workers' compensation programs alone do not adequately protect workers. In addition, although not necessary to support this conclusion, OSHA takes notice of several recent studies highlighting the general decline in the adequacy and fairness of State worker's compensation programs, the significant variability among State worker compensation programs, and the compensation inadequacies that ultimately shift these costs back to the workers or to the government (www.propublica.org/article/the-demolition-of-workers-compensation and http://www.dol.gov/osha/report/20150304-inequality.pdf).

(1) <u>Failure to Provide Compensation for Most Occupational Diseases</u>

The first, and most important, reason that workers' compensation is not an adequate alternative, is that State workers' compensation programs tend not to provide benefits for most work-related diseases—including those resulting from silica exposure, such as silicosis and lung cancer. Several related factors account for this:

- Most occupational diseases have multiple causes and are indistinguishable from ordinary diseases of life. Therefore it is difficult for workers' compensation to trace the cause of these diseases to the workplace;
- Many occupational diseases have long latency periods, which tends to obscure the actual cause of disease or the place of employment where exposure occurred;
- Workers (as well as medical personnel) often do not realize that a disease is work-related and, therefore, fail to file a workers' compensation claim; and
- Most States have statutes of limitations that are 10 years or less for filing workers' compensation claims. This may preclude claims for illnesses involving long latency periods. Also, many States have a minimum exposure time period before a disease can be attributed to an occupational cause.

With the exception of musculoskeletal disorders, workers' compensation actually covers only 5 percent of occupational diseases (including silica-related occupational diseases) and 1.1 percent of occupational fatalities (Ashford, 2007, Document ID 1702, p. 1714).

(2) <u>Limitations on Payouts</u>

The second reason that employers do not fully pay the costs of work-related injuries and disease under the workers' compensation system is that, even for those claims that are accepted into the system, states have imposed significant limitations on payouts. Depending on the State, these limitations and restrictions include:

- Caps on wage replacement based on the average wage in the State rather than the injured workers' actual wage;

- Restrictions on which medical care services are compensated and the amount of that compensation;
- No compensation for non-pecuniary losses, such as pain and suffering or impairment not directly related to earning power;
- Either no, or limited, cost-of-living increases;
- Restrictions on permanent, partial, and total disability benefits, either by specifying a maximum number of weeks for which benefits can be paid or by imposing an absolute ceiling on dollar payouts;
- A low absolute ceiling on death benefits.

The last two restrictions may be the most limiting for occupational diseases with long-term health effects and possible fatal outcomes, such as those associated with worker exposure to silica.

(3) __A Divergence between Workers' Compensation Premiums and Workplace Risk__

The third reason workers' compensation does not adequately shift the costs of work-related injuries and illnesses to employers is that the risk-spreading objective of workers' compensation conflicts with, and ultimately helps to undermine, the cost-internalization objective.[11] For the 99 percent of employers who rely on workers' compensation insurance,[12] the payment of premiums represents their primary cost for occupational injuries and illnesses, such as silica-related illnesses. However, the mechanism for determining an employer's workers' compensation insurance premium typically fails to reflect the actual occupational risk present in that employer's workplace.

Approximately 85 percent of employers have their premiums set based on a "class rating," which is based on *industry* illness and injury history. Employers in this class are typically the smallest firms and represent only about 15 percent of workers (Ashford, 2007, Document ID 1702, p. 1713). Small firms are often ineligible for experience rating because of insufficient claims history or because of a high year-to-year variance in their claim rates. These firms are granted rate reductions only if the experience of the entire class improves. The remaining 14 percent of employers, larger firms representing approximately 70 percent of workers, have their premiums set on the basis of a

[11] Recall from the earlier discussion of externalities that the failure to internalize costs leads to allocative distortions and inefficiencies in the market.

[12] Only the largest firms, constituting approximately 1 percent of employers and representing approximately 15 percent of workers, are self-insured. These individual firms accomplish risk-spreading as a result of the large number of workers they cover. See Ashford (2007), Document ID 1702, p. 1712.

combination of “class rating” and “experience rating,” which adjusts the class rating to reflect a firm’s individual claims experience. A firm’s experience rating is generally based on the history of workers’ compensation payments to workers injured at that firm’s workplace, not on the quality of the firm’s overall worker protection program or safety and health record. Thus, for example, the existence of circumstances that may lead to catastrophic future losses are not included in an experience rating—only actual past losses are included.[13]

Insurance companies do have the right to refuse to provide workers’ compensation insurance to an employer—and frequently exercise that right based on their inspections and evaluations of a firm’s health and safety practices. However, almost all States have assigned risk pools that insist that any firm that cannot obtain workers’ compensation policies from any insurer must be provided workers’ compensation insurance at a State-mandated rate that reflects a combination of class and experience rating.

Workers’ compensation insurance does protect individual employers against a catastrophic financial loss due to work-related injury or illness claims. As a result of risk spreading, however, employers’ efforts to reduce the incidence of occupational injuries and illnesses are not fully reflected in reduced workers’ compensation premiums. Conversely, employers who devote fewer resources to promoting worker safety and health may not incur commensurately higher workers’ compensation costs. This creates a type of moral hazard, in that the presence of risk spreading in workers’ compensation insurance may induce employers to make fewer investments in equipment and training to reduce the risk of workplace injuries and illnesses.

In short, the premiums most individual employers pay for workers’ compensation insurance coverage do not reflect the actual cost burden those employers impose on the worker’s compensation system. Consequently, employers considering measures to lower the incidence of workplace injuries and illnesses can expect to receive a less-than-commensurate reduction in workers’ compensation premiums. Thus, for all of the reasons discussed above, the workers’ compensation system does not provide adequate incentives to employers to control occupational risks to worker safety and health.

Tort Liability Options

[13] In order to spread risks in an efficient manner, it is critical that insurers have adequate information to set individual premiums that reflect each individual employer’s risks. As the preceding discussion has made clear, by and large, they do not. In that sense, insurers can be added to employers and workers as possessing imperfect information about job hazards.

Another alternative to OSHA regulation would be for workers to use the tort system to seek redress for work-related injuries and diseases, including silica-related ones. A tort is a civil wrong (other than breach of contract), for which the courts can provide a remedy by awarding damages. The application of the tort system to occupational injury and disease would allow workers to sue their employer, or other responsible parties (e.g., “third parties” such as suppliers of hazardous material or equipment used in the workplace) to recover damages. In theory, the tort system could shift the liability for the direct costs of occupational injury and illness from the worker to the employer or to other responsible parties. In turn, the employer or third parties would be induced to improve worker safety and health.

With limited exceptions, the tort system has not been a viable alternative to occupational safety and health regulation because State statutes make workers’ compensation the “exclusive remedy” for work-related injuries and illnesses. Workers’ compensation is essentially a type of no-fault insurance. In return for employers’ willingness to provide, through workers’ compensation, timely wage-loss and medical coverage for workers’ job-related injuries and diseases, regardless of fault, workers are barred from suing their employers for damages, except in cases of intentional harm or, in some States, gross negligence (Ashford and Caldart, 1996, Document ID 0538, p. 233). Practically speaking, in most cases, workers’ compensation is the exclusive legal remedy available to workers for workplace injuries and illnesses.

Workers are thus generally barred from suing their own employers in tort for occupational injuries or disease, but may attempt to recover damages for work-related injuries and disease from third parties through the tort system. However, the process may be lengthy, adversarial, and expensive. In addition, in tort cases involving chronic occupational disease, the likelihood of prevailing in court and ultimately obtaining compensation may be small because:

- In a tort action, the burden of proof is on the plaintiff (i.e., the worker) to demonstrate by “a preponderance of the evidence” that the defendant (i.e., the responsible third party) owed a duty to the plaintiff, that the defendant breached that duty, and that the breach caused the worker’s injury or disease;
- To establish third-party liability the worker must typically show that the third party’s products or equipment or instructions were defective or negligently designed. Liability is often in dispute and difficult to prove;
- In cases of chronic disease, especially those with long latency periods, it is typically even more difficult to prove that the third-party was causally responsible. The worker must prove that not only was the disease the result of occupational exposure and not an ordinary disease of life or the result of non-

occupational exposure, but also the causal exposure was due to the defendant's product at the plaintiff's particular worksite rather than exposure to some other third party's product or exposure at some other worksite;

- For chronic diseases, the potentially lengthy latency period between worker exposure and manifestation of disease lowers the probability that the responsible third party will still be in business when tort claims are ultimately filed and have sufficient assets to cover the claims;[14] and
- Workers may be deterred from filing tort actions because of the substantial costs involved—including attorney fees, court costs, and the costs of obtaining evidence and securing witnesses—and the lengthy period before a final decision is rendered.

In sum, the use of the tort system as an alternative to regulation is severely limited because of the "exclusive remedy" provisions in workers' compensation statutes; because of the various legal and practical difficulties in seeking recovery from responsible third parties, particularly in cases of occupational disease such as silicosis and lung cancer; and because of the substantial costs associated with a tort action. The tort system, therefore, does not adequately protect workers from exposure to hazards in the workplace.

PUBLIC COMMENTS ON THE NEED FOR REGULATION

Some commenters argued that OSHA had not demonstrated a need for additional regulation because (1) various studies have shown that reported cases of silicosis are decreasing under the current OSHA silica standard and (2) improved enforcement of the existing silica standard would be superior to adding the costly new requirements in the proposed rule. These commenters include the American Foundry Society (Document ID 4229, p. 6), the Construction Industry Safety Coalition (CISC) (Document ID 4217, p. 6, fn 2), Halliburton Energy Services, Inc. (Document ID 2302, p. 10), the National Association of Home Builders (Document ID 2296, p. 14) and others (See, e.g. Document ID 2191; 4225; 2210; 2222; 4228, pp. 4-6; 2136; 2309, pp. 4-5; 2185, p. 3; 2182, p. 4; 3580, Tr. 1470; 3589, Tr. 4210 and 2024). In brief, OSHA disagrees with the conclusion reached by these commenters. OSHA has determined that significant risk to workers remains under the current OSHA silica standard, even with full enforcement, and that the final rule would significantly reduce that risk. The commenters appear to ignore OSHA's statutory duty to act to reduce the risk to the extent feasible, and disagree with OSHA's finding that the benefits of achieving the new PEL exceed the costs. A detailed discussion of the first issue—including the associated comments themselves and OSHA's full position—is presented in the preamble supporting the final rule, primarily in the risk

[14] The same qualification about the firm being in business and having sufficient assets to pay claims may also apply to liability insurers, in those cases where the firm has purchased liability insurance.

assessment, the justification for the new PEL, and the examination of the pertinent legal authority for the rule. A discussion of the second issue is presented later in this FEA in the examination of the net benefits of the rule.

One of those commenters suggested that the need for regulation may already have been satisfied by OSHA's proposal. During testimony, Bradford Hammock, counsel for CISC, suggested that OSHA could improve compliance with the existing silica rule simply by publishing a proposed rule without necessarily following that up with a final rule (Document ID 3580, Tr. 1471). While proposed rules may help to raise awareness and induce employers to comply in anticipation of a final rule, they do not give OSHA any authority to enforce the provisions of the rule. This is essentially another request for information sharing in lieu of regulation, and OSHA rejects it for the previously noted reasons.

Dr. Michael Marlow, an Affiliated Scholar at the Mercatus Center at George Mason University, offered the most comprehensive comment on OSHA's preliminary Need for Regulation chapter (Document ID 1819). Dr. Marlow noted, "While OSHA has made a reasonable general theoretical case for regulation, it fails to develop what an optimal regulation might look like" (Document ID 1819, p. 2). However, OSHA's purpose in the Need for Regulation chapter is simply to provide a general case for regulation. OSHA explains and justifies the rule in detail in the preamble and identifies and evaluates the regulatory alternatives in the Regulatory Alternatives chapter of the FEA and in the Final Regulatory Flexibility Analysis of the FEA.

Dr. Marlow did offer several criticisms of OSHA's justification for the need for regulation. For example, Dr. Marlow—as well as Mr. Danner of the National Federation of Independent Business (NFIB)—argued that OSHA's market failure evidence is too general and not specific to silica (Document ID 2210, p. 4). Dr. Marlow particularly noted that OSHA offered "little to no supporting evidence on the specifics of information problems directly associated with silica" (Document ID 1819, p. 3). OSHA disagrees. The Agency identified several characteristics of silica exposure risks that create information problems, including the inability to distinguish many diseases resulting from occupational silica exposure from ordinary diseases of life and frequently the long latency period from silica exposure to manifestation of disease. Further, concerning the inability of workers to process risk information, OSHA relied in large part on materials from the behavioral economics literature, which argues that the reported problems in risk processing are almost universal human biases. Hence, these risk processing problems would apply to employees working with silica.

Dr. Marlow also questioned the Agency's imperfect information arguments because, as OSHA acknowledges, many firms have already responded to the silica exposure risks facing their employees by voluntarily implementing control programs, some of which go beyond the requirements of the rule. Mr. Danner of NFIB offered a related criticism that OSHA failed to acknowledge that the Agency has already intervened in the market, with success (Document ID 2210, p. 4).

In OSHA's view, the fact that many employers have implemented controls to protect their workers does not contradict the Agency's market failure arguments to justify regulation. For example, the fact that some employers are aware of the occupational risks of respirable crystalline silica does not mean that all are, or that even for those who are knowledgeable there is sufficient economic incentive for them to protect their employees. The market fails even if only some employers fail to protect workers when the social benefits exceed the social costs, not just if all employers fail to protect workers. Furthermore, OSHA is statutorily obligated to provide "safe and healthful working conditions" to "*every* working man and woman in the Nation." (italics added) (29 U.S.C. 651(b)). The record includes numerous statements indicating that there are still many workers who did not understand the risks associated with working with silica until after they were exposed and permanently injured. See, e.g., hearing testimony of Mr. Ruiz, foundry worker (Document ID 3583, Tr. 2328 and 2332-2333); Mr. Mendoza, construction worker and New Labor Safety Liaison (Document ID 3583, Tr. 2465); Mr. Ward, bricklayer (Document ID 3585, Tr. 3016-3018); Mr. McNabb, former tile setter (Document ID 3585, Tr. 3023-3025 and 3054); Mr. Todd, bricklayer (Document ID 3585, Tr. 3030-3035; Mr. Barrett, terrazzo project manager (Document ID 3585, Tr. 3038 and 3055); Mr. Garcia Hernandez, construction worker and safety trainer (Document ID 3586, Tr. 3167 and 3230); J. Schultz (Document ID 3586, Tr. 3177); and Mr. Schultz, former foundry worker (Document ID 3583, Tr. 3197-3198). Kevin Turner, the Director of Safety for the East Division of Hunt Construction Group, noted that the dangers of silica are not as self-evident as other hazards:

> From my experience, … I don't even know if it's a misunderstanding, it's just lack of knowledge. …We're required to work with smaller businesses, various entities. A lot of those are literally a few folks and a pickup truck, and their knowledge of OSHA is minimal. * * * This is one of those things that typically it's just dust. Silica is not seen typically. You don't taste it. It doesn't have an odor. So in their minds, it doesn't exist; it's not an issue. It's not like falling 30 stories (Document ID 3580, Tr. 1468-1469).

Kellie Vazquez, Vice President of Holes Incorporated, also emphasized the lack of awareness of silica hazards:

> I think it is a lack of knowledge. I do think people think it is just dust. I was recently doing some safety audits … I saw two guys polishing inside of a garage dry, and they just had handkerchiefs wrapped around their face (Document ID 3580, Tr. 1470).

Some of the testimony also highlighted the efforts of some employers to avoid protection costs or shift them to workers in the absence of regulation, with the implication that they would continue to avoid providing protections absent OSHA requirements. Ms. Casillas-Pabellón, the Director of a day-laborer support group, New Labor, described employer efforts to limit worker access to information and safety equipment:

> Often, these contractors do not even give workers the correct company names, phone numbers, or they are giving workers fake names. The work is performed in neighborhoods far from where the workers live, or the workers don't speak the language, which becomes a challenge for workers to demand personal protective equipment or the right tools to perform their jobs. Workers are often left to their own devices and creativity to try to protect themselves or to perform daily job tasks (Document ID 3583, Tr. 2449-2450).

Under questioning from AFL-CIO representative Rebecca Reindel, construction worker Santos Armendariz acknowledged the pressures on employees to suppress the distribution of safety information:

> MS. REINDEL: . . . what happens when [workers who are not trained in safety] bring their safety concerns to their employers?
> MR. ARMENDARIZ: I think for the most part there is a lot of fear. People are afraid of losing their jobs … in a lot of the small companies, it’s very common that you see… a group of workers here one day and then it’s a different group the next day. And that’s because the boss doesn’t want to spend money (Document ID 3583, Tr. 2483-2484) .

Another construction worker, Jose Granados, concurred:

> in terms of your previous question about what would happen if we bring these issues [about worker exposure to silica dust] to the boss, I have done this in the past. I have brought these issues to his attention and the boss told me that I was crazy. And he told my co-workers not to listen to me because he said that I was crazy. And then he basically told me that I had to take more days off or sent me home for more days (Document ID 3583, Tr. 2485).

Finally, Dr. Marlow asserts that OSHA overstates its externality argument for regulation because the source of the externality is not silica exposure, but rather workers’ compensation and social insurance programs that shift the costs of silica exposure onto third parties. OSHA agrees that workers overexposed to silica are not the source of the externality, but the victims of it. The final rule is an attempt to help mitigate the effects of the externality using a method that is under OSHA's purview.

SUMMARY

OSHA's primary reasons for going forward with this final rule are based on the requirements of the OSH Act and are discussed in Section II of the preamble, Pertinent Legal Authority. As shown in the preamble to the final silica rule and this FEA, OSHA has determined that some workers in certain industries are exposed to silica and face a significant risk of developing silicosis, lung cancer, and end-stage renal disease. This section has shown that the private market— even when augmented by information dissemination programs, workers' compensation systems, and tort liability options—appears to still operate at a level of risk for these workers that is higher than socially optimal due to a lack of information about health risks, the presence of externalities or imperfect competition, and other factors discussed above.

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CHAPTER III: PROFILE OF AFFECTED INDUSTRIES

INTRODUCTION

In this chapter, OSHA presents profile data for industries with potential silica exposure. As a first step, OSHA identifies the North American Industrial Classification System (NAICS) industries, both in general industry and maritime and in the construction sector, with potential worker exposure to silica. OSHA's final profile ranges from industries where worker exposure is documented and ongoing to industries where current occupational exposure is uncertain.[1] OSHA included preliminary profile data in the Preliminary Economic Analysis (PEA) and received public comment on those profiles. In this chapter, OSHA reviews the public comments on the preliminary profile and presents the Agency's response to those comments.

Next, OSHA provides revised summary statistics for the affected industries, including the number of affected entities and establishments, the number of workers whose exposure to silica could result in disease or death ("at-risk workers"), and the average revenue for affected entities and establishments.[2] This information is provided for each affected

[1] The following list explains how OSHA categorized the various industries potentially affected by OSHA's final rule:
Group 1: Industries identified in the technological feasibility sections as belonging to a given application group and whose silica samples encompass the bulk of the data points underlying the exposure profiles for that group.
Group 2: Industries for which some exposure samples are available for one or more activities for a given application group, but where the primary economic focus for these industries does not correspond to the primary focus of the application group. Captive foundries are the primary example. These exposure samples are included in one or more exposure profile for the application group and the extent of these activities is judged to be sufficient to add the industry to the list of affected industries and to include it in the cost and benefit estimates. The judgment about whether to include an industry in this group reflected whether industry representatives testified as to the potential for silica exposure in their industry.
Group 3: Similar to Group 2 except that the available samples and other industry information (from testimony or otherwise) were not sufficient to conclude that a significant number of establishments in the industry engage in activities corresponding to the application group. Although the sample data might be used for developing exposure profiles for the application group, the industry is not specifically added to the list of affected industries and is not included in the cost and benefit estimates. Also included in this group are industries for which OIS or IMIS silica sample data exist, but for which the data are insufficient to conclude that such exposures reflect regular, well-defined activities within these industries that have the potential for silica exposures. For industries in Group 3, a description of the industry and the existence of such data are mentioned qualitatively. Examples include NAICS 325314–Fertilizer (Mixing Only) Manufacturing; NAICS 339999-All Other Miscellaneous Manufacturing; and NAICS 423320-Brick, Stone, and Related Construction Material Merchant Wholesalers.

[2] The Census Bureau defines an establishment as a single physical location at which business is conducted or services or industrial operations are performed. The Census Bureau defines a business firm or entity as a business organization consisting of one or more domestic establishments in the same state and industry that were specified under common ownership or control. The firm and the establishment are the same for single-establishment firms. For each multi-establishment firm, establishments in the same industry

industry in total, as well as for small entities as defined by the Small Business Administration (SBA) and for small entities with fewer than 20 employees in each affected industry.

After analyzing the affected industries, OSHA presents silica exposure profiles for at-risk workers and addresses comments on silica exposure among unclassified construction workers and the effect of exposure variability on the profile of affected workplaces. These data are presented by sector and job category. Summary data are also provided for the number of workers in each affected industry who are currently exposed above the new silica PEL of 50 $\mu g/m^3$, as well as above an alternative PEL of 100 $\mu g/m^3$ for economic analysis purposes (while recognizing that the preceding PEL for construction is 250 $\mu g/m^3$). Then, OSHA examines its preliminary and final estimates to adjust for variables such as turnover rates and current baseline practices.

Finally, the Agency discusses methodological issues associated with calculating profit rates, profit, and revenue for affected employers. The factors associated with OSHA's use of survey data to support economic analysis are also discussed.

The methodological basis for the industry and at-risk worker data presented in this chapter comes from the PEA, the Eastern Research Group (ERG) analysis supporting the PEA (2007a, 2007b, 2008a, and 2008b), and ERG's analytic support in preparing this FEA. The data used in this chapter come from the rulemaking record (Docket OSHA-2010-0034), the technological feasibility analyses presented in Chapter IV of this Final Economic Analysis (FEA), and from (OSHA (2016), which updated the earlier PEA spreadsheets to reflect the most recent industry data available. To do so, ERG first matched the BLS Occupational Employment Statistics (OES) survey occupational titles with the at-risk job categories, by NAICS industry. They then calculated the percentages of production employment represented by each at-risk job title within industry (see OSHA, 2016 for details on the calculation of employment percentages and the mapping of at-risk job categorizations into OES occupations).[3] ERG's expertise for identifying the appropriate OES occupations and calculating the employment percentages enabled OSHA to estimate the number of employees in the at-risk job categories by NAICS industry (Id.).

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within a state will be counted as one firm- the firm employment and annual payroll are summed from the associated establishments. (U.S. Census Bureau, Statistics of U.S. Businesses, Definitions. 2015, http://www.census.gov/econ/susb/definitions.html?cssp=SERP)

[3] Production employment includes workers in building and grounds maintenance; forestry, fishing, and farming; installation and maintenance; construction; production; and material handling occupations.

SELECTION OF NAICS INDUSTRIES FOR ANALYSIS

The technological feasibility analyses presented in Chapter IV of this FEA identify the general industry and maritime sectors and the construction activities potentially affected by the final silica standard. The following section discusses OSHA's preliminary methodology for profiling affected application groups in general industry and maritime, followed by public comments on the Agency's preliminary profile of general industry and maritime, and the Agency's final conclusions based on a review of the comments and updated data.

Hydraulic fracturing (HF), a major application group within general industry, is analyzed within a separate section, due to the lengthy and detailed comments provided by HF stakeholders in response to the PEA's treatment of that sector.

The final portion of this section addresses OSHA's preliminary profile of construction application groups, public comments on that profile, and the Agency's response to those comments.

General Industry and Maritime

Employees engaged in various activities in general industry and maritime routinely encounter crystalline silica as a molding material, as an inert mineral additive, as a refractory material, as a sandblasting abrasive, or as a natural component of the base materials with which they work. Some industries use various forms of silica for multiple purposes. As a result, employers are faced with the challenge of limiting worker exposure to silica in dozens of job categories throughout the general industry and maritime sectors.

For the PEA, job categories in general industry and maritime were selected for analysis based on data from the technical industrial hygiene literature, evidence from OSHA Special Emphasis Program (SEP) results, and, in several cases, information from ERG site visit reports. These data sources provided evidence of silica exposures in numerous sectors. While the available data were not entirely comprehensive, OSHA preliminarily concluded in the PEA that silica exposures in other sectors are quite limited.

The 25 industry application groups in the overall general industry and maritime sectors that OSHA identified in the PEA as being potentially affected by the proposed silica standard are as follows:

- Asphalt Paving Products
- Asphalt Roofing Materials
- Industries with Captive Foundries[4]
- Concrete Products
- Cut Stone
- Dental Equipment and Supplies
- Dental Laboratories
- Flat Glass[5]
- Iron Foundries[6]
- Jewelry
- Mineral Processing
- Mineral Wool[7]
- Nonferrous Sand Casting Foundries[8]

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[4] Captive foundries is a subsector of the overall foundries industry described in Chapter IV of this FEA and includes establishments with foundry processes incidental to the primary products manufactured (e.g., heavy equipment manufacturing). Because the number of manufacturing establishments with captive foundry operations is not reported, ERG estimated the number of such establishments by industry using occupational employment information from BLS (2012) presenting, by industry, the number of employees in key foundry occupations. ERG identified those non-foundry industries reporting employment in the "pourers and casters, metal" and "foundry moldmakers and coremakers" occupational categories and then estimated overall employment in captive foundry operations by inflating the number of pourers and casters and foundry moldmakers and coremakers to account for other foundry workers. The Occupational Employment Statistics (OES) survey 6-digit NAICS-based estimates for foundries were then converted to 6-digit NAICS industries with employment in the key foundry occupations. See ERG (2008) for further discussion of the preliminary identification of industries and the development of estimates of the numbers of establishments in this subsector; see OSHA (2016) for the final identification of industries and estimates of the number of establishments.

[5] Flat glass is a subsector of the glass industry described in Chapter IV of this FEA. See also ERG (2008).

[6] Iron foundries are included within a subsector of the overall foundries industry described in Chapter IV of this FEA. See also ERG (2008).

[7] Mineral wool is a subsector of the glass industry described in Chapter IV of this FEA. See also ERG (2008).

[8] Nonferrous sand casting foundries are included within a subsector of the overall foundries industry described in Chapter IV of this FEA. See also ERG (2008).

- Non-Sand Casting Foundries[9]
- Other Ferrous Sand Casting Foundries[10]
- Other Glass Products[11]
- Paint and Coatings
- Porcelain Enameling
- Pottery
- Railroads[12]
- Ready-Mix Concrete
- Refractories
- Refractory Repair
- Shipyards
- Structural Clay

Based on a review of the record, including further analysis of OSHA's Occupational Safety and Health Information System (OIS) data, OSHA has added, for this FEA, the following application groups to the profile of affected employers.

- Engineered Stone Products
- Landscaping Contractors

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[9] Non-sand casting foundries are found within a subsector of the overall foundries industry described in Chapter IV of this FEA. See also in ERG (2008).

[10] Other ferrous sand casting foundries are found within a subsector of the overall foundries industry described in Chapter IV of this FEA. See also ERG (2008).

[11] Other Glass Products is a subsector of the glass industry described in Chapter IV of this FEA. See also ERG (2008).

[12] While the railroad activities that can cause silica exposures are related to track work covered by OSHA's construction standard, OSHA is analyzing railroads in this section because railroads are mainly engaged in operating railroads, not in construction, and are usually grouped with other employers in "general industry" for purposes of economic analysis.

Public Comments on the Preliminary Profile of General Industry and Maritime

Several commenters stated that the PEA appeared to omit NAICS codes (i.e., industries) that would be affected by an OSHA silica standard.

Composite Manufacturing Processes

OSHA did not explicitly account for composite manufacturing processes in its preliminary profile. The American Composite Manufacturers Association questioned whether OSHA's preliminary cost and benefits estimates covered the composites industry manufacturing processes, but did not provide any additional data to assist OSHA in developing its profile of that industry (Document ID 1732, p. 1).

However, some composite manufacturers may have been included among the establishments profiled within two application groups: Cut Stone and Concrete Products. Composite manufacturing was included in NAICS 327999, All Other Miscellaneous Nonmetallic Mineral Product Manufacturing, which OSHA analyzed in the PEA for exposure, compliance costs, and other impacts facing employers and employees in the Concrete Products application group. Furthermore, composite manufacturing processes were addressed in the application group identified as Cut Stone in the PEA and all business entities in NAICS 327991, Cut Stone and Stone Product Manufacturing were included in OSHA's preliminary profile. For this final profile of the final silica rule, OSHA has again analyzed the impacts on the various composite manufacturing processes as part of the industries covered by the same two NAICS codes as in the PEA, but has updated the number of affected establishment and employees to the totals reported in the 2012 Economic Census.

Other Manufacturing

The National Association of Manufacturers (NAM) identified four NAICS codes that they believed were excluded from OSHA's preliminary profile.

> . . . we discovered that several NAM members have NAICS codes that OSHA did not include in the 24 subsectors listed, although these manufacturers know their employees work with silica-containing materials and may be exposed to silica. For example, we identified the following codes that were not included: 332215 (metal kitchen cookware, utensil, cutlery and flatware), 333249 (other industrial machinery manufacturing), 326191 (plastics plumbing fixture manufacturing), and 331529 (other non-ferrous metal foundries—except die-casting) (Document ID 3449, pp. 7-8).

OSHA notes that NAM was referencing the 2012 edition of NAICS and that of the four NAICS codes identified by NAM, two codes (331529 – other non-ferrous metal foundries—except die-casting and 332215 – metal kitchen cookware, utensil, cutlery and flatware) are in fact recognized in the PEA by their 2007 NAICS code (respectively, 332528 and 332214). For this FEA, OSHA has updated all NAICS codes to the 2012 edition.

The other two NAICS codes identified by NAM – 2012 NAICS, 333249, Other Industrial Machinery (2007 NAICS: 333220, 333292, & 333298); and 2012 NAICS 326191, Plastic Plumbing Fixtures (same code in 2007) – were not included in the PEA. For this FEA, OSHA reviewed the Agency's health sampling data from enforcement records for 1979-2014 (Document ID 3958; 4185) and found no significant respirable crystalline silica exposures associated with NAICS 326191 and 333249.[13] Therefore, OSHA concludes that no establishments in those two industries will be required to incur any costs to comply with the final standard, and OSHA is not attributing any benefits from the rule to these industries.

Electric Power Generation, Transmission and Distribution

The Edison Electric Institute (EEI) commented that the PEA did not include Electric Power Generation, Transmission and Distribution (NAICS 2211) within the profile of affected application groups (Document ID 2357, p. 39). As discussed in Chapter IV, Technological Feasibility, OSHA analyzed exposure data for the general industry tasks identified by EEI as potentially affected and the Agency determined that exposures during those tasks rarely if ever exceed the action level. Therefore, OSHA determined that NAICS 2211 will not be significantly affected by the final silica standard for general industry. For analysis of significant worker exposure in construction tasks undertaken by or for electric utilities, see the section titled Construction; Electric utilities later in this chapter.

[13] For NAICS 326191, Plastic Plumbing Fixtures, OSHA determined that there are exposure data for this NAICS code in the OIS (2011-2014) and no exposure data for this NAICS in the most recent Integrated Management Information System (IMIS) (2009-2014). Some IMIS activity on the NAICS code were identified for 1979-2002, and the establishment(s) appeared to be involved in the production of marble plumbing fixtures, such as vanities with marble counter tops, where the crystalline silica helped to create a "swirl" look of faux marble. However, based on discussions with industry experts, OSHA believes that employers in this segment of the industry have substituted away from silica.
For NAICS 333249, Other Industrial Machinery Manufacturing, OSHA determined that there are no data for this NAICS code in OIS (2011-2014); there are no data for this NAICS code in the most recent IMIS (2009-2014); and that results that are present in the "legacy" IMIS (1979-2002) and are in the more recent IMIS (2009-2014) for the legacy SIC codes associated with this NAICS code have little if any silica detected in samples or are engaged in industrial applications that are unlikely to involve significant silica exposures.

Auto Body Operations

In public testimony (Document ID 3587, Tr. 3718-3719) and in comments submitted for the record (Document ID 2358; 4019, p. 1; 4198, p. 1), the National Automobile Dealers Association (NADA) identified three NAICS industries that were omitted from OSHA's preliminary analysis but might potentially have silica exposures: NAICS 42311, 44111, and 811121. NADA stated the following in pre-hearing comments.

> Franchised automobile dealerships fall under North American Industry Classification System (NAICS) 44111 (SIC 5511) and commercial truck dealerships under NAICS 42311 (SIC 5012). The fact that neither of these NAICS codes is listed in OSHA's profile of affected industries is appropriate given that the overwhelming majority of dealership employees are rarely, if ever, exposed to airborne crystalline silica in their workplaces.
>
> At the same time, approximately 34% of automobile and truck dealerships involve auto body operations. This percentage has declined over time from approximately 60% in the mid-1980s. Dealership auto body operations are a profit center focused on motor vehicle collision and paint repair. These operations employ some 62,000 employees nationwide. The work taking place in auto body operations at franchised automobile and truck dealerships is similar to that at body shops falling within *Automotive Body, Paint, and Interior Repair, and Maintenance*, NAICS 811121 (SIC 7532). Notably, NAICS 811121 was also excluded from the proposal's profile of affected industries (Document ID 2358, p. 1).

NADA's concern was that historically the potential for airborne crystalline silica in auto body operations has been limited to two scenarios involving auto body technicians and painting prep workers: (1) sanding of vehicles and vehicle body panel surfaces and (2) the removal of paint or rust from vehicles or vehicle body panels. In those operations, small amounts of respirable crystalline silica were found in body fillers, paint system components, and abrasives (Document ID 2358, p. 4).

However, according to NADA, "[c]urrent work practices combined with the use of crystalline silica-free products and appropriate respiratory protection have served to largely eliminate any significant concerns regarding exposures to respirable crystalline silica in the auto body shop environment" (Document ID 2358, p. 2). Because significant exposures have largely been eliminated, NADA requested that OSHA exclude automobile dealerships and body shops from the scope of the rule on the grounds that silica exposures in these industries are *de minimis* (Document ID 2358, p. 3).

Because NADA has identified the continued presence, however minor, of silica in auto body shops in automobile and truck dealerships, OSHA in this final profile of affected industries has included NAICS 44111, 42311, and 811121 within the scope of the analysis to examine what costs the rule might generate for this industry.[14] In Chapter V, Costs of Compliance, in this FEA, OSHA addresses the compliance strategy, and associated costs, anticipated for the automobile industry. OSHA expects these costs to be incurred even if no auto body entity falling within these NAICS codes is ultimately determined to be within the scope of the rule.

Concrete Processing and Transportation

The National Concrete Masonry Association questioned the completeness of OSHA's preliminary profile of tasks in concrete plants:

> A number of position descriptions in a concrete block plant have exposure to respirable silica in outdoor storage and staging areas. These include those operating forklifts primarily for product transport, front-end loaders primarily for aggregate transport, and others associated with sorting/stacking and loading trucks (Document ID 2279, p. 6).

In the PEA, for the application group Concrete Products, OSHA addressed the broader group of material handlers as affected by the proposed standard; forklift operators are included within that group. In the final technological feasibility analysis, Chapter IV, fuller attention is given to baseline conditions and exposure reduction for material handlers, including forklift operators and other material transport personnel.

Closely associated with the manufacture of concrete products are the processing, transporting, and use of portland cement. The Portland Cement Association (PCA) requested that cement distribution terminals be excluded from the scope of the final rule because PCA survey data appear to indicate that "there is no probability that RCS [respirable crystalline silica] exposures can be generated above the proposed action limit among employees at cement terminals" (Document ID 3751, p. 2). In response, OSHA observes that NAICS 327310, Cement Manufacturing, and NAICS 423320, Brick, Stone, and Related Construction Material Merchant Wholesalers (within which cement terminals are classified), were not included within the preliminary profile. Due to the

[14] Because of the limited impacts expected for employers in these industries, NAICS 42311, 44111, and 811121 may not appear in all industry-wide tables throughout this FEA.

Agency's final determination that silica exposures in cement distribution terminals rarely exceed the action level (see Chapter IV of this FEA, for ready-mix concrete), NAICS 327310 and 423320 are not included in the final profile of affected industries.

Petrochemical Facilities

The American Fuel and Petrochemical Manufacturers (AFPM) questioned whether OSHA had adequately analyzed the impacts of the rule on oil refineries and petrochemical facilities employers, including AFPM members:

> Under normal production cycles, AFPM members do not work with silica related products and do not have employee exposure to RCS. During limited circumstances such as some maintenance, construction and turnaround activities, some of AFPM members' employees work in settings with the potential for exposure to RCS. Accordingly, our members have a substantial interest in this rulemaking . . . . (Document ID 2350, pp. 1-2).

Elsewhere in their comment, AFPM clarified that contracted construction operations at petrochemical facilities can create exposure to silica:

> The nature of the operations in the oil refining and petrochemical industries presents similar compliance difficulties that have not been taken into account in the NPRM. Facility turnarounds and large-scale construction projects require employers in these industries to contract construction, maintenance and repair work. Many of these activities will undoubtedly generate RCS in a variety of activities to levels that will trigger obligations under the proposed rule for both the contractor and the host employer. Yet the NPRM provides no comment and no economic or cost benefit analysis on this issue (Document ID 2350, p. 4).

In response, OSHA states that the PEA intended to include construction tasks conducted at oil and petrochemical plants within OSHA's preliminary profile if occupational exposure to silica prompted coverage under the proposed rule. However, the Agency recognizes that some construction tasks, including facility turnaround, may not have been thoroughly profiled for purposes of estimating costs and benefits for the PEA. For this FEA, OSHA has made every effort to ensure that all types of OSHA-regulated oil and petrochemical sites that are subject to the scope of the final rule are addressed in the final profile of affected workplaces and in the final analysis of costs and other impacts (including costs and impacts in construction), although it is still possible that some covered sites might not be included because of lack of information in the record.

Fertilizer Production and Distribution

The Fertilizer Institute (TFI) identified four NAICS codes that it believed were improperly excluded from OSHA's preliminary profile:

> First, although OSHA's economic analysis appears to have properly excluded [Mine Safety and Health Administration]-regulated entities from the range of NAICS codes in its economic analysis, it did not include an analysis of several fertilizer industries that may have activities that will fall within the scope of the Silica Proposal. For example, in the case of fertilizer production and distribution, TFI cannot rule out the possibility that certain companies in the Phosphate Fertilizer Manufacturing (NAICS: 325312), Nitrogenous Fertilizer Manufacturing (NAICS: 325311), Fertilizer (Mixing Only) Manufacturing (NAICS: 325314), and Farm Supplies Merchant Wholesalers (NAICS: 424910) could be affected by the Silica Proposal. Thus, unless OSHA adopts a clear threshold (*e.g.*, 5% of potentially-respirable crystalline silica) for triggering the operative provisions of a final rule, the incidental presence of naturally-occurring silica minerals in some fertilizer materials could require a much broader regulatory impact analysis. The same may be true within other industries that are anticipated to comment on the Silica Proposal (Document ID 2101, p. 11).

To investigate TFI's claim that the four NAICS industries identified in their comment (325311, 325312, 325314, and 424910) were erroneously omitted from OSHA's preliminary profile, the Agency searched inspection records for evidence of exposure samples in these industries for inclusion in the final profile. For NAICS 325314, Fertilizer (Mixing Only) Manufacturing, as noted in the Technological Feasibility section for Mineral Processing, OSHA identified silica exposure and determined that, at the time of sampling, the workers were performing tasks that were very similar to the tasks performed in Mineral Processing and therefore the NAICS code was appropriately included in the final profile of that application group.

However, for the other three NAICS codes, (325311, 325312, and 424910), OSHA determined that the available sample data and other industry information were not sufficient to conclude that a significant number of establishments in those industries engage in activities corresponding to Mineral Processing and that workers in those industries are exposed to respirable crystalline silica. Neither TFI nor any other commenter provided any sample data or other indication that workers in these NAICS codes are exposed to respirable crystalline silica in the course of their normal work. Therefore, OSHA did not include those three NAICS industries in the final profile.

Railroads

The International Brotherhood of Teamsters (IBT) identified several railroad job categories associated with maintenance-of-way track work where silica exposure can occur, including "laborers, machine operators, heavy equipment operators, on-track roadway maintenance machine operators, welders, and foremen" (Document ID 2318, p. 8). In the PEA, OSHA identified two main job categories, Ballast Dumper and Machine Operator, where significant silica exposures have been recorded. Within the Machine Operator category, OSHA's preliminary industry profile and technological feasibility analysis recognized ballast regulators, broom operators, tamper operators, and other operators.

For this FEA, OSHA evaluated the potential for silica exposure among all affected railroad job categories, including those listed above by IBT, and the Agency determined that, as in the PEA, Ballast Dumper and Machine Operator are the job categories whose workers face significant risk of silica-related disease. Therefore, in this final profile and in the technological feasibility analysis in Chapter IV, OSHA identifies the number of affected workers in the Ballast Dumper and Machine Operator job categories that were sampled for silica exposure and the distribution of these populations across exposure ranges (see Tables III-8 and III-9, below; and OSHA, 2016). OSHA recognizes that a number of workers could be nearby and thus exposed during ballast dumping activities, but they are accounted for in this analysis because they would either be considered engaged in the ballast dumping activities (categorized as ballast dumpers or operators) and protected by the required controls or the employer would ensure that they would not be exposed to silica because they would be removed to a safe area during the dust-producing portions of ballast dumping activities in accordance with the written exposure control plan required by paragraph (g) of the construction standard.

Mineral Wool

The North American Insulation Manufacturers Association questioned OSHA's source of data used in developing the Agency's preliminary profile of the Mineral Wool application group. They asserted that OSHA's PEA "included mineral wool manufacturing in its analysis of the glass industry, along with flat glass manufacturing, other pressed blown glass and glassware manufacturing, and glass container manufacturing," but complained that OSHA's exposure data were drawn from a subset of those activities:

> [N]o actual mineral wool manufacturing facility data was used for OSHA's baseline conditions and exposure profile for the larger glass industry. Rather, OSHA used only data from two National Institute for

> Occupational Safety and Health ("NIOSH") reports summarizing site visits to two large flat glass manufacturing facilities and an OSHA Special Emphasis Program ("SEP") inspection report concerning a large glass products facility. Together these provide 12 silica exposure measurements divided between two employee categories: (1) "Material Handlers" and (2) "Batch Operators and associated workers, including workers performing housekeeping/maintenance in the vicinity of such operations." OSHA used only these 12 exposure samples to develop baseline conditions and an exposure profile for the entire and diverse glass industry. Based on this sparse information, OSHA determined that exposures in these two job categories could exceed the proposed PEL and made feasibility findings for the entire glass industry.
>
> In sum, OSHA's data does not present substantial evidence for its feasibility conclusions regarding the Mineral Wool Industry. NAIMA requests that OSHA modify its PEA with an acknowledgement that none of its data came from the Mineral Wool Industry
> (Document ID 2348, pp. 18-19)(citations omitted).

In response, OSHA notes that in the PEA, Mineral Wool Manufacturing (NAICS 327993) was included in the profile as an affected industry, with an exposed worker population of 1,090 employees in 195 entities operating 321 establishments (100 percent of the entities and establishments reported by the Census Bureau). For this FEA, the 2012 Economic Census is the basic source of OSHA's estimate of affected workers, entities and establishments (see Table III-6). Chapter IV, Technological Feasibility, Section IV-11, Glass, presents details for OSHA's final exposure profile for affected workers in mineral wool manufacturing; see Table III-8 for a summary of the final exposure profile.

Determination of industries affected by the general industry and maritime standard

As described in the PEA, based on the ERG analysis (2008b), OSHA identified the six-digit NAICS codes for these subsectors to develop a list of industries potentially affected by the proposed silica standard.[15] In some cases, such as in the foundry and glass industries, affected sectors discussed in ERG (2008b) were disaggregated to facilitate the

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[15] For the PEA, ERG (2008) discussed potential silica exposures in the engineered stone and landscape contracting industries. These industries were judged to generate negligible levels of silica exposure in the United States and, as a result, no compliance costs were estimated for these industries. Accordingly, these industries were not shown in the remainder of the scope, cost, and impact tables in the PEA.

For this FEA, OSHA identified silica exposure at levels that warranted further consideration in terms of potential impacts under the scope of the final rule. See Section IV-9, Engineered Stone, and Section IV-13, Landscape Contracting, in Chapter IV of this FEA for a full exposition of the exposure profile and analysis of control technology to reduce exposure to silica for Engineered Stone and Landscape Contracting.

cost and economic impact analysis in the PEA and in this FEA. Table III-1 presents OSHA's final set of affected application groups along with their corresponding six-digit NAICS industries.

When evaluating Table III-1 in relation to OSHA's preliminary profile of affected application groups, the following two points must be understood.

First, OSHA is aware that many industries have some silica exposure below the action level. Such industries will incur no costs as a result of the final rule. OSHA has only provided more explicit consideration of such industries when information for those industries entered the record, but the absence of discussion of exposures in an industry does not indicate that OSHA intended to exempt employers in that industry from compliance with the silica standard if it turns out that significant exposures exist. In other words, lack of record evidence showing significant exposures in the past, or affirmative evidence of exposures well below the action level, does not mean that an industry is permanently outside the scope of the rule if, in reality, their employees are, or will foreseeably be, subject to exposures at or above the action level once the rule goes into effect.

Second, OSHA's review of the rulemaking record leads the Agency to conclude that, while there may be some inevitable over- and under-inclusion of industries and over- and under-estimation of exposure levels, the costs and benefits estimated in this FEA are based on the best available evidence. The possible effects of occasional exposure in an industry on economic feasibility will be discussed in Chapter VI: Economic Feasibility Analysis and Final Regulatory Flexibility Determination.

Table III-1: General Industry and Maritime Application Groups and Industries Affected by OSHA's Final Silica Rule

Application Group	NAICS	Industry
Asphalt Paving Products	324121	Asphalt paving mixture and block manufacturing
Asphalt Roofing Materials	324122	Asphalt shingle and coating materials mfg.
Captive Foundries	331110	Iron and steel mills and ferroalloy mfg.
	331210	Iron and steel pipe and tube mfg. from purchased steel
	331221	Rolled steel shape manufacturing
	331222	Steel wire drawing
	331314	Secondary smelting and alloying of aluminum
	331420	Copper rolling, drawing, extruding, and alloying
	331492	Secondary smelting, refining, and alloying of nonferrous metal (except copper and aluminum)
	332111	Iron and steel forging
	332112	Nonferrous forging
	332117	Powder metallurgy part manufacturing
	332119	Metal crown, closure, and other metal stamping (except automotive)
	332215	Metal kitchen cookware, utensil, cutlery, and flatware (except precious) manufacturing
	332216	Saw blade and handtool manufacturing
	332439	Other metal container manufacturing
	332510	Hardware manufacturing
	332613	Spring manufacturing
	332618	Other fabricated wire product manufacturing
	332710	Machine shops
	332911	Industrial valve manufacturing
	332912	Fluid power valve and hose fitting mfg.
	332913	Plumbing fixture fitting and trim mfg.
	332919	Other metal valve and pipe fitting mfg.
	332991	Ball and roller bearing manufacturing
	332996	Fabricated pipe and pipe fitting mfg.
	332999	All other miscellaneous fabricated metal product manufacturing

Table III-1: General Industry and Maritime Application Groups and Industries Affected by OSHA's Final Silica Rule (Continued)

Application Group	NAICS	Industry
Captive Foundries (contd.)	333318	Other commercial & service industry machinery manufacturing
	333413	Industrial and Commercial Fan and Blower and Air Purification Equipment Manufacturing
	333414	Heating Equipment (except Warm Air Furnaces) Manufacturing
	333511	Industrial Mold Manufacturing
	333514	Special Die and Tool, Die Set, Jig, and Fixture Manufacturing
	333515	Cutting Tool and Machine Tool Accessory Manufacturing
	333517	Machine Tool Manufacturing
	333519	Rolling Mill and Other Metalworking Machinery Manufacturing
	333612	Speed changer, industrial high-speed drive, and gear manufacturing
	333613	Mechanical power transmission equipment manufacturing
	333911	Pump and pumping equipment manufacturing
	333912	Air & gas compressor manufacturing
	333991	Power-driven handtool manufacturing
	333992	Welding & soldering equipment manufacturing
	333993	Packaging machinery manufacturing
	333994	Industrial process furnace and oven mfg.
	333995	Fluid power cylinder and actuator mfg.
	333996	Fluid power pump and motor manufacturing
	333997	Scale and balance manufacturing
	333999	All other miscellaneous general purpose machinery manufacturing
	334519	Other measuring and controlling device manufacturing
	336111	Automobile manufacturing
	336112	Light truck and utility vehicle manufacturing
	336120	Heavy duty truck manufacturing
	336211	Motor vehicle body manufacturing
	336212	Truck trailer manufacturing
	336213	Motor home manufacturing
	336310	Motor vehicle gasoline engine and engine parts manufacturing

Table III-1: General Industry and Maritime Application Groups and Industries Affected by OSHA's Final Silica Rule (Continued)

Application Group	NAICS	Industry
Captive Foundries (contd.)	336320	Motor Vehicle Electrical and Electronic Equipment Manufacturing
	336330	Motor vehicle steering and suspension components (except spring) manufacturing
	336340	Motor vehicle brake system manufacturing
	336350	Motor vehicle transmission and power train parts manufacturing
	336370	Motor vehicle metal stamping
	336390	Other motor vehicle parts manufacturing
	336992	Military armored vehicle, tank, and tank component manufacturing
	337215	Showcase, partition, shelving, & locker mfg.
	339910	Jewelry and Silverware Manufacturing
Concrete Products	327331	Concrete block and brick manufacturing
	327332	Concrete pipe manufacturing
	327390	Other concrete product manufacturing
	327999	All other miscellaneous nonmetallic mineral product manufacturing
Cut Stone	327991	Cut stone and stone product manufacturing
	337110	Wood kitchen cabinet and countertop manufacturing
	444110	Home centers
Dental Equipment and Supplies	339114	Dental equipment and supplies manufacturing
Dental Laboratories	339116	Dental laboratories
	621210	Offices of dentists
Engineered Stone Products	327991	Cut stone and stone product manufacturing
Ferrous Sand Casting Foundries	331511	Iron foundries
	331513	Steel foundries (except investment foundries)
Fertilizer Manufacturing	325314	Fertilizer (mixing only) manufacturing
Flat Glass	327211	Flat glass manufacturing
Hydraulic Fracturing	213112	Support activities for oil and gas operations
Jewelry, Fine	339910	Jewelry and silverware manufacturing
Jewelry, Costume	339910	Jewelry and silverware manufacturing
Landscape Contracting	561730	Landscaping services
Mineral Processing	327992	Ground or treated mineral and earth manufacturing
Mineral Wool	327993	Mineral wool manufacturing
Nonferrous Sand Casting Foundries	331524	Aluminum foundries (except die-casting)

Table III-1: General Industry and Maritime Application Groups and Industries Affected by OSHA's Final Silica Rule (Continued)

Application Group	NAICS	Industry
	331529	Other nonferrous metal foundries (except die-casting)
Non-Sand Casting Foundries	331512	Steel investment foundries
Other Glass Products	327212	Other pressed and blown glass and glassware manufacturing
	327213	Glass container manufacturing
Paint and Coatings	325510	Paint and coating manufacturing
Porcelain Enameling	332323	Ornamental and architectural metal work manufacturing
	332812	Metal coating and allied services
	332999	All other miscellaneous fabricated metal product manufacturing
	335210	Small electrical appliance manufacturing
	335221	Household cooking appliance manufacturing
	335222	Household refrigerator and home freezer manufacturing
	335224	Household laundry equipment manufacturing
	335228	Other major household appliance manufacturing
	339950	Sign manufacturing
Pottery	327110	Pottery, ceramics, and plumbing fixture manufacturing
Railroads	482110	Rail transportation
Ready-Mix Concrete	327320	Ready-mix concrete manufacturing
Refractories	327120	Clay building material and refractories manufacturing
Refractory Repair	423840	Industrial supplies merchant wholesalers
Shipyards*	336611	Ship building and repairing
	336612	Boat building
Structural Clay	327120	Clay building material and refractories manufacturing

* The maritime industry encompasses the shipbuilding and repair industry (shipyards) as well as the marine cargo handling industry. Abrasive blasting with silica-containing abrasive is a widely-recognized source of silica exposure in the maritime industry and is addressed in this part of the analysis.

Source: OSHA, Directorate of Standards and Guidance, based on OSHA, 2016.

Hydraulic Fracturing

OSHA received a disproportionate amount of comments on the profile characteristics for, and economic effects of the standard on, hydraulic fracturing in the oil and gas extraction industry. The review of the preliminary industry profile of hydraulic fracturing presented below is lengthier than the profile discussion for any other affected application group for two reasons: (1) the preliminary profile for hydraulic fracturing involved uniquely complex challenges for modeling the production activities on an oil and gas well drilling site, and (2) because of those production modeling complexities, detailed stakeholder commentary required OSHA, in turn, to reevaluate a number of the model's methodological assumptions and adjust the profile where necessary.

In this section, OSHA presents a brief description of the hydraulic fracturing application group and its activities. OSHA then identifies the NAICS industries with potential worker exposure to silica during hydraulic fracturing. Next, OSHA (1) reviews the preliminary summary statistics for the affected entities and establishments, and the average revenue for affected entities and establishments (2) discusses public comments concerning OSHA's preliminary profile, and (3) addresses the issues on the industrial profile of hydraulic fracturing raised by commenters.

The information in this profile is provided for each affected NAICS industry in total, as well as for small entities as defined by SBA. Finally, in this profile of hydraulic fracturing, OSHA provides other production estimates that will be useful for subsequent cost estimates. The following paragraphs summarize production and process information on the industry; see the PEA and Chapter IV, Technological Feasibility, of this FEA for a fuller discussion of these topics.

Hydraulic fracturing is a process used to extract natural gas and oil deposits from shale and other tight geologic formations. The process begins once well drilling is complete. Workers in the oil and gas industry pump fracturing fluid, composed of base fluid (usually water); a proppant (usually sand); and chemical additives, into the new well bore under extremely high pressures (e.g., 7,000 psi to 9,000 psi) (Esswein, 2012, Document ID 1578). The high pressure fractures the shale or rock formation, allowing the natural gas trapped in the formation to flow into the well. Silica sand that is used as a proppant contains a high percentage of crystalline silica, typically ranging from 60 percent to 100 percent depending on the source (Halliburton MSDS, 2008, Document ID 1529; Carmeuse MSDS, 2009, Document ID 1525). Therefore, when silica sand is used as a proppant in hydraulic fracturing, high concentrations of respirable silica dust can become airborne as workers deliver, convey, and mix the sand with fracturing fluid. [16]

Hydraulic fracturing crews work as a team that travels from well site to well site. Individual workers are specialized and have defined roles. Those whose jobs keep them in the central area near the sand-handling equipment can experience high levels of respirable silica exposure. Ancillary workers who have work locations on the perimeter can experience elevated silica exposures, although they are not in the immediate vicinity of the dust emissions. Workers whose jobs either do not require entry into the central work area or only require entry intermittently experience variable exposure depending on the amount of time they spend near dusty activities.

Hydraulic Fracturing -- Affected Industries by NAICS

Oilfield activities are classified primarily into five NAICS codes, but only one encompasses hydraulic fracturing:

- NAICS 211111 (Crude Petroleum and Natural Gas Extraction)
- NAICS 211112 (Natural Gas Liquid Extraction)
- NAICS 213111 (Drilling Oil and Gas Wells)
- NAICS 213112 (Support Services for Oil and Gas Operations)
- NAICS 333132 (Oil and Gas Field Machinery and Equipment Manufacturing)

U.S. Census (Census Bureau, 2015b) identifies NAICS 213112 (Support Services for Oil and Gas Operations), as the industry that includes the establishments involved in hydraulic fracturing. This NAICS code also captures a range of other oilfield service activities (other oil and gas field services; oil and gas exploration services; oil and gas well surveying; cementing oil and gas wells; and running, cutting, and pulling casings,

[16] Hydraulic fracturing crews frequently spend several days performing active hydraulic fracturing at a site where a well has several zones, with additional days for equipment setup and removal on the days before and after hydraulic fracturing. The stay can be longer when multiple wells are located at the same site. Once the job is complete, the crew moves onto another site, where the process is repeated. The hydraulic fracturing process is a relatively brief phase of well installation, which can take three or four months, including site preparation, drilling, installing pipelines, and the initial stages of environmental reclamation (Rader, 2102, Document ID 1535). Over this period, a number of different specialized work crews will occupy the site, often for overlapping periods. During hydraulic fracturing several dozen workers can be on the site, but most work occurs outside the central sand-handling zone, which is only occupied by fracturing sand workers. The number of fracturing sand workers typically ranges from a half-dozen to two dozen, depending on the size of the project and whether multiple hydraulic fracturing crews are involved. A crew of ten to twelve workers is typical (STEPS, 2012, Document ID 1537).

The worksite around the wellhead is known as the well pad. The size of the well pad will vary, depending on the location, but it is typically between 1.5 and 5.7 acres. A well pad may contain one well, but it has become common to drill multiple wells from a single well pad (NYSDEC, 2011, Document ID 1595).

tubes, or rods) designed to support oilfield exploration or to supplement the production from oil and gas wells. In 2012, hydraulic fracturing represented 21.6 percent of the economic activity in NAICS 213112 (Census Bureau, 2015b). Table III-2 presents the seven- and eight-digit NAICS service divisions within NAICS 213112 where significant shipment values were reported.

Discussions held by ERG with industry personnel and a review of the available literature confirm the Census data: hydraulic fracturing is performed almost entirely by oilfield service contractors that are classified in NAICS 213112. These contractors are employed by oil and gas firms. Some industry contacts also mentioned that a few oil and gas producers own and deploy their own fracturing crews, but noted that the share of fracturing activity performed by oil and gas firms is negligible. Therefore, in the analysis in both the PEA and this FEA, OSHA has ignored the portion of hydraulic fracturing that might be performed by oil and gas production companies and focused on NAICS 213112. OSHA requested comment on the size and scope of hydraulic fracturing performed by oil and gas production companies; public comments are presented below.

The character of the hydraulic fracturing application group is blurred by the additional services the companies engaged in hydraulic fracturing might provide. At the large firms, extensive engineering and well management services are often provided. Firms also manufacture some well equipment and otherwise reflect the diversity of activities in the oilfield. In an online business publication produced by Dun & Bradstreet, some of the largest entities are classified in multiple NAICS codes (Dun & Bradstreet, 2013, Document ID 1569).[17] These NAICS designations might be accurate, as the various companies engage in a range of oilfield activities.

Even among the smallest firms, companies performing hydraulic fracturing might also offer various well services (e.g., acidizing, where acid pumped into the formation helps to improve flow) that might help keep low-pressure wells producing. Most of these other activities offered by the smallest firms, however, are within the coverage of NAICS 213112.

[17] As information provided to both Dun & Bradstreet and Census is self-reported by the employer and is not subject to audit, some of the listings or data might be erroneous and subject to revision at each publication cycle.

Table III-2: Product Line Breakdown for Support Services for Oil and Gas Operations (NAICS 213112)

Product code	Industry	Value of shipments for the product code (1,000)	Percentage of Industry Value (%)[a]
213112	**Support activities for oil & gas operations**	**$80,766,512**	**100%**
21311235	Other oil & gas field services	$41,383,751	51.2%
21311233	**Hydraulic fracturing of oil & gas wells**	**17,465,941**	**21.6%**
213112W	Support activities for oil & gas operations, not specified by kind	9,515,774	11.8%
21311231	Cementing oil & gas wells	3,397,211	4.2%
21311232	Oil & gas well surveying & well logging	3,114,888	3.9%
21311234	Running, cutting, & pulling casings, tubes, or rods	2,987,921	3.7%
21311211	Oil & gas field exploration services	2,901,026	3.6%

[a] Total does not equal the sum of components as result of rounding.

Source: U.S. Census Bureau, 2015b[18]

Characteristics of Affected Entities and Establishments

Number of Entities

Based on discussions with industry contacts, a review of the literature by ERG, and an examination of websites advertising hydraulic fracturing services, OSHA estimated in the PEA that approximately 200 entities (firms) were engaged in hydraulic fracturing. Three large companies accounted for approximately 30 percent of the hydraulic fracturing market (measured in dollar volume of fracturing activity), whereas a second tier of approximately 10 firms served a substantial share of the remaining market, had sufficient equipment to handle the largest hydraulic fracturing jobs, but did not provide the same range of technical services as the largest three firms. A third tier consisted of approximately 40 to 50 firms that also had capability for large hydraulic fracturing jobs but were not as widely active across oil and gas regions in the United States.

In the preliminary analysis, the final, fourth tier consisted of small, possibly single-crew, hydraulic fracturing companies that only had sufficient capacity to handle minor, low-

[18] U.S. Census Bureau, 2012 Economic Census, Table EC1221I2: Mining: Industry Series: Product or Service Statistics for the U.S. Census.

pressure refracturing jobs on conventional oil and gas wells.[19] All of the major oil and gas producing regions host a number of these very small hydraulic fracturing firms, and although no reliable figures were identified, OSHA, based on ERG's interviews with industry representatives, estimated that there were approximately 150 of them. Employment within these small companies can be as low as 20 or fewer workers, as very small hydraulic fracturing jobs might be accomplished with as few as 5 or 6 workers. With additional administrative and technical support personnel, it is estimated that the smallest firm size would require at least 10 employees. One industry contact noted that it is possible that some operations are run by sole proprietors who then assemble a temporary hydraulic fracturing crew for individual jobs (ERG, 2013b). The frequency of this arrangement was not known and was likely very limited because of the difficulty of assembling a sufficiently experienced crew for individual jobs.

Number of Establishments

To estimate the number of establishments in the hydraulic fracturing application group, ERG examined the company websites of some of the largest firms in that group in order to gauge the approximate number of establishments each firm operated. While the small firms are almost certainly operating in one or two locations, ERG noted that the largest firms operate up to 30 locations in the United States. From these data and discussions with experts on hydraulic fracturing, ERG estimated the number of establishments per entity across various size classes in order to derive the aggregate number of affected establishments. Using these judgments, ERG estimated that the 200 entities in hydraulic fracturing operate 444 establishments and 530 fleets (the operational unit for hydraulic fracturing entities). OSHA relied on these estimates in the PEA, and the estimates supporting this calculation were shown in Table A-4 in the PEA and are reproduced below in Table III-3.[20]

[19] Refracturing is an operation to restimulate a well after an initial period of production. It is performed to restore well productivity to near original or even higher rates of production and to extend the productive life of a well (Schlumberger, 2013).

[20] The discussion in the previous section referred to three large hydraulic fracturing companies accounting for 30 percent of the market (in terms of dollar volume). As shown in Table III-3, four hydraulic fracturing companies (entities) have an estimated employment of 500 or more workers per entity.

Table III-3: Estimated Number of Hydraulic Fracturing Establishments and Fleets in OSHA's PEA

Employee Size Category	Estimated Number of Entities in Hydraulic Fracturing	Estimated No. of Establishments per Entity	Total Establishments	Total Fleets
10-19	100	1	100	100
20-99	50	1.2	60	60
100-499	46	4	184	184
500+	4	25	100	186
Total	**200**		**444**	**530**

Source: OSHA, Directorate of Standards and Guidance, Office of Regulatory Analysis, based on ERG, 2013b.

In its comments, the American Petroleum Institute and the Independent Petroleum Association of America (API/IPAA or "the Associations") presented data on typical fleet size and numbers of affected employees.

> OSHA's estimate that there are 530 hydraulic fracturing fleets with 15.6 million [hydraulic horsepower] HHP operating in the United States (derived from a 2012 analysis by PacWest Consulting Partners) may be a reasonable estimate for 2012, but it is not the most current or accurate estimate. As noted in PacWest's more recent May 2013 analysis of aggregate pumping capacity, domestic hydraulic fracturing capacity was projected to increase by 700,000 HHP from the 2012 estimate utilized by OSHA and ERG, "bringing total US capacity to 16.3 million HHP," by the end of 2013. Our recent discussion with another well-regarded source of industry financial information, Richard Spears, generally corroborates this estimate regarding the increase in industry capacity by the end of calendar year 2013.
>
> PacWest, however, did not estimate the number of fleets it associated with the increase aggregate pumping capacity. Applying the 4.29% increase in HHP that PacWest reported between 2012 and 2013 to its earlier estimate that 530 fleets operated in 2012, the best available evidence strongly suggests that there are now approximately 553 hydraulic fracturing fleets operating in the United States. Importantly, the 23-fleet increase between 2012 and 2013 is further ratified by dividing the total reported HHP increase of 700,000 by OSHA's estimate of "30,000 horsepower for a typical fleet."

> While we appreciate the difficulty in affixing an estimate to a changing demographic, we believe that OSHA must rely on the most recent data available from the sources on which it bases its analysis. As such, the Associations request that OSHA update its employment/fleet profile, and all calculations derived therefrom, based on this "best available evidence" (Document ID 2301, pp. 18-19)(citations omitted).

As indicated in the PEA, the Census data are not sufficiently precise to isolate the hydraulic fracturing component from the larger NAICS (213112) covering oilfield services. Nevertheless, OSHA did not base the estimated size distribution of the hydraulic fracturing application group on Census or other published data. OSHA notes that API/IPAA's number of fleets does not vary significantly from the estimate that OSHA used in the PEA: the available data on the number of fracturing fleets, as estimated by PacWest, placed the number at 530 fleets while API/IPAA offered an estimate of 553 fleets. OSHA judges these totals to be roughly consistent with the establishment estimates below given that larger establishments will likely operate more than one hydraulic fracturing fleet.

OSHA is not accepting API/IPAA's higher estimate for the number of fleets because there is no record evidence to support API/IPAA's hypothesis that employers increased their fleet size in response to a single-year snapshot of increased pumping capacity. API/IPAA's estimate is extrapolated entirely from a 4.29 percent increase in aggregate pumping capacity that the commenters argued reflected an upturn in the hydraulic fracturing industry several years ago, occurring after the timeframe of OSHA's estimate, that theoretically could have caused employers to increase their number of fleets. But although API/IPAA shared feedback from its member organizations about actual increases in crew size, it did not provide any such evidence that an increase in fleets actually followed the increase in aggregate pumping capacity, or that the aggregate pumping capacity has remained at that level. In fact, even if the hydraulic fracturing employers had increased their fleets during a brief upturn in the industry, by the same logic the employers would also decrease the number of fleets during a downturn in the industry. While the industry did experience growth in recent years, there is no evidence that the growth continued. OSHA therefore concludes that the estimates of establishments and fleets based on objective third-party data, the source of which is not disputed by the commenter, provides better evidence of production activity in the industry than API/IPAA's manipulation of that data based on extrapolations and assumptions based on a short period of past growth. (However, see Chapter VI of this FEA for a discussion of the uncertainties concerning the future of the hydraulic fracturing industry.)

Table III-4 presents the estimated number of hydraulic fracturing firms and establishments; all entities in the table will be affected by the final standard.[21] Table III-4 is identical to Table III-3, as there are no changes from OSHA's preliminary estimates.

Table III-4: Final Estimate of the Number of Hydraulic Fracturing Establishments Affected by the Final Rule

Employee Size Category (Entity)	Estimated Number of Entities Specializing in Hydraulic Fracturing	Estimated No. of Establishments per Entity	Total Establish-ments	Total Fleets
10-19	100	1	100	100
20-99	50	1.2	60	60
100-499	46	4	184	184
500+	4	25	100	186
Total	**200**		**444**	**530**

Source: OSHA, Directorate of Standards and Guidance, Office of Regulatory Analysis, based on OSHA, 2016.

Number of Employees

API/IPAA also addressed OSHA's estimates of the numbers of employees involved in hydraulic fracturing:

> The Associations further believe that OSHA and ERG underestimated the average number of workers in the "large crews" required for deeper, more complex, higher pressure fractures with horizontal components, and that this difference in the size of large crews should also change OSHA's estimates regarding the size of a "typical" or average crew. OSHA estimated that large crews employ between 15 and 20 workers and assigned a midpoint estimate of 17.5, but never explained the basis for this estimate. Elsewhere, OSHA provided its understanding of the functional

[21] As discussed above, API/IPAA commented that an estimate of 150 small entities was unaccountably changed into an estimate of only 100 small entities. In the table below, however, the 150 'small' entities were always intended to include the entities in both the 10-to-19 and the 20-to-99 size categories. Among the establishments in the 20-to-99 category, ERG judged that these firms were clustered at the lower end of that category. The term 'small' was that used by ERG's industry consultants and was not based on the Small Business Administration's definition or any other precise definition. Neither ERG nor other sources could provide detailed information on the size distribution of hydraulic fracturing firms.

distribution of a “typical hydraulic fracturing crew,” consisting of 16 workers:

Estimated Number of Workers	**Primary Function**
5	Sand Mover Operators
1	Conveyor Belt Tender
2	Blender Tenders
1	Hydration Unit Operator
2	Water/Chemical Hands
3	Pump Operator Technicians
1	Supervisor
1	Ground Guide (Sand Coordinator)
16	

Members of the Associations have stated that crew size and functional distribution are variable depending on region, well size, depth, pressure needs, complexity, and company policies. While they viewed the distribution above as a reasonable portrayal of a hydraulic fracturing crew generally, they did not view it as an accurate portrayal of a “large crew.” In particular, members of the Associations stated that large fracturing jobs frequently require more than five sand movers – sometimes as many as eight or more, with one sand mover operator per sand mover. A large fleet and the crew that is a part of that fleet will thus have more than the five sand mover operators shown in the table above; we would estimate six to be an appropriate average. Similarly, OSHA’s profile incorrectly assumes only one hydration unit operator in the crew. On a large crew, however, there are commonly three to four hydration unit operators. Members of the Associations further reported that “large crews” would likely have up to five pump operator technicians, and, if two blenders were in use, could have twice as many blender tenders [as] well. Additionally, large crews would also likely include repair and maintenance personnel and other technicians and support personnel. As such, the Associations believe it is more accurate to estimate that a large hydraulic fracturing fleet typically contains between 20 and 25 workers, and, in some cases, even more. We will assume 24 as the average crew size for a large crew, and we request that OSHA utilize a similar figure for its estimate of “large crew” size.
* * *

In the Table below, we estimate total industry employment of 29,368 hydraulic fracturing workers in the crews working with these fleets.

Fleet Size	Avg. # Workers Per Crew	# Primary Crews Per Fleet	# Rotation/Relief Crews Per Fleet	# Fleets	Total # of Workers
Small	8	1	0	104	832
Medium	16	2	1	255	12,240
Large	24	2	1 1/2	194	16,296
					29,368

(Document ID 2301, pp. 18-22)(citations omitted)

OSHA finds this analysis convincing and is increasing the number of crews per fleet in response to the higher estimates of employees presented by the Associations. In the PEA, OSHA estimated hydraulic fracturing-specific employment based on an estimated average crew size of 16 workers, allowing for two crews per fleet on average. This calculation was intended to take into account both single crew (daytime-only crews) and around-the-clock hydraulic fracturing operations in which three crews (day, night and relief crews) would be assigned to a single fleet of equipment, resulting in a total of 16,960 workers across 530 fleets. For this final profile, OSHA finds that the average number of crews per fleet is likely to be larger than two because the small crews and firms represent a smaller share of all activities than was estimated in the PEA. OSHA has therefore increased the fleet size in its final estimate to an average of three crews per fleet. Table III-17 presents the breakdown of employment by job function in OSHA's final profile of hydraulic fracturing.

As noted earlier, however, the Associations criticized OSHA's estimate of 16,960 workers, arguing that the largest crews were larger than OSHA's preliminary estimates, and OSHA has accepted the Associations' estimates on fleet sizes. For this final profile, OSHA concluded that the average number of crews per fleet is likely to be larger than two because the small crews and firms represent a smaller share of all activities than was estimated in the PEA. Allowing for three crews per fleet, the total hydraulic fracturing industry employment is estimated to be 25,440 workers. The difference between OSHA's final employment estimate (25,440) and the Associations' employment estimate (29,368) is explained by the estimates of industry fleets (OSHA, 530 fleets; the Associations, 553 fleets).

Hydraulic fracturing - Small Entity definition

When OSHA was preparing the PEA, the SBA definition of a small entity for NAICS 213112, Support Activities for Oil and Gas Operations, was a firm that earns receipts no greater than $7 million per year. Examining the 10-19 employee size category, OSHA noted in the PEA that an entity averaging $25,000 per hydraulic fracturing job would only earn the industry-wide Census Bureau per-firm estimate of $2.1 million per year if it performed 84 small hydraulic fracturing jobs per year,[22] or substantially less than the upper limit of the SBA small entity definition. If these small hydraulic fracturing jobs typically only require one day to complete, then such a firm would have a utilization rate for its hydraulic fracturing equipment of 23 percent of the days of the year. A firm with a less conservatively low utilization rate, namely a rate three times as high (69 percent), would generate $6.3 million per year, or nearly the small business revenue limit (ERG, 2013b). Because firms with revenue of that amount would still meet the SBA's definition of a small entity, OSHA preliminarily concluded that all 100 entities with 10-19 employees would qualify as small entities under the SBA criteria.

For firms in the 20-99 employee size category, however, OSHA preliminarily concluded that only a fraction were appropriately categorized as small businesses.[23] OSHA noted in the PEA that the average reported revenues were calculated at $5.9 million. Nevertheless, OSHA's conclusion in the PEA was that this revenue amount was too low. Most of the firms in this size category are likely to compete for new well completion work, which is considerably more lucrative than the small refracturing jobs. Most new wells require fracturing of multiple stages (sections of the well), with one to three stages often being performed per day.[24] A typical single stage of a new well fracturing job is estimated to generate roughly $100,000. One hydraulic fracturing company reported that its annual average revenue per stage for 2011was $136,335 (FTSI, 2011, Document ID 1583).

As a result, OSHA noted in the PEA that the average revenue figures in the Census data appeared to be substantially too low. A firm in the 20-99 employee size category, if performing new well fracturing, would have performed only 52 stages before reaching the average revenue level and 70 stages of work before reaching the small business size limit. While it is possible that a few firms would fall below the SBA size limit, OSHA

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[22] $2.1 million per year/$25,000 per job = 84 jobs.

[23] OSHA could not estimate a precise percentage of firms in this category that are small as defined by SBA, but believes that the percentage is low for the reasons discussed below.

[24] A stage in hydraulic fracturing refers to the completion of the fracturing process for a given geologic zone and section of drill pipe. Shallow wells might require only one stage while most deep wells and horizontal wells require fracturing of more than ten zones and thus more than ten stages.

judged in the PEA that the large majority of firms in this size category would exceed the small business revenue limit of $7 million per year.

API/IPAA provided extensive comments on OSHA's preliminary analysis of impacts on hydraulic fracturing, including questioning OSHA's calculation of the number of small entities in that industry. The Associations "largely [found] OSHA's assumptions for the economic profile to be rational and supportable" (Document ID 2301, pp. 15). However, they stated:

> . . . we have concerns that OSHA and ERG may have underestimated the number of smaller entities in the hydraulic fracturing industry, and therefore also underestimated the proportion of the hydraulic fracturing industry that is made up of small entities. While both ERG and OSHA note that certain "very small frac jobs might be accomplished with as few as 5 or 6 workers," and that "small fracking crews commonly range from 6 to 10 workers," OSHA assumed that there were no hydraulic fracturing companies with less than 10 workers.
>
> In addition to concluding that there are no hydraulic fracturing entities with less than 10 employees, OSHA and ERG appear to have changed their initial estimate that there are 150 "very small fracking firms" that can "handle only minor, low-pressure refracturing jobs on conventional oil and gas wells." These 150 very small firms that can handle only minor jobs on conventional wells presumably must have between 10 and 19 employees because the next larger size class (firms with 20 to 99 employees), "compete for new well completion work, which is considerably more lucrative than the small refracturing jobs."
>
> But, without any explanation, OSHA in Table A-4 of Appendix A contradicted the Agency's earlier estimate that there are 150 of these very small firms with between 10 and 19 employees that constitute SBA "small entities," and showed instead in the first row of the table that there are only 100 such firms. This is confusing. * * * Instead of using the 150-entity estimate that was proffered and discussed by both ERG and OSHA, every subsequent analysis conducted by ERG and OSHA was based on an industry profile that only contains 100 entities with between 10 and 19 employees.
>
> . . . The Associations fully appreciate the difficulty of compiling a profile of the hydraulic fracturing industry in the absence of Census data delineated with a discrete NAICS code, and we generally believe that ERG and OSHA made fair assumptions and estimates. However, in this instance, we are concerned that small entities may be undercounted and underrepresented in the industry profile. As such, the Associations request that, at a minimum, OSHA amend its analysis to reflect its initial estimate

> (recommended by ERG based on its research), that the hydraulic fracturing industry includes 150 entities with between 10 and 19 employees (Document ID 2301, pp. 15-16)(citations omitted).

The Agency's PEA estimate was that 150 entities (100 with fewer than 20 employees and 50 with 20-99 employees) were limited to small jobs. In the 2014 SBA Table of Small Business Size Standards, SBA redefined a small entity for NAICS 213112, as a firm that earns receipts no greater than $38.5 million per year.[25] Now that the SBA has raised that cutoff for being considered a small entity in this industry to $38.5 million in receipts, all of those 150 entities are small business entities as defined by SBA. The revenue estimates for hydraulic fracturing businesses, including small entities, are presented in more detail in the Revenue and Profit section later in this chapter.

OSHA therefore concludes that, for purposes of the regulatory flexibility screening analysis, all 150 entities in the 10-99 employee size category (see Table III-4) are capable of performing hydraulic fracturing work and yet are small enough to remain below the SBA small business cutoff of $38.5 million in annual receipts.

To support the small business analysis, OSHA examined the activities of entities with fewer than 100 employees. OSHA concluded that there were no significant number of hydraulic fracturing entities with fewer than 10 employees, and therefore focuses in this FEA on the next higher employee size categories of firms, those with 10 to 19 employees and 20 to 99 employees. Moreover, OSHA concludes that only a negligible number of firms in the next larger size category (100-499) would also be small entities.

Construction

The construction sector is an integral part of the nation's economy, accounting for approximately 4.5 percent of total private sector employment.[26] Establishments in this industry are involved in a wide variety of activities, including land development and subdivision, homebuilding, construction of nonresidential buildings and other structures, heavy construction work (including roadways and bridges), and myriad special trades such as plumbing, roofing, electrical, excavation, and demolition work.

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[25] The 2014 revision to the SBA size standard for NAICS 213112 was retained for the 2016 SBA table of size standards. See U.S. Small Business Administration, Table of Small Business Size Standards Matched to North American Industry Classification System Codes, 2016. **https://www.sba.gov/sites/default/files/files/Size_Standards_Table.pdf**.

[26] 2012 County Business Patterns (NAICS), http://censtats.census.gov/cgi-bin/cbpnaic/cbpsect.pl. 5,260,942 paid employees, NAICS 23, Construction; 115,938,468 paid employees, all sectors.

Construction activities were selected for analysis based on historical data of recorded samples of construction worker exposures from the OSHA IMIS and the National Institute for Occupational Safety and Health (NIOSH). In addition, OSHA reviewed the industrial hygiene literature across the full range of construction activities and focused on dusty operations where silica sand was most likely to be fractured or abraded by work operations. These physical processes have been found to cause the silica exposures that pose the greatest risk of silicosis for workers (See Table III-8: Distribution of Silica Exposures by Application Group and Job Category or Activity – Final Profile, and Chapter IV, Technological Feasibility, for details on exposures in construction operations).

In the PEA, the 12 construction activities, by job category, that OSHA identified as being potentially affected by the proposed silica standard as follows:

- Abrasive blasters
- Drywall finishers
- Heavy equipment operators
- Hole drillers using hand-held drills
- Jackhammer and impact drillers
- Masonry cutters using portable saws
- Masonry cutters using stationary saws
- Millers using portable or mobile machines
- Rock and concrete drillers
- Rock-crushing machine operators and tenders
- Tuckpointers and grinders
- Underground construction workers.

Based on the ERG Technological Feasibility Study for Construction (ERG, 2008a), the PEA recognized that these construction activities occur in the following construction industries, accompanied by their four-digit NAICS codes:

- 2361 Residential Building Construction
- 2362 Nonresidential Building Construction
- 2371 Utility System Construction

- 2372 Land Subdivision
- 2373 Highway, Street, and Bridge Construction
- 2379 Other Heavy and Civil Engineering Construction
- 2381 Foundation, Structure, and Building Exterior Contractors
- 2382 Building Equipment Contractors
- 2383 Building Finishing Contractors
- 2389 Other Specialty Trade Contractors

In addition, the PEA noted that some public employees in state and local governments are exposed to elevated levels of respirable crystalline silica. These employees were included in the construction sector because their exposures are the result of construction activities. As discussed earlier in this chapter, OSHA requested comment on which other industries, if any, perform construction work outside the construction sector that involves worker exposure to respirable crystalline silica, and the amount of such work performed. The public comments related to these questions, and OSHA's response to those comments, appear below.[27]

Public Comments on the Preliminary Profile of Construction

Four-digit versus six-digit NAICS codes

In the PEA, OSHA used four-digit NAICS codes, rather than six-digit NAICS codes, in its economic analysis of the construction sector. OSHA had selected the broader four-digit codes both because of limitations in the BLS's Occupational Employment Statistics Survey and IRS data on profitability. The National Association of Home Builders (NAHB) noted that more recent versions of both data sets contain "somewhat more detail," and NAHB objected to OSHA's method of mapping affected construction contractors to four-digit NAICS:

> For example, the mapping produces no costs for electrical or plumbing and [heating, ventilation, and air conditioning] HVAC contractors—two large subcategories of the specialty trades that each has hundreds of thousands of employees…
>
> Electrical and plumbing/HVAC contractors [6-digit NAICS codes] account for roughly 93 percent of all employment in the 4-digit NAICS

[27] For a detailed discussion of changes to the scope of the analysis of affected construction application groups, see Chapter IV-5 of this FEA.

code for Building Equipment Contractors (according to the BLS Quarterly Census of Employment and Wages for 2012). Assuming away all assessment costs for 93 percent of employees (which is inconsistent with the general language of the proposed rule) but including them in the base revenue and profits is one of the ways the PEA produces unrealistically low estimates of costs as a share of revenue and profits for Building Equipment Contractors (Document ID 2296, p. 17).

OSHA acknowledges NAHB's point about relying on four-digit NAICS information and in this final profile has applied occupational data at the six-digit NAICS level now that such information is available. However, it is not the case that OSHA uses the revenue and profit base of the entire industry while using costs only in affected establishments. In each industry OSHA uses the costs and revenues per establishment as compared to costs to the establishment. As in the PEA, OSHA analyzes cost impacts per establishment-wide revenue and profit, a micro analysis that presents greater precision than NAHB's implied alternative that involved estimation of revenue and profit shares associated with the percentage of affected occupational categories within entire NAICS codes but overlooks the firm-specific technological distinctions recognized by OSHA's analysis of construction activities. OSHA also notes that its change to the scope of the final construction standard is intended to exclude workers who are only occasionally exposed to silica at low levels, making it even more likely that NAHB's approach would over-estimate the costs of the rule.[28]

OSHA's Treatment of Specialty Trades

Landscapers

NAHB identified several job categories that would be affected by the OSHA silica rule. Among these affected job categories is Landscapers, a group preliminarily judged in the PEA to "generate negligible levels" of respirable crystalline silica (see PEA III-4, fn 11):

> Home builders, as well as remodelers, typically subcontract the majority of their construction work. On average, 25 specialty trade subcontractors are used to build a single-family detached house. A major reason for subcontracting is due to the increasing complexity, features, and amenities supplied with new homes that require specialized expertise that trade [contractors] have. Below are some of the job categories, mostly performed by Specialty Trade Contractors, for which workers are potentially exposed to respirable crystalline silica in the residential construction industry (*i.e.,* home building):

[28] See the discussion below on OSHA's final profile of low-silica exposed construction trades.

. . .

- Landscapers – cutting pavers, stone, rock, concrete, and installation for patios and moving soil during landscaping activities. (Document ID 2296, p. 33)[29]

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[29] For this comment response, OSHA focused on landscapers because this occupation is one that would represent a unique addition for the final profile. NAHB's complete list of job categories is as follows, but each of the other silica-related activities are already encompassed in the final profile

- Brick and Block Masons – cutting and installing brick and block, as well as mixing mortar, and possibly disturbing ―in-place mortar (*i.e.*, tuck pointing).
- Stone Masons / Exterior Façade Applicators – cutting and installing/fixing stones to structure.
- Concrete Mixing – mixing water, cement, sand, and gravel.
- Concrete Installers – handling, depositing, and placing concrete.
- Concrete Finishing – moving concrete horizontally into final position and finishing, such as screeding, bullfloating, jointing, floating, troweling, patterned-stamping the surface, and sawing control or expansion joints.
- Tile and Marbles Installers – cutting performed onsite and installation of tile and marble for floors, countertops, and walls, and also mixing grout.
- Stucco Installers – mixing stucco material and applying to the structure.
- Counter Installers – cutting performed onsite and installing granite and quartz countertops.
- Siding Installers – sawing, cutting, and installing cementitious siding (*i.e.*, fiber-cement siding).
- Demolition Crew – jack hammering, cutting, and grinding materials such as concrete, bricks, blocks, drywall, and plaster.
- Laborers / clean-up crew – dry sweeping that is likely to be performed in basements or garages after saw cutting.
- Electricians – drilling holes through concrete, block, and siding to run conduit.
- HVAC Installers – drilling holes through concrete (*i.e.*, basement walls), block, and siding to run conduit.
- Plumbers – drilling holes through concrete or block for water and drain lines.
- Roofers – cutting and installing concrete and clay tiles on roofs.
- Landscapers – cutting pavers, stone, rock, concrete, and installation for patios and moving soil during landscaping activities.
- Drywall Installers – installing (*i.e.*, hanging) drywall (also known as plasterboard, wallboard, gypsum board, sheetrock, or gyprock) and cement board, which is used in lieu of drywall in some rooms in a home, such as a bathroom.
- Drywall Finishers – finishing (*i.e.*, taping, texturing, and sanding) of drywall and cement board.
- Carpenters – drilling into concrete to attach framing.
- Heavy Equipment Operators – equipment operators (*i.e.*, backhoe, bulldozer, grader, skid steer loader/Bobcat) moving soil during land development and landscaping activities.
- Rock/well drilling – boring or drilling in the ground to access groundwater in underground aquifers.
- Iron Workers – erecting and installing pre-cast concrete beams, columns and panels.
- Deck builders – mixing concrete for post footings.
- Construction Managers – supervising the construction project's progress, which may include: obtaining construction work permits; ordering materials; overseeing trade contractors; troubleshooting emergencies; and scheduling walk-throughs/inspections of a jobsite (Document ID 2296, pp. 33-34).

In a profile supporting the PEA, ERG (2008) discussed potential silica exposures in the landscape contracting industry. This industry was judged to generate negligible levels of silica exposure in the United States and, as a result, no compliance costs were estimated for landscaping contractor employers and the industry was not included in the PEA.

After reviewing the record, including testimony and post-hearing comments from NAHB (Document ID 3587; 3750) on remodeling activities associated with residential sites and evidence pointing to the likelihood that exposures can reach significant levels, OSHA has elected to include landscaping contractors in this final industry profile, the final technological feasibility analysis (see Chapter IV, Section IV-13 of this FEA), and the final analysis of costs and economic impacts. Accordingly, OSHA includes NAICS 561730, Landscaping Services in this final profile of affected industries and elsewhere throughout this final economic analysis.[30]

With respect to the other job categories identified in NAHB's comment, OSHA's final exposure profile and technological feasibility analysis in Chapter IV evaluate the significance of exposure for all construction trades potentially affected during residential remodeling and other construction activities.

Exhibit III-A below presents the final set of construction activities analyzed for technological feasibility and the associated Table 1 tasks in the NPRM and the final rule. For the technological feasibility analysis of all construction tasks not addressed by Table 1, see Chapter IV-5, Technological Feasibility for the Construction Industry.

Exhibit III-A: Construction Activities Analyzed for Technological Feasibility in Relation to Table 1 of the Final Silica Rule.

Final Table 1 Equipment / Task	NPRM Table 1 Equipment/Task	FEA Construction Activity (Technological Feasibility chapter sections)

[30] OSHA judged that Landscaping Services qualified as a general industry application group (and not a construction application group) due to the typical work performed—remodeling and renovation.

(i) Stationary masonry saws	Using Stationary Masonry saws	5.7 Masonry Cutters Using Stationary Saws
(ii) Handheld power saws (any blade diameter)	Using Hand-Held Masonry Saws	5.6 Masonry and Concrete Cutters Using Portable Saws
(iii) Handheld power saws for cutting fiber-cement board (with blade diameter of 8 inches or less)	Using Hand-Held Masonry Saws	5.6 Masonry and Concrete Cutters Using Portable Saws
(iv) Walk-behind saws	Using Portable Walk-Behind or Drivable Masonry Saws	5.6 Masonry and Concrete Cutters Using Portable Saws
(ix) Vehicle-mounted drilling rigs for rock and concrete	Operating Vehicle-Mounted Drilling Rigs for Rock **and** Operating Vehicle-Mounted Drilling Rigs for Concrete	5.9 Rock and Concrete Drillers
(v) Drivable or ride-on concrete saws	Using Portable Walk-Behind or Drivable Masonry Saws	5.6 Masonry and Concrete Cutters Using Portable Saws
(vi) Rig-mounted core saws or drills	Using Hand-Held Masonry Saws	5.6 Masonry and Concrete Cutters Using Portable Saws
(vii) Handheld and stand-mounted drills (including impact and rotary hammer drills)	Using Rotary Hammers or Drills (except overhead)	5.4 Hole Drillers Using Handheld or Stand-Mounted Drills
(viii) Dowel drilling rigs for concrete	Using Hand-Held Masonry Saws	5.9 Rock and Concrete Drillers
(x) Jackhammers and handheld powered chipping tools	Using Jackhammers and Other impact Drillers	5.5 Jackhammers and Other Powered Handheld Chipping Tools
(xi) Handheld grinders for mortar removal (e.g., tuckpointing)	Tuckpointing	5.11 Tuckpointers and Grinders
(xii) Handheld grinders for uses other than mortar removal	Using Hand-Operated Grinders	5.11 Tuckpointers and Grinders
(xiii) Walk-behind milling machines and floor grinders	Milling	5.8 Millers Using Portable or Mobile Machines
(xiv) Small driveable milling machine (less than half-lane)	Milling	5.8 Millers Using Portable or Mobile Machines

Exhibit III-A: Construction Activities Analyzed for Technological Feasibility in Relation to Table 1 of the Final Silica Rule, continued

Final Table 1 Equipment / Task	NPRM Table 1 Equipment/Task	FEA Construction Activity (Technological Feasibility chapter sections)
(xv) Milling machines (half-lane and larger with cuts of four inches in depth or less)	Milling	5.8 Millers Using Portable or Mobile Machines
(xvi) Crushing machines	Rock Crushing	5.10 Mobile Crushing Machine Operators and Tenders
(xvii) Heavy equipment and utility vehicles used to abrade or fracture silica-containing materials (e.g., hoe-ramming, rock ripping) or used during the demolition of concrete or masonry structures	Use of Heavy Equipment during Earthmoving	5.3 Heavy Equipment Operators and Ground Crew Laborers
(xviii) Heavy equipment and utility vehicles for tasks such as grading and excavating but not including: demolition of concrete or masonry structures or abrading or fracturing silica-containing materials	Use of Heavy Equipment during Earthmoving	5.3 Heavy Equipment Operators and Ground Crew Laborers

Source: OSHA, Directorate of Standards and Guidance, Office of Regulatory Analysis and Office of Technological Feasibility.

Electricians, carpenters, plumbers, and other low-silica exposed trades

Commenting on OSHA's preliminary profile for construction, the Construction Industry Safety Coalition (CISC), comprised of 25 construction trade associations, made similar points as the NAHB critique of OSHA's estimate of the scope of construction tasks affected by the proposed rule as being under-inclusive:

> OSHA has inexplicably omitted from the Agency's analysis of the economic costs and impacts of the Proposed Standard at least 1.2 million additional workers in the construction industry who also routinely perform dusty tasks on silica-containing materials. These workers – members of large construction trades such as plumbers and plumber helpers, roofers, electricians and electrician helpers, and including specialty trades such as plasterers and stucco masons and helpers and tile and marble setters – perform tasks identical or similar to those performed by occupations included by OSHA in the Agency's cost analysis such as bricklayers, concrete finishers and construction laborers. Together the additional occupations increase OSHA's base estimate of the affected construction workforce by more than one-third.
>
> Not only do workers in these additional occupations engage in some of the single tasks used by OSHA to identify other at-risk occupations (e.g., drilling holes in concrete or masonry to affix anchors as performed by carpenters), they are known to perform multiple silica-generating tasks during the course of their work day. For example, an electrician may both drill pass-through holes in masonry or other silica-containing construction materials using a hand-held drill and also open silica-containing wall, ceiling, and floor surfaces to install, repair or replace wiring, equipment, or fixtures (Document ID 4217, p. 73).

In post-hearing comments, CISC acknowledged that the 19 occupations OSHA identified in the PEA addressed the majority of the drilling, cutting, breaking, abrading and other construction work with silica-containing materials that result in potential silica exposures, but CISC also stated that "many other construction occupations also perform such tasks and generate sometimes significant silica exposures" (Document ID 4217, p. 74). They claimed that OSHA's approach made two types of omissions:

- OSHA has failed to include other occupations that include large numbers of construction workers who routinely engage in drilling, cutting, breaking and abrading of masonry and other silica-laden materials, albeit often for fractions of worker time smaller than many (but not all) of OSHA's selected occupations.

- OSHA's profile for carpenters, one of the largest construction occupations addressed in the Agency's analysis, includes only hole-drilling into masonry materials for the purpose of affixing anchors, while failing to include other silica-exposure-generating tasks commonly performed by carpenters such as sawing through masonry; demolition or removal of silica-containing walls, ceilings or floors; drilling through brick, block or plaster for the purpose of passing something through the hole rather than affixing an anchor; grinding or otherwise abrading surfaces such as stone countertops or plaster and lath walls; and more. These additional tasks may individually amount to small fractions of a carpenter's work day, but most carpenters will perform one or more of such tasks at least weekly, if not daily. Taken together, these additional at-risk tasks contribute to an increased exposure profile in which the typical carpenter is spending several times more than the 1% of his work year that OSHA estimates performing dusty tasks.

> The additional construction occupations that we include in cost analysis account for 1.26 million additional workers beyond OSHA's occupations, and the additional carpenter time that we also include results in three times as many affected carpenter FTEs as OSHA estimates among the 860,000 carpenters and helpers (Document ID 4217, Appendix B, p. 10).

To address the first type of omission alleged by CISC (failing to include other occupations that include large numbers of construction workers engaged in silica tasks for short periods of time), OSHA compared exposure data for "classified" and "unclassified" sources of silica exposure from the Agency's OIS inspection files (2011-April 2014). Classified sources were defined as exposure samples that could be grouped by NAICS into an application group or industry and could be identified as part of a job category associated with that application group or industry (for examples, an abrasive blasting operator in the Cut Stone application group, categorized in NAICS 327991 - Cut Stone and Stone Product Manufacturing); whereas unclassified sources were defined as samples that could not be classified by NAICS into an application group, or by job description into a job category associated with an application group (for example, a carpenter employed in NAICS 238310 - Drywall and Insulation Contractors, where the job description may have been excluded from the inspection report). Significantly, data are unclassified because of lack of data, not because these unclassified sources of silica exposure represent new application groups that have not been covered. Because of the complexity of American industry, it is almost inevitable that there will occasionally be silica exposures as a result of rare instances where a person does silica related work without being classified in a relevant occupation in government statistical data sources.

As shown in Table III-10 later in this chapter, OSHA determined that for 56 OIS construction data samples where classification was not possible, 41 samples, or 73 percent, were below the 50 μg/m^3 PEL, compared with 55 of 107 samples, or 51 percent, for exposure data where classification was possible.[31] From this review of recent OSHA inspection data, OSHA concluded that for the majority of exposures where the encounter with silica is so incidental or scattered as to lack classification in the inspection records, risk levels for those atypical encounters would fall below the level of significance.[32] Because the use of silica in the industries that are unclassified is very rare, the viability of these industries will not be threatened by this rule.

For the second type of omission alleged by CISC, carpenters, OSHA notes that the PEA included Carpenters as an occupational category in the application group, Hole drillers using hand-held drills. For this FEA, OSHA has assigned the Carpenters job category to two tasks, Hole Drillers Using Hand-Held Drills and Masonry Cutters using Portable Saws (see OSHA, 2016). Based on OIS exposure data (see Chapter IV), OSHA has concluded that, other than those two job categories, carpenters are not significantly exposed to silica during sawing or demolition activities and therefore carpenters are not included in the final profile for those activities.

In order to address questions concerning the worker categories newly identified by CISC, OSHA has expanded the preliminary profile of construction trades to include new trade categories, while determining that other silica-related activities identified by CISC were captured in the PEA. Specifically, OSHA has added plumbers, electricians, sheet metal workers, and their helpers to the hole drilling task (which already included carpenters and carpenter helpers); terrazzo workers and finishers to the milling task; and roofers and their helpers to the stationary masonry saw task in response to CISC comments. OSHA did not include any additional tasks that commenters claimed for these workers because the Agency's technological feasibility analysis indicates that these tasks do not generate hazardous levels of respirable crystalline silica and commenters provided no exposure data or other evidence to support the need to include them in this analysis.

The Agency also notes that it has modified the scope of the construction standard so that the final rule excludes exposure "where employee exposure will remain below 25 micrograms per cubic meter of air (25 μg/m^3) as an 8 hour time-weighted average (TWA) under any foreseeable conditions" (paragraph (a) of the standard for construction). As

[31] Also shown in Table III-10 is a distribution of exposures for unclassified general industry OIS samples. Of 169 unclassified general industry samples, (excluding abrasive blasting) 119samples (70 percent) were below 25μg/m^3 and 21 samples (12 percent) were between 25μg/m^3 and 50 μg/m^3.

[32] For a complete discussion of OSHA's use of OIS data for the final silica exposure profile, see Chapter IV-01, Technological Feasibility – Introduction,

discussed in the summary and explanation of that scope provision, OSHA's analysis of the rulemaking record indicates that a substantial number of employees in the construction sector perform tasks involving occasional, brief exposures to respirable crystalline silica that are incidental to their primary work. Where employees perform tasks that involve exposure to respirable crystalline silica for a very short period of time, OSHA finds that exposures for many tasks are below 25 $\mu g/m^3$ as an 8-hour TWA. Therefore, OSHA expects that a significant proportion of employers of employees in these groups will be excluded from the standard.

The Associated Builders and Contractors (ABC) raised objections, similar to those of NAHB and CISC, to what they viewed as an incomplete preliminary profile.

> One of the main problems with OSHA's economic analysis is it omitted 1.5 million workers who perform tasks that could expose them to respirable crystalline silica. For example, OSHA has omitted plumbers, roofers and electricians—all of whom perform tasks similar to those of carpenters and [plasters] who were included in the cost estimate. OSHA's analysis left out a significant portion of the workforce, by adding in these occupations it increases OSHA's estimate of the affected construction workforce by about 50 percent (Document ID 2289, p. 5).

Several other groups provided examples of other construction tasks that they believed would be impacted by the rule and should therefore be included in industry profiles. ABC identified specific construction tasks – cement mixing, overhead drilling, handling of paving stones and compaction of interlocking pavers – that it believed were improperly excluded from OSHA's preliminary profile of affected application groups (Document ID 2289, p. 3).

With respect to ABC's concerns about excluded construction tasks, OSHA notes that in the final technological feasibility analysis (see Chapter IV), cement mixing was included within the application group Concrete Products; overhead drilling was included within the application group Hole Drillers using Handheld Drills; and in the application group Landscape Contracting, interlocking paving was included but handling of paving stones was excluded based on comments by the Interlocking Concrete Paving Institute (Document ID 2246, p. 8-10).

The National Electrical Contractors Association (NECA) also submitted a list of tasks potentially affected by the proposed rule (Document ID 2295, p. 3):

- Overhead anchor drilling and installation
- Floor, sidewalk and asphalt cutting

•Installation and demolition of concrete-encased electrical duct-banks
•Mixing, pouring and finishing of concrete pads for equipment and transformer
•Light pole base installation
•Underground excavations in all types of soil where rock and dust are encountered
•Anchoring of equipment on poured-in-place concrete walls and block masonry walls
•Exposure to conveyors and equipment in production and manufacturing plants that uses and as raw materials for the finished product when maintenance and servicing is being performed
•Sand blasting equipment for renovations
•Cutting drywall and wall board for the installation of boxes and fixtures
•Core drilling of concrete floors and walls for conduit penetrations
•Working adjacent to areas where concrete and wall finishers are sanding and grouting
•Working in surface and underground mines where raw material is extracted from the earth
•Working in underground tunnels
•Earthmoving equipment operations

NECA further stated (id.): "This list does not include all electrical construction activities that may also result in exposures greater than OSHA proposed PEL limits. All of these tasks are usually performed on an intermittent basis. Employee exposure is minimal and with the right training, employees are qualified to protect themselves and those around them."

The Building and Construction Trades Department, AFL-CIO (BCTD) also identified several categories of exposed construction workers (Document ID 4223, pp. 39-40):

- Terrazzo workers and finishers (47-2053)
- Plumbers and plumber helpers (47-2152 and 47-3015)
- Roofers (47-2180)
- Painters and helpers (47-2141).

It is important to note that while OSHA did not explicitly identify "painters and helpers" by name, it did consider workers performing abrasive blasting. OSHA included an additional 15,446 full-time equivalent (FTE) construction workers performing abrasive blasting in its total FTEs for all industry sectors. The FTEs performing abrasive blasting were distributed between the categories Building and Finishing Contractors (11,043 FTEs) and Other Specialty Trade Contractors (4,403 FTEs).

- Sheet Metal Workers (47-2210)

> As the testimony demonstrates, when the workers in these classifications are engaged in silica-generating tasks, their potential exposures may be intense, and they therefore must be covered by the provisions of the proposed standard. However, because only a limited number of such workers are engaged in silica-generating tasks and their exposures are brief or intermittent, the addition of these workers to OSHA's cost assessment should not have a significant impact on OSHA's cost estimate.

OSHA has expanded the profile of affected workers to include the job categories identified by BCTD that OSHA determined potentially involve substantial silica exposure. See Tables III-8 and III-9 below, OSHA, 2016, Chapter IV, Technological Feasibility, and Chapter V, Costs of Compliance, for the presentation of OSHA's final profile of affected construction workers and the categorization of construction occupations within Table 1 tasks.

By the same token, OSHA has not expanded the profile where it concludes that the types of workers identified by CISC, ABC, NECA, as well as NAHB, as improperly excluded from the scope of the analysis are not for the most part significantly exposed to silica. As will be discussed in greater detail below under Silica Exposure Profile Of At-Risk Workers and in Chapter IV, Technological Feasibility, OSHA reviewed exposure data from the Agency's inspection database and other sources (e.g., NIOSH and ERG site visits) and determined that for silica exposure samples where neither the NAICS code nor the job category could be classified within the preliminary profile, 73 percent of the readings (41 samples of 56 total) were below the new PEL of 50 μg/m^3. In order to address the remaining 27 percent of workers, OSHA has expanded the preliminary profile of construction trades to include new trade categories, while reviewing the PEA and determining that other silica-related activities identified by commenters were already captured in the PEA. Specifically, as previously noted, OSHA has added, in response to CISC comments, the following occupations potentially affected by the final rule: plumbers, electricians, sheet metal workers, and their helpers; terrazzo workers and finishers; and roofers and their helpers. See OSHA (2016).

Concrete segmental retaining wall installation

The National Concrete Masonry Association (NCMA) identified the installation of concrete segmental retaining wall (SRW) systems as an activity that would bring NCMA contractors under the scope of the proposed standard (Document ID 2279, p. 10). In the final technological feasibility analysis, drilling and cutting of SRW systems are broadly grouped within tasks involving brick, concrete, stone, and related landscaping materials;

these general industry tasks are addressed in Chapter IV, section IV-13, Landscape Contracting. Where installation of SRW systems constitutes construction, sections IV-29, Masonry Cutters Using Portable Saws, IV-30, Masonry Cutters Using Stationary Saws, and IV-32, Rock and Concrete Drillers address the feasible controls for protecting employees of NCMA contractors and other construction employers from exposure to silica. Tables III-8 and III-9 in this chapter present the distribution of exposures for the job categories in these application groups and the exposure distribution for affected NAICS divisions, while Chapters V and VI present, respectively, OSHA's final estimate of compliance costs and economic impacts for the affected NAICS divisions within general industry and construction.

Construction laborers

The Laborers Health and Safety Fund of North America cautioned OSHA to not overlook the risks from exposure to silica facing laborers on construction projects:

> Laborers often work in and near silica hazards created by other trades (e.g., operators, blasters, cement masons). Laborers also operate dust-creating equipment (e.g., jackhammers, chipping guns, handheld grinders and drywall sanders). Whether it is due to helping other trades, operating heavy equipment, mortar mixing or housekeeping, laborers have a unique and often overlooked exposure profile. Their hazard exposure can be driven as much by their bystander experience as their task or tool use. This can lead to laborers being omitted from respiratory protection planning. Therefore, we strongly support requiring the use of controls for all dust-generating tools and providing protection to everyone in the defined work area. We believe these proactive measures will go a long way toward protecting workers whose exposure profiles are difficult to characterize but nonetheless very real (Document ID 2253, pp. 1-2).

Chapter IV, Technological Feasibility, of this FEA addresses exposure to silica among laborers as a distinct group, and Chapter V, Costs of Compliance, of this FEA specifically estimates the number of construction laborers directly involved in silica-generating tasks and estimates compliance costs for those workers as a distinct group. For construction laborers not directly engaged in silica-generating tasks, OSHA anticipates that after the final rule is issued, silica exposure among these laborers will be minimized through the use of engineering and administrative controls, including written exposure control plans, to such an extent that few if any additional controls will be needed to reduce exposures indirectly impacting laborers. Nonetheless, to the extent construction laborers are covered by the final standard through ancillary requirements alone, OSHA addresses costs for those requirements in Chapter V, Costs of Compliance.

Public employees

The American Federation of State, County and Municipal Employees (AFSCME) submitted comments addressing silica exposure among public employees in construction and in general industry:

> AFSCME represents approximately 275,000 members employed in public works, maintenance and highway departments. These workers perform many tasks that expose them to silica, including highway maintenance and repair, masonry work, sidewalk and concrete repair or removal, sandblasting and other abrasive blasting, excavation and earth removal, and bridge repair and maintenance. Other members are exposed to silica while engaged in maintenance and repair activities in school and university settings. Because these public employees perform various tasks in diverse settings, both the silica general industry and construction standards apply.
>
> AFSCME's concern for public employee exposure to silica is substantiated in published literature. We submitted with our testimony, *Highway Repair: A New Silicosis Threat,* (Valiante et al. American Journal of Public Health; May 2004, Vol 94, no.5) [footnote omitted]. In that study, researchers found that large populations of highway workers are at risk of developing silicosis. Their conclusions stated the need for engineering controls, medical screenings and protective health standards to protect workers from occupational disease related to silica exposure.
>
> Although our public works and highway workers are the most likely to be exposed to silica, employees in other job classifications also risk exposure. For example, we represent workers employed in dental facilities in public health and university settings. These workers face potential exposure while making certain dental molds (Document ID 4203, pp. 1-2).

OSHA recognizes that this rule will have an indirect effect on public employees through adoption of the rule by states that have state plans applicable to state employees (Section 18 of the OSH Act requires authorized state plans to cover public employees "to the extent permitted by law," 29 U.S.C. 667(c)(6)); there are twenty-six such states, ranging in size from Vermont to California, plus Puerto Rico and the US Virgin Islands. Although the rule itself is not directly applicable to public employees, and OSHA cannot enforce it in the public sector, the Agency generally considers costs and benefits in this sector for this reason. With respect to AFSCME's last point, OSHA notes that in the PEA, dental technicians in dental laboratories were included within the profile of affected job categories. For this final economic analysis, OSHA evaluated silica exposure among dental technicians and all other public employees identified by AFSCME and the Agency has revised the final profile, presented below and in Chapter IV, Technological

Feasibility, to recognize distinctly the exposures facing that category of workers. To present a broad overview of affected public employees, OSHA estimates that approximately 44,000 full-time-equivalent public employees in State Plan States (and thus protected by this standard) are engaged in at-risk construction tasks. Of these, roughly 83 percent will be employed in the application group Tuckpointers and Grinders, while smaller groups of at-risk public employees will be found in all other affected construction application groups with the exception of Underground Construction Workers and Abrasive Blasters. Further details on the final profile of affected public employees can be found in OSHA, 2016.

Sole proprietors ("self-employed" workers)

A final category of worker raised in comments was "self-employed" workers, which OSHA typically refers to as sole proprietors. The PEA did not mention or include self-employed persons in the exposure profile or cost calculations because they are not "employers" subject to OSH Act. However, comments raised the issue that, particularly because of the unique approach presented by Table 1, the activities of sole proprietors could impact the exposures of others, so appropriate costs need to be taken to the extent that OSHA expects affected employers to act to control those exposures. Below, OSHA reviews and responds to the comments, while the actual self-employment data and estimated effect on employer costs are presented in Chapter V of this FEA.

CISC, in its pre-hearing comments, cited a report it commissioned and claimed that there would be costs applied to 2.5 million self-employed persons who perform construction work consistent with Table 1 specifications (Document ID 2319, p. 84). In its post-hearing comments, CISC predicted that many self-employed persons would comply with the requirements in Table 1 for a number of reasons:

- Concerned, self-interested self-employed workers will recognize the Table 1 specifications as the safe way to perform their work;
- Construction general contractors will demand that anyone working on their site, whether self-employed or not, do the job safely and in conformity with regulatory requirements;
- Regulated construction trade contractors will demand a level playing field relative to their self-employed competitors; and
- Regulated construction workers working with or near self-employed workers will demand that they not suffer increased silica exposures from inappropriate practices by self-employed workers.

> We think it reasonable to expect that all self-employed construction workers will eventually come to perform silica-generating tasks consistent with the Table 1 specifications in the Proposed Standard. We believe the costs for self-employed workers to change their practices in this manner should be counted as a cost of the Proposed Standard -- absent the Proposed Standard, they would not perform their work in this way and would not incur the costs of doing so.
>
> We do not believe, though, that self-employed workers will be induced to meet the ancillary requirements of the Proposed Standard. We assume that they will choose not to incur costs to comply with administrative requirements (Document ID 4217, p. 80).

BCTD disagreed with CISC's assertion as follows:

> In the best of all worlds, OSHA standards would apply to all types of workers so everyone in the country could be assured a safe and healthy workplace. The reality is that self-employed workers are not covered by the Occupational Safety and Health Act, which applies only to "employee[s] of . . . employer[s]." 29 U.S.C. § 652(6). OSHA cannot enforce its standards on self-employed workers and these individuals have no legal obligation to comply with OSHA requirements.
>
> During the hearing, industry representatives suggested that self –employed workers would choose to comply with the standard's provisions. Although that would certainly be beneficial, not only to the health of the self - employed worker but to others working in the same vicinity, OSHA is neither responsible for nor has to account for the voluntary actions of those not covered by the Act. By the same token, to the extent that industry representatives suggested that general contractors might require their self-employed subcontractors to comply with the standard, such voluntary actions would similarly fall outside the ambit of OSHA's authority (Document ID 4223, pp. 54-55).

OSHA concurs with BCTD's view that applicable costs will not be incurred by the self-employed persons themselves in response to any requirement in this standard, as they are not required to comply with OSHA's standard. However, OSHA concurs with CISC's assessment that employers covered by the rule will incur costs for engineering controls to protect against exposures generated by sole proprietors acting as subcontractors in certain multi-employer settings. The reason is that other employers are required by the new standard to ensure that their employees on the worksite are protected against silica exposures above the PEL even if those exposures are generated by a party not subject to the OSH Act. In such circumstances, and where the exposure cannot be prevented by other means such as re-scheduling or distancing the self-employed worker from affected workers, the Agency has concluded that the engineering control costs would be borne by another employer (possibly the host employer or controlling employer)—either by providing the controls to the sole proprietor or by reimbursing the self-employed contractor for the costs of the controls.

OSHA further agrees with CISC that engineering control costs would be the only costs associated with self-employed workers for the host employer; OSHA is not factoring these employees into its profile for compliance with the ancillary or respirator provisions because a self-employed person's compliance with those provisions would not contribute to the protection of other employees protected by the standard.

NAHB introduced a related argument concerning host employers having to incur ancillary costs, specifically exposure monitoring costs, for sole proprietors, which they called "non-employers":

> Although these [non-employers] are technically outside the scope of the silica rule, general contractors may have trouble distinguishing among small subcontractors depending on whether or not they have payrolls, resulting in hundreds of thousands of extra assessments beyond those considered in the PEA (Document ID 2296, p. 19).

OSHA does not accept the premise of this argument. The possibility that a general contractors may mistakenly (or even knowingly) treat a sole proprietor as an employer covered by the rule's requirements for controlling exposures should not transform the associated costs into direct costs of the standard and do not provide any grounds for including "non-employers" in an industry profile of the employers impacted by the new rule. The Agency therefore has not adjusted its industry profiles or added ancillary costs in response to the NAHB comment. NAHB's comment is noted again in the section in Chapter V of this FEA concerning exposure monitoring costs in construction.

Electric utilities

The Edison Electric Institute (EEI) questioned whether OSHA's preliminary profile had recognized the electric utility industry:

> EEI is concerned that, in spite of the potential impact of the rule upon the industry, OSHA's Preliminary Economic Analysis (PEA) did not include Electric Power Generation, Transmission & Distribution (NAICS 2211). OSHA should assess the health risk respirable crystalline silica poses to the industry, which, to our knowledge, has no history of silicosis disease. Further, the agency should determine whether the proposed rule is economically and technically feasible to the electric utility industry. The

> proposed rule contains no discussion on these matters (Document ID 2357, p. 39)(footnote deleted).

Another employer association in the electric utility industry, the National Rural Electric Cooperative Association, presented a request that appears contradictory to EEI's request in relation to OSHA's final profile:

> Rural electric cooperatives and electric utilities in general, are not included in those listed by the agency as affected industries. This makes sense due to the very limited exposure of our workers to RCS. Therefore NRECA recommends that the utility industry not be listed as an affected industry. In support of this recommendation, Federated Rural Electric Insurance Exchange, the provider of workers' compensation insurance to over half of the 900 member cooperatives of NRECA, reports ZERO cases of silicosis in over 25 years (Document ID 2365, p. 13).

For this final profile of electric utilities, OSHA determined that significant exposures to silica in electric utilities occur during the following Table 1 construction tasks: Jackhammers and handheld powered chipping tools; Heavy equipment and utility vehicles (all uses); and Drills and Drilling rigs (all forms). Tables III-8 and III-9 below present OSHA's final exposure profile for NAICS 2211, Electric Utilities. The costs, benefits, and other impacts facing the electric utility industry are presented later in this FEA.

CHARACTERISTICS OF AFFECTED INDUSTRIES

In the sections that follow, OSHA presents its final profile of affected industries; included within the profile is the Agency's response to additional concerns raised by commenters. The profile includes revenue and profit information, which is explained in the section that follows on Revenue and Profit.

Table III-5 provides an overview of the industries and estimated number of workers affected by the final rule. Included in Table III-5 are summary statistics for each of the affected industries, subtotals for construction and for general industry and maritime, and totals for all affected industries combined.

The first five columns in Table III-5 identify the NAICS code for each industry in which workers are routinely exposed to respirable crystalline silica and the name or title of the industry, followed by the total number of entities, establishments, and employees for that industry.[33] Note that, while the industries are characterized by such exposure, not every entity, establishment, and employee in these affected industries engage in activities involving silica exposure. Hence, figures for total entities, establishments, and employees are given for each affected industry, but, in separate columns, so too are the subset of figures for affected entities, establishments, and employees (totals and full-time-employment (FTE) equivalents).

Thus, columns six through eight in Table III-5 show, for each affected industry, the number of entities and establishments in which workers are actually exposed to silica and the total number of workers exposed to silica; while column nine shows the FTE estimates (for construction only).[34] The number of affected establishments was set equal to the total number of establishments in an industry (based on Census data) unless the number of affected establishments would exceed the number of affected employees in the industry. In that case, the number of affected establishments in the industry was set equal to the number of affected employees, and the number of affected entities in the industry was reduced so as to maintain the same ratio of entities to establishments in the industry.[35]

Finally, the last three columns (ten through twelve) present data on total revenues in the affected industry (not just affected entities), revenues per entity, and revenues per establishment. Because OSHA did not have data to distinguish revenues for affected entities and establishments in any industry, average revenue per entity and average revenue per affected entity (as well as average revenue per establishment and average revenue per affected establishment) within any industry are estimated to be equal in value.

Public comments relating to this Table, as it was presented in the PEA (PEA Table III-2), are discussed after Table III-5.

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[33] The source of these industry data is the U.S. Census Bureau, Statistics of U.S. Businesses, 2012.

[34] Estimates of the numbers of affected employees in general industry and maritime are based on an assessment for each sector of the job categories of workers who perform tasks where silica exposures can occur. OSHA matched occupational titles from the 2012 BLS OES survey with these at-risk job categories and then used OES occupational employment statistics to generate industry-specific estimates of the numbers of affected employees. To ensure data compatibility, OES occupational employment statistics were benchmarked to the 2012 County Business Pattern employment totals for each industry.

[35] For the PEA, OSHA determined that removing this assumption would have a negligible impact on total costs and would reduce the cost and economic impact on the average affected establishment or entity. OSHA requested comment on this methodological test and received none. Therefore, OSHA has applied this methodology in this FEA and again has determined that removing this assumption would have a negligible impact on total costs and would reduce the cost and economic impact on the average affected establishment or entity.

Table III-5: Characteristics of Industries Affected by OSHA's Final Standard for Silica – All Entities

NAICS	Industry	Total Entities [a]	Total Establish-ments [a]	Total Employment [a]	Total Affected Entities [b]	Total Affected Establish-ments [b]	Total Affected Employ-ment [b]	Total FTE Affected Employ-ees [b]	Total Revenues ($1,000) [a]	Revenues Per Entity ($1,000)	Revenues per Establish-ment ($1,000)
Construction											
236100	Residential Building Construction	149,938	151,034	519,070	149,938	151,034	210,773	16,717	$190,342,871	$1,269	$1,260
236200	Nonresidential Building Construction	39,813	41,018	521,112	39,813	41,018	209,136	22,796	$280,695,881	$7,050	$6,843
237100	Utility System Construction	17,446	18,686	466,099	17,446	18,686	190,044	65,949	$118,254,327	$6,778	$6,328
237200	Land Subdivision	6,055	6,182	53,045	2,106	2,150	5,726	1,519	$40,050,602	$6,614	$6,479
237300	Highway, Street, and Bridge Construction	9,271	10,043	251,065	9,271	10,043	148,254	40,171	$100,657,731	$10,857	$10,023
237900	Other Heavy and Civil Engineering Construction	4,092	4,222	79,390	4,092	4,222	37,611	11,077	$24,201,269	$5,914	$5,732
238100	Foundation, Structure, and Building Exterior Contractors	85,082	85,801	657,508	85,082	85,801	324,954	56,183	$111,574,869	$1,311	$1,300
238200	Building Equipment Contractors	165,862	170,002	1,629,581	139,065	142,536	326,154	21,455	$304,014,454	$1,833	$1,788
238300	Building Finishing Contractors	101,727	102,700	608,945	76,597	77,330	140,813	17,985	$88,148,669	$867	$858
238900	Other Specialty Trade Contractors	62,522	63,214	475,127	62,522	63,214	259,906	87,322	$102,228,982	$1,635	$1,617
221100	Electric Utilities	1,831	10,401	509,704	821	4,662	6,541	2,363	$427,201,520	$233,316	$41,073
999200	State governments [c]	N/A	N/A	N/A	N/A	0	33,558	8,088	N/A	N/A	N/A
999300	Local governments [c]	N/A	N/A	N/A	N/A	0	123,946	36,084	N/A	N/A	N/A
	Subtotals - Construction	**643,639**	**663,303**	**5,770,646**	**586,752**	**600,695**	**2,017,417**	**387,710**	**$1,787,371,175**	**$2,777**	**$2,695**

Table III-5: Characteristics of Industries Affected by OSHA's Final Standard for Silica – All Entities (continued)

NAICS	Industry	Total Entities [a]	Total Establish-ments [a]	Total Employ-ment [a]	Total Affected Entities [b]	Total Affected Establish-ments [b]	Total Affected Employ-ment [b]	Total FTE Affected Employ-ees [b]	Total Revenues ($1,000) [a]	Revenues Per Entity ($1,000)	Revenues Per Establishment ($1,000)
General Industry and Maritime											
213112	Support Activities for Oil and Gas Operations	8,877	10,872	272,357	200	444	16,960	N/A	$17,396,813	$86,984	$39,182
324121	Asphalt Paving Mixture and Block Manufacturing	472	1,362	14,353	472	1,362	4,737		$13,137,706	$27,834	$9,646
324122	Asphalt Shingle and Coating Materials Manufacturing	132	223	9,074	132	223	3,158		$10,506,586	$79,595	$47,115
325510	Paint and Coating Manufacturing	971	1,161	35,328	646	772	2,511		$23,628,642	$24,334	$20,352
327110	Pottery, Ceramics, and Plumbing Fixture Manufacturing	636	655	13,096	636	655	6,269		$2,131,885	$3,352	$3,255
327120	Clay Building Material and Refractories Manufacturing	417	586	20,985	417	586	7,893		$5,109,750	$12,254	$8,720
327211	Flat Glass Manufacturing	63	85	8,990	41	56	221		$3,168,243	$50,290	$37,273
327212	Other Pressed and Blown Glass and Glassware Manufacturing	407	442	13,434	157	171	674		$3,337,290	$8,200	$7,550
327213	Glass Container Manufacturing	33	74	13,684	28	62	686		$3,832,809	$116,146	$51,795
327320	Ready-Mix Concrete Manufacturing	2,115	5,377	66,196	2,115	5,377	27,123		$20,360,217	$9,627	$3,787

Table III-5: Characteristics of Industries Affected by OSHA's Final Standard for Silica – All Entities (continued)

NAICS	Industry	Total Entities [a]	Total Establish-ments [a]	Total Employ-ment [a]	Total Affected Entities [b]	Total Affected Establish-ments [b]	Total Affected Employ-ment [b]	Total FTE Affected Employ-ees [b]	Total Revenues ($1,000) [a]	Revenues Per Entity ($1,000)	Revenues Per Establishment ($1,000)
327331	Concrete Block and Brick Manufacturing	511	817	14,896	511	817	7,182		$3,891,212	$7,615	$4,763
327332	Concrete Pipe Manufacturing	157	352	8,229	157	352	3,967		$2,013,573	$12,825	$5,720
327390	Other Concrete Product Manufacturing	1,633	1,973	45,284	1,633	1,973	21,832		$8,640,490	$5,291	$4,379
327991	Cut Stone and Stone Product Manufacturing	1,801	1,859	24,537	1,801	1,859	9,429		$3,513,346	$1,951	$1,890
327992	Ground or Treated Mineral and Earth Manufacturing	153	249	7,129	153	249	5,432		$3,326,599	$21,742	$13,360
327993	Mineral Wool Manufacturing	175	269	13,925	113	174	789		$4,753,466	$27,163	$17,671
327999	All Other Miscellaneous Nonmetallic Mineral Product Manufacturing	302	452	10,118	302	452	7,952		$4,045,718	$13,396	$8,951
331110	Iron and Steel Mills and Ferroalloy Manufacturing	414	562	105,309	206	280	594		$113,226,448	$273,494	$201,471
331210	Iron and Steel Pipe and Tube Manufacturing from Purchased Steel	212	262	25,592	89	110	145		$14,371,958	$67,792	$54,855
331221	Rolled Steel Shape Manufacturing	150	167	7,836	37	41	44		$5,991,188	$39,941	$35,875
331222	Steel Wire Drawing	251	294	14,241	66	78	81		$5,654,358	$22,527	$19,233

Table III-5: Characteristics of Industries Affected by OSHA's Final Standard for Silica – All Entities (continued)

NAICS	Industry	Total Entities [a]	Total Establish-ments [a]	Total Employ-ment [a]	Total Affected Entities [b]	Total Affected Establish-ments [b]	Total Affected Employ-ment [b]	Total FTE Affected Employ-ees [b]	Total Revenues ($1,000) [a]	Revenues Per Entity ($1,000)	Revenues Per Establishment ($1,000)
331314	Secondary Smelting and Alloying of Aluminum	92	114	5,415	25	30	30		$5,623,100	$61,121	$49,325
331420	Copper Rolling, Drawing, Extruding, and Alloying	179	249	21,408	77	107	119		$23,357,388	$130,488	$93,805
331492	Secondary Smelting, Refining, and Alloying of Nonferrous Metal (except Copper and Aluminum)	228	261	10,913	51	58	62		$14,552,929	$63,829	$55,758
331511	Iron Foundries	361	407	38,286	361	407	13,583		$10,816,325	$29,962	$26,576
331512	Steel Investment Foundries	109	128	15,190	109	128	5,487		$3,728,493	$34,206	$29,129
331513	Steel Foundries (except Investment)	194	208	18,236	194	208	6,469		$4,536,694	$23,385	$21,811
331524	Aluminum Foundries (except Die-Casting)	383	406	15,446	383	406	5,601		$2,830,636	$7,391	$6,972
331529	Other Nonferrous Metal Foundries (except Die-Casting)	293	300	9,522	293	300	3,451		$2,412,855	$8,235	$8,043
332111	Iron and Steel Forging	315	356	24,030	110	125	136		$10,673,965	$33,886	$29,983
332112	Nonferrous Forging	54	62	6,182	25	29	35		$2,388,185	$44,226	$38,519
332117	Powder Metallurgy Part Manufacturing	121	133	8,160	42	46	46		$2,023,839	$16,726	$15,217

Table III-5: Characteristics of Industries Affected by OSHA's Final Standard for Silica – All Entities (continued)

NAICS	Industry	Total Entities [a]	Total Establish-ments [a]	Total Employ-ment [a]	Total Affected Entities [b]	Total Affected Establish-ments [b]	Total Affected Employ-ment [b]	Total FTE Affected Employ-ees [b]	Total Revenues ($1,000) [a]	Revenues Per Entity ($1,000)	Revenues Per Establishment ($1,000)
332119	Metal Crown, Closure, and Other Metal Stamping (except Automotive)	1,417	1,499	53,018	272	288	299		$11,816,815	$8,339	$7,883
332215	Metal Kitchen Cookware, Utensil, Cutlery, and Flatware (except Precious) Manufacturing	178	188	7,374	35	37	42		$3,743,875	$21,033	$19,914
332216	Saw Blade and Handtool Manufacturing	935	1,012	27,852	136	147	157		$6,750,376	$7,220	$6,670
332323	Ornamental and Architectural Metal Work Manufacturing	2,175	2,214	29,694	39	40	40		$5,806,852	$2,670	$2,623
332439	Other Metal Container Manufacturing	298	346	11,749	53	62	66		$3,724,262	$12,498	$10,764
332510	Hardware Manufacturing	553	607	26,540	122	134	150		$7,494,634	$13,553	$12,347
332613	Spring Manufacturing	334	392	14,829	70	82	84		$3,595,394	$10,765	$9,172
332618	Other Fabricated Wire Product Manufacturing	829	911	24,626	124	137	139		$5,393,567	$6,506	$5,920
332710	Machine Shops	19,062	19,270	245,538	1,369	1,384	1,387		$38,834,064	$2,037	$2,015

Table III-5: Characteristics of Industries Affected by OSHA's Final Standard for Silica – All Entities (continued)

NAICS	Industry	Total Entities [a]	Total Establish-ments [a]	Total Employ-ment [a]	Total Affected Entities [b]	Total Affected Establish-ments [b]	Total Affected Employ-ment [b]	Total FTE Affected Employ-ees [b]	Total Revenues ($1,000) [a]	Revenues Per Entity ($1,000)	Revenues Per Establishment ($1,000)
332812	Metal Coating, Engraving (except Jewelry and Silverware), and Allied Services to Manufacturers	2,314	2,518	49,911	1,488	1,620	4,113		$13,159,283	$5,687	$5,226
332911	Industrial Valve Manufacturing	401	517	35,657	138	177	201		$12,406,422	$30,939	$23,997
332912	Fluid Power Valve and Hose Fitting Manufacturing	303	371	34,663	114	139	196		$10,351,141	$34,162	$27,901
332913	Plumbing Fixture Fitting and Trim Manufacturing	108	121	7,567	32	36	43		$3,879,892	$35,925	$32,065
332919	Other Metal Valve and Pipe Fitting Manufacturing	224	243	14,260	69	75	80		$4,852,328	$21,662	$19,968
332991	Ball and Roller Bearing Manufacturing	118	176	22,522	66	99	127		$6,811,132	$57,721	$38,700
332996	Fabricated Pipe and Pipe Fitting Manufacturing	700	765	29,914	146	160	169		$8,539,434	$12,199	$11,163
332999	All Other Miscellaneous Fabricated Metal Product Manufacturing	3,483	3,553	70,118	388	396	405		$14,774,444	$4,242	$4,158
333318	Other Commercial and Service Industry Machinery Manufacturing	1,284	1,378	54,518	241	258	308		$17,379,403	$13,535	$12,612

Table III-5: Characteristics of Industries Affected by OSHA's Final Standard for Silica – All Entities (continued)

NAICS	Industry	Total Entities [a]	Total Establish-ments [a]	Total Employ-ment [a]	Total Affected Entities [b]	Total Affected Establish-ments [b]	Total Affected Employ-ment [b]	Total FTE Affected Employ-ees [b]	Total Revenues ($1,000) [a]	Revenues Per Entity ($1,000)	Revenues Per Establishment ($1,000)
333413	Industrial and Commercial Fan and Blower and Air Purification Equipment Manufacturing	414	491	24,138	110	131	136		$6,017,917	$14,536	$12,256
333414	Heating Equipment (except Warm Air Furnaces) Manufacturing	441	472	17,959	95	102	102		$5,305,649	$12,031	$11,241
333511	Industrial Mold Manufacturing	1,629	1,669	35,194	190	194	199		$6,097,671	$3,743	$3,653
333514	Special Die and Tool, Die Set, Jig, and Fixture Manufacturing	2,444	2,477	42,810	233	236	242		$7,694,694	$3,148	$3,106
333515	Cutting Tool and Machine Tool Accessory Manufacturing	1,472	1,519	28,451	156	161	161		$5,277,212	$3,585	$3,474
333517	Machine Tool Manufacturing	662	689	24,322	124	129	137		$7,477,416	$11,295	$10,853
333519	Rolling Mill and Other Metalworking Machinery Manufacturing	355	371	11,582	59	62	66		$3,166,299	$8,919	$8,534
333612	Speed Changer, Industrial High-Speed Drive, and Gear Manufacturing	213	246	16,072	66	76	91		$5,093,290	$23,912	$20,704
333613	Mechanical Power Transmission Equipment Manufacturing	206	245	15,545	69	82	88		$4,671,836	$22,679	$19,069

Table III-5: Characteristics of Industries Affected by OSHA's Final Standard for Silica – All Entities (continued)

NAICS	Industry	Total Entities [a]	Total Establish-ments [a]	Total Employ-ment [a]	Total Affected Entities [b]	Total Affected Establish-ments [b]	Total Affected Employ-ment [b]	Total FTE Affected Employ-ees [b]	Total Revenues ($1,000) [a]	Revenues Per Entity ($1,000)	Revenues Per Establishment ($1,000)
333911	Pump and Pumping Equipment Manufacturing	441	539	33,772	135	165	191		$15,242,314	$34,563	$28,279
333912	Air and Gas Compressor Manufacturing	262	306	21,225	85	99	120		$10,412,455	$39,742	$34,028
333991	Power-Driven Handtool Manufacturing	141	151	8,859	35	37	50		$4,253,527	$30,167	$28,169
333992	Welding and Soldering Equipment Manufacturing	325	344	15,781	55	58	89		$5,881,450	$18,097	$17,097
333993	Packaging Machinery Manufacturing	535	580	20,010	99	108	113		$5,690,862	$10,637	$9,812
333994	Industrial Process Furnace and Oven Manufacturing	327	352	11,009	58	62	62		$2,743,937	$8,391	$7,795
333995	Fluid Power Cylinder and Actuator Manufacturing	264	324	24,208	86	106	137		$6,560,865	$24,852	$20,250
333996	Fluid Power Pump and Motor Manufacturing	129	148	10,554	44	51	60		$4,065,318	$31,514	$27,468
333997	Scale and Balance Manufacturing	82	88	3,725	20	21	21		$969,400	$11,822	$11,016
333999	All Other Miscellaneous General Purpose Machinery Manufacturing	1,590	1,654	51,495	251	261	291		$15,072,973	$9,480	$9,113
334519	Other Measuring and Controlling Device Manufacturing	858	905	34,604	155	164	196		$11,468,826	$13,367	$12,673

Table III-5: Characteristics of Industries Affected by OSHA's Final Standard for Silica – All Entities (continued)

NAICS	Industry	Total Entities [a]	Total Establish-ments [a]	Total Employ-ment [a]	Total Affected Entities [b]	Total Affected Establish-ments [b]	Total Affected Employ-ment [b]	Total FTE Affected Employ-ees [b]	Total Revenues ($1,000) [a]	Revenues Per Entity ($1,000)	Revenues Per Establishment ($1,000)
335210	Small Electrical Appliance Manufacturing	119	127	8,216	19	20	24		$3,412,551	$28,677	$26,870
335221	Household Cooking Appliance Manufacturing	95	98	10,408	14	15	30		$4,480,046	$47,158	$45,715
335222	Household Refrigerator and Home Freezer Manufacturing	23	30	9,374	8	11	27		$3,533,056	$153,611	$117,769
335224	Household Laundry Equipment Manufacturing	8	9	4,438	3	3	13		$912,032	$114,004	$101,337
335228	Other Major Household Appliance Manufacturing	30	36	9,059	10	12	26		$4,514,574	$150,486	$125,405
336111	Automobile Manufacturing	159	173	62,686	36	39	354		$103,913,316	$653,543	$600,655
336112	Light Truck and Utility Vehicle Manufacturing	63	78	56,524	22	27	319		$118,710,290	$1,884,290	$1,521,927
336120	Heavy Duty Truck Manufacturing	68	85	30,756	32	40	174		$30,162,164	$443,561	$354,849
336211	Motor Vehicle Body Manufacturing	656	741	40,544	168	190	229		$11,284,629	$17,202	$15,229
336212	Truck Trailer Manufacturing	374	421	28,304	108	121	160		$8,276,216	$22,129	$19,658
336213	Motor Home Manufacturing	54	62	7,395	14	16	42		$2,420,705	$44,828	$39,044

Table III-5: Characteristics of Industries Affected by OSHA's Final Standard for Silica – All Entities (continued)

NAICS	Industry	Total Entities [a]	Total Establish-ments [a]	Total Employ-ment [a]	Total Affected Entities [b]	Total Affected Establish-ments [b]	Total Affected Employ-ment [b]	Total FTE Affected Employ-ees [b]	Total Revenues ($1,000) [a]	Revenues Per Entity ($1,000)	Revenues Per Establishment ($1,000)
336310	Motor Vehicle Gasoline Engine and Engine Parts Manufacturing	788	849	52,752	182	196	298		$31,854,605	$40,425	$37,520
336320	Motor Vehicle Electrical and Electronic Equipment Manufacturing	618	678	50,017	183	200	283		$20,449,859	$33,090	$30,162
336330	Motor Vehicle Steering and Suspension Components (except Spring) Manufacturing	210	245	28,663	92	108	162		$11,779,510	$56,093	$48,080
336340	Motor Vehicle Brake System Manufacturing	156	195	21,859	80	100	123		$10,032,414	$64,310	$51,448
336350	Motor Vehicle Transmission and Power Train Parts Manufacturing	424	503	58,248	165	196	329		$34,304,884	$80,908	$68,201
336370	Motor Vehicle Metal Stamping	645	773	81,018	296	355	458		$31,438,874	$48,742	$40,671
336390	Other Motor Vehicle Parts Manufacturing	1,302	1,508	122,041	440	510	689		$58,108,630	$44,630	$38,534
336611	Ship Building and Repairing	604	689	108,311	309	353	3,038		$25,050,036	$41,474	$36,357
336612	Boat Building	836	871	28,054	301	313	787		$7,015,414	$8,392	$8,054

Table III-5: Characteristics of Industries Affected by OSHA's Final Standard for Silica – All Entities (continued)

NAICS	Industry	Total Entities [a]	Total Establish-ments [a]	Total Employ-ment [a]	Total Affected Entities [b]	Total Affected Establish-ments [b]	Total Affected Employ-ment [b]	Total FTE Affected Employ-ees [b]	Total Revenues ($1,000) [a]	Revenues Per Entity ($1,000)	Revenues Per Establishment ($1,000)
336992	Military Armored Vehicle, Tank, and Tank Component Manufacturing	60	71	10,990	26	31	62		$5,815,339	$96,922	$81,906
337110	Wood Kitchen Cabinet and Countertop Manufacturing	6,795	6,862	76,052	204	206	223		$10,670,228	$1,570	$1,555
337215	Showcase, Partition, Shelving, and Locker Manufacturing	1,042	1,097	33,437	169	177	189		$6,526,548	$6,263	$5,949
339114	Dental Equipment and Supplies Manufacturing	706	727	15,835	706	727	4,956		$5,194,250	$7,357	$7,145
339116	Dental Laboratories	6,533	6,818	44,097	6,533	6,818	31,105		$4,606,911	$705	$676
339910	Jewelry and Silverware Manufacturing	2,102	2,119	24,436	2,102	2,119	6,772		$7,520,912	$3,578	$3,549
339950	Sign Manufacturing	5,405	5,499	69,051	357	363	384		$10,586,158	$1,959	$1,925
423840	Industrial Supplies Merchant Wholesalers	5,192	7,614	82,871	1,148	1,683	1,773		$64,188,699	$12,363	$8,430
444110	Home Centers	2,167	6,569	609,186	35	107	107		$13,942,008	$6,434	$2,122
482110	Rail transportation [d]	N/A	N/A	N/A	N/A	N/A	16,895		N/A	N/A	N/A

Table III-5: Characteristics of Industries Affected by OSHA's Final Standard for Silica – All Entities (continued)

NAICS	Industry	Total Entities [a]	Total Establish-ments [a]	Total Employ-ment [a]	Total Affected Entities [b]	Total Affected Establish-ments [b]	Total Affected Employ-ment [b]	Total FTE Affected Employ-ees [b]	Total Revenues ($1,000) [a]	Revenues Per Entity ($1,000)	Revenues Per Establishment ($1,000)
561730	Landscaping Services	91,251	92,976	548,662	25,500	25,982	43,033		$52,657,318	$577	$566
621210	Offices of Dentists	125,151	133,107	873,172	8,015	8,525	8,525		$104,740,291	$837	$787
	Subtotals – General Industry and maritime	**323,353**	**351,998**	**5,335,502**	**65,887**	**75,074**	**294,844**		**$1,475,562,403**	**$4,563**	**$4,192**
	Totals – All Industries	**966,992**	**1,015,301**	**11,106,148**	**652,639**	**675,770**	**2,312,261**	**387,710**	**$3,262,933,578**	**$3,374**	**$3,214**

[a] US Census Bureau, Statistics of US Businesses, 2012.

[b] OSHA estimates of "affected" categories represent associated entities and establishments with employees potentially exposed to silica. Affected entities and establishments constrained to be less than or equal to the number of affected employees (see discussion above in the text introducing this table). Full-time-equivalent estimate does not apply to general industry and maritime. Estimates of the numbers of affected employees in general industry and maritime are based on an assessment for each sector of the job categories of workers who perform tasks where silica exposures can occur. OSHA matched occupational titles from the 2012 BLS OES survey with these at-risk job categories and then used OES occupational employment statistics to generate industry-specific estimates of the numbers of affected employees. To ensure data compatibility, OES occupational employment statistics were benchmarked to the 2012 County Business Pattern employment totals for each industry.

[c] State-plan states only. State and local governments are included under the construction sector because the silica risks for public employees are the result of construction-related activities.

[d] For NAICS 482110, Rail Transportation, data on entities, establishments and revenues were not available from the US Census Bureau. OSHA's final profile of rail transportation is drawn from supplementary government and industry sources; see Chapter VI, Economic Feasibility Analysis and Regulatory Flexibility Determination.

Source: OSHA, Directorate of Standards and Guidance, Office of Regulatory Analysis, based on OSHA, 2016.

The National Concrete Masonry Association (NCMA) objected to OSHA's preliminary estimate of the size of the NAICS code within which their members are classified:

> The National Concrete Masonry Association represents the manufacturers of Concrete Block and Brick as well as the manufacturers of related products such as Segmental Retaining Wall Units and Manufactured Stone. While it is unclear which producers are classified into which concrete products categories, we will assume that all of our members fall into NAICS Code 327331. NCMA estimates that its members constitute about 1/3 of the producing entities under this code and represent about 2/3 of the production capacity. While we do not have definitive data to contradict the 599 entities and 951 establishments referenced in Table III-2, we would believe that these numbers may be more reflective of the industry prior to the recent recession and they are inflated by about 20-30% (Document ID 2279, pp. 2-3).

In response, OSHA notes that (1) as shown in Table III-5, the estimated number of affected firms and establishments for NAICS 327331, Concrete Block and Brick Manufacturing, will total 511 and 817, respectively, or approximately 15 percent lower than the preliminary estimates, and (2) NAICS 327331 may include concrete block and brick manufacturers who are not members of NCMA. NCMA's comment did not foreclose that possibility. Therefore, OSHA's final estimate of affected concrete block and brick producers may be closer to NCMA's industry profile and should meet the concrete masonry association's objections.

As shown in Table III-5, only slightly more than 66 percent of the entities and establishments, and about 21 percent of the workers in affected industries, actually engage in activities involving silica exposure.[36] However, a total of approximately 652,600 entities (586,800 in construction; 65,900 in general industry and maritime), 675,800 establishments (600,700 in construction; 75,100 in general industry and maritime), and 2.3 million workers (2.0 million in construction; 0.3 million in general industry and maritime) are shown to be affected by the final silica rule.

OSHA notes that a fraction of the workforce exposed to silica is likely exposed to other substances currently regulated by OSHA and therefore may benefit from existing controls. OSHA has not attempted to quantify the extent to which silica exposures, and

[36] These percentages vary significantly depending on the industry sector and, within an industry sector, depending on the NAICS industry. For example, about 35 percent of the workers in construction, but only 6 percent of workers in general industry, actually engage in activities involving silica exposure. As an example within construction, about 59 percent of workers in highway, street, and bridge construction, but only 11 percent of workers in land subdivision, actually engage in activities involving silica exposure.

exposure control, overlap with other OSHA-regulated substances, but estimates that any effect (for example, a reduction in compliance costs in relation to an OSHA silica standard) would be minor.

OSHA requested comment on the overlap of other health and safety regulations with silica protection. Dr. Ruth Ruttenberg, an economic consultant to the AFL-CIO, identified four areas where overlap of the silica standard with existing regulations would reduce silica compliance costs: respirators, exposure assessment, portability of records, and ventilation technology (Document ID 2257, Attachment 4, p. 5). Similarly, the International Union of Operating Engineers (IUOE) stated that measures for practicing good industrial hygiene and implementing measures to control exposure to dust, noise, and diesel fuel will also help to protect workers from silica exposure (Document ID 2262, p. 2). OSHA agrees in principle with these statements on the potential overlap of silica controls with the controls required under other standards but did not attempt to calculate cost savings. In Chapter V, Costs of Compliance, the Agency addresses in greater detail the concerns raised by Dr. Ruttenberg and IUOE.

Full-Time-Equivalent Workers

For construction, an industry profile must recognize a distinction between an estimate of the total number of workers involved in a production activity and a measure that translates that level of worker involvement into actual workday exposures. This distinction is necessary because, unlike in general industry, affected construction workers may spend large amounts of time working on tasks with no risk of exposure to respirable crystalline silica. The ninth column in Table III-9, with data only for construction, shows for each affected NAICS construction industry the number of full-time-equivalent (FTE) affected workers that corresponds to the total number of affected construction workers in the previous column.[37] As shown in Table III-5, the 2.0 million affected workers in construction converts to approximately 387,700 FTE affected workers. In contrast, OSHA based its analysis of the affected workers in general industry and maritime on the evidence-based assumption that they were engaged full time in activities with some silica exposure.

Small entities

[37] FTE affected workers becomes a relevant variable in the estimation of control costs in the construction industry in Chapter V of this FEA. The reason is that, consistent with the costing methodology, control costs depend only on how many worker-days there are in which exposures are above the PEL. These are the worker-days in which controls are required. For the derivation of FTEs, see FEA Chapters IV and V, ERG (2007a), and OSHA (2016).

Similar information to that provided in Table III-5 for all entities in each affected industry is also provided for all small entities, as defined by SBA, in each affected industry (in Table III-6) and for all small entities with fewer than 20 employees in each affected industry (in Table III-7).

Table III-6: Characteristics of Industries Affected by OSHA's Final Standard for Silica – Small Entities

NAICS	Industry	SBA Small Business Classification (Limit for revenues or employment)	Small Business or Gov. Entities [b]	Establish-ments for SBA Entities [b]	SBA Entity Employ-ment [b]	Affected Small Business or Gov. Entities [c]	Affected Employ-ment (at risk) for SBA Entities	Affected FTE Employ-ees (at risk) for SBA	Total Revenues for SBA Entities ($1,000) [b]	Revenues Per SBA Entity ($1,000)	Revenues per SBA Establish-ment ($1,000)
Construction											
236100	Residential Building Construction	$36.5 million	149,765	150,046	468,717	149,765	190,327	15,096	$140,284,900	$937	$935
236200	Nonresidential Building Construction	$36.5 million	39,073	39,246	336,236	39,073	134,940	14,709	$158,164,988	$4,048	$4,030
237100	Utility System Construction	$36.5 million	16,757	16,845	166,685	16,757	67,963	23,585	$40,279,007	$2,404	$2,391
237200	Land Subdivision	$36.5 million	5,908	5,928	25,577	2,106	2,761	732	$12,663,407	$2,143	$2,136
237300	Highway, Street, and Bridge Construction	$36.5 million	8,737	8,789	110,597	8,737	65,307	17,696	$38,823,727	$4,444	$4,417
237900	Other Heavy and Civil Engineering Construction	$36.5 million	3,960	3,971	31,547	3,960	14,945	4,402	$8,354,541	$2,110	$2,104
238100	Foundation, Structure, and Building Exterior Contractors	$15 million	84,369	84,600	519,277	84,369	256,638	44,372	$86,767,762	$1,028	$1,026
238200	Building Equipment Contractors	$15 million	163,980	164,543	1,097,627	139,065	219,686	14,451	$185,320,952	$1,130	$1,126
238300	Building Finishing Contractors	$15 million	101,161	101,406	485,839	76,597	112,346	14,349	$70,433,090	$696	$695
238900	Other Specialty Trade Contractors	$15 million	61,966	62,117	356,969	61,966	195,271	65,606	$75,548,938	$1,219	$1,216
221100	Electric Utilities	1,000	1,751	3,124	86,731	624	1,113	402	$85,494,181	$48,826	$27,367
999200	State governments [e]	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
999300	Local governments [e]	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

Table III-6: Characteristics of Industries Affected by OSHA's Final Standard for Silica – Small Entities

NAICS	Industry	SBA Small Business Classification (Limit for revenues or employment)	Small Business or Gov. Entities [b]	Establish-ments for SBA Entities [b]	SBA Entity Employ-ment [b]	Affected Small Business or Gov. Entities [c]	Affected Employ-ment (at risk) for SBA Entities	Affected FTE Employ-ees (at risk) for SBA	Total Revenues for SBA Entities ($1,000) [b]	Revenues Per SBA Entity ($1,000)	Revenues per SBA Establish-ment ($1,000)
	Subtotals – Construction		**637,427**	**640,615**	**3,685,802**	**583,018**	**1,261,297**	**215,399**	**$902,135,493**	**$1,415**	**$1,408**

Table III-6: Characteristics of Industries Affected by OSHA's Final Standard for Silica – Small Entities (continued)

NAICS	Industry	SBA Small Business Classification (Limit for revenues or employment) [a]	Small Business or Gov. Entities [b]	Establish-ments for SBA Entities [b]	SBA Entity Employ-ment [b]	Affected Small Business or Gov. Entities [c]	Affected Employ-ment (at risk) for SBA Entities [c]	Affected FTE Employ-ees (at risk) for SBA Entities [c]	Total Revenues for SBA Entities ($1,000) [b]	Revenues Per SBA Entity ($1,000)	Revenues per SBA Establish-ment ($1,000)
General Industry and Maritime											
213112	Support Activities for Oil and Gas Operations	$38.5 million	8,467	8,608	79,137	150	3,036	N/A	$1,884,313	$12,562	$11,777
324121	Asphalt Paving Mixture and Block Manufacturing	500 employees	422	650	7,207	422	2,379		$5,768,080	$13,668	$8,874
324122	Asphalt Shingle and Coating Materials Manufacturing	750 employees	118	140	3,029	118	1,054		$2,644,917	$22,415	$18,892
325510	Paint and Coating Manufacturing	1,000 employees	938	1,008	19,984	646	1,420		$7,345,684	$7,831	$7,287
327110	Pottery, Ceramics, and Plumbing Fixture Manufacturing	1,000 employees	620	625	7,540	620	3,609		$980,162	$1,581	$1,568

Table III-6: Characteristics of Industries Affected by OSHA's Final Standard for Silica – Small Entities (continued)

NAICS	Industry	SBA Small Business Classification (Limit for revenues or employment) [a]	Small Business or Gov. Entities [b]	Establish-ments for SBA Entities [b]	SBA Entity Employ-ment [b]	Affected Small Business or Gov. Entities [c]	Affected Employ-ment (at risk) for SBA Entities [c]	Affected FTE Employ-ees (at risk) for SBA Entities [c]	Total Revenues for SBA Entities ($1,000) [b]	Revenues Per SBA Entity ($1,000)	Revenues per SBA Establish-ment ($1,000)
327120	Clay Building Material and Refractories Manufacturing	750 employees	393	465	13,476	393	5,069		$3,035,982	$7,725	$6,529
327211	Flat Glass Manufacturing	1,000 employees	53	53	1,605	39	39		$384,922	$7,263	$7,263
327212	Other Pressed and Blown Glass and Glassware Manufacturing	1,250 employees	389	402	5,901	157	296		$1,219,275	$3,134	$3,033
327213	Glass Container Manufacturing	1,250 employees	26	29	13,068	26	655		$3,660,316	$140,781	$126,218
327320	Ready-Mix Concrete Manufacturing	500 employees	2,062	3,477	44,676	2,062	18,306		$12,296,401	$5,963	$3,536
327331	Concrete Block and Brick Manufacturing	500 employees	486	614	9,655	486	4,655		$2,425,580	$4,991	$3,950
327332	Concrete Pipe Manufacturing	750 employees	147	181	4,104	147	1,978		$913,837	$6,217	$5,049
327390	Other Concrete Product Manufacturing	500 employees	1,591	1,736	31,536	1,591	15,204		$5,466,741	$3,436	$3,149
327991	Cut Stone and Stone Product Manufacturing	500 employees	1,785	1,815	21,919	1,785	8,423		$3,027,967	$1,696	$1,668
327992	Ground or Treated Mineral and Earth Manufacturing	500 employees	123	156	3,451	123	2,630		$1,233,679	$10,030	$7,908

Table III-6: Characteristics of Industries Affected by OSHA's Final Standard for Silica – Small Entities (continued)

NAICS	Industry	SBA Small Business Classification (Limit for revenues or employment) [a]	Small Business or Gov. Entities [b]	Establish-ments for SBA Entities [b]	SBA Entity Employ-ment [b]	Affected Small Business or Gov. Entities [c]	Affected Employ-ment (at risk) for SBA Entities [c]	Affected FTE Employ-ees (at risk) for SBA Entities [c]	Total Revenues for SBA Entities ($1,000) [b]	Revenues Per SBA Entity ($1,000)	Revenues per SBA Establish-ment ($1,000)
327993	Mineral Wool Manufacturing	1,500 employees	163	201	5,272	113	299		$1,415,931	$8,687	$7,044
327999	All Other Miscellaneous Nonmetallic Mineral Product Manufacturing	500 employees	277	302	5,123	277	4,026		$1,603,051	$5,787	$5,308
331110	Iron and Steel Mills and Ferroalloy Manufacturing	1,500 employees	366	402	23,833	122	135		$20,728,440	$56,635	$51,563
331210	Iron and Steel Pipe and Tube Manufacturing from Purchased Steel	1,000 employees	183	205	13,133	66	74		$6,266,899	$34,245	$30,570
331221	Rolled Steel Shape Manufacturing	1,000 employees	136	143	6,597	36	37		$4,725,515	$34,746	$33,046
331222	Steel Wire Drawing	1,000 employees	231	253	10,368	54	59		$3,575,511	$15,478	$14,132
331314	Secondary Smelting and Alloying of Aluminum	750 employees	77	83	3,004	16	17		$2,184,402	$28,369	$26,318
331420	Copper Rolling, Drawing, Extruding, and Alloying	1,000 employees	159	179	10,812	53	60		$8,454,702	$53,174	$47,233

Table III-6: Characteristics of Industries Affected by OSHA's Final Standard for Silica – Small Entities (continued)

NAICS	Industry	SBA Small Business Classification (Limit for revenues or employment) [a]	Small Business or Gov. Entities [b]	Establish-ments for SBA Entities [b]	SBA Entity Employ-ment [b]	Affected Small Business or Gov. Entities [c]	Affected Employ-ment (at risk) for SBA Entities [c]	Affected FTE Employ-ees (at risk) for SBA Entities [c]	Total Revenues for SBA Entities ($1,000) [b]	Revenues Per SBA Entity ($1,000)	Revenues per SBA Establish-ment ($1,000)
331492	Secondary Smelting, Refining, and Alloying of Nonferrous Metal (except Copper and Aluminum)	750 employees	205	218	5,817	31	33		$9,435,665	$46,028	$43,283
331511	Iron Foundries	1,000 employees	327	343	20,152	327	7,149		$4,476,250	$13,689	$13,050
331512	Steel Investment Foundries	1,000 employees	100	106	7,367	100	2,661		$1,322,114	$13,221	$12,473
331513	Steel Foundries (except Investment)	500 employees	175	180	8,872	175	3,147		$1,813,149	$10,361	$10,073
331524	Aluminum Foundries (except Die-Casting)	500 employees	371	382	11,733	371	4,254		$1,768,873	$4,768	$4,631
331529	Other Nonferrous Metal Foundries (except Die-Casting)	500 employees	278	282	6,185	278	2,241		$1,455,544	$5,236	$5,162
332111	Iron and Steel Forging	750 employees	282	296	12,388	67	70		$4,614,071	$16,362	$15,588
332112	Nonferrous Forging	750 employees	39	40	2,098	12	12		$656,551	$16,835	$16,414
332117	Powder Metallurgy Part Manufacturing	500 employees	104	106	4,605	25	26		$922,537	$8,871	$8,703

Table III-6: Characteristics of Industries Affected by OSHA's Final Standard for Silica – Small Entities (continued)

NAICS	Industry	SBA Small Business Classification (Limit for revenues or employment) [a]	Small Business or Gov. Entities [b]	Establish-ments for SBA Entities [b]	SBA Entity Employ-ment [b]	Affected Small Business or Gov. Entities [c]	Affected Employ-ment (at risk) for SBA Entities [c]	Affected FTE Employ-ees (at risk) for SBA Entities [c]	Total Revenues for SBA Entities ($1,000) [b]	Revenues Per SBA Entity ($1,000)	Revenues per SBA Establish-ment ($1,000)
332119	Metal Crown, Closure, and Other Metal Stamping (except Automotive)	500 employees	1,369	1,417	41,467	226	234		$8,285,627	$6,052	$5,847
332215	Metal Kitchen Cookware, Utensil, Cutlery, and Flatware (except Precious) Manufacturing	750 employees	167	171	4,173	23	24		$1,045,189	$6,259	$6,112
332216	Saw Blade and Handtool Manufacturing	750 employees	912	961	18,643	100	105		$3,437,258	$3,769	$3,577
332323	Ornamental and Architectural Metal Work Manufacturing	500 employees	2,150	2,170	24,255	32	33		$4,414,269	$2,053	$2,034
332439	Other Metal Container Manufacturing	500 employees	280	298	6,549	35	37		$1,537,878	$5,492	$5,161
332510	Hardware Manufacturing	750 employees	528	545	14,198	78	80		$3,337,279	$6,321	$6,123
332613	Spring Manufacturing	500 employees	320	348	9,761	51	55		$2,033,847	$6,356	$5,844
332618	Other Fabricated Wire Product Manufacturing	500 employees	802	852	19,644	104	111		$4,104,644	$5,118	$4,818
332710	Machine Shops	500 employees	18,944	19,075	227,314	1,275	1,284		$34,386,902	$1,815	$1,803

Table III-6: Characteristics of Industries Affected by OSHA's Final Standard for Silica – Small Entities (continued)

NAICS	Industry	SBA Small Business Classification (Limit for revenues or employment) [a]	Small Business or Gov. Entities [b]	Establish-ments for SBA Entities [b]	SBA Entity Employ-ment [b]	Affected Small Business or Gov. Entities [c]	Affected Employ-ment (at risk) for SBA Entities [c]	Affected FTE Employ-ees (at risk) for SBA Entities [c]	Total Revenues for SBA Entities ($1,000) [b]	Revenues Per SBA Entity ($1,000)	Revenues per SBA Establish-ment ($1,000)
332812	Metal Coating, Engraving (except Jewelry and Silverware), and Allied Services to Manufacturers	500 employees	2,260	2,372	39,930	1,488	3,290		$7,402,914	$3,276	$3,121
332911	Industrial Valve Manufacturing	750 employees	361	384	15,547	83	88		$4,282,460	$11,863	$11,152
332912	Fluid Power Valve and Hose Fitting Manufacturing	1,000 employees	276	293	13,659	73	77		$3,051,276	$11,055	$10,414
332913	Plumbing Fixture Fitting and Trim Manufacturing	1,000 employees	101	105	4,531	25	26		$1,553,472	$15,381	$14,795
332919	Other Metal Valve and Pipe Fitting Manufacturing	750 employees	194	202	7,455	40	42		$2,232,937	$11,510	$11,054
332991	Ball and Roller Bearing Manufacturing	1,250 employees	98	106	4,340	23	25		$987,990	$10,082	$9,321
332996	Fabricated Pipe and Pipe Fitting Manufacturing	500 employees	658	676	18,064	99	102		$4,574,694	$6,952	$6,767
332999	All Other Miscellaneous Fabricated Metal Product Manufacturing	750 employees	3,425	3,476	60,724	346	351		$11,823,244	$3,452	$3,401

Table III-6: Characteristics of Industries Affected by OSHA's Final Standard for Silica – Small Entities (continued)

NAICS	Industry	SBA Small Business Classification (Limit for revenues or employment) [a]	Small Business or Gov. Entities [b]	Establish-ments for SBA Entities [b]	SBA Entity Employ-ment [b]	Affected Small Business or Gov. Entities [c]	Affected Employ-ment (at risk) for SBA Entities [c]	Affected FTE Employ-ees (at risk) for SBA Entities [c]	Total Revenues for SBA Entities ($1,000) [b]	Revenues Per SBA Entity ($1,000)	Revenues per SBA Establish-ment ($1,000)
333318	Other Commercial and Service Industry Machinery Manufacturing	1,000 employees	1,239	1,271	34,477	190	195		$9,898,889	$7,989	$7,788
333413	Industrial and Commercial Fan and Blower and Air Purification Equipment Manufacturing	500 employees	382	402	11,713	63	66		$2,659,363	$6,962	$6,615
333414	Heating Equipment (except Warm Air Furnaces) Manufacturing	500 employees	418	426	11,777	65	67		$3,203,678	$7,664	$7,520
333511	Industrial Mold Manufacturing	500 employees	1,596	1,624	30,463	169	172		$5,266,410	$3,300	$3,243
333514	Special Die and Tool, Die Set, Jig, and Fixture Manufacturing	500 employees	2,410	2,432	37,173	208	210		$6,227,983	$2,584	$2,561
333515	Cutting Tool and Machine Tool Accessory Manufacturing	500 employees	1,450	1,481	23,017	127	130		$3,930,472	$2,711	$2,654
333517	Machine Tool Manufacturing	500 employees	633	648	18,669	103	105		$4,340,326	$6,857	$6,698

Table III-6: Characteristics of Industries Affected by OSHA's Final Standard for Silica – Small Entities (continued)

NAICS	Industry	SBA Small Business Classification (Limit for revenues or employment) [a]	Small Business or Gov. Entities [b]	Establish-ments for SBA Entities [b]	SBA Entity Employ-ment [b]	Affected Small Business or Gov. Entities [c]	Affected Employ-ment (at risk) for SBA Entities [c]	Affected FTE Employ-ees (at risk) for SBA Entities [c]	Total Revenues for SBA Entities ($1,000) [b]	Revenues Per SBA Entity ($1,000)	Revenues per SBA Establish-ment ($1,000)
333519	Rolling Mill and Other Metalworking Machinery Manufacturing	500 employees	337	344	8,090	45	46		$1,973,588	$5,856	$5,737
333612	Speed Changer, Industrial High-Speed Drive, and Gear Manufacturing	750 employees	189	204	7,514	39	42		$2,133,164	$11,287	$10,457
333613	Mechanical Power Transmission Equipment Manufacturing	750 employees	179	187	6,790	37	38		$1,715,478	$9,584	$9,174
333911	Pump and Pumping Equipment Manufacturing	750 employees	399	418	12,325	67	70		$4,316,665	$10,819	$10,327
333912	Air and Gas Compressor Manufacturing	1,000 employees	235	247	9,493	51	54		$3,426,242	$14,580	$13,871
333991	Power-Driven Handtool Manufacturing	500 employees	125	126	2,500	14	14		$875,346	$7,003	$6,947
333992	Welding and Soldering Equipment Manufacturing	1,250 employees	313	317	7,565	42	43		$2,144,757	$6,852	$6,766
333993	Packaging Machinery Manufacturing	500 employees	508	520	12,733	70	72		$3,100,493	$6,103	$5,962

Table III-6: Characteristics of Industries Affected by OSHA's Final Standard for Silica – Small Entities (continued)

NAICS	Industry	SBA Small Business Classification (Limit for revenues or employment) [a]	Small Business or Gov. Entities [b]	Establish-ments for SBA Entities [b]	SBA Entity Employ-ment [b]	Affected Small Business or Gov. Entities [c]	Affected Employ-ment (at risk) for SBA Entities [c]	Affected FTE Employ-ees (at risk) for SBA Entities [c]	Total Revenues for SBA Entities ($1,000) [b]	Revenues Per SBA Entity ($1,000)	Revenues per SBA Establish-ment ($1,000)
333994	Industrial Process Furnace and Oven Manufacturing	500 employees	314	325	8,026	44	45		$1,915,695	$6,101	$5,894
333995	Fluid Power Cylinder and Actuator Manufacturing	750 employees	234	248	10,018	53	57		$2,339,672	$9,999	$9,434
333996	Fluid Power Pump and Motor Manufacturing	1,250 employees	117	118	3,401	19	19		$934,236	$7,985	$7,917
333997	Scale and Balance Manufacturing	500 employees	76	77	1,763	10	10		$362,388	$4,768	$4,706
333999	All Other Miscellaneous General Purpose Machinery Manufacturing	500 employees	1,507	1,529	30,690	171	173		$7,218,588	$4,790	$4,721
334519	Other Measuring and Controlling Device Manufacturing	500 employees	799	815	17,901	100	102		$4,485,121	$5,613	$5,503
335210	Small Electrical Appliance Manufacturing	1,500 employees	114	120	6,030	17	18		$1,953,370	$17,135	$16,278
335221	Household Cooking Appliance Manufacturing	1,500 employees	92	94	4,814	14	14		$1,768,769	$19,226	$18,817
335222	Household Refrigerator and Home Freezer Manufacturing	1,250 employees	19	20	1,690	5	5		$599,015	$31,527	$29,951

Table III-6: Characteristics of Industries Affected by OSHA's Final Standard for Silica – Small Entities (continued)

NAICS	Industry	SBA Small Business Classification (Limit for revenues or employment) [a]	Small Business or Gov. Entities [b]	Establish-ments for SBA Entities [b]	SBA Entity Employ-ment [b]	Affected Small Business or Gov. Entities [c]	Affected Employ-ment (at risk) for SBA Entities [c]	Affected FTE Employ-ees (at risk) for SBA Entities [c]	Total Revenues for SBA Entities ($1,000) [b]	Revenues Per SBA Entity ($1,000)	Revenues per SBA Establish-ment ($1,000)
335224	Household Laundry Equipment Manufacturing [e]	1,250 employees	6	6	56	0	0		$28,909	$4,818	$4,818
335228	Other Major Household Appliance Manufacturing	1,000 employees	21	21	1,310	4	4		$441,427	$21,020	$21,020
336111	Automobile Manufacturing	1,500 employees	144	145	3,541	20	20		$1,878,126	$13,043	$12,953
336112	Light Truck and Utility Vehicle Manufacturing	1,500 employees	54	54	1,345	8	8		$938,895	$17,387	$17,387
336120	Heavy Duty Truck Manufacturing	1,500 employees	61	67	6,157	32	35		$2,891,153	$47,396	$43,152
336211	Motor Vehicle Body Manufacturing	1,000 employees	629	668	25,589	136	145		$6,414,400	$10,198	$9,602
336212	Truck Trailer Manufacturing	1,000 employees	361	386	15,138	80	86		$3,568,924	$9,886	$9,246
336213	Motor Home Manufacturing	1,250 employees	48	50	1,750	9	10		$434,439	$9,051	$8,689
336310	Motor Vehicle Gasoline Engine and Engine Parts Manufacturing	1,000 employees	744	759	18,368	102	104		$5,916,326	$7,952	$7,795
336320	Motor Vehicle Electrical and Electronic Equipment Manufacturing	1,000 employees	583	615	25,020	134	141		$8,512,242	$14,601	$13,841

Table III-6: Characteristics of Industries Affected by OSHA's Final Standard for Silica – Small Entities (continued)

NAICS	Industry	SBA Small Business Classification (Limit for revenues or employment) [a]	Small Business or Gov. Entities [b]	Establish-ments for SBA Entities [b]	SBA Entity Employ-ment [b]	Affected Small Business or Gov. Entities [c]	Affected Employ-ment (at risk) for SBA Entities [c]	Affected FTE Employ-ees (at risk) for SBA Entities [c]	Total Revenues for SBA Entities ($1,000) [b]	Revenues Per SBA Entity ($1,000)	Revenues per SBA Establish-ment ($1,000)
336330	Motor Vehicle Steering and Suspension Components (except Spring) Manufacturing	1,000 employees	188	194	9,316	51	53		$4,000,227	$21,278	$20,620
336340	Motor Vehicle Brake System Manufacturing	1,250 employees	134	146	9,365	49	53		$3,193,783	$23,834	$21,875
336350	Motor Vehicle Transmission and Power Train Parts Manufacturing	1,500 employees	390	415	20,749	110	117		$8,551,074	$21,926	$20,605
336370	Motor Vehicle Metal Stamping	1,000 employees	609	670	48,191	247	272		$14,466,209	$23,754	$21,591
336390	Other Motor Vehicle Parts Manufacturing	1,000 employees	1,213	1,288	57,421	305	324		$22,664,879	$18,685	$17,597
336611	Ship Building and Repairing	1,250 employees	585	629	27,170	309	762		$5,792,725	$9,902	$9,209
336612	Boat Building	1,000 employees	828	848	21,663	301	608		$4,987,015	$6,023	$5,881
336992	Military Armored Vehicle, Tank, and Tank Component Manufacturing	1,500 employees	53	56	3,759	20	21		$1,316,132	$24,833	$23,502
337110	Wood Kitchen Cabinet and Countertop Manufacturing	750 employees	6,777	6,808	59,255	173	173		$6,790,800	$1,002	$997

Table III-6: Characteristics of Industries Affected by OSHA's Final Standard for Silica – Small Entities (continued)

NAICS	Industry	SBA Small Business Classification (Limit for revenues or employment) [a]	Small Business or Gov. Entities [b]	Establish-ments for SBA Entities [b]	SBA Entity Employ-ment [b]	Affected Small Business or Gov. Entities [c]	Affected Employ-ment (at risk) for SBA Entities [c]	Affected FTE Employ-ees (at risk) for SBA Entities [c]	Total Revenues for SBA Entities ($1,000) [b]	Revenues Per SBA Entity ($1,000)	Revenues per SBA Establish-ment ($1,000)
337215	Showcase, Partition, Shelving, and Locker Manufacturing	500 employees	1,018	1,050	24,235	133	137		$4,477,476	$4,398	$4,264
339114	Dental Equipment and Supplies Manufacturing	750 employees	697	706	11,166	697	3,495		$3,038,524	$4,359	$4,304
339116	Dental Laboratories	500 employees	6,518	6,563	35,642	6,518	25,141		$3,349,429	$514	$510
339910	Jewelry and Silverware Manufacturing	500 employees	2,091	2,095	18,391	2,091	5,097		$4,122,129	$1,971	$1,968
339950	Sign Manufacturing	500 employees	5,376	5,447	59,488	326	330		$8,839,427	$1,644	$1,623
423840	Industrial Supplies Merchant Wholesalers	100 employees	4,881	5,527	46,368	876	992		$22,906,414	$4,693	$4,144
444110	Home Centers	500 employees	2,150	2,538	33,352	5	6		$7,153,918	$3,327	$2,819
482110	Rail transportation	N/A	N/A	N/A	N/A	N/A	NA		N/A	N/A	N/A
561730	Landscaping Services	100 employees	90,813	91,080	401,492	25,500	31,490		$39,976,044	$440	$439
621210	Offices of Dentists	100 employees	124,892	128,347	819,369	7,784	7,999		$97,490,376	$781	$760
	Subtotals – General Industry and Maritime		**319,487**	**328,302**	**3,077,198**	**62,730**	**178,406**		**$597,130,071**	**$1,869**	**$1,819**
	Totals – All Industries		**956,914**	**968,917**	**6,762,999**	**645,749**	**1,439,703**	**215,399**	**$1,499,265,564**	**$1,567**	**$1,547**

[a] Data were not available specifically for small entities with more than 500 employees. For SBA small business classifications specifying 750 or fewer employees, OSHA used data for small businesses with 500 or fewer employees. For SBA small business classifications specifying 1,000 or fewer employees, OSHA used data for all entities in the industry.

[b] US Census Bureau, Statistics of US Businesses, 2012.

[c] OSHA estimates of employees potentially exposed to silica and associated entities and establishments. Affected entities and establishments constrained to be less than or equal to the number of affected employees. Full-time equivalent estimate does not apply to general industry and maritime.

[d] State-plan states only. State and local governments are included under the construction sector because the silica risks for public employees are the result of construction-related activities.

[e] For NAICS 335224, affected SBA entities and affected employment for SBA entities total to values that fall between zero and one but were rounded to the nearest integer (zero) for presentation in this table. Later in this FEA, the costs and impacts presented for this industry reflect the use of the actual (non-zero) values for entities and employment.

Source: OSHA, Directorate of Standards and Guidance, Office of Regulatory Analysis, based on OSHA, 2016.

Table III-7: Characteristics of Industries Affected by OSHA's Final Standard for Silica – Entities with Fewer than 20 Employees

NAICS	Industry	Entities with <20 Employees [a]	Estab. For Entities with <20 Employees [a]	Employment for Entities with <20 Employees[a]	Affected Entities with <20 Employees [b]	Affected Employees for Entities with <20 Employees [b]	Affected FTE Employees for Entities with <20 Employees[b]	Total Revenues for Entities with <20 Employees ($1,000) [a]	Revenues Per Entity with <20 Employees ($1,000)	Revenue per Estab. For Entities with <20 Employees ($1,000)
Construction										
236100	Residential Building Construction	146,823	146,851	360,372	146,304	146,332	11,606	$100,203,852	$682	$682
236200	Nonresidential Building Construction	34,409	34,424	167,228	34,409	67,113	7,315	$69,489,248	$2,020	$2,019
237100	Utility System Construction	14,297	14,305	70,708	14,297	28,830	10,005	$16,198,831	$1,133	$1,132
237200	Land Subdivision	5,613	5,616	15,121	1,631	1,632	433	$6,154,243	$1,096	$1,096
237300	Highway, Street, and Bridge Construction	6,891	6,897	35,405	6,891	20,907	5,665	$12,773,940	$1,854	$1,852
237900	Other Heavy and Civil Engineering Construction	3,541	3,541	15,083	3,541	7,146	2,105	$3,812,866	$1,077	$1,077
238100	Foundation, Structure, and Building Exterior Contractors	78,217	78,244	288,459	78,217	142,563	24,648	$48,524,264	$620	$620

Table III-7: Characteristics of Industries Affected by OSHA's Final Standard for Silica – Entities with Fewer than 20 Employees

NAICS	Industry	Entities with <20 Employees [a]	Estab. For Entities with <20 Employees [a]	Employment for Entities with <20 Employees[a]	Affected Entities with <20 Employees [b]	Affected Employees for Entities with <20 Employees [b]	Affected FTE Employees for Entities with <20 Employees[b]	Total Revenues for Entities with <20 Employees ($1,000) [a]	Revenues Per Entity with <20 Employees ($1,000)	Revenue per Estab. For Entities with <20 Employees ($1,000)
238200	Building Equipment Contractors	151,032	151,069	609,177	121,895	121,924	8,020	$94,507,036	$626	$626
238300	Building Finishing Contractors	96,172	96,192	303,118	70,079	70,093	8,953	$43,353,995	$451	$451
238900	Other Specialty Trade Contractors	57,826	57,849	206,233	57,826	112,814	37,903	$42,192,221	$730	$729
221100	Electric Utilities	761	827	4,155	49	53	19	$5,314,217	$6,983	$6,426
999200	State governments [c]	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
999300	Local governments [c]	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	Subtotals - Construction	**595,582**	**595,815**	**2,075,059**	**535,139**	**719,408**	**116,672**	**$442,524,713**	**$743**	**$743**

Table III-7: Characteristics of Industries Affected by OSHA's Final Standard for Silica – Entities with Fewer than 20 Employees (continued)

NAICS	Industry	Entities with <20 Employees [a]	Estab. For Entities with <20 Employees [a]	Employment for Entities with <20 Employees[a]	Affected Entities with <20 Employees [b]	Affected Employees for Entities with <20 Employees [b]	Affected FTE Employees for Entities with <20 Employees[b]	Total Revenues for Entities with <20 Employees ($1,000) [a]	Revenues Per Entity with <20 Employees ($1,000)	Revenue per Estab. For Entities with <20 Employees ($1,000)
General Industry and Maritime										
213112	Support Activities for Oil and Gas Operations	7,237	7,261	29,764	100	1,301	N/A	$570,313	$5,703	$5,703

Table III-7: Characteristics of Industries Affected by OSHA's Final Standard for Silica – Entities with Fewer than 20 Employees (continued)

NAICS	Industry	Entities with <20 Employees [a]	Estab. For Entities with <20 Employees [a]	Employment for Entities with <20 Employees[a]	Affected Entities with <20 Employees [b]	Affected Employees for Entities with <20 Employees [b]	Affected FTE Employees for Entities with <20 Employees[b]	Total Revenues for Entities with <20 Employees ($1,000) [a]	Revenues Per Entity with <20 Employees ($1,000)	Revenue per Estab. For Entities with <20 Employees ($1,000)
324121	Asphalt Paving Mixture and Block Manufacturing	248	252	1,332	248	440		$1,329,128	$5,359	$5,274
324122	Asphalt Shingle and Coating Materials Manufacturing	73	73	405	73	141		$312,264	$4,278	$4,278
325510	Paint and Coating Manufacturing	669	673	4,202	297	299		$1,180,637	$1,765	$1,754
327110	Pottery, Ceramics, and Plumbing Fixture Manufacturing	526	527	2,018	526	966		$196,954	$374	$374
327120	Clay Building Material and Refractories Manufacturing	217	217	1,290	217	485		$225,480	$1,039	$1,039
327211	Flat Glass Manufacturing	30	30	116	3	3		$22,194	$740	$740
327212	Other Pressed and Blown Glass and Glassware Manufacturing	335	337	1,405	70	70		$222,459	$664	$660
327213	Glass Container Manufacturing	15	15	120	6	6		$33,713	$2,248	$2,248
327320	Ready-Mix Concrete Manufacturing	1,309	1,361	9,529	1,309	3,904		$2,467,464	$1,885	$1,813
327331	Concrete Block and Brick Manufacturing	320	333	2,219	320	1,070		$495,228	$1,548	$1,487

Table III-7: Characteristics of Industries Affected by OSHA's Final Standard for Silica – Entities with Fewer than 20 Employees (continued)

NAICS	Industry	Entities with <20 Employees [a]	Estab. For Entities with <20 Employees [a]	Employment for Entities with <20 Employees[a]	Affected Entities with <20 Employees [b]	Affected Employees for Entities with <20 Employees [b]	Affected FTE Employees for Entities with <20 Employees[b]	Total Revenues for Entities with <20 Employees ($1,000) [a]	Revenues Per Entity with <20 Employees ($1,000)	Revenue per Estab. For Entities with <20 Employees ($1,000)
327332	Concrete Pipe Manufacturing	73	73	541	73	261		$106,437	$1,458	$1,458
327390	Other Concrete Product Manufacturing	1,168	1,172	7,323	1,168	3,531		$1,092,122	$935	$932
327991	Cut Stone and Stone Product Manufacturing	1,477	1,480	8,504	1,477	3,268		$1,049,161	$710	$709
327992	Ground or Treated Mineral and Earth Manufacturing	64	64	428	64	326		$149,184	$2,331	$2,331
327993	Mineral Wool Manufacturing	98	98	626	35	35		$127,328	$1,299	$1,299
327999	All Other Miscellaneous Nonmetallic Mineral Product Manufacturing	199	199	1,093	199	859		$271,715	$1,365	$1,365
331110	Iron and Steel Mills and Ferroalloy Manufacturing	179	179	1,296	0	0		$459,119	$2,565	$2,565
331210	Iron and Steel Pipe and Tube Manufacturing from Purchased Steel	87	87	617	0	0		$128,481	$1,477	$1,477
331221	Rolled Steel Shape Manufacturing	66	66	338	0	0		$257,456	$3,901	$3,901
331222	Steel Wire Drawing	143	143	648	0	0		$222,341	$1,555	$1,555
331314	Secondary Smelting and Alloying of Aluminum	34	34	181	0	0		$124,282	$3,655	$3,655

Table III-7: Characteristics of Industries Affected by OSHA's Final Standard for Silica – Entities with Fewer than 20 Employees (continued)

NAICS	Industry	Entities with <20 Employees [a]	Estab. For Entities with <20 Employees [a]	Employment for Entities with <20 Employees[a]	Affected Entities with <20 Employees [b]	Affected Employees for Entities with <20 Employees [b]	Affected FTE Employees for Entities with <20 Employees[b]	Total Revenues for Entities with <20 Employees ($1,000) [a]	Revenues Per Entity with <20 Employees ($1,000)	Revenue per Estab. For Entities with <20 Employees ($1,000)
331420	Copper Rolling, Drawing, Extruding, and Alloying	67	67	432	0	0		$222,202	$3,316	$3,316
331492	Secondary Smelting, Refining, and Alloying of Nonferrous Metal (except Copper and Aluminum)	123	123	716	0	0		$564,574	$4,590	$4,590
331511	Iron Foundries	153	153	941	153	334		$221,432	$1,447	$1,447
331512	Steel Investment Foundries	30	30	271	30	98		$50,082	$1,669	$1,669
331513	Steel Foundries (except Investment)	89	89	544	89	193		$104,629	$1,176	$1,176
331524	Aluminum Foundries (except Die-Casting)	223	223	1,384	223	502		$171,113	$767	$767
331529	Other Nonferrous Metal Foundries (except Die-Casting)	179	179	1,345	179	487		$213,224	$1,191	$1,191
332111	Iron and Steel Forging	176	176	832	0	0		$247,047	$1,404	$1,404
332112	Nonferrous Forging	18	18	101	0	0		$23,569	$1,309	$1,309
332117	Powder Metallurgy Part Manufacturing	50	50	458	0	0		$100,803	$2,016	$2,016
332119	Metal Crown, Closure, and Other Metal	801	801	6,076	0	0		$1,078,509	$1,346	$1,346

Table III-7: Characteristics of Industries Affected by OSHA's Final Standard for Silica – Entities with Fewer than 20 Employees (continued)

NAICS	Industry	Entities with <20 Employees [a]	Estab. For Entities with <20 Employees [a]	Employment for Entities with <20 Employees[a]	Affected Entities with <20 Employees [b]	Affected Employees for Entities with <20 Employees [b]	Affected FTE Employees for Entities with <20 Employees[b]	Total Revenues for Entities with <20 Employees ($1,000) [a]	Revenues Per Entity with <20 Employees ($1,000)	Revenue per Estab. For Entities with <20 Employees ($1,000)
	Stamping (except Automotive)									
332215	Metal Kitchen Cookware, Utensil, Cutlery, and Flatware (except Precious) Manufacturing	127	127	579	0	0		$98,264	$774	$774
332216	Saw Blade and Handtool Manufacturing	672	674	3,658	0	0		$482,660	$718	$716
332323	Ornamental and Architectural Metal Work Manufacturing	1,813	1,813	8,871	12	12		$1,250,229	$690	$690
332439	Other Metal Container Manufacturing	184	184	973	0	0		$204,264	$1,110	$1,110
332510	Hardware Manufacturing	380	380	2,223	0	0		$411,885	$1,084	$1,084
332613	Spring Manufacturing	198	199	1,499	0	0		$228,072	$1,152	$1,146
332618	Other Fabricated Wire Product Manufacturing	554	556	3,491	0	0		$652,779	$1,178	$1,174
332710	Machine Shops	15,839	15,850	83,260	0	0		$10,484,341	$662	$661

Table III-7: Characteristics of Industries Affected by OSHA's Final Standard for Silica – Entities with Fewer than 20 Employees (continued)

NAICS	Industry	Entities with <20 Employees [a]	Estab. For Entities with <20 Employees [a]	Employment for Entities with <20 Employees[a]	Affected Entities with <20 Employees [b]	Affected Employees for Entities with <20 Employees [b]	Affected FTE Employees for Entities with <20 Employees[b]	Total Revenues for Entities with <20 Employees ($1,000) [a]	Revenues Per Entity with <20 Employees ($1,000)	Revenue per Estab. For Entities with <20 Employees ($1,000)
332812	Metal Coating, Engraving (except Jewelry and Silverware), and Allied Services to Manufacturers	1,707	1,714	10,051	825	828		$1,206,020	$707	$704
332911	Industrial Valve Manufacturing	195	195	1,371	0	0		$387,162	$1,985	$1,985
332912	Fluid Power Valve and Hose Fitting Manufacturing	152	152	1,023	0	0		$219,740	$1,446	$1,446
332913	Plumbing Fixture Fitting and Trim Manufacturing	57	57	312	0	0		$101,771	$1,785	$1,785
332919	Other Metal Valve and Pipe Fitting Manufacturing	101	101	704	0	0		$231,744	$2,294	$2,294
332991	Ball and Roller Bearing Manufacturing	47	47	235	0	0		$48,024	$1,022	$1,022
332996	Fabricated Pipe and Pipe Fitting Manufacturing	421	421	2,851	0	0		$516,759	$1,227	$1,227
332999	All Other Miscellaneous Fabricated Metal Product Manufacturing	2,628	2,628	14,049	0	0		$2,147,704	$817	$817
333318	Other Commercial and Service Industry Machinery Manufacturing	837	842	4,774	0	0		$1,152,952	$1,377	$1,369

Table III-7: Characteristics of Industries Affected by OSHA's Final Standard for Silica – Entities with Fewer than 20 Employees (continued)

NAICS	Industry	Entities with <20 Employees [a]	Estab. For Entities with <20 Employees [a]	Employment for Entities with <20 Employees[a]	Affected Entities with <20 Employees [b]	Affected Employees for Entities with <20 Employees [b]	Affected FTE Employees for Entities with <20 Employees[b]	Total Revenues for Entities with <20 Employees ($1,000) [a]	Revenues Per Entity with <20 Employees ($1,000)	Revenue per Estab. For Entities with <20 Employees ($1,000)
333413	Industrial and Commercial Fan and Blower and Air Purification Equipment Manufacturing	220	220	1,517	0	0		$318,231	$1,447	$1,447
333414	Heating Equipment (except Warm Air Furnaces) Manufacturing	275	275	1,633	0	0		$399,286	$1,452	$1,452
333511	Industrial Mold Manufacturing	1,155	1,156	7,450	0	0		$1,083,039	$938	$937
333514	Special Die and Tool, Die Set, Jig, and Fixture Manufacturing	1,917	1,917	11,467	0	0		$1,479,663	$772	$772
333515	Cutting Tool and Machine Tool Accessory Manufacturing	1,156	1,157	6,292	0	0		$863,096	$747	$746
333517	Machine Tool Manufacturing	363	363	2,815	0	0		$491,006	$1,353	$1,353
333519	Rolling Mill and Other Metalworking Machinery Manufacturing	218	218	1,521	0	0		$284,636	$1,306	$1,306
333612	Speed Changer, Industrial High-Speed Drive, and Gear Manufacturing	102	103	755	0	0		$149,116	$1,462	$1,448

Table III-7: Characteristics of Industries Affected by OSHA's Final Standard for Silica – Entities with Fewer than 20 Employees (continued)

NAICS	Industry	Entities with <20 Employees [a]	Estab. For Entities with <20 Employees [a]	Employment for Entities with <20 Employees[a]	Affected Entities with <20 Employees [b]	Affected Employees for Entities with <20 Employees [b]	Affected FTE Employees for Entities with <20 Employees[b]	Total Revenues for Entities with <20 Employees ($1,000) [a]	Revenues Per Entity with <20 Employees ($1,000)	Revenue per Estab. For Entities with <20 Employees ($1,000)
333613	Mechanical Power Transmission Equipment Manufacturing	100	100	789	0	0		$188,937	$1,889	$1,889
333911	Pump and Pumping Equipment Manufacturing	252	252	1,780	0	0		$629,824	$2,499	$2,499
333912	Air and Gas Compressor Manufacturing	143	143	922	0	0		$262,077	$1,833	$1,833
333991	Power-Driven Handtool Manufacturing	89	89	510	0	0		$132,008	$1,483	$1,483
333992	Welding and Soldering Equipment Manufacturing	224	224	1,257	0	0		$286,775	$1,280	$1,280
333993	Packaging Machinery Manufacturing	328	328	2,079	0	0		$366,971	$1,119	$1,119
333994	Industrial Process Furnace and Oven Manufacturing	189	189	1,493	0	0		$315,182	$1,668	$1,668
333995	Fluid Power Cylinder and Actuator Manufacturing	129	129	829	0	0		$167,181	$1,296	$1,296
333996	Fluid Power Pump and Motor Manufacturing	79	79	520	0	0		$140,160	$1,774	$1,774
333997	Scale and Balance Manufacturing	52	52	315	0	0		$61,927	$1,191	$1,191
333999	All Other Miscellaneous General Purpose Machinery Manufacturing	1,035	1,037	6,341	0	0		$1,377,283	$1,331	$1,328

Table III-7: Characteristics of Industries Affected by OSHA's Final Standard for Silica – Entities with Fewer than 20 Employees (continued)

NAICS	Industry	Entities with <20 Employees [a]	Estab. For Entities with <20 Employees [a]	Employment for Entities with <20 Employees[a]	Affected Entities with <20 Employees [b]	Affected Employees for Entities with <20 Employees [b]	Affected FTE Employees for Entities with <20 Employees[b]	Total Revenues for Entities with <20 Employees ($1,000) [a]	Revenues Per Entity with <20 Employees ($1,000)	Revenue per Estab. For Entities with <20 Employees ($1,000)
334519	Other Measuring and Controlling Device Manufacturing	566	566	3,223	0	0		$699,604	$1,236	$1,236
335210	Small Electrical Appliance Manufacturing	76	76	383	1	1		$136,556	$1,797	$1,797
335221	Household Cooking Appliance Manufacturing	63	63	263	0	0		$68,855	$1,093	$1,093
335222	Household Refrigerator and Home Freezer Manufacturing	12	12	58	0	0		$19,301	$1,608	$1,608
335224	Household Laundry Equipment Manufacturing	5	5	22	0	0		$7,040	$1,408	$1,408
335228	Other Major Household Appliance Manufacturing	12	12	59	0	0		$24,955	$2,080	$2,080
336111	Automobile Manufacturing	120	120	469	0	0		$491,468	$4,096	$4,096
336112	Light Truck and Utility Vehicle Manufacturing	40	40	205	0	0		$169,629	$4,241	$4,241
336120	Heavy Duty Truck Manufacturing	32	34	160	0	0		$131,860	$4,121	$3,878
336211	Motor Vehicle Body Manufacturing	369	369	2,493	0	0		$528,443	$1,432	$1,432
336212	Truck Trailer Manufacturing	209	210	1,376	0	0		$249,279	$1,193	$1,187

Table III-7: Characteristics of Industries Affected by OSHA's Final Standard for Silica – Entities with Fewer than 20 Employees (continued)

NAICS	Industry	Entities with <20 Employees [a]	Estab. For Entities with <20 Employees [a]	Employment for Entities with <20 Employees[a]	Affected Entities with <20 Employees [b]	Affected Employees for Entities with <20 Employees [b]	Affected FTE Employees for Entities with <20 Employees[b]	Total Revenues for Entities with <20 Employees ($1,000) [a]	Revenues Per Entity with <20 Employees ($1,000)	Revenue per Estab. For Entities with <20 Employees ($1,000)
336213	Motor Home Manufacturing	32	34	208	0	0		$45,255	$1,414	$1,331
336310	Motor Vehicle Gasoline Engine and Engine Parts Manufacturing	597	597	2,553	0	0		$537,948	$901	$901
336320	Motor Vehicle Electrical and Electronic Equipment Manufacturing	384	386	2,111	0	0		$434,323	$1,131	$1,125
336330	Motor Vehicle Steering and Suspension Components (except Spring) Manufacturing	115	115	698	0	0		$231,760	$2,015	$2,015
336340	Motor Vehicle Brake System Manufacturing	77	77	379	0	0		$84,056	$1,092	$1,092
336350	Motor Vehicle Transmission and Power Train Parts Manufacturing	246	247	1,301	0	0		$411,993	$1,675	$1,668
336370	Motor Vehicle Metal Stamping	228	228	1,905	0	0		$467,088	$2,049	$2,049
336390	Other Motor Vehicle Parts Manufacturing	789	789	4,354	0	0		$1,323,201	$1,677	$1,677
336611	Ship Building and Repairing	380	381	2,215	62	62		$524,986	$1,382	$1,378

Table III-7: Characteristics of Industries Affected by OSHA's Final Standard for Silica – Entities with Fewer than 20 Employees (continued)

NAICS	Industry	Entities with <20 Employees [a]	Estab. For Entities with <20 Employees [a]	Employment for Entities with <20 Employees[a]	Affected Entities with <20 Employees [b]	Affected Employees for Entities with <20 Employees [b]	Affected FTE Employees for Entities with <20 Employees[b]	Total Revenues for Entities with <20 Employees ($1,000) [a]	Revenues Per Entity with <20 Employees ($1,000)	Revenue per Estab. For Entities with <20 Employees ($1,000)
336612	Boat Building	636	636	3,139	88	88		$772,459	$1,215	$1,215
336992	Military Armored Vehicle, Tank, and Tank Component Manufacturing	26	26	178	0	0		$61,782	$2,376	$2,376
337110	Wood Kitchen Cabinet and Countertop Manufacturing	6,221	6,226	26,735	78	78		$2,645,220	$425	$425
337215	Showcase, Partition, Shelving, and Locker Manufacturing	702	702	3,822	0	0		$552,142	$787	$787
339114	Dental Equipment and Supplies Manufacturing	588	588	2,798	588	876		$396,229	$674	$674
339116	Dental Laboratories	6,205	6,208	21,877	6,205	15,431		$1,818,804	$293	$293
339910	Jewelry and Silverware Manufacturing	1,862	1,863	7,131	1,862	1,976		$1,165,697	$626	$626
339950	Sign Manufacturing	4,652	4,662	20,958	116	116		$2,311,357	$497	$496
423840	Industrial Supplies Merchant Wholesalers	4,123	4,263	20,600	426	441		$10,326,416	$2,505	$2,422
444110	Home Centers	1,637	1,669	10,451	2	2		$2,214,029	$1,352	$1,327

Table III-7: Characteristics of Industries Affected by OSHA's Final Standard for Silica – Entities with Fewer than 20 Employees (continued)

NAICS	Industry	Entities with <20 Employees [a]	Estab. For Entities with <20 Employees [a]	Employment for Entities with <20 Employees[a]	Affected Entities with <20 Employees [b]	Affected Employees for Entities with <20 Employees [b]	Affected FTE Employees for Entities with <20 Employees[b]	Total Revenues for Entities with <20 Employees ($1,000) [a]	Revenues Per Entity with <20 Employees ($1,000)	Revenue per Estab. For Entities with <20 Employees ($1,000)
482110	Rail transportation	N/A	N/A	N/A	N/A	N/A		N/A	N/A	N/A
561730	Landscaping Services	86,928	86,976	258,430	20,258	20,269		$27,811,525	$320	$320
621210	Offices of Dentists	120,994	122,356	704,674	6,803	6,880		$83,677,753	$692	$684
	Subtotals – General Industry and Maritime	**289,340**	**291,090**	**1,382,533**	**44,186**	**65,640**		**$183,202,424**	**$633**	**$629**
	Totals – All Industries	**884,922**	**886,905**	**3,457,592**	**579,325**	**785,048**	**116,672**	**$625,727,137**	**$707**	**$706**

[a] US Census Bureau, Statistics of US Businesses, 2012.

[b] OSHA estimates of employees potentially exposed to silica and associated entities and establishments. Affected entities and establishments constrained to be less than or equal to the number of affected employees. Full-time equivalent estimate does not apply to general industry and maritime.

[c] State-plan states only. State and local governments are included under the construction sector because the silica risks for public employees are the result of construction-related activities.

Source: OSHA, Directorate of Standards and Guidance, Office of Regulatory Analysis, based on OSHA, 2016.

SILICA EXPOSURE PROFILE OF AT-RISK WORKERS

The preliminary exposure profile was presented in detail in the technological feasibility analysis in the PEA and relied on information from a wide variety of sources available to OSHA and reviewed in ERG's reports (ERG, 2008a; ERG, 2008b), including:

(1) Published literature;

(2) OSHA silica SEP inspection reports;

(3) NIOSH reports, including health hazard evaluations [HHE], control technology [CT] assessments, in-depth surveys, recommendations for exposure control, and engineering control feasibility studies;

(4) Workplace evaluation reports related to programs on "sentinel event notification system for occupational risks" (SENSOR) for silica from the states of Michigan, New Jersey, and Ohio;

(5) ERG and OSHA site visits;

(6) Unpublished information (e.g., unpublished data and research obtained through personal communications, meetings, and presentations); and

(7) Information available from other federal agencies, state agencies, labor organizations, industry associations, and other groups.

ERG also obtained OSHA IMIS data from 1979 through mid-2002, which were used primarily to identify the industries initially considered for inclusion in the preliminary technological feasibility analysis. ERG contractor reports primarily relied on information sources published from 1990 through 2001, updated with some information through 2007. In a few cases, where sources more recent than 1990 were limited and earlier information existed, information from the 1980s was used. Some sources of exposure data span several years, or even decades, and provide valuable insight into how exposure levels change as processes and controls are upgraded.

As noted above, OSHA primarily relied on the contractor reports, ERG (2008a) and ERG (2008b); however, OSHA considered and referenced additional material where available. The exposure profiles only included silica exposure data for workers in the United States. Information on international exposure levels was occasionally offered for perspective or in discussion of control options.

Public Comments on OSHA's Preliminary Exposure Profile

URS Corporation, an engineering consultant to the American Chemistry Council (ACC), objected to the sampling and analytical methodology applied in OSHA's determination of the exposure profile for the at-risk worker population. URS claims that OSHA's preliminary exposure analysis was based on exposure data collected using the current "American Conference of Government Industrial Hygienists (ACGIH) method," not the proposed "International Organization for Standardization/European Committee for Standardization (ISO/CEN) method," with the result that OSHA's data, and the Agency's resulting technological and economic feasibility determinations, could be defective because of differences that the two methods might produce:

> [T]he switch to the ISO/CEN definition will have two impacts on feasibility. First, it will add uncertainty regarding OSHA's technological feasibility determination because greater reductions in exposure will be required to achieve a 50 μg/m^3 PEL measured by the ISO/CEN definition than by the ACGIH definition that OSHA applied. Second, OSHA's use of the ACGIH definition to estimate compliance costs causes the Agency to underestimate the costs of achieving the 50 g/m^3 PEL because OSHA did not account for the additional workers whose exposures would exceed the proposed PEL under the ISO/CEN definition but who would be exposed below the proposed PEL if measured under the ACGIH definition (Document ID 2307, Attachment 8b, p. 8).

OSHA disagrees with URS's suggestion that OSHA's feasibility determinations might be affected by the distinction between sampling methodology. First, the device used by OSHA for its enforcement sampling, the Dorr Oliver cyclone, so closely adheres to the ISO/CEN that there should not be any significant difference in any of the data gathered by OSHA through this process. Many employers and researchers use other popular cyclones (e.g., SKC aluminum, Higgens-Dewell) allowed under the NIOSH silica method to assess compliance, and these sampling protocols also conform to the ISO/CEN, so much of the other data not gathered by OSHA is likely to meet the new standards as well.

Further, OSHA must fulfill its statutory mandate by relying on the best available data for the purpose of developing its exposure monitoring profiles and conducting rulemaking analyses. No data are available to show that a significant difference would have occurred if OSHA's exposure profile was re-tested using the devices OSHA will require after promulgation of the standard. Neither URS nor other commenters made available exposure data indicating that such significant differences would have occurred between these different sampling methodologies.

This issue is addressed at greater depth in the discussion on sampling and analysis methods in Chapter IV, Technological Feasibility.

Final Exposure Profile

The technological feasibility analyses presented in Chapter IV of this FEA contain data and discussion of worker exposures to silica throughout industry. Exposure profiles, by job category, were developed from individual exposure measurements that were judged to be substantive and to contain sufficient accompanying description to allow interpretation of the circumstance of each measurement. The resulting exposure profiles show the job categories with current overexposures to silica and, thus, the workers for whom silica controls would be needed in order to comply with the final rule.

Table III-8 summarizes, from the exposure profiles, the number of workers at risk from respirable crystalline silica exposure and the distribution of 8-hour TWA respirable crystalline silica exposures by job category for general industry and maritime sectors and for construction activities. Exposures are grouped into the following ranges: less than 25 μg/m^3; ≥ 25 μg/m^3 and ≤ 50 μg/m^3; > 50 μg/m^3 and ≤ 100 μg/m^3; > 100 μg/m^3 and ≤ 250 μg/m^3; and greater than 250 μg/m^3. These frequencies represent the percentages of production employees in each job category and sector currently exposed at levels within the indicated range.

Table III-9 presents data by NAICS code—for each affected general, maritime, and construction industry—on the estimated number of workers currently at risk from silica exposure, as well as the estimated number of workers at risk of silica exposure at or above 25 μg/m^3, above 50 μg/m^3, and above 100 μg/m^3, based on 8-hour TWAs. OSHA developed Table III-9 by mapping occupation shown in Table III-8 into industries using OES data. As shown, an estimated 1,249,250 workers (1,097,000 in construction; 152,300 in general industry and maritime) currently have silica exposures at or above the new action level of 25 μg/m^3; an estimated 948,100 workers (847,700 in construction; 100,400 in general industry and maritime) currently have silica exposures above the new PEL of 50 μg/m^3; and an estimated 578,000 workers (519,200 in construction; 58,800 in general industry and maritime) currently have silica exposures above 100 μg/m^3—an alternative PEL investigated by OSHA for economic analysis purposes.

Table III-10 compares classified OSHA OIS exposure data with unclassified OSHA OIS exposure data for construction, general industry overall, and general industry abrasive blasting. Classified data are exposure samples that could be grouped by NAICS into an application group or industry and could be identified as part of a job category associated with that application group or industry, whereas unclassified data could not be grouped by NAICS or identified by job category for an application group or industry. The analysis summarized in the table demonstrates that a significant percentage of unclassified exposures for construction and general industry overall fall below the new PEL. For unclassified general industry abrasive blasting, unclassified exposures are evenly divided between exposure above the new PEL and exposure below the new PEL.

Table III-8: Distribution of Silica Exposures by Application Group and Job Category or Activity – Final Profile

		Silica Exposure Range					
Application Group	**Job Category/Activity**	**<25 μg/m³**	**25-50 μg/m³**	**50-100 μg/m³**	**100-250 μg/m³**	**>250 μg/m³**	**Total[a]**
Construction							
	Abrasive Blasters	21.1%	9.9%	15.5%	18.3%	35.2%	100.0%
	Drywall Finishers	86.7%	6.7%	6.7%	0.0%	0.0%	100.0%
	Heavy Equipment Operators	74.3%	17.1%	5.7%	2.9%	0.0%	100.0%
	Hole Drillers Using Hand-Held Drills	33.3%	19.0%	23.8%	19.0%	4.8%	100.0%
	Demolition Workers Using Jackhammers and Handheld Power Chipping Tools	24.6%	6.0%	15.7%	22.4%	31.3%	100.0%
	Masonry Cutters Using Portable Saws	54.4%	12.1%	7.3%	18.0%	8.3%	100.0%
	Masonry Cutters Using Stationary Saws	23.3%	26.7%	23.3%	3.3%	23.3%	100.0%
	Millers Using Portable or Mobile Machines	58.1%	16.3%	18.6%	2.3%	4.7%	100.0%
	Rock and Concrete Drillers	37.3%	15.7%	17.6%	15.7%	13.7%	100.0%
	Rock-Crushing Machine Operators and Tenders	37.5%	0.0%	25.0%	25.0%	12.5%	100.0%
	Tuckpointers and Grinders	12.5%	9.6%	13.3%	18.3%	46.3%	100.0%
	Underground Construction Workers	59.3%	18.5%	11.1%	7.4%	3.7%	100.0%
General Industry/Maritime							
Hydraulic Fracturing							
	Fracturing Sand Workers	8.6%	8.6%	14.3%	27.1%	41.4%	100.0%
	Ancillary Workers	25.0%	25.0%	12.5%	12.5%	25.0%	100.0%
	Remote/Intermittent Support Workers	38.9%	13.9%	25.0%	13.9%	8.3%	100.0%
Asphalt Paving Products		**80.0%**	**0.0%**	**20.0%**	**0.0%**	**0.0%**	**100.0%**
	Front-End Loader Operator	50.0%	0.0%	50.0%	0.0%	0.0%	100.0%
	Maintenance Worker	100.0%	0.0%	0.0%	0.0%	0.0%	100.0%
	Plant Operator	100.0%	0.0%	0.0%	0.0%	0.0%	100.0%

Table III-8: Distribution of Silica Exposures by Application Group and Job Category or Activity – Final Profile (Continued)

		Silica Exposure Range					
Application Group	**Job Category/Activity**	**<25 μg/m³**	**25-50 μg/m³**	**50-100 μg/m³**	**100-250**	**>250 μg/m³**	**Total[a]**
Asphalt Roofing Materials		**0.0%**	**77.8%**	**11.6%**	**10.6%**	**0.0%**	**100.0%**
	Material Handler	0.0%	64.2%	21.5%	14.3%	0.0%	100.0%
	Production Operator	0.0%	80.0%	10.0%	10.0%	0.0%	100.0%
Captive Foundries		**45.3%**	**20.8%**	**13.2%**	**9.4%**	**11.3%**	**100.0%**
	Abrasive Blasting Operator	42.9%	14.3%	14.3%	0.0%	28.6%	100.0%
	Cleaning/Finishing Operator	60.0%	20.0%	20.0%	0.0%	0.0%	100.0%
	Coremaker	100.0%	0.0%	0.0%	0.0%	0.0%	100.0%
	Furnace Operator	66.7%	0.0%	33.3%	0.0%	0.0%	100.0%
	Housekeeping Worker	50.0%	50.0%	0.0%	0.0%	0.0%	100.0%
	Knockout Operator	66.7%	33.3%	0.0%	0.0%	0.0%	100.0%
	Maintenance Operator	50.0%	10.0%	0.0%	0.0%	40.0%	100.0%
	Molder	75.0%	25.0%	0.0%	0.0%	0.0%	100.0%
	Shakeout Operator	7.7%	30.8%	23.1%	38.5%	0.0%	100.0%
Concrete Products		**63.0%**	**11.0%**	**9.6%**	**9.6%**	**6.8%**	**100.0%**
	Abrasive Blasting Operator	11.8%	5.9%	23.5%	23.5%	35.3%	100.0%
	Finishing operator	52.0%	18.0%	8.0%	12.0%	10.0%	100.0%
	Forming Line operator	86.2%	6.2%	6.2%	1.5%	0.0%	100.0%
	Material Handler	56.5%	17.4%	13.0%	8.7%	4.3%	100.0%
	Mixer Operator	74.3%	5.7%	2.9%	14.3%	2.9%	100.0%
	Packaging Operator	33.3%	0.0%	33.3%	16.7%	16.7%	100.0%
Cut Stone		**38.3%**	**14.6%**	**15.8%**	**20.8%**	**10.4%**	**100.0%**
	Abrasive Blasting Operations	20.0%	30.0%	10.0%	20.0%	20.0%	100.0%
	Fabricator	48.9%	12.6%	11.9%	13.3%	13.3%	100.0%
	Machine Operator	16.7%	16.7%	22.2%	33.3%	11.1%	100.0%
	Sawyer	33.3%	16.7%	22.9%	20.8%	6.3%	100.0%

Table III-8: Distribution of Silica Exposures by Application Group and Job Category or Activity – Final Profile (Continued)

		Silica Exposure Range					
Application Group	**Job Category/Activity**	**<25 μg/m³**	**25-50 μg/m³**	**50-100 μg/m³**	**100-250**	**>250 μg/m³**	**Total[a]**
Cut Stone (contd.)	Splitter/chipper	17.2%	13.8%	20.7%	48.3%	0.0%	100.0%
Dental Equipment and Supplies		**60.0%**	**0.0%**	**20.0%**	**20.0%**	**0.0%**	**100.0%**
	Production operator	60.0%	0.0%	20.0%	20.0%	0.0%	100.0%
Dental Laboratories		**83.3%**	**13.9%**	**2.8%**	**0.0%**	**0.0%**	**100.0%**
	Dental technician	83.3%	13.9%	2.8%	0.0%	0.0%	100.0%
Engineered Stone		**100.0%**	**0.0%**	**0.0%**	**0.0%**	**0.0%**	**100.0%**
	Production Worker	100.0%	0.0%	0.0%	0.0%	0.0%	100.0%
Glass		**28.6%**	**7.1%**	**28.6%**	**21.4%**	**14.3%**	**100.0%**
	Batch operations and Associated Workers	50.0%	0.0%	25.0%	12.5%	12.5%	100.0%
	Material handler	0.0%	16.7%	33.3%	33.3%	16.7%	100.0%
Ferrous Sand Casting Foundries		**21.6%**	**23.9%**	**25.4%**	**18.6%**	**10.5%**	**100.0%**
	Abrasive blasting operator	4.9%	27.9%	26.2%	29.5%	11.5%	100.0%
	Cleaning/Finishing operator	16.2%	18.9%	18.9%	22.4%	23.7%	100.0%
	Coremaker	28.7%	28.7%	29.6%	9.3%	3.7%	100.0%
	Furnace operator	54.5%	18.2%	0.0%	9.1%	18.2%	100.0%
	Housekeeping worker	18.2%	18.2%	54.5%	9.1%	00.0%	100.0%
	Knockout operator	14.3%	37.1%	22.9%	22.9%	2.9%	100.0%
	Maintenance operator	20.8%	25.0%	25.0%	8.3%	20.8%	100.0%
	Material handler	27.8%	22.2%	30.6%	19.4%	0.0%	100.0%
	Molder	34.2%	22.8%	26.6%	15.8%	0.6%	100.0%
	Pouring operator	30.0%	20.0%	20.0%	30.0%	0.0%	100.0%
	Sand systems operator	17.9%	19.6%	25.0%	25.0%	12.5%	100.0%
	Shakeout operator	13.3%	30.0%	34.4%	14.4%	7.8%	100.0%
Jewelry Industry		**63.6%**	**0.0%**	**0.0%**	**18.2%**	**18.2%**	**100.0%**

Table III-8: Distribution of Silica Exposures by Application Group and Job Category or Activity – Final Profile (Continued)

		Silica Exposure Range					
Application Group	**Job Category/Activity**	**<25 μg/m³**	**25-50 μg/m³**	**50-100 μg/m³**	**100-250**	**>250 μg/m³**	**Total[a]**
	Jewelers	100.0%	0.0%	0.0%	0.0%	0.0%	100.0%
Jewelry Industry (contd.)	Jewelers (IMIS)	33.3%	0.0%	0.0%	33.3%	33.3%	100.0%
Landscape Contracting		**42.9%**	**28.6%**	**28.6%**	**0.0%**	**0.0%**	**100.0%**
	Landscape Worker	66.7%	33.3%	0.0%	0.0%	0.0%	100.0%
	Landscape Worker (IMIS)	25.0%	25.0%	50.0%	0.0%	0.0%	100.0%
Mineral Processing		**48.5%**	**30.3%**	**15.2%**	**6.1%**	**0.0%**	**100.0%**
	Production Worker (Before engineering improvements)	55.6%	22.2%	16.7%	5.6%	0.0%	100.0%
	Production Worker (With engineering controls)	66.7%	33.3%	0.0%	0.0%	0.0%	100.0%
	Production Worker (other conditions)	0.0%	50.0%	33.3%	16.7%	0.0%	100.0%
Mineral Wool		**28.6%**	**7.1%**	**28.6%**	**21.4%**	**14.3%**	**100.0%**
	Batch operator	50.0%	0.0%	33.3%	0.0%	16.7%	100.0%
	Material handler	0.0%	16.7%	33.3%	33.3%	16.7%	100.0%
Nonferrous Sand Casting Foundries		**64.3%**	**19.8%**	**13.1%**	**2.0%**	**0.8%**	**100.0%**
	Abrasive Blasting Operator	54.5%	36.4%	9.1%	0.0%	0.0%	100.0%
	Cleaning/Finishing Operator	50.0%	25.0%	22.7%	0.0%	2.3%	100.0%
	Coremaker	90.6%	5.7%	3.8%	0.0%	0.0%	100.0%
	Furnace Operator	100.0%	0.0%	0.0%	0.0%	0.0%	100.0%
	Knockout Operator	53.8%	30.8%	15.4%	0.0%	0.0%	100.0%
	Maintenance Operator	100.0%	0.0%	0.0%	0.0%	0.0%	100.0%
	Material Handler	50.0%	50.0%	0.0%	0.0%	0.0%	100.0%
	Molder	63.9%	21.3%	11.5%	1.6%	1.6%	100.0%
	Pouring Operator	100.0%	0.0%	0.0%	0.0%	0.0%	100.0%
	Sand Systems Operator	60.0%	20.0%	20.0%	0.0%	0.0%	100.0%
	Shakeout Operator	38.7%	25.8%	22.6%	12.9%	0.0%	100.0%

Table III-8: Distribution of Silica Exposures by Application Group and Job Category or Activity – Final Profile (Continued)

Application Group	Job Category/Activity	Silica Exposure Range					Total[a]
		<25 μg/m³	25-50 μg/m³	50-100 μg/m³	100-250	>250 μg/m³	
Non-Sand Casting Foundries		**55.6%**	**18.5%**	**11.3%**	**7.3%**	**7.3%**	**100.0%**
	Abrasive blasting operator	53.8%	7.7%	15.4%	7.7%	15.4%	100.0%
	Cleaning/Finishing operator	52.9%	32.4%	5.9%	5.9%	2.9%	100.0%
	Coremaker	100.0%	0.0%	0.0%	0.0%	0.0%	100.0%
	Furnace operator	75.0%	25.0%	0.0%	0.0%	0.0%	100.0%
	Housekeeping worker	100.0%	0.0%	0.0%	0.0%	0.0%	100.0%
	Knockout operator	26.7%	20.0%	33.3%	0.0%	20.0%	100.0%
	Maintenance operator	100.0%	0.0%	0.0%	0.0%	0.0%	100.0%
	Material handler	66.7%	0.0%	0.0%	33.3%	0.0%	100.0%
	Molder	55.2%	20.7%	13.8%	6.9%	3.4%	100.0%
	Pattern Assembler	100.0%	0.0%	0.0%	0.0%	0.0%	100.0%
	Pouring Operator	85.7%	0.0%	0.0%	14.3%	0.0%	100.0%
	Shakeout Operator	14.3%	14.3%	14.3%	28.6%	28.6%	100.0%
Paint and Coatings		**82.6%**	**4.3%**	**0.0%**	**4.3%**	**8.7%**	**100.0%**
	Material Handler	100.0%	0.0%	0.0%	0.0%	0.0%	100.0%
	Mixer Operator	66.7%	8.3%	0.0%	8.3%	16.7%	100.0%
Porcelain Enameling		42.9%	14.3%	22.9%	5.7%	14.3%	100.0%
	Enamel Preparer	20.0%	20.0%	40.0%	20.0%	0.0%	100.0%
	Porcelain Applicator	46.7%	13.3%	20.0%	3.3%	16.7%	100.0%
Pottery		**34.5%**	**21.8%**	**28.7%**	**8.0%**	**6.9%**	**100.0%**
	Coatings Operator (Automated spraying)	20.0%	20.0%	60.0%	0.0%	0.0%	100.0%
	Coatings Operator (Manual/semiautomatic spraying)	30.8%	15.4%	23.1%	23.1%	7.7%	100.0%
	Coatings Preparer	8.3%	8.3%	41.7%	8.3%	33.3%	100.0%
	Finishing Operator	60.0%	20.0%	20.0%	0.0%	0.0%	100.0%

Table III-8: Distribution of Silica Exposures by Application Group and Job Category or Activity – Final Profile (Continued)

		Silica Exposure Range					
Application Group	**Job Category/Activity**	**<25 μg/m³**	**25-50 μg/m³**	**50-100 μg/m³**	**100-250**	**>250 μg/m³**	**Total[a]**
	Forming Line Operator (LEV in use)	50.0%	50.0%	0.0%	0.0%	0.0%	100.0%
	Forming Line Operator (No LEV)	25.0%	50.0%	25.0%	0.0%	0.0%	100.0%
Pottery (contd.)	Forming Line Operator (No information about controls available)	42.9%	21.4%	28.6%	7.1%	0.0%	100.0%
	Material Handler (Fully or partially automated process)	50.0%	50.0%	0.0%	0.0%	0.0%	100.0%
	Material Handler (LEV in use)	0.0%	33.3%	66.7%	0.0%	0.0%	100.0%
	Material Handler (No LEV)	0.0%	0.0%	33.3%	33.3%	33.3%	100.0%
	Material Handler (No information about controls available)	66.7%	33.3%	0.0%	0.0%	0.0%	100.0%
Railroads		**31.7%**	**33.3%**	**16.7%**	**11.1%**	**7.1%**	**100.0%**
	Ballast dumper	50.0%	26.9%	7.7%	7.7%	7.7%	100.0%
	Machine Operator (Ballast Regulator)	21.1%	34.2%	21.1%	10.5%	13.2%	100.0%
	Machine Operator (Broom Operator)	9.5%	28.6%	33.3%	23.8%	4.8%	100.0%
	Machine Operator (Tamper Operator)	37.1%	40.0%	11.4%	8.6%	2.9%	100.0%
	Machine Operator (Other Operator)	66.7%	33.3%	0.0%	0.0%	0.0%	100.0%
Ready-Mix Concrete Industry		**69.7%**	**6.1%**	**12.1%**	**6.1%**	**6.1%**	**100.0%**
	Batch operator	87.5%	0.0%	12.5%	0.0%	0.0%	100.0%
	Maintenance operator	60.0%	20.0%	20.0%	0.0%	0.0%	100.0%
	Material handler	69.2%	7.7%	15.4%	7.7%	0.0%	100.0%
	Quality control technician	100.0%	0.0%	0.0%	0.0%	0.0%	100.0%
	Truck driver	0.0%	0.0%	0.0%	33.3%	67.7%	100.0%
Refractories		**52.4%**	**25.4%**	**11.1%**	**9.5%**	**1.6%**	**100.0%**
	Ceramic fiber furnace operator	100.0%	0.0%	0.0%	0.0%	0.0%	100.0%
	Finishing operator	100.0%	0.0%	0.0%	0.0%	0.0%	100.0%
	Forming operator	25.0%	62.5%	12.5%	0.0%	0.0%	100.0%

Table III-8: Distribution of Silica Exposures by Application Group and Job Category or Activity – Final Profile (Continued)

		Silica Exposure Range					
Application Group	**Job Category/Activity**	**<25 μg/m³**	**25-50 μg/m³**	**50-100 μg/m³**	**100-250**	**>250 μg/m³**	**Total[a]**
	Material handler	41.9%	19.4%	19.4%	16.1%	3.2%	100.0%
	Packaging operator	50.0%	41.7%	0.0%	8.3%	0.0%	100.0%
Refractory Repair		**33.3%**	**33.3%**	**16.7%**	**16.7%**	**0.0%**	**100.0%**
Refractory Repair (contd.)	Production operator	33.3%	33.3%	16.7%	16.7%	0.0%	100.0%
Shipyards (Maritime) Industry		**22.2%**	**22.2%**	**11.1%**	**11.1%**	**33.3%**	**100.0%**
	Painter	33.3%	33.3%	0.0%	0.0%	33.3%	100.0%
	Painter's Helper	0.0%	0.0%	33.3%	33.3%	33.3%	100.0%
Structural Clay		**39.3%**	**13.3%**	**20.7%**	**17.8%**	**8.9%**	**100.0%**
	Forming Line Operators (Clay Powder Formers)	0.0%	0.0%	0.0%	100.0%	0.0%	100.0%
	Forming Line Operators (Coatings Applicators - Automated)	0.0%	22.2%	44.4%	33.3%	0.0%	100.0%
	Forming Line Operators (Coatings Applicators - Manual)	26.7%	6.7%	13.3%	26.7%	26.7%	100.0%
	Forming Line Operators (Coatings Blender)	20.0%	0.0%	50.0%	30.0%	0.0%	100.0%
	Forming Line Operators (Pug Mill operators)	0.0%	14.3%	14.3%	28.6%	42.9%	100.0%
	Forming Line Operators (Wet Clay Formers)	60.0%	30.0%	10.0%	0.0%	0.0%	100.0%
	Grinding Operator	23.5%	5.9%	23.5%	23.5%	23.5%	100.0%
	Material Handler/Loader Operator	42.9%	0.0%	42.9%	14.3%	0.0%	100.0%
	Material Handler/Post-Production Handlers	70.3%	18.9%	8.1%	2.7%	0.0%	100.0%
	Material Handler/Production Line Handlers	40.0%	15.0%	25.0%	15.0%	5.0%	100.0%

[a] Due to rounding, in each row the sum of the data may not equal the total.

Source: Technological feasibility analysis in Chapter IV in the FEA.

Table III-9: Numbers of Workers Exposed to Silica (by Affected Industry and Exposure Level (μg/m³))

				Number of Employees Exposed to Silica				
NAICS	**Industry**	**Number of Establishments**	**Number of Employees**	**>=0**	**>=25**	**>=50**	**>=100**	**>=250**
Construction								
236100	Residential Building Construction	151,034	519,070	210,773	132,901	102,275	61,678	24,625
236200	Nonresidential Building Construction	41,018	521,112	209,136	117,311	91,266	56,168	24,155
237100	Utility System Construction	18,686	466,099	190,044	97,838	78,748	51,241	24,122
237200	Land Subdivision	6,182	53,045	5,726	3,061	2,414	1,616	831
237300	Highway, Street, and Bridge Construction	10,043	251,065	148,254	58,604	45,462	28,110	14,153
237900	Other Heavy and Civil Engineering Construction	4,222	79,390	37,611	18,389	14,994	9,837	4,739
238100	Foundation, Structure, and Building Exterior Contractors	85,801	657,508	324,954	216,714	167,943	113,372	65,852
238200	Building Equipment Contractors	170,002	1,629,581	326,154	212,327	152,945	77,880	17,104
238300	Building Finishing Contractors	102,700	608,945	140,813	89,565	67,634	40,922	16,650
238900	Other Specialty Trade Contractors	63,214	475,127	259,906	89,844	73,598	45,621	21,705
221100	Electric Utilities	10,401	509,704	6,541	3,050	2,133	1,088	238
999200	State governments [d]	Not Applicable	Not Applicable	33,558	12,743	10,889	7,418	3,514
999300	Local governments [d]	Not Applicable	Not Applicable	123,946	44,639	37,414	24,240	10,815
	Subtotals - Construction	**663,303**	**5,770,646**	**2,017,417**	**1,096,986**	**847,715**	**519,190**	**228,503**
General Industry and Maritime								
213112	Support Activities for Oil and Gas Operations	10,872	272,357	16,960	13,819	11,207	8,671	5,280
324121	Asphalt Paving Mixture and Block Manufacturing	1,362	14,353	4,737	48	48	0	0
324122	Asphalt Shingle and Coating Materials Manufacturing	223	9,074	3,158	3,158	1,410	672	0
325510	Paint and Coating Manufacturing	1,161	35,328	2,511	515	386	386	258
327110	Pottery, Ceramics, and Plumbing Fixture Manufacturing	655	13,096	6,269	3,989	2,496	767	257
327120	Clay Building Material and Refractories Manufacturing	586	20,985	7,893	4,915	3,198	1,756	520
327211	Flat Glass Manufacturing	85	8,990	221	134	126	67	30
327212	Other Pressed and Blown Glass and Glassware Manufacturing	442	13,434	674	411	386	206	90
327213	Glass Container Manufacturing	74	13,684	686	419	394	209	92
327320	Ready-Mix Concrete Manufacturing	5,377	66,196	27,123	20,690	19,941	18,611	12,156
327331	Concrete Block and Brick Manufacturing	817	14,896	7,182	2,902	2,045	1,217	521

Table III-9: Numbers of Workers Exposed to Silica (by Affected Industry and Exposure Level (μg/m³)) (continued)

				Number of Employees Exposed to Silica				
NAICS	**Industry**	**Number of Establishments**	**Number of Employees**	**>=0**	**>=25**	**>=50**	**>=100**	**>=250**
327332	Concrete Pipe Manufacturing	352	8,229	3,967	1,603	1,130	672	288
327390	Other Concrete Product Manufacturing	1,973	45,284	21,832	8,821	6,216	3,700	1,583
327991	Cut Stone and Stone Product Manufacturing	1,859	24,537	9,429	6,794	5,243	3,406	931
327992	Ground or Treated Mineral and Earth Manufacturing	249	7,129	5,432	2,798	1,152	329	0
327993	Mineral Wool Manufacturing	269	13,925	789	489	457	244	106
327999	All Other Miscellaneous Nonmetallic Mineral Product Manufacturing	452	10,118	7,952	4,096	1,687	482	0
331110	Iron and Steel Mills and Ferroalloy Manufacturing	562	105,309	594	186	93	41	17
331210	Iron and Steel Pipe and Tube Manufacturing from Purchased Steel	262	25,592	145	45	23	10	4
331221	Rolled Steel Shape Manufacturing	167	7,836	44	14	7	3	1
331222	Steel Wire Drawing	294	14,241	81	25	13	5	2
331314	Secondary Smelting and Alloying of Aluminum	114	5,415	30	10	5	2	1
331420	Copper Rolling, Drawing, Extruding, and Alloying	249	21,408	119	37	19	8	3
331492	Secondary Smelting, Refining, and Alloying of Nonferrous Metal (except Copper and Aluminum)	261	10,913	62	19	10	4	2
331511	Iron Foundries	407	38,286	13,583	10,089	6,876	3,583	1,173
331512	Steel Investment Foundries	128	15,190	5,487	1,729	962	589	203
331513	Steel Foundries (except Investment)	208	18,236	6,469	4,805	3,275	1,706	559
331524	Aluminum Foundries (except Die-Casting)	406	15,446	5,601	1,727	656	127	43
331529	Other Nonferrous Metal Foundries (except Die-Casting)	300	9,522	3,451	1,064	404	78	26
332111	Iron and Steel Forging	356	24,030	136	42	21	9	4
332112	Nonferrous Forging	62	6,182	35	11	5	2	1
332117	Powder Metallurgy Part Manufacturing	133	8,160	46	14	7	3	1
332119	Metal Crown, Closure, and Other Metal Stamping (except Automotive)	1,499	53,018	299	93	47	20	9
332215	Metal Kitchen Cookware, Utensil, Cutlery, and Flatware (except Precious) Manufacturing	188	7,374	42	13	6	3	1
332216	Saw Blade and Handtool Manufacturing	1,012	27,852	157	49	25	11	5
332323	Ornamental and Architectural Metal Work Manufacturing	2,214	29,694	40	21	16	8	7

Table III-9: Numbers of Workers Exposed to Silica (by Affected Industry and Exposure Level (μg/m³)) (continued)

				Number of Employees Exposed to Silica				
NAICS	Industry	Number of Establishments	Number of Employees	>=0	>=25	>=50	>=100	>=250
332439	Other Metal Container Manufacturing	346	11,749	66	21	10	5	2
332510	Hardware Manufacturing	607	26,540	150	47	23	10	4
332613	Spring Manufacturing	392	14,829	84	26	13	6	2
332618	Other Fabricated Wire Product Manufacturing	911	24,626	139	43	22	9	4
332710	Machine Shops	19,270	245,538	1,387	433	216	95	40
332812	Metal Coating, Engraving (except Jewelry and Silverware), and Allied Services to Manufacturers	2,518	49,911	4,113	2,205	1,654	823	678
332911	Industrial Valve Manufacturing	517	35,657	201	63	31	14	6
332912	Fluid Power Valve and Hose Fitting Manufacturing	371	34,663	196	61	31	13	6
332913	Plumbing Fixture Fitting and Trim Manufacturing	121	7,567	43	13	7	3	1
332919	Other Metal Valve and Pipe Fitting Manufacturing	243	14,260	80	25	13	5	2
332991	Ball and Roller Bearing Manufacturing	176	22,522	127	40	20	9	4
332996	Fabricated Pipe and Pipe Fitting Manufacturing	765	29,914	169	53	26	12	5
332999	All Other Miscellaneous Fabricated Metal Product Manufacturing	3,553	70,118	405	131	68	30	14
333318	Other Commercial and Service Industry Machinery Manufacturing	1,378	54,518	308	96	48	21	9
333413	Industrial and Commercial Fan and Blower and Air Purification Equipment Manufacturing	491	24,138	136	43	21	9	4
333414	Heating Equipment (except Warm Air Furnaces) Manufacturing	472	17,959	102	32	16	7	3
333511	Industrial Mold Manufacturing	1,669	35,194	199	62	31	14	6
333514	Special Die and Tool, Die Set, Jig, and Fixture Manufacturing	2,477	42,810	242	75	38	16	7
333515	Cutting Tool and Machine Tool Accessory Manufacturing	1,519	28,451	161	50	25	11	5
333517	Machine Tool Manufacturing	689	24,322	137	43	21	9	4
333519	Rolling Mill and Other Metalworking Machinery Manufacturing	371	11,582	66	21	10	4	2
333612	Speed Changer, Industrial High-Speed Drive, and Gear Manufacturing	246	16,072	91	28	14	6	3

Table III-9: Numbers of Workers Exposed to Silica (by Affected Industry and Exposure Level (µg/m³)) (continued)

				Number of Employees Exposed to Silica				
NAICS	Industry	Number of Establishments	Number of Employees	>=0	>=25	>=50	>=100	>=250
333613	Mechanical Power Transmission Equipment Manufacturing	245	15,545	88	27	14	6	3
333911	Pump and Pumping Equipment Manufacturing	539	33,772	191	60	30	13	5
333912	Air and Gas Compressor Manufacturing	306	21,225	120	37	19	8	3
333991	Power-Driven Handtool Manufacturing	151	8,859	50	16	8	3	1
333992	Welding and Soldering Equipment Manufacturing	344	15,781	89	28	14	6	3
333993	Packaging Machinery Manufacturing	580	20,010	113	35	18	8	3
333994	Industrial Process Furnace and Oven Manufacturing	352	11,009	62	19	10	4	2
333995	Fluid Power Cylinder and Actuator Manufacturing	324	24,208	137	43	21	9	4
333996	Fluid Power Pump and Motor Manufacturing	148	10,554	60	19	9	4	2
333997	Scale and Balance Manufacturing	88	3,725	21	7	3	1	1
333999	All Other Miscellaneous General Purpose Machinery Manufacturing	1,654	51,495	291	91	45	20	8
334519	Other Measuring and Controlling Device Manufacturing	905	34,604	196	61	31	13	6
335210	Small Electrical Appliance Manufacturing	127	8,216	24	13	10	5	4
335221	Household Cooking Appliance Manufacturing	98	10,408	30	16	12	6	5
335222	Household Refrigerator and Home Freezer Manufacturing	30	9,374	27	15	11	5	5
335224	Household Laundry Equipment Manufacturing	9	4,438	13	7	5	3	2
335228	Other Major Household Appliance Manufacturing	36	9,059	26	14	11	5	4
336111	Automobile Manufacturing	173	62,686	354	111	55	24	10
336112	Light Truck and Utility Vehicle Manufacturing	78	56,524	319	100	50	22	9
336120	Heavy Duty Truck Manufacturing	85	30,756	174	54	27	12	5
336211	Motor Vehicle Body Manufacturing	741	40,544	229	72	36	16	7
336212	Truck Trailer Manufacturing	421	28,304	160	50	25	11	5
336213	Motor Home Manufacturing	62	7,395	42	13	7	3	1
336310	Motor Vehicle Gasoline Engine and Engine Parts Manufacturing	849	52,752	298	93	46	20	9
336320	Motor Vehicle Electrical and Electronic Equipment Manufacturing	678	50,017	283	88	44	19	8

Table III-9: Numbers of Workers Exposed to Silica (by Affected Industry and Exposure Level (μg/m³)) (continued)

				Number of Employees Exposed to Silica				
NAICS	**Industry**	**Number of Establishments**	**Number of Employees**	**>=0**	**>=25**	**>=50**	**>=100**	**>=250**
336330	Motor Vehicle Steering and Suspension Components (except Spring) Manufacturing	245	28,663	162	51	25	11	5
336340	Motor Vehicle Brake System Manufacturing	195	21,859	123	39	19	8	4
336350	Motor Vehicle Transmission and Power Train Parts Manufacturing	503	58,248	329	103	51	22	9
336370	Motor Vehicle Metal Stamping	773	81,018	458	143	71	31	13
336390	Other Motor Vehicle Parts Manufacturing	1,508	122,041	689	215	107	47	20
336611	Ship Building and Repairing	689	108,311	3,038	2,633	2,228	1,620	1,013
336612	Boat Building	871	28,054	787	682	577	420	262
336992	Military Armored Vehicle, Tank, and Tank Component Manufacturing	71	10,990	62	19	10	4	2
337110	Wood Kitchen Cabinet and Countertop Manufacturing	6,862	76,052	223	114	86	59	28
337215	Showcase, Partition, Shelving, and Locker Manufacturing	1,097	33,437	189	59	29	13	5
339114	Dental Equipment and Supplies Manufacturing	727	15,835	4,956	1,983	1,983	991	0
339116	Dental Laboratories	6,818	44,097	31,105	5,184	864	0	0
339910	Jewelry and Silverware Manufacturing	2,119	24,436	6,772	2,455	2,434	2,422	1,210
339950	Sign Manufacturing	5,499	69,051	384	217	163	77	56
423840	Industrial Supplies Merchant Wholesalers	7,614	82,871	1,773	1,182	591	591	591
444110	Home Centers	6,569	609,186	107	55	41	29	13
482110	Rail transportation	Not Applicable	Not Applicable	16,895	10,668	5,340	2,948	1,233
561730	Landscaping Services	92,976	548,662	43,033	24,747	12,612	497	156
621210	Offices of Dentists	133,107	873,172	8,525	1,421	237	0	0
	Subtotals – General Industry and Maritime	**351,998**	**5,335,502**	**294,844**	**152,263**	**100,375**	**58,779**	**29,718**
	Totals	**1,015,301**	**11,106,148**	**2,312,261**	**1,249,249**	**948,090**	**577,969**	**258,221**

Source: OSHA, Directorate of Standards and Guidance, Office of Regulatory Analysis, based on Table III-5 and the technological feasibility analysis presented in Chapter IV of this FEA.

Table III-10: Comparison of Classified vs. Unclassified OSHA OIS Exposure Data (8-Hour TWA) for Respirable Crystalline Silica ("classified" status assigned where NAICS and job category were identified)

Classified / Unclassified	Group	Count of Exposure Samples	Average of Resp. Dust ($\mu g/m^3$)	Average of % Silica	Average of RCS ($\mu g/m^3$)	Max of RCS ($\mu g/m^3$)	<25 $\mu g/m^3$	25-50 $\mu g/m^3$	50-100 $\mu g/m^3$	100-250 $\mu g/m^3$	250-500 $\mu g/m^3$	>500 $\mu g/m^3$
Classified	Construction	107	2.872	7.9	393	12,983	43	12	15	13	10	14
							40%(a)	11%	14%	12%	9%	13%
Unclassified	Construction	56	1.513	3.3	54	1,360	39	2	9	4	1	1
							70%	4%	16%	7%	2%	2%
Classified	General Industry	563	0.864	7.8	77	3,400	348	78	55	47	14	21
							62%	14%	10%	8%	2%	4%
Unclassified	General Industry	169	0.602	5.3	36	708	119	21	13	12	2	2
							70%	12%	8%	7%	1%	1%
Classified	General Industry Abrasive Blasting	29	1.587	8.2	142	1,330	8	6	3	8	2	2
							28%	21%	10%	28%	7%	7%
Unclassified	General Industry Abrasive Blasting	44	7.198	11.3	955	11,540	15	6	6	7	3	7
							34%	14%	14%	16%	7%	16%

	Count of Exposure Samples	<=50 $\mu g/m^3$	>50 $\mu g/m^3$
Classified Construction	107	55	52
		51%	49%
Unclassified Construction (Not a silica NAICS/job category)	56	41	15
		73%	27%

Table III-10: Comparison of Classified vs. Unclassified OSHA OIS Exposure Data for Respirable Crystalline Silica (“classified” status assigned where NAICS and job category identified) (contd.)

	Count of Exposure Samples		<=50 μg/m³	>50 μg/m³	
Classified General Industry	563		426	137	
			76%	24%	
Unclassified General Industry (Not a silica NAICS/job category)	169		140	29	
			83%	17%	

Classified vs. Unclassified Data

Classified data are exposure samples that could be grouped by NAICS into an application group or industry and could be identified as part of a job category associated with that application group or industry.

Unclassified data are exposure samples that could not be classified by NAICS into an application group, or by job description into a job category associated with an application group.

(a) Due to rounding, percentages within rows may not sum to 100%.

Source: OSHA, Directorate of Standards and Guidance, Office of Regulatory Analysis, based on OIS data 2011-April17, 2014 (Document ID 3958, Attachment 1).

EMPLOYEE TURNOVER

For the PEA, OSHA applied employee turnover rates in the cost calculations for medical surveillance and training to account for the additional program costs incurred by employers resulting from the departure (separation) of existing employees and the hiring of new employees throughout a typical year.

In order to estimate turnover rates in general industry (including hydraulic fracturing) and maritime, OSHA used the hires rate of 27.2 percent as estimated by the Bureau of Labor Statistics (BLS, 2008). However, OSHA judged that not all new hires would require initial medical testing. As specified in the proposed rule, employees who had received a qualifying medical examination within the previous twelve months would be exempt from the initial medical examination, even if they had been with a different employer. OSHA estimated that 25 percent of new hires in general industry and maritime would be exempt from the initial medical examination.

In order to estimate turnover rates in construction, OSHA used the hires rate of 64.0 percent in construction as estimated by the BLS in its Job Opening and Labor Turnover Survey (JOLTS) (BLS, 2008). However, as for general industry and maritime, OSHA judged that not all new hires would require initial medical testing. As specified in the proposed rule, employees who had received a qualifying medical examination within the previous twelve months would be exempt from the initial medical examination. OSHA estimated that 60 percent of new hires in construction would be exempt from the initial medical examination.

Comments on Employee Turnover

Public comments on OSHA's preliminary application of turnover rates generally confirmed the necessity of including employee turnover estimates in any analysis of economic impacts. Only a few commenters examined this issue; all agreed that it was important to include a turnover rate, but none provided evidence to suggest that OSHA's preliminary turnover rate was inaccurate.

The executive director of a Wyoming policy center observed a high rate of turnover in his state's oil and gas industry:

> Continuing education is particularly important in this industry. The physical demands of much of the work, competition for workers, and the transient nature of these moving job sites result in continuous turnover. Moreover, booms in the industry induce the rapid expansion in numbers of jobs.

> In the first quarter of 2000, there were 7,809 jobs in oil and gas extraction, oil and gas drilling, and in jobs supporting oil and gas operations in Wyoming. A year later, those numbers climbed to 9,563, an inkling of the boom that hit full force in the middle of the decade. By the fourth quarter of 2008, there were 20,006 of those jobs in Wyoming. Job numbers declined to 16,248 in the first quarter of 2013, still a 108 percent increase compared to the first quarter of 2000.
>
> It's possible to track the turnover, too. In the first quarter of 2000, nearly 1,200 more workers than jobs – 8,971 – worked in oil and gas in Wyoming. At the peak of the boom in the fourth quarter 2008, 23,378 workers were paid wages by the industry, 3,372 more workers than jobs. We believe this makes a strong case for requiring continuing education and training of both supervisors and workers about the hazards of silica and how they can be avoided (Document ID 3601, p. 3)(citations omitted).

CISC did not object to OSHA's preliminary estimate for the construction turnover rate, and pointed to the "transient nature of the workforce" and "the turnover rate in the construction industry" as reasons why medical surveillance would be "impractical" (Document ID 4217, p. 21).

Dr. Ruttenberg questioned whether the figures reported in the BLS JOLTS database and applied by OSHA in the PEA accurately reflected employee turnover in the context of employer compliance with an OSHA standard, but Dr. Ruttenberg did not provide any evidence to contradict it other than to point to general statements about OSHA's general track record with estimating costs and benefits:

> . . .
>
> > 7. Oversimplification of Turnover Rates Inflates Cost. OSHA cites turnover rates of 64 percent for construction and 27.2 percent in general industry (FR, p. 56286) and uses these in assessing the costs of medical surveillance, training, etc. But, when individuals leave their jobs, it does not mean that they leave their industry. An abrasive blaster may well continue as an abrasive blaster on another job. A master craftsperson in drywall finishing, is more likely to stay in drywall finishing than not. Likewise with tuck-pointing or heavy equipment operating. Portability of training and medical surveillance will help avoid duplication of services (Document ID 2257, Attachment 4, pp. 2 and 6).

OSHA accepts Dr. Ruttenberg's argument that use of the BLS JOLTS figure for turnover rates may blur the distinction of intra-industry, inter-employer movement or workers from inter-industry employee movement. Nonetheless, lacking the means of refining the

BLS turnover rate, OSHA finds the BLS rate the most convenient, widely accepted measure of new hires. Moreover, as discussed in the section on medical surveillance and training costs, OSHA notes that its preliminary estimates did include portability of medical surveillance in those costs estimates, although in the discussion of training costs OSHA notes that silica training is unlikely to be as portable as Dr. Ruttenberg suggests.

The above comments address OSHA's use of turnover rates as defined by BLS. Other comments in the record associated with OSHA's use of turnover rates generally focused on broader methodological considerations in the areas of compliance costs and benefits; the issues raised by those comments are addressed in Chapter V, Costs of Compliance, and Chapter VII, Benefits and Net Benefits.

Seasonal employment

Joseph Liss, a master's candidate in the field of leadership and public policy, questioned the apparent absence of seasonality in OSHA's preliminary profile of construction workers:

> Additionally, there was no prominent mention of any adjustment for seasonal workers in OSHA's PEA or the preamble of its proposed rule, despite seasonality being a major part of the construction industry. Bureau of Labor Statistics data indicates that, in 1990, there was a more than 5% seasonal adjustments [sic] for construction employees . . . . (Document ID 1950, p. 10).

OSHA acknowledges that seasonal variations in employment can affect the estimation of the population at risk of exposure to toxic substances, including silica. OSHA's primary source of data on the affected workforce, the Bureau of Labor Statistics' OES Survey, defines "employment" as follows.

> ***Employment*** refers to the number of workers who can be classified as full- or part-time employees, including workers on paid vacations or other types of paid leave; salaried officers, executives, and staff members of incorporated firms; employees temporarily assigned to other units; and noncontract employees for whom the reporting unit is their permanent duty station regardless of whether that unit prepares their paychecks. The OES survey includes all full- and part-time wage and salary workers in nonfarm industries. Self-employed workers, owners and partners in unincorporated firms, household workers, and unpaid family workers are excluded.[38]

[38] Survey Methods and Reliability Statement for the May 2014 Occupational Employment Statistics Survey, p. 3. http://www.bls.gov/oes/current/methods_statement.pdf. Accessed July 29, 2015.

Seasonal workers are part-year employees; hence, such workers would be included in the OES survey response if they were present in the workplace sampling frame. Furthermore, in the OES survey methodology, over the course of a 3-year cycle, approximately 200,000 establishments are sampled twice each year, in May and November (for a total of 1.2 million establishments). Therefore, because average annual employment estimates produced by the OES survey would capture most seasonal workers, OSHA's final profile of the affected would also reflect seasonal employment factors.

Revised Employee Turnover Rates for the FEA

The comments received on employee turnover did not identify significant flaws in OSHA's preliminary estimates regarding employee turnover, so the Agency employed the same methodology and data source used in the PEA to update to the 2012 BLS JOLTS estimates of job turnover for this FEA. In order to estimate turnover rates, OSHA used the hires rate (resulting from layoffs, quits, retirements) of 25.0 percent in general industry (including hydraulic fracturing) and maritime and of 70.2 percent in construction as estimated by the BLS (BLS, 2012). As in the PEA, OSHA judged that not all new hires would require initial medical testing. As specified in the final rule, employees who receive a qualifying medical examination within the previous twelve months do not need a second "initial" medical examination when they change employers. As in the PEA, OSHA estimated that 25 percent of new hires in general industry and maritime and 60 percent of new hires in construction would not incur any additional costs for their employers due to the initial medical examination.

CURRENT COMPLIANCE

In the preliminary analysis of the proposed standard's economic impacts, OSHA estimated current compliance as indicated in the following table. For the reasons explained below, OSHA is applying the same baseline compliance judgments in the FEA.

Table III-11 Baseline Compliance Judgments Applied in the PEA

Requirement	General Industry	Construction
Engineering Controls	The percentage of at-risk workers with exposures below PEL (based on the exposure profile) were judged to be in compliance	Same as General Industry
Exposure Assessment	No baseline compliance	No baseline compliance
Regulated area/exposure control plan	No baseline compliance	No baseline compliance
Respirator Use	No baseline compliance	Compliance rate of 56% based on BLS/NIOSH respirator survey (2001)
Respirator program	50% compliance rate	56% compliance rate (see above)
Medical surveillance	No baseline compliance	No baseline compliance
Training	50% have existing silica training program	Same as General Industry

Source: OSHA, Directorate of Standards and Guidance, Office of Regulatory Analysis.

OSHA requested comment on the estimates of baseline practice (current compliance) in the PEA but the Agency received very little information with the exception of two comments discussed immediately below.

Compliance rate - general practices

James Hardie Building Products, Inc. (Hardie) submitted extensive comments on OSHA's preliminary estimate of current compliance. Hardie criticized OSHA's analysis for not identifying sufficient support for its baseline compliance estimates, but did not go so far as to state that OSHA should not account for any existing rate of compliance, nor did it provide any new data or information that would assist OSHA in identifying a different rate. The following excerpt presents Hardie's comments on OSHA's estimates of baseline compliance with the ancillary requirements of the proposed silica standard:

> In building its analysis, OSHA has made a number of assumptions regarding how work is currently performed in the industries that will be affected by the proposed change in the PEL. These assumed practices provide the basis for evaluating the impacts of proposed regulatory changes, i.e., the impact is assessed on the basis of how required future operating practices differ from current (baseline) practices.

Accordingly, it is quite important to characterize baseline conditions accurately. In this regard, I have several concerns with how OSHA has characterized existing practices in the residential construction industry and related industries. . . .

Job site air monitoring-As described below, the vast majority of firms in the residential construction industry, and the related industries that serve it, are very small. OSHA has not provided information in the record to indicate how much small residential construction firms are currently spending on exposure monitoring. Therefore, OSHA's apparent assumption that firms in these industries already are maintaining compliance with the existing standard through a combination of monitoring and active engineering controls is inappropriate, as are any adjustments to calculated cost impacts that are based on an assumed substantial level of activity in this regard (i.e., high baseline costs leading to low incremental compliance costs).

Respiratory protection-The residential construction industry, allied industries, and their representatives are aware of respiratory hazards on construction sites and with the use of respirators. It is reasonable to assume that most home builders and their subcontractors have at least half-face respirators available to employees who need them for work that is likely to generate large amounts of airborne dust. With that said, the extent to which such employees wear respirators during normal operations is unclear.

Training and hazard communication-The practice of workplace safety has come a long way during the past few decades, and there is now a high level of awareness across U.S. industry that training and effective communication are keys to achieving improved safety performance in industrial settings. Accordingly, many larger companies have established comprehensive, and in some cases, very sophisticated occupational safety and health programs. These programs may have designated senior corporate officials responsible for their deployment and performance, be supported by formal management systems, and include a variety of training courses, learning aids, and other tools that are useful in promoting the behavior-based approach to safety on the job that has proven to be most effective in achieving results. Although it is reasonable to infer that manufacturing firms and large construction companies have and operate safety programs with these attributes, it is not reasonable to assume that homebuilders and their major subcontractors, most of which are very small, do as well, in the absence of any substantiating evidence. OSHA has provided no such evidence in the record. Accordingly, any assumptions that OSHA may have made about such companies already providing training, tailored communications, employee health monitoring, and other such practices to their employees are unreasonable and may

> have artificially inflated OSHA's estimated baseline costs (Document ID 2322, pp. 9 and 11).

One CISC representative, Stuart Sessions, did not directly challenge OSHA's preliminary estimates of current compliance for anything other than respirator use, but speculated generally that compliance rates might be lower at small businesses:

> OSHA assumes that small and large businesses have an identical fraction of their employees at risk of silica exposure and an identical fraction of exposed employees who are overexposed. Both of these assumptions are debatable, particularly the second. I might guess that compliance rates are lower and exposure levels are somewhat higher at small businesses in contrast to large businesses, probably because of lesser ability to afford compliance expenditures and lesser ability to devote management attention to compliance responsibilities (Document ID 4231, p. 2).

Mr. Sessions then proceeded to theorize on possible differences related to economies of scale between large and small plants in terms of per-establishment cost impacts. However, Mr. Sessions did not provide evidence that compliance rates for small establishments are lower than those for large plants, nor did Mr. Sessions document the basis for theorizing that economies of scale exist universally across industry.

Nevertheless, in response to the concerns raised by Hardie and Sessions, OSHA has eliminated the compliance rate estimates in this FEA, as compared to the PEA. OSHA notes, as indicated in the PEA table, the industry-wide baseline level of exposure assessment was estimated to be zero, the baseline level of respiratory protection in construction was assigned a value of 56 percent (an estimate not inconsistent with Hardie's broad perceptions on current practices), and the baseline level of training was estimated to be 50 percent (an estimate not inconsistent with Hardie's perception across the size range of construction employers).

As noted above in relation to Hardie's comments, for this final analysis, OSHA has revised the preliminary estimates of baseline compliance to account for the absence of silica training (except for Hazard Communication training) and other occupational health programs at the baseline throughout affected employers, irrespective of entity size. Table III-12 outlines OSHA's final baseline compliance judgments. Further details on the final estimates of baseline compliance are given in Chapter V, Costs of Compliance.

Compliance rate - training

For this final analysis, OSHA has revised the preliminary estimates of baseline compliance with initial training from 50 percent to zero percent and assigned one hour of training to all affected employees. This initial training on silica hazards will supplement the training currently required by the Hazard Communication Standard (1910.1200, 1926.59), for which OSHA assigned 100 percent current (baseline) compliance and zero costs. The basis for the reduction in baseline compliance is discussed in greater detail in Chapter V of this FEA concerning the costs of compliance.

Compliance rate – respirators and engineering controls in construction

For the final analysis of baseline compliance for engineering controls in construction, OSHA (1) estimates zero baseline compliance for those currently above the PEL; and (2) applies an exception in cases where the construction equipment already comes with a control attached – for example, a cutting tool that comes with a water attachment because cutting "dry" would damage the blade. Details on the final estimates of baseline compliance for engineering controls in construction are given in Chapter V, Costs of Compliance.

Stuart Sessions, an economic consultant to CISC and ACC, disagreed with OSHA's preliminary estimate of the current rate of respirator usage and described his preferred alternative approach along with submitting an alternative worksheet:

> OSHA estimates 56% current compliance, via a generally plausible approach relying on the NIOSH respirator survey. However, we suggest some adjustments to the 56% figure that OSHA derived:
>
> 1. OSHA has not considered the frequency (days/yr) with which the workers who now use respirators will need to use them after the new rule in comparison with the frequency with which they use them now. The NIOSH Survey doesn't address how frequently a current respirator user uses one; it asks only about use/not use
> 2. OSHA appears to have omitted blasters in construction industries from the current compliance analysis. Blasters presumably already use respirators now, and will be required to continue using them
> 3. OSHA has not considered respirator needs among construction workers who, under the proposed rule, will need to use respirators because they are exposed above the proposed PEL when performing tasks that are not listed in Table 1, e.g., mixing cement, installing segmented concrete pavers (Document ID 4023, Att. 2, Excel spreadsheet Tab 12B- Reduce Credit for currUse)

OSHA includes a more complete discussion of its response to Mr. Sessions's critique of the respirator use in Chapter V, Costs of Compliance. For the purposes of this analysis, OSHA has significantly lowered its estimate of the existing compliance rate for respirator use, partly in response to changes in Table 1. In the preliminary analysis of the construction sector, only those workers currently above the PEL were judged to require Table 1 controls. For those workers (only those exposed above the PEL), OSHA estimated in the PEA zero baseline compliance with the engineering controls required in Table 1. In the final rule, OSHA assigned all tasks being performed by construction workers and listed in Table 1 as being covered by the requirements of Table 1. This change in Table 1 coverage requires that OSHA modify its baseline compliance estimates. As in the PEA, OSHA estimated zero compliance with the engineering controls required in Table 1 for those workers currently exposed above the PEL. However, based on OIS data in the record, for workers currently exposed at or below the final PEL of 50 $\mu g/m^3$ that are using Table 1, for this FEA, OSHA estimated baseline compliance rate of 44 percent for these workers. OSHA lowered this compliance rate from 56 percent in the PEA to account for the concerns raised by Mr. Sessions and for the changes to Table 1. In an appendix to this chapter, Tables III-A-1 and III-A-2 present the OIS exposure data supporting OSHA's baseline compliance estimate.

Table III-12 Baseline Compliance Judgments Applied in this FEA

Requirement	General Industry	Construction
Engineering Controls	The percentage of at-risk workers with exposures below PEL (based on the exposure profile) were judged to be in compliance	Based on the analysis in the appendix, OSHA estimates that 44% of workers with exposure below the PEL have such exposure as a result of using the controls required in Table 1, and the remainder will need to use the controls in Table 1.
Exposure Assessment	No baseline compliance	No baseline compliance
Regulated area/exposure control plan	No baseline compliance	No baseline compliance
Respirator Use	No baseline compliance	Compliance rate of 56% based on BLS/NIOSH respirator survey (2001)
Respirator program	50% compliance rate	56% compliance rate (see above)
Medical surveillance	No baseline compliance	No baseline compliance
Training	100% have existing HazCom training program; None have existing silica training program	Same as General Industry

Source: OSHA, Directorate of Standards and Guidance, Office of Regulatory Analysis.

REVENUES AND PROFITS

Revenue and Profit Estimates for General Industry/Maritime and Construction

For the PEA, revenues were estimated on the basis of six-digit NAICS codes by applying revenue data from the Census Bureau's *Statistics of U.S. Businesses* for 2006 (U.S. Census Bureau, 2010). Although that data source from the Census Bureau provides annual industry-specific estimates of employment, establishments, firms, and payroll, revenue data are published only for years that coincide with the Economic Census.[39] However, 2006 revenues were estimated by extrapolating the 2002 revenue data based on the assumption that the ratio of revenues to payroll for each industry would be unchanged between the two years. Revenues were then inflated to 2009 dollars and distributed

[39] Estimates were drawn from US Census 2006 County Business Patterns six-digit level NAICS establishment totals (U.S. Bureau of the Census, 2010).

among size categories (small entities, very small entities) in accordance with the proportion of total payroll found in those categories within each industry. For further details on the methodology used to estimate per-entity revenue by size class, see ERG (2007b).

Additionally, before-tax profit rates were estimated using corporate balance sheet data from the Internal Revenue Service's *Corporation Source Book* (IRS, 2007). For each of the years 2000 through 2006, profit rates were calculated as the ratio of net income to total receipts (numerator includes only firms with net income; denominator includes firms with and without net income) by NAICS group and averaged profit rates across the seven-year (2000-2006) period. Since some data provided by the IRS were not available at disaggregated levels for all industries and profit rates, data at more highly aggregated levels were used as proxy for such industries—that is, where data were not available for each six-digit NAICS code, corresponding four- and five-digit NAICS codes were used as appropriate.

Public comments on OSHA's Preliminary Estimates of Revenues and Profits

Among the profile data presented in Tables III-5, III-6, and III-7 of this FEA are revenue per business entity and revenue per establishment for, respectively, all affected entities, entities defined as small by the SBA, and entities with fewer than 20 employees. As described above, for the PEA, OSHA estimated current revenues by extrapolating the 2002 revenue data based on the assumption that the ratio of revenues to payroll for each industry would be unchanged between the years 2002 and 2006. Revenues were then inflated to 2009 dollars and distributed among size categories (small entities, very small entities) in accordance with the proportion of total payroll found in those categories within each industry.

Dr. Ruttenberg pointed out a statement on estimated revenues for hydraulic fracturing in the PEA that appeared to imply the need for an adjustment to the impacts analysis and suggested that OSHA make that adjustment:

> OSHA itself states, in its appendix of the PEA on Hydraulic Fracturing, "that the industry-wide average revenue estimate appears to underestimate the average revenues for hydraulic fracturing firms." (PEA, p. A-11) These higher revenues will reduce the burden of compliance to the hydraulic fracturing companies whose workers are exposed to silica (Document ID 2257, Attachment 4, p. 8).

In response to Dr. Ruttenberg, OSHA notes that it has revised its estimate of revenues for the hydraulic fracturing application group based on 2012 Census data and other sources.

In testimony at the hearings and in post-hearing comments, ACC's economist, Mr. Stuart Sessions, criticized OSHA's use of the IRS Corporation Source Book. From the ACC post-hearing testimony:

- The CSB provides data only for much larger 3- or 4-digit NAICS industries instead of the finer detail that is needed on the particular 6-digit NAICS industries that will be affected by the proposed standard. Use of CSB data at the 3- or 4-digit NAICS level to represent 6-digit industries results in two problems:

  i. OSHA has no ability to distinguish the likely differences in profitability and ability to bear regulatory costs across multiple affected 6-digit industries that are grouped within a single 3- or 4-digit CSB amalgamation. For example, OSHA purports to estimate the specific regulatory costs faced by the eight different affected 6-digit industries within the 4-digit "clay, refractory and other nonmetallic mineral processing" industry; yet because of reliance on the CSB, which provides no detail beyond the 4-digit level, OSHA is limited to assigning all eight of these industries an identical estimate of profitability. I cited information suggesting that these eight industries within this CSB grouping are likely to have quite different profitabilities, but OSHA misses the opportunity to reflect this differentiation.

  ii. In some instances, the 6-digit affected industry constitutes only a small portion of a qualitatively very different and much larger 3- or 4-digit industry for which the CSB provides data. I cited as an example the affected 6-digit industry "Asphalt Shingle and Coating Materials Manufacturing", to which OSHA assigns whatever profitability the CSB shows for the more-than-100-times-larger 4-digit industry that is dominated by petroleum refineries. There is little reason why the profitability of a relatively small residential construction-oriented industry such as asphalt shingle manufacturing should be identical to that for petroleum refining.

- The CSB is available now only through the year 2011, thus failing to provide more recent, timely and relevant information about the current profitability of the affected industries and their ability to bear regulatory costs three or four years from today when compliance with the proposed standard will be expected (Document ID 4013, Attachment 7, pp. 1-2).

To address these apparent shortcomings inherent in the use of CSB profit data, Mr. Sessions suggested that OSHA consider alternative data sources (specifically, Risk Management Association's (RMA's) Statement Studies, Bizminer, and Dun & Bradstreet's Industry Norms and Key Business Ratios) to supplement its use of CSB. Dr. Sessions declined to recommend the Dun & Bradstreet source because of size and accessibility issues that lower its profile relative to CSB, RMA, and Bizminer. Of the three remaining sources of data, Mr. Sessions's evaluation was as follows:

> - The CSB does not provide any profitability information at the 6-digit level. Using the CSB, profitability for every one of the affected 6-digit industries must be represented inaccurately by the profitability of the much larger overarching 3-digit or 4 digit industry.
>
> - RMA's Statement Studies provide much more granular information on profitability at the 5- or 6-digit level for more than half of the industries, but these estimates are likely biased high to an unknown degree.
>
> - Bizminer provides profitability information at the 6-digit level for all the affected industries. In nearly all instances, data have been obtained and compiled from a large number of entities within each 6 digit industry.
>
> In sum, I suggest that OSHA draw the available information on profitability of the affected 6-digit industries from both the CSB and from the alternative sources. OSHA should then judge for each industry, after considering the entire range of important factors (granularity/precision in representing the 6-digit industry, recentness, likelihood of bias) how to combine the data from the various sources into a best estimate of profitability (Document ID 4013, Attachment 7, pp. 5 and 7-8).

In a final (post-hearing) brief, Mr. Sessions summarized his specific recommendations for estimating profitability for affected industries:

> - OSHA should start with an unbiased source of information on industry profitability, specifically the CSB. OSHA should choose data from the CSB for the larger 3-or 4- (or more, if available) digit industry as representing the profitability of the component affected 6-digit general industry. OSHA should use "Net Income (less deficit)" in calculating profitability from the CSB data, thus reflecting the profitability of all companies within the affected industry, not only the profitable ones. OSHA should choose a reasonably long series of years of data, ending with the most recent year available in the CSB (2011 at present), as

representing an industry's likely future profitability when compliance with the Proposed Standard is expected. Averaging the profitability information from CSB over the twelve years from 2000 through 2011 (or the 13 years through 2012, if the additional year becomes available) seems reasonable.

- OSHA should use one of the other data sources, probably Bizminer or perhaps RMA, to obtain information on i) how profitability for a smaller component industry may diverge from the profitability of the larger 3- or 4-digit industry of which it is a part; and ii) how profitability for the large and small business segments of an industry may diverge from the profitability of the entire industry. The CSB can provide an unbiased "anchor" estimate of profitability, while Bizminer or RMA can be used to estimate the percentage by which profitability for a component industry lags or exceeds this anchor figure. I have described the specific two-step procedure that I recommend for developing this further detail in footnote 11 of this Post-Hearing Brief on pages 12 and 13. I expect that Bizminer would be better for this purpose than RMA, as I believe that Bizminer covers more of the affected six-digit general industries than does RMA, and I believe that for most industries, Bizminer has obtained profitability information from more companies than has RMA, and hence is likely less subject to bias. I do not recommend Dun & Bradstreet for this purpose (Document ID 4231, pp. 37-38).

In response, OSHA agrees that the use of six-digit NAICS profit rates would be the optimal metric for measuring the profitability of six-digit-level industries, and OSHA requested such data in the PEA. However, with few if any exceptions, stakeholders declined to submit into the record financial data that would enable the Agency to refine its preliminary estimate of profitability. Therefore, OSHA relied on the IRS CSB database for its final analysis of economic impacts, with an expanded analysis as described in this chapter and in Chapter VI, Economic Feasibility Analysis and Regulatory Flexibility Determination.

Responding to Mr. Sessions's criticism of OSHA's use of CSB financial data exclusively in lieu of RMA or Bizminer data, OSHA notes that RMA restricted OSHA's public display of its data, making it too difficult for OSHA to rely on it while providing the transparency appropriate for the rulemaking process (see Document ID 3768, Attachment 2). BizMiner's Terms of Service, as displayed on the company's web site,[40] also prohibit

[40] See http://www.bizminer.com/terms.php, accessed November 28, 2014, which provides in part:

> You may use a purchased report for internal personal or business purposes…but not to publish or otherwise distribute the Profile or the information in it. You may integrate the

publication of their data, thereby creating the same obstacle to its use in an OSHA rulemaking. Because the public display of RMA and BizMiner data carries severe limitations, OSHA's decision for this FEA is to rely almost exclusively on the IRS CSB data for estimating industry profitability. OSHA believes that despite any weaknesses, the CSB data represent the best publicly available collection of financial information nationwide.

In response to Mr. Sessions's objection to OSHA's calculation of profit rates using net income from one IRS database (firms with net income) and using total receipts from another IRS database (firms with and without net income), the Agency has recalculated profit rates for 2000 to 2012 using the source and method recommended by Mr. Sessions, where all data are taken from the IRS CSB: Net income for firms with and without net income / Total receipts for firms with and without net income.

This new approach has some advantages and some disadvantages. The major advantage is that it includes all potentially affected firms. The major disadvantage is that it unnaturally skews average profit rates downward by including firms that have large losses (negative profits) and have already closed or are in the process of closing irrespective of any action by OSHA. The inclusion of such firms cannot capture what OSHA is intended to assess for economic feasibility purposes-those firms that are viable in the absence of a regulation. Thus, OSHA's revised estimates underestimate true average profit rates and ultimately affect OSHA's economic impact determinations by making it seem like the cost of the rule has more impact on the industry as a percentage of profits than it actually does, but this conservative approach helps to ensure that OSHA's economic feasibility determinations are strong.

In another critique of OSHA's preliminary method for calculating average profit rates, the National Association of Home Builders argued in favor of an alternate approach involving more recent years:

> . . . [T]he main problem with the profit data is the time period from which it is drawn, which is historically far from typical and drastically different from the recent experience. The PEA's justification for the 2000-2006 period is "because of the weakness of the profitability data (e.g., missing data points) and the desire to average out short-term profit swings over a full business cycle." In residential construction, 2000-2006 comes

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nowhere near capturing a business cycle. In the four decades between 1960 and 2000, total housing starts averaged about 1.5 million per year. In 2000-[2006], starts were above 1.5 million every year, and above 1.8 million for the last four of those years.

In contrast, 2008, 2009, 2010, 2011, 2012 and 2013 have been the six worst years for housing starts since World War II. This severe downturn was accompanied by a decline in nominal house prices at the national level, something that was also unprecedented since World War II.
The drastic changes in the industry after 2006 are also apparent in the average profit rates (owner's compensation and net income before taxes as a share of revenue) from NAHB's *Cost of Doing Business Study:*

Average Profit for Home Builders

2000	2002	2004	2006	2008	2010	2012
8.1%	9.9%	9.3%	9.0%	-1.3%	2.1%	5.7%

Source: NAHB Cost of Doing Business Study, various years

Not only did profit rates decline markedly for the home building industry as a whole after 2006, the relationship between large and small builders reversed itself (larger builders tended to be more profitable through 2006, smaller builders thereafter).

Average Profit for Single-family Home Builders, Based on Number of Starts

	2002	2004	2006	2008	2010	2012
Small Volume Builders (<26 starts)	10.3%	7.9%	6.7%	1.4%	4.7%	6.0%
Production Builders (26+ starts)	10.7%	9.5%	9.4%	-2.6%	1.2%	5.6%

Source: NAHB Cost of Doing Business Study, various years

Thus, the PEA uses C corporation profit from a 6-year boom period, mischaracterizes it as a full business cycle, applies the same rate indiscriminately to small entities, and ignores the drastically different state of the industry that has prevailed since 2006. For this reason, the economic feasibility section of the PEA for the Residential Construction Industry is not credible (Document ID 3522, pp. 9-10).

Commenters from the concrete industry also complained that the years selected for the analysis in the PEA were not representative of current revenues in their industry. Smithtown Concrete Products Corp., a small concrete products producer in New York, disagreed with OSHA’s preliminary estimate of revenues and profits for their industry:

Further, we believe that OSHA's economic justification for the rule is flawed relative to revenue projections for our industry based on data that

> they collected over the years of 2002-2006. These years represents [sic] strong economic times and OSHA fails to consider the impact of the recession on our businesses. To illustrate this point, our company's revenues in 2013 were more than 50% of our average revenues from 2000 to 2006. To make matters worse, our profits in 2013 are non-existent and have been for a considerable number of years. Therefore, the impact on this ruling on our business efficacy is much greater than OSHA portrays it to be (Document ID 2138, pp. 1-2).

Both sets of comments are representative of comments received from other producers who submitted similar letters.

As noted elsewhere in this chapter, OSHA's final estimate of profit rates is derived as an average over thirteen years of IRS corporate income data and thus is an expansion of the range of years covered in the preliminary calculation of average profit rates. The Agency's final estimate of per-entity revenue is based on the 2012 Economic Census. Both of these estimates now encompass recession-era data, as requested by the commenters. OSHA has revised its preliminary profit rate methodology to derive average profit rates for 2000 to 2012, with all data taken from the IRS CSB and calculated as follows: Net income for firms with and without net income / Total receipts for firms with and without net income. OSHA acknowledges the variation in revenues and profits among establishments within NAICS industries and the data sourcing employed in the final analysis is an attempt to capture the financial profile of the typical affected firm.

Table III-22, later in this section, presents yearly and multi-year averages of profit rates for affected NAICS codes using OSHA's revised methodology for the computation of profit rates. As shown for NAICS 236100, Residential Building Construction, using IRS data for the years reported in the NAHB cost study yields profit rates considerably lower than the rates reported by NAHB. Thus, OSHA's average profit rates for the home building industry may be conservatively low and may overstate the worst-case impacts of compliance costs on net earnings.

Revenue and Profit Estimates for Hydraulic Fracturing

Hydraulic fracturing - Revenues

OSHA's preliminary industry characterization for hydraulic fracturing firms estimated total revenues, revenues per entity, and revenues per establishment in the hydraulic fracturing portion of the industry and in the small business entities in the industry. Because small business entities typically have fewer than twenty employees, OSHA, in that analysis, did not report separately the results for entities with fewer than 20 employees.

Applying the following methodology, and as summarized in Table III-13, the reported Census figures for revenue per establishment for NAICS 213112 were revised to generate estimates of revenue that appeared reasonable for active hydraulic fracturing firms. First, estimates were developed of the likely revenue per stage for hydraulic fracturing work. At the low end, $25,000 per stage was estimated to be representative of the work on low-pressure, shallow, conventional wells. At the high end, estimates were drawn from the average revenue per stage ($136,335) reported by a large hydraulic fracturing company in its 2011 annual report (FTSI, 2011, Document ID 1583). The estimate in the second size category ($50,000) allowed for a mix of small hydraulic fracturing jobs and jobs on new wells. Work on new wells dominates the industry activities, and typical revenues per stage for hydraulic fracturing work on new wells are estimated to be much closer to the $100,000 figure. Thus, the $50,000 average revenue per stage was judged by OSHA to be a conservative estimate.

Table III-13: Preliminary Derivation of Adjusted Per-Establishment Revenue Estimates for Firms in the Hydraulic Fracturing (HF) Industry

Employee Size Category	HF Entities	Estimated HF Establishments	Census-Based Revenue Per Establishment Estimate (a)	Estimated HF Revenue Per Stage (b)	Estimated Establishment Revenues ($1,000) at Different Utilization Rates (Percent)(d)		
					25	50	75
10-19	100	100	$2,064,073	$25,000	$2,281	$4,563	$6,844
20-99	50	60	$5,158,959	$50,000	$4,563	$9,125	$13,688
100-499	46	184	$15,005,003	$100,000	$9,125	$18,250	$27,375
500+	4	100	$24,000,429	$136,335 (c)	$12,441	$24,881	$37,322
Hydraulic Fracturing Industry – Total Entities and Establishments; Weighted Average Revenue @ 50% Utilization Rate	200	444				$15,428	

(a) Estimated by ERG.

(b) Estimated by ERG.

(c) FTSI, 2011.

(d) Utilization is defined as performance of one stage per day for the specified percentage of days in the year. In actuality, many hydraulic fracturing jobs will accomplish more than one stage in a day.

Source: OSHA, Directorate of Standards and Guidance, based on ERG, 2013b.

A range of revenues was estimated using annual equipment utilization rates of 25, 50 and 75 percent.[41] For simplicity, utilization is defined for this estimate as the completion of one stage in a day. Although in this analysis, very small hydraulic fracturing firms are modeled to engage in a single stage of activity at a time, in fact, hydraulic fracturing firms of all sizes can often perform more than one stage per day. For small firms, this might mean traveling to a second well on a single day to perform a second hydraulic fracturing job. On large wells, the rate at which stages are completed varies with the depth at which stages are performed. Therefore, because of the mobility and flexibility of hydraulic fracturing firms, the definition of utilization applied in the PEA was a conservative factor in the definition of revenues.

In the final step of its model, revenues were calculated using the range of equipment utilization rates described above. Because the hydraulic fracturing industry has been extremely active for the last several years before this record closed, actual utilization rates were quite high and many firms purchased new equipment (PacWest Consulting Partners, 2012, Document ID 1597). For this analysis, however, to avoid overestimating revenues, a 50 percent utilization rate was used for estimating revenues per establishment. Nonetheless, uncertainty regarding utilization rates for the smallest operators in the hydraulic fracturing market remains. In addition, while most information suggests that new-well hydraulic fracturing dominates industry activities, OSHA has limited information on the scale of activities among the small hydraulic fracturing firms. The focus on the robust new-well hydraulic fracturing activity might overstate the market and the viability of the smallest hydraulic fracturing operators. Using the 50 percent utilization estimate, average revenues were estimated for hydraulic fracturing firms as ranging from $4.6 million for a 10-19 employee establishment to $24.9 million for one of the largest establishments. OSHA applied those revenue estimates in the PEA. OSHA requested data on equipment utilization rates among hydraulic fracturing firms and information on the scale of activities of all hydraulic fracturing firms, particularly firms defined as small by the SBA definition. In the following discussion, comments by the public and OSHA's response to those comments lead to the Agency's final resolution in those profile areas.

Table III-14a presents OSHA's preliminary estimate of revenues for firms in the hydraulic fracturing industry affected by the standard. For comparison, Table III-14b

[41] For purposes of a sensitivity analysis, ERG and OSHA also examined impacts at utilization rates of 40 percent, 60 percent, and 80 percent (see Document ID 1781, Workbook #1). This is the range that the commenters focused on, and thus is the range discussed most frequently in this part of the FEA. Throughout the discussion here and below, for hydraulic fracturing, OSHA and commenters may at times refer to a utilization range of 40 percent to 80 percent and also refer to a utilization range of 25 percent to 75 percent.

presents OSHA's final estimate of revenues, the derivation of which is explained following the table.

Table III-14a: Preliminary Revenue for Entities in the Hydraulic Fracturing Industry Affected by OSHA's Proposed Standard for Silica – NAICS 213112

Industry Portion	Revenues ($1,000)	Revenues Per Entity ($1,000)	Revenues per Establishment ($1,000)
Total for Entire NAICS	$34,524,044	$5,044	$4,311
Hydraulic fracturing firms only	$8,219,837	$41,099	$18,513
Hydraulic fracturing entities with fewer than 20 employees	$547,500	$5,475	$5,475
Hydraulic fracturing SBA entities	$547,500	$5,475	$5,475

Source: OSHA, Directorate of Standards and Guidance, based on ERG, 2013b.

Table III-14b: Final Revenues for Entities in the Hydraulic Fracturing Industry Affected by OSHA's Standard for Silica – NAICS 213112

Industry Portion	Revenues ($1,000)	Revenues Per Entity ($1,000)	Revenues per Establishment ($1,000)
Total for Entire NAICS	$78,060,509	$8,794	$7,180
Hydraulic fracturing firms only	$17,396,813	$86,984	$39,182
Hydraulic fracturing entities with fewer than 20 employees	$570,313	$5,703	$5,703
Hydraulic fracturing SBA entities [a]	$1,884,313	$12,562	$11,777

[a] The 2014 SBA size standard for NAICS 213112 was $38.5 million (changed from $7.5 million when the PEA was developed); therefore, because establishments with 20-99 employees fell within the SBA size standard (unlike in the PEA), SBA entities in the final analysis include establishments with 10-19 employees and 20-99 employees.

Source: OSHA, Directorate of Standards and Guidance, based on OSHA, 2016.

For most industries covered in this FEA, where an industry contained both establishments that used processes causing silica exposures and establishments that did not use such processes, OSHA has assumed that the establishments using processes that cause silica exposures are financially typical of the industry as a whole. In the case of hydraulic fracturing, however, such an assumption required further analysis. NAICS 213112 includes some firms with fewer than 10 employees. As discussed earlier, given that even the smallest hydraulic fracturing firms have substantial equipment requirements, and that minimal crew sizes imply a need for at least ten employees, OSHA in the PEA preliminarily determined that the number of fracturing firms with fewer than 10 employees was negligible.[42] Therefore, the Agency removed firms with 9 or fewer

[42] As mentioned above, NAICS 213112 includes a range of other oilfield service activities, such as other oil and gas field services; oil and gas exploration services; oil and gas well surveying; cementing oil and gas well; and running, cutting, and pulling casings, tubes, or rods. These activities, which do not involve hydraulic fracturing, can more reasonably be performed by firms with fewer than ten employees. Firms that perform these types of non-fracturing services are judged to dominate the smallest size categories in the industry.

employees from consideration for the preliminary analysis. OSHA did not receive any comments challenging this determination, so it has used the same approach in the FEA.

Even with this adjustment, the revenue data for typical firms in oil and gas well drilling support services still seemed to be low for hydraulic fracturing firms. For example, for the smallest size category considered (10-19 employees), based on ERG's analysis, OSHA estimated that such firms would not be performing any large-scale fracturing jobs but would be restricted to small jobs generating roughly $5,000 to $50,000 in revenues. Using an average revenue for the smallest fracturing jobs of $25,000 per job and the industry-wide Census Bureau revenue estimate of $2.1 million per year per firm, OSHA in the PEA estimated that the average hydraulic fracturing establishment with 10-19 employees would, on average, be able to perform only 84 hydraulic fracturing jobs per year without exceeding the Census revenue estimate. OSHA estimated that most of the jobs would be single-day jobs and that a firm could do far more than 84 jobs a year. Thus, OSHA concluded that the industry-wide average revenue estimate appeared to underestimate the average revenues for hydraulic fracturing firms.

OSHA requested comment on the typical lengths of time involved in the major stages of well fracturing work and the range of revenues earned for hydraulic fracturing jobs. API/IPAA generally endorsed OSHA's analytical approach, taking issue with only OSHA's utilization rate underlying its revenue estimate for small entities. Therefore OSHA has applied a similar methodology using updated Census data for NAICS 213112. Moreover, OSHA reiterates that an underestimation of revenues for hydraulic fracturing firms relative to the other oilfield service firms with equivalent numbers of employees would be expected because hydraulic fracturing firms use much more, and much more expensive, capital equipment than other firms, and as a result have higher costs which are, in turn, paid for by customers. For example, as noted in the PEA, companies can offer wireline services with relatively light, mobile rigs that are much less expensive than the equipment necessary for hydraulic fracturing. While commenters disagreed with some aspects of OSHA's revenue estimates, no one suggested that these estimates would be improved by using data from NAICS 213112 as a whole.

With respect to the utilization rates of small entities, API/IPAA preferred that OSHA use a higher rate of 80 percent rather than the lower percentage used in the proposal:

> Our only corrections relate to the assumptions on which the revenue estimate for small entities was built. More specifically, we agree that small entities "have sufficient capacity to handle only minor, low-pressure refracturing jobs on conventional oil and gas wells" and with OSHA's assumption that those jobs generate an average revenue of $25,000, but we do not agree with the 60% utilization rate OSHA and

ERG employed in order to estimate the average annual revenues these small businesses generate in performing these jobs. * * *

The "utilization rate," as defined by OSHA and ERG, represents the "performance of 1 stage per day for the specified percentage of days in the years," The 60% utilization rate, therefore, represents an assumption by OSHA and ERG that hydraulic fracturing establishments will fracture 219 stages per year. OSHA and ERG's sole basis for this conclusion is a 2012 press release from PacWest Consulting Partners, which stated that there was "a net reduction of frac capacity utilization of 26% over the course of 2012."

Both ERG and OSHA cite to the 2012 PacWest press release as evidence that "actual utilization rates are quite high and many firms have purchased new equipment." While the 2012 PacWest press release estimates a 75% capacity utilization rate, according to PacWest "[c]apacity utilization is defined as the average annual frac demand divided by average annual frac supply." The PacWest "utilization rate" estimate represents the relative balance between overall demand and supply in the hydraulic fracturing market – not the number of days per year on which hydraulic fracturing fleets are performing fractures. Nor can such conclusions be drawn from this data. If anything, the PacWest data show that ERG and OSHA's assumptions on fracture frequency are inflated. The 2012 PacWest press release reported that declining rig counts were driving down demand for hydraulic fracturing services at the same time the hydraulic fracturing industry was adding new capacity. As such, PacWest estimated that capacity would fall to 75 percent. This 75 estimate, however, does not support that companies are fracturing 274 stages per year (75% of 365). It means that, at any given time, one quarter of all hydraulic fracturing fleet capacity is sitting idle waiting for a customer.

Not only is ERG and OSHA's 60% utilization rate unsupported (and entirely undermined by the only evidence they cite), it makes no sense from an operational level. ERG and OSHA applied this 60% ration across all tiers of hydraulic fracturing entities. For entities with more than one establishment, ERG and OSHA assumed that each establishment would complete 219 fractures per year. This utilization may be plausible for some, however, because larger establishments can operate more than one fleet. With sufficient demand, establishments with multiple fleets may indeed fracture 219 stages per year. Additionally, larger companies conduct hydraulic fracturing in multi-day projects on large multistage wells. As such, they do not have to conduct site preparation activities, or transport, assemble, and then disassemble their equipment between each stage or between projects with anywhere near the frequency as small companies will need to do in completing single-day, single well projects.

Importantly, the Associations are not suggesting that a 60% fracture frequency is appropriate for large companies. We are simply pointing out that these large-entity utilization efficiencies are not shared by the small hydraulic fracturing entities. As OSHA notes, the small entities are one-fleet businesses that have only been able to enter the hydraulic fracturing market "by purchasing second-hand equipment that is in need of servicing and that is sufficient for use on relatively low-pressure jobs. These low-pressure jobs "typically only require one day to complete."

Consequently, OSHA's 60% fracture frequency assumes that small entities will be able to conduct hydraulic fracturing at 219 different well sites in a single year. This assumption is simply not realistic. OSHA's estimate allows for, at most, a single day's travel time between each well site and the next well site or the small entity's base if the fleet returns to reequip after a job. OSHA's utilization assumption does not build in time for site preparation, equipment assembly, equipment dismantling, crew member leave, supply coordination and delay, or the equipment servicing that OSHA assumes is required on small entities' second-hand equipment. Indeed, while OSHA is correct that the actual low-pressure refracturing of a shallow conventional well can typically be accomplished in a day, it significantly underestimates the preparation and mobilization time that is required for such an accomplishment.

As both ERG and OSHA note that these estimates for small entities are "uncertain," based on "limited information," and "might overstate the market and the viability of the smallest HF operators," the Associations herein provide a more realistic estimate of fracture frequency among small hydraulic fracturing entities. Based on the experiences of members of the Associations, we believe that it is more accurate to assume that small hydraulic fracturing companies with less than 20 employees could refracture 97 existing, shallow conventional wells per year, with typically one stage per well. With a reasonable time assumed for mobilization, site preparation, assembly, and deconstruction, this scenario presumes crews and equipment will be deployed 292 days per year for 80% utilization over the course of a year, with utilization being defined as having the fleet in the field, committed to a job and unavailable for another job. For the typical low pressure refracture job performed by a small firm and small fleet, we assume one day to travel from base to well site and set up and await completion of pre-fracture activities, one day to perform the fracture, and one day to take down, return to base and demobilize. Importantly, based on OSHA's estimate that small entities earn $25,000 in revenue per job, these small entities at 80% utilization for their fleets, would generate $2,425,000 per year in revenues – more than reasonable given their size and, significantly, only about $300,000 more than what the Census estimated as the average revenue for all service

> companies in NAICS 213112 with between 10 and 19 employees (Document ID 2301, pp. 25-27).

OSHA considered the API/IPAA comments on average earnings for firms performing hydraulic fracturing and derived alternative estimates of revenues using lower estimates of the number of stages. API/IPAA asserted that small crews could only manage one stage of fracturing every three days, with one day for set-up and one day for travel. OSHA judges that this assumption might underestimate the extent to which smaller operators might participate in multi-well pad operations where multiple stages are fractured from an individual location and overstate the average distances being traveled, considering that at least some jobs will be performed at sites that are close to each other. Travel times might be limited for hydraulic fracturing operations, for example, in regions of shallow drilling or with closely grouped wells. In any case, OSHA concludes that data are extremely limited on which to base these estimates and to vary the small crew estimates from the industry averages.

OSHA judges that, even allowing for some variability on the utilization issue, its estimates of hydraulic fracturing revenues and profits have been conservative and its estimate that small hydraulic fracturing firms are able to compete only for the single-zone, small (average $25,000) fracturing jobs remains very conservative.

Moreover, Mr. Kenny Jordan, Executive Director of the Association of Energy Service Companies testified in the public hearings that some small companies offer other services in addition to hydraulic fracturing, such as tool rental, and that such small hydraulic fracturing establishments operate only in very limited geographic areas (Document ID 3589, p. 4099). Mr. Jordan described a group of small hydraulic fracturing firms that do not appear to travel large distances at all, as has been presumed for small crews. OSHA therefore judges that if travel times are fairly minimal, crews would generally be deployable at a rate greater than one single-zone fracturing job in three days, assuming their services are in demand.

OSHA's estimates of the hydraulic fracturing revenue stream are based on estimates of the average revenue per stage of well fracturing and the number of stages fractured per year for average establishments. While OSHA identified some data on the number of stages fractured per year, OSHA did not find data on how the work is distributed across the size spectrum of industry firms.

For the PEA, total revenues for NAICS 213112 were estimated at $34.5 billion for 2006, extrapolating data from the 2002 Economic Census and assuming that the ratio of revenues to payroll was unchanged from 2002 to 2006. According to the updated version of the same data, the Economic Census data for 2012, revenues for NAICS 213112 total

$86.8 billion (Census Bureau, 2015a). Of this total, approximately $8.7 billion included receipts from secondary products and services (i.e., products not classified in this NAICS). Eliminating these secondary receipts from consideration, OSHA estimates that 2012 revenues from oil and gas field services totaled $78.1 billion.

Table III-15 summarizes the data for the entire NAICS code, and not just hydraulic fracturing. These data include an estimate of aggregate receipts; this total has been distributed across the entity and establishment size categories based on the distribution of payroll by size category. Tables III-16 and III-17 present OSHA's final profile characteristics of hydraulic fracturing entities and crews affected by the final rule, respectively.

Table III-15: Economic Census Statistics on Entities and Establishments in NAICS 213112, Oil and Gas Well Support Services, 2012

Employee Size Category	Entities (a)	Establishments (a)	Employ-ment (a)	Payroll ($1,000) (a)	Receipts ($1,000) (b) (c)	Revenue per Entity	Revenue per Establishment
Total NAICS	8,877	10,872	272,357	$21,739,034	$78,060,509	$8,793,569	$7,179,959
10-19	1,041	1,057	14,132	$826,000	$2,966,000	$2,849,184	$2,806,055
20-99	1,230	1,347	49,373	$3,280,279	$11,778,824	$9,576,279	$8,744,487
100-499	283	519	47,386	$3,388,438	$12,167,201	$42,993,643	$23,443,547
500+	127	1,745	145,834	$13,289,086	$47,718,441	$375,735,758	$27,345,812
Total for Selected Employment Size Categories (d)	2,681	4,668	256,725	$20,783,803	$74,630,466	$27,836,802	$15,987,675

(a) From Census, 2015a.

(b) Estimate for total receipts associated with oil and gas well drilling was derived from Census, 2015a (Economic Census. Report for Mining: Industry Series) by eliminating receipts for secondary production activities (see discussion in text above).

(c) Receipts distributed within size categories based on the share of payroll in each category, excluding establishments below 10 employees.

(d) Revenue per Entity and Revenue per Establishment are averages across all employee size categories in NAICS 213112.

Source: OSHA, Directorate of Standards and Guidance, Office of Regulatory Analysis, based on OSHA, 2016.

Table III-16: Characteristics of Industries Affected by OSHA's Final Standard for Silica - Entities in NAICS 213112

Industry Portion	Entities	Establishments	Employment	Affected Entities	Affected Establish-ments (b)	Affected Employ-ment (c)	Revenues ($1,000)	Revenues Per Entity ($1,000)	Revenues per Establishment ($1,000)
Total for Entire NAICS	8,877 (a)	10,872 (a)	272,357 (a)				$78,060,509	$8,794	$7,180
HF firms only				200	444	25,440	$17,396,813	$86,984	$39,182
HF entities with fewer than 20 employees				100	100	1,301	$570,313	$5,703	$5,703
HF SBA Entities				150	160	3,036	$1,884,313	$12,562	$11,777

(a) Census, 2015

(b) Estimated by ERG.

(c) ERG used the midpoint of the employment range 10-19 to estimate the average employees per entity for entities with fewer than 20 employees.

Source: OSHA, Directorate of Standards and Guidance, Office of Regulatory Analysis, based on OSHA, 2016.

Table III-17: Distribution of HF Crew by Function and NIOSH Sampling Classification in OSHA's Final Profile of Hydraulic Fracturing

Est. Workers Per Site	Percent of Total	Primary Function	Classification Used in NIOSH Sampling Work	Aggregate Number of Workers
5	31.25%	Sand mover operator	Fracturing Sand Worker in the Central Area	7,950
1	6.25%	Conveyor belt tender	Fracturing Sand Worker in the Central Area	1,590
2	12.50%	Blender tender	Fracturing Sand Worker in the Central Area	3,180
1	6.25%	Hydration unit operator	Ancillary Support Worker	1,590
2	12.50%	Water/chemical hands	Ancillary Support Worker	3,180
3	18.75%	Pump operator technicians	Ancillary Support Worker	4,770
1	6.25%	Supervisor	Remote/Intermittent Worker	1,590
1	6.25%	Ground guide (Sand coordinator)	Remote/Intermittent Worker	1,590
16	100.00%	Total- Hydraulic Fracturing Crew		25,440

Source: OSHA, Directorate of Standards and Guidance, Office of Regulatory Analysis, based on OSHA, 2016.

For the PEA, OSHA estimated that the smallest hydraulic fracturing firms would average $25,000 per stage of well fracturing activity. The estimate of $25,000 per stage was not tied to the Census figures and thus is not subject to revision with more recent data. Nevertheless, the increase in revenues for the NAICS code overall suggests that substantially higher revenues were being generated for fracturing firms in 2012 compared to 2006.

Data from PacWest, a marketing research firm, indicated in 2014 that approximately 92 percent of the stages on fractured wells during that year were expected to involve horizontal fracturing (PacWest, 2014). Thus, a very large majority of industry activities are of the sophisticated variety (i.e., horizontal fracturing) that is generally not performed by the smallest firms. Further, small firms most likely operate only a modest share of the remaining 8 percent of the total wells fractured, which consist of vertical wells. These data suggest that shallow, vertical well fracturing represents a very small share of all hydraulic fracturing activity and that there would be very few wells fractured for $25,000 in revenues per stage of well fracturing activity, which is the estimated average for the smallest establishments. Because the vast majority of hydraulic fracturing entities are small establishments (150 out of 200; see Table III-16), it is unlikely that there would be enough of these small wells to account for all of the entities. This evidence further suggests that even very small hydraulic fracturing firms might compete effectively for somewhat larger and more lucrative fracturing jobs, and thus would receive greater amounts of revenue than estimated by OSHA when these smaller entities were assumed to only operate small wells.

According to the Census, the average revenue reported for the 10-to-19-employee establishment size category for NAICS 213112 in 2006 was $2.1 million and the 2012 data raise that estimate to $2.8 million per year. In the PEA, OSHA noted that if the NAICS-wide average revenue was judged to be representative of hydraulic fracturing firms, the revenue total and the per-stage revenue estimate would suggest that small hydraulic fracturing entities were only performing 84 of these small fracturing jobs per year in 2006. OSHA judged this rate of activity to be too low to be representative of even the smallest spectrum of establishments given the industry data on well drilling discussed earlier.

In the PEA, OSHA also used utilization rates of 40, 60, and 80 percent to reflect possible and more likely revenue levels. At the mid-range (60 percent utilization figure), for example, OSHA calculated that hydraulic fracturing entities with 10 to 19 employees would complete 219 stages in a year and generate $5.5 million in revenues. Industry commenters pointed out, however, that any calculation of utilization rates for the industry must be distinguished from time expended for travel to and from jobs, a factor not considered in OSHA's preliminary estimates (Document ID 2301, pp. 26-27).

Table III-18 presents OSHA's final methodology for calculating per-establishment revenue in hydraulic fracturing. Although OSHA disagrees with API/IPAA on recent trends in the frequency of job stages and rate of well-pad usage, and has therefore included estimates of stages per day that moved upward since the PEA, the Agency finds persuasive the Associations' point that "declining rig counts were driving down demand for hydraulic fracturing services at the same time the hydraulic fracturing industry was adding new capacity" (Document ID 2301, p. 26). Therefore, for this final analysis, OSHA revised downward the preliminary range of utilization rates – from 40, 60, and 80 percent to 35, 50, and 65 percent – to reflect lower estimates of the number of days during the year in which a stage is fractured. Combined, the various changes generate a set of revenue estimates and an aggregate estimate of the stages fractured that do not alter OSHA's overall conclusion of economic feasibility for this application group (see Chapter VI**).** The middle estimate of 50 percent in the final range of utilization is equivalent to approximately 183 stages per year. At this rate, and assigning on average OSHA's preliminary estimate of $25,000 per stage performed, the smallest strata of hydraulic fracturing establishments (10-19 employees) would generate revenues of $4.6 million per year.

Finally, as reflected in Table III-19, OSHA arrayed the stages per-day estimates from 1.25 for the smallest strata to 5 and 6 stages per day for the larger establishments.

In response to criticism by API/IPAA on OSHA's preliminary estimate of hydraulic fracturing utilization rates, OSHA considered the possibility that a 50-60 percent mid-level utilization rate might overstate the number of days per year in which the smallest firms are actually performing hydraulic fracturing. Nevertheless, OSHA disagrees with the Associations that such firms are likely to complete no more than one stage at one job for every three days during the year, with a complete day before and after the job for travel. Even small fracturing jobs on shallow wells might involve drill pads with multiple wells where different wells or different stages of the same wells are fractured on the same day or on consecutive days. Some small jobs only take an hour, once set-up is completed (OSHA, 2016). Also, the smallest firms are unlikely to travel very far. Finally, even small hydraulic fracturing crews mobilize more than $1 million of equipment. Their revenues must sustain a return on that investment, as well as cover all labor and operating costs. To do that, they would need to be engaged in more fracturing stages per day than the commenters asserted.

Table III-19 presents the remaining unit data supporting OSHA's final methodological approach to profiling the hydraulic fracturing industry. In response to the criticism noted above that the preliminary per-stage revenue estimates were too high, OSHA lowered the per-stage hydraulic fracturing revenue for the larger establishments. Table III-20 shows the calculation of the number of stages fractured in a year.

Table III-16, presented earlier in this section, summarizes the overall revenue figures for the NAICS industry and the estimated hydraulic fracturing sector, which are drawn from the estimates listed in Table III-19. Although the revenue for small businesses has actually increased significantly, OSHA has conservatively reflected only a very small increase in per-establishment revenue in this final analysis. The per-establishment revenue for the smallest strata of hydraulic fracturing entity (10 to 19 employees) is estimated at $5.7 million per year; whereas the corresponding per-establishment revenue estimate in the PEA was $5.48 million. For the small entities, revenues for the entity and for the establishment are the same on the assumption that these smallest firms are only operating out of one facility.

Table III-18: Final Methodology for Estimating Per-Establishment Revenue among Hydraulic Fracturing Establishments (Preliminary Per-Stage Revenue)

Employee Size Category	Estimated Number of Entities in Hydraulic Fracturing	Estimated No. of Establishments per Entity	Total Establish-ments (a)	Preliminary Estimated HF Revenue Per Stage (b)	Estimated Per Establishment Revenues at Varied Estimates of the Days per Year of Frac Operations (Percent) (c)		
					35%	50%	65%
10-19	100	1	100	$25,000	$3,193,750	$4,562,500	$5,931,250
20-99	50	1.2	60	$50,000	$6,387,500	$9,125,000	$11,862,500
100-499	46	4	184	$100,000	$12,775,000	$18,250,000	$23,725,000
500+	4	25	100	$136,335	$17,416,796	$24,881,138	$32,345,479
Total	**200**		**444**				

(a) Estimates of the number of entities and the number of establishments per entity remain unchanged from the PEA.

(b) Estimated revenues per stage derived in the PEA. The revised per-stage revenue estimates are presented in the next table.

(c) The utilization rates have been revised from the PEA to account for travel time. Utilization is defined as performance of one stage per day for the specified percentage of days in the year.

Source: OSHA, Directorate of Standards and Guidance, Office of Regulatory Analysis, based on OSHA, 2016.

Table III-19: Final Methodology for Estimating Per-Establishment Revenue among Hydraulic Fracturing Establishments

(Final Per-Stage Revenue)

Employee Size Category	Estimated Number of Entities in Hydraulic Fracturing	Estimated No. of Establish-ments per Entity	Total Establish-ments (a)	Estimated HF Revenue Per Stage (b)	Stages Per Day of Frac Operations (c)	Estimated Per Establishment Revenues at Varied Estimates of the Days per Year of Frac Operations (Percent) (d)			Aggregate HF Revenues (e)
						35%	50%	65%	50%
10-19	100	1	100	$25,000	1.25	$3,992,188	$5,703,125	$7,414,063	$570,312,500
20-99	50	1.2	60	$40,000	3	$15,330,000	$21,900,000	$28,470,000	$1,314,000,000
100-499	46	4	184	$50,000	5	$31,937,500	$45,625,000	$59,312,500	$8,395,000,000
500+	4	25	100	$65,000	6	$49,822,500	$71,175,000	$92,527,500	$7,117,500,000
Total	**200**		**444**						$17,396,813

(a) Estimates of the number of entities and the number of establishments per entity were unchanged from the PEA.

(b) The revised revenues per stage are lower than previous estimates to reflect available data.

(c) Stages per day revised from the PEA.

(d) The utilization rates have been revised from the PEA to account for travel time. Utilization is defined as performance of one stage per day for the specified percentage of days in the year.

(e) Aggregate revenue estimate derived here matches that generated by the Census data for hydraulic fracturing activity (Census, 2015b).

Source: OSHA, Directorate of Standards and Guidance, Office of Regulatory Analysis, based on OSHA, 2016.

Table III-20: Derivation of Estimates of the Annual Number of Stages Fractured in OSHA's Final Hydraulic Fracturing Profile

Employee Size Category	Estimated Number of Entities in Hydraulic Fracturing	Estimated No. of Establishments per Entity	Total Establish-ments (a)	Stages Per Day of Frac Operations (b)	Percent of Days on Which Fracking Occurs/Number of Stages Per Year (c)			Aggregate HF Stages
					35%	50%	65%	50%
10-19	100	1	100	1.25	160	228	297	22,813
20-99	50	1.2	60	3	383	548	712	32,850
100-499	46	4	184	5	639	913	1186	167,900
500+	4	25	100	6	767	1,095	1,424	109,500
Total	**200**		**444**					333,063

(a) Estimates of the number of entities and the number of establishments per entity were unchanged from the PEA.

(b) Stages per day revised from the PEA.

(c) The utilization rates have been revised from the PEA to account for travel time. Utilization is defined as performance of one stage per day for the specified percentage of days in the year.

Source: OSHA, Directorate of Standards and Guidance, Office of Regulatory Analysis, based on OSHA, 2016.

Hydraulic Fracturing – Profits

Table III-21a presents OSHA's preliminary estimate of profits in the hydraulic fracturing industry, with the revenue information included for reference.

Table III-21a: Preliminary Profit and Revenue for Entities in the Hydraulic Fracturing Industry Affected by OSHA's Proposed Standard for Silica – NAICS 213112

Industry Portion	Profit Rate [a]	Revenues ($1,000)	Profit ($1,000)	Revenues Per Entity ($1,000)	Profit Per Entity ($1,000)	Revenues per Establishment ($1,000)	Profit Per Establishment ($1,000)
Total for Entire NAICS	10.31%	$34,524,044	$3,559,429	$5,044	$520	$4,311	$444
Hydraulic fracturing firms only	10.31%	$8,219,837	$847,465	$41,099	$4,237	$18,513	$1,909
Hydraulic fracturing entities with fewer than 20 employees	10.31%	$547,500	$56,447	$5,475	$564	$5,475	$564
Hydraulic fracturing SBA entities	10.31%	$547,500	$56,447	$5,475	$564	$5,475	$564

Source: OSHA, Directorate of Standards and Guidance, Office of Regulatory Analysis, based on OSHA, 2016.

API/IPAA objected to, but acknowledged that they could not provide an alternative to, OSHA's preliminary estimate of profitability for hydraulic fracturing companies:

> As opposed to revenues, which the Associations believe are largely determinable within a reasonable range of precision, the Associations do not believe that profits are determinable for the hydraulic fracturing industry. OSHA derived its profit estimates from its estimates of industry revenues. It utilized a presumed . . . profit rate of 10.31% and, once again, applied it equally across all sizes of hydraulic fracturing companies. * * * [I]t is wrong of ERG to attempt to estimate profitability for an entire industry by reviewing tax return data for only those companies in the industry that earned positive profits in the year in question. Profitability for an entire industry ought to reflect the financial performance of both those firms that made money and those that did not
> (Document ID 2301, pp. 27-28)(citations omitted).

OSHA's profit estimates are consistent with the methodology for calculating profit rates used in other recent OSHA economic analyses, and the Associations did not supply data that would allow OSHA to reach a different determination for the subset of affected hydraulic fracturing entities within the overall NAICS industry. OSHA therefore based its final profits estimate on the best available data for the NAICS industry (213112) most closely associated with hydraulic fracturing. OSHA notes that it was limited to six-digit NAICS industries because of limitations in the IRS data required for the calculations.

However, as discussed more fully earlier, OSHA has made several adjustments in its profit calculations, one of which addresses concerns raised by the Association. OSHA included firms without net income when it calculated profit rates as the ratio of net income for firms (with and without net income) to total receipts for the same group of firms. Applying this methodology to calculate profit rates for all establishments in NAICS 213112, OSHA estimates that the average profit rate for 2000-2012 was 7.09 percent for the hydraulic fracturing industry; this average profit rate was applied by the Agency in its impact analysis, presented in Chapter VI. Table III-21b below represents OSHA's final profit estimates for the hydraulic fracturing industry, with the revenue information included for reference.

Table III-21b: Final Profit and Revenue for Entities in the Hydraulic Fracturing Industry Affected by OSHA's Standard for Silica – NAICS 213112

Industry Portion	Profit Rate [a]	Revenues ($1,000)	Profit ($1,000)	Revenues Per Entity ($1,000)	Profit Per Entity ($1,000)	Revenues per Establish-ment ($1,000)	Profit Per Establish-ment ($1,000)
Total for Entire NAICS	7.09%	$78,060,509	$5,533,076	$8,794	$623	$7,180	$509
Hydraulic fracturing firms only	7.09%	$17,396,813	$1,233,119	$86,984	$6,166	$39,182	$2,777
Hydraulic fracturing entities with fewer than 20 employees	7.09%	$570,313	$40,425	$5,703	$404	$5,703	$404
Hydraulic fracturing SBA entities	7.09%	$1,884,313	$133,564	$12,562	$890	$11,777	$835

Source: OSHA, Directorate of Standards and Guidance, Office of Regulatory Analysis, based on OSHA, 2016.

Summary of Profit Rates

Table III-22 summarizes the profit rates for all NAICS codes, including general industry, maritime, hydraulic fracturing, and construction.

Table III-22: Estimated Profit Rates for Industries Affected by the Final Standard -- (Net income from IRS Table 1 [Returns with and without net income] / Total Receipts from IRS Table 1 [Returns with and without net income])

NAICS	Title	Average Profit Rate	Profit Rates												
			2012	2011	2010	2009	2008	2007	2006	2005	2004	2003	2002	2001	2000
236100	Residential Building Construction	2.2%	1.7%	0.8%	-0.2%	-1.4%	-0.8%	1.1%	4.4%	5.9%	4.4%	3.6%	3.2%	3.4%	3.1%
236200	Nonresidential Building Construction	2.2%	1.7%	0.8%	-0.2%	-1.4%	-0.8%	1.1%	4.4%	5.9%	4.4%	3.6%	3.2%	3.4%	3.1%
237100	Utility System Construction	3.1%	3.5%	3.2%	3.9%	4.3%	4.3%	6.6%	4.9%	3.8%	1.9%	0.2%	0.4%	1.2%	2.1%
237200	Land Subdivision	-1.3%	-8.3%	-11.6%	-15.7%	-24.4%	-15.9%	-1.0%	6.5%	14.2%	11.2%	7.3%	7.6%	7.3%	5.9%
237300	Highway, Street, and Bridge Construction	2.9%	2.7%	1.9%	2.1%	1.6%	1.9%	5.4%	5.2%	6.2%	3.9%	1.5%	1.8%	1.2%	2.1%
237900	Other Heavy and Civil Engineering Construction	2.9%	2.7%	1.9%	2.1%	1.6%	1.9%	5.4%	5.2%	6.2%	3.9%	1.5%	1.8%	1.2%	2.1%
238100	Foundation, Structure, and Building Exterior Contractors	3.4%	4.1%	2.8%	2.9%	3.6%	4.1%	4.8%	4.6%	3.8%	2.8%	1.9%	2.3%	3.1%	3.4%
238200	Building Equipment Contractors	3.7%	4.4%	3.1%	3.0%	4.9%	5.3%	4.9%	4.5%	3.5%	3.1%	1.5%	2.4%	3.3%	3.6%
238300	Building Finishing Contractors	3.4%	4.1%	2.8%	2.9%	3.6%	4.1%	4.8%	4.6%	3.8%	2.8%	1.9%	2.3%	3.1%	3.4%
238900	Other Specialty Trade Contractors	3.4%	4.2%	2.7%	2.8%	3.2%	3.8%	4.9%	4.8%	4.1%	2.8%	2.1%	2.4%	3.2%	3.3%
221100	Electric Utilities	0.7%	-7.16%	-6.02%	0.18%	-2.62%	0.54%	7.36%	4.84%	0.83%	-0.14%	-1.37%	2.53%	2.31%	7.39%
213112	Support Activities for Oil and Gas Operations	7.1%	7.6%	6.4%	6.5%	1.1%	12.7%	17.6%	19.3%	6.8%	3.4%	-0.9%	0.4%	8.1%	3.2%
324121	Asphalt Paving Mixture and Block Manufacturing	6.0%	6.1%	5.2%	6.9%	6.6%	6.2%	7.4%	8.0%	8.6%	8.0%	2.6%	3.4%	4.0%	4.6%

Table III-22: Estimated Profit Rates for Industries Affected by the Final Standard -- (Net income from IRS Table 1 [Returns with and without net income] / Total Receipts from IRS Table 1 [Returns with and without net income])

324122	Asphalt Shingle and Coating Materials Manufacturing	**6.0%**	6.1%	5.2%	6.9%	6.6%	6.2%	7.4%	8.0%	8.6%	8.0%	2.6%	3.4%	4.0%	4.6%

Table III-22: Estimated Profit Rates for Industries Affected by the Final Standard -- (Net income from IRS Table 1 [Returns with and without net income] / Total Receipts from IRS Table 1 [Returns with and without net income]) (continued)

NAICS	Title	Average Profit Rate	Profit Rates												
			2012	2011	2010	2009	2008	2007	2006	2005	2004	2003	2002	2001	2000
325314	Fertilizer (Mixing Only) Manufacturing	**9.7%**	9.3%	8.6%	9.9%	13.4%	8.6%	9.1%	9.9%	20.6%	7.4%	8.3%	7.2%	6.8%	7.2%
325510	Paint and Coating Manufacturing	**3.9%**	3.9%	3.9%	4.0%	3.3%	2.7%	5.2%	5.1%	5.5%	4.8%	0.8%	3.8%	3.7%	3.6%
327110	Pottery, Ceramics, and Plumbing Fixture Manufacturing	**1.3%**	3.5%	3.5%	1.1%	1.8%	2.8%	-5.1%	-2.1%	6.3%	3.4%	0.0%	-0.4%	0.9%	1.8%
327120	Clay Building Material and Refractories Manufacturing	**1.3%**	3.5%	3.5%	1.1%	1.8%	2.8%	-5.1%	-2.1%	6.3%	3.4%	0.0%	-0.4%	0.9%	1.8%
327211	Flat Glass Manufacturing	**2.6%**	4.1%	4.8%	7.0%	1.8%	0.2%	8.9%	2.1%	0.2%	-0.3%	0.2%	0.9%	2.6%	1.6%
327212	Other Pressed and Blown Glass and Glassware Manufacturing	**2.6%**	4.1%	4.8%	7.0%	1.8%	0.2%	8.9%	2.1%	0.2%	-0.3%	0.2%	0.9%	2.6%	1.6%
327213	Glass Container Manufacturing	**2.6%**	4.1%	4.8%	7.0%	1.8%	0.2%	8.9%	2.1%	0.2%	-0.3%	0.2%	0.9%	2.6%	1.6%
327320	Ready-Mix Concrete Manufacturing	**1.4%**	-1.1%	-4.3%	-5.7%	-7.4%	-2.7%	4.7%	4.2%	10.3%	5.2%	3.1%	2.8%	3.4%	6.2%
327331	Concrete Block and Brick Manufacturing	**1.4%**	-1.1%	-4.3%	-5.7%	-7.4%	-2.7%	4.7%	4.2%	10.3%	5.2%	3.1%	2.8%	3.4%	6.2%
327332	Concrete Pipe Manufacturing	**1.4%**	-1.1%	-4.3%	-5.7%	-7.4%	-2.7%	4.7%	4.2%	10.3%	5.2%	3.1%	2.8%	3.4%	6.2%
327390	Other Concrete Product Manufacturing	**1.4%**	-1.1%	-4.3%	-5.7%	-7.4%	-2.7%	4.7%	4.2%	10.3%	5.2%	3.1%	2.8%	3.4%	6.2%
327991	Cut Stone and Stone Product Manufacturing	**1.8%**	1.1%	-0.3%	-1.1%	-3.7%	-1.2%	3.9%	2.6%	7.5%	3.7%	1.8%	1.7%	2.7%	4.0%

Table III-22: Estimated Profit Rates for Industries Affected by the Final Standard -- (Net income from IRS Table 1 [Returns with and without net income] / Total Receipts from IRS Table 1 [Returns with and without net income]) (continued)

NAICS	Title	Average Profit Rate	Profit Rates												
			2012	2011	2010	2009	2008	2007	2006	2005	2004	2003	2002	2001	2000
327992	Ground or Treated Mineral and Earth Manufacturing	1.8%	1.1%	-0.3%	-1.1%	-3.7%	-1.2%	3.9%	2.6%	7.5%	3.7%	1.8%	1.7%	2.7%	4.0%
331110	Iron and Steel Mills and Ferroalloy Manufacturing	1.4%	1.8%	0.6%	-0.6%	-6.3%	5.8%	6.4%	9.0%	7.7%	7.3%	-3.9%	-2.6%	-6.4%	-1.2%
331210	Iron and Steel Pipe and Tube Manufacturing from Purchased Steel	2.1%	2.4%	1.8%	1.1%	-3.4%	4.4%	7.0%	7.5%	6.4%	5.6%	-1.8%	-1.3%	-2.5%	0.6%
331221	Rolled Steel Shape Manufacturing	2.1%	2.4%	1.8%	1.1%	-3.4%	4.4%	7.0%	7.5%	6.4%	5.6%	-1.8%	-1.3%	-2.5%	0.6%
331222	Steel Wire Drawing	2.1%	2.4%	1.8%	1.1%	-3.4%	4.4%	7.0%	7.5%	6.4%	5.6%	-1.8%	-1.3%	-2.5%	0.6%
331314	Secondary Smelting and Alloying of Aluminum	2.5%	1.3%	2.2%	2.2%	-1.8%	1.8%	7.8%	6.2%	4.9%	3.7%	1.4%	-0.2%	0.7%	2.5%
331420	Copper Rolling, Drawing, Extruding, and Alloying	2.1%	2.4%	1.8%	1.1%	-3.4%	4.4%	7.0%	7.5%	6.4%	5.6%	-1.8%	-1.3%	-2.5%	0.6%
331492	Secondary Smelting, Refining, and Alloying of Nonferrous Metal (except Copper and Aluminum)	2.1%	2.4%	1.8%	1.1%	-3.4%	4.4%	7.0%	7.5%	6.4%	5.6%	-1.8%	-1.3%	-2.5%	0.6%
331511	Iron Foundries	4.4%	9.8%	7.6%	7.1%	4.0%	6.4%	7.1%	5.8%	5.0%	1.6%	-0.4%	0.3%	1.5%	1.0%
331512	Steel Investment Foundries	4.4%	9.8%	7.6%	7.1%	4.0%	6.4%	7.1%	5.8%	5.0%	1.6%	-0.4%	0.3%	1.5%	1.0%
331513	Steel Foundries (except Investment)	4.4%	9.8%	7.6%	7.1%	4.0%	6.4%	7.1%	5.8%	5.0%	1.6%	-0.4%	0.3%	1.5%	1.0%
331524	Aluminum Foundries (except Die-Casting)	4.4%	9.8%	7.6%	7.1%	4.0%	6.4%	7.1%	5.8%	5.0%	1.6%	-0.4%	0.3%	1.5%	1.0%
331529	Other Nonferrous Metal Foundries (except Die-Casting)	4.4%	9.8%	7.6%	7.1%	4.0%	6.4%	7.1%	5.8%	5.0%	1.6%	-0.4%	0.3%	1.5%	1.0%
332111	Iron and Steel Forging	3.8%	7.2%	4.9%	6.6%	1.7%	3.6%	4.8%	5.0%	4.5%	2.7%	2.3%	2.5%	0.4%	3.3%
332112	Nonferrous Forging	3.8%	7.2%	4.9%	6.6%	1.7%	3.6%	4.8%	5.0%	4.5%	2.7%	2.3%	2.5%	0.4%	3.3%

Table III-22: Estimated Profit Rates for Industries Affected by the Final Standard -- (Net income from IRS Table 1 [Returns with and without net income] / Total Receipts from IRS Table 1 [Returns with and without net income]) (continued)

NAICS	Title	Average Profit Rate	Profit Rates												
			2012	2011	2010	2009	2008	2007	2006	2005	2004	2003	2002	2001	2000
332117	Powder Metallurgy Part Manufacturing	3.8%	7.2%	4.9%	6.6%	1.7%	3.6%	4.8%	5.0%	4.5%	2.7%	2.3%	2.5%	0.4%	3.3%
332119	Metal Crown, Closure, and Other Metal Stamping (except Automotive)	3.8%	7.2%	4.9%	6.6%	1.7%	3.6%	4.8%	5.0%	4.5%	2.7%	2.3%	2.5%	0.4%	3.3%
332215	Metal Kitchen Cookware, Utensil, Cutlery, and Flatware (except Precious) Manufacturing	4.1%	5.7%	4.8%	5.2%	3.5%	4.7%	5.3%	6.1%	5.8%	4.7%	1.1%	0.9%	1.6%	4.1%
332216	Saw Blade and Handtool Manufacturing	4.1%	5.7%	4.8%	5.2%	3.5%	4.7%	5.3%	6.1%	5.8%	4.7%	1.1%	0.9%	1.6%	4.1%
332323	Ornamental and Architectural Metal Work Manufacturing	2.7%	3.3%	-0.1%	-0.2%	0.8%	3.3%	5.4%	5.4%	4.5%	2.9%	0.5%	1.8%	3.7%	3.9%
332439	Other Metal Container Manufacturing	2.9%	6.1%	3.0%	4.7%	2.7%	3.7%	4.4%	0.2%	5.8%	2.4%	1.2%	3.2%	-0.2%	0.9%
332510	Hardware Manufacturing	4.6%	6.3%	4.9%	4.7%	2.6%	4.8%	6.0%	5.7%	7.2%	5.1%	2.7%	2.9%	2.5%	5.0%
332613	Spring Manufacturing	4.6%	6.3%	4.9%	4.7%	2.6%	4.8%	6.0%	5.7%	7.2%	5.1%	2.7%	2.9%	2.5%	5.0%
332618	Other Fabricated Wire Product Manufacturing	4.6%	6.3%	4.9%	4.7%	2.6%	4.8%	6.0%	5.7%	7.2%	5.1%	2.7%	2.9%	2.5%	5.0%
332710	Machine Shops	4.6%	6.3%	4.9%	4.7%	2.6%	4.8%	6.0%	5.7%	7.2%	5.1%	2.7%	2.9%	2.5%	5.0%
332812	Metal Coating, Engraving (except Jewelry and Silverware), and Allied Services to Manufacturers	3.0%	7.7%	5.9%	5.1%	-4.3%	4.1%	3.2%	4.6%	3.0%	3.3%	0.6%	0.7%	-0.3%	5.0%
332911	Industrial Valve Manufacturing	6.0%	7.4%	6.8%	5.8%	3.7%	5.9%	7.4%	6.7%	9.5%	6.5%	4.1%	4.2%	3.3%	6.2%
332912	Fluid Power Valve and Hose Fitting Manufacturing	6.0%	7.4%	6.8%	5.8%	3.7%	5.9%	7.4%	6.7%	9.5%	6.5%	4.1%	4.2%	3.3%	6.2%
332913	Plumbing Fixture Fitting and Trim Manufacturing	6.0%	7.4%	6.8%	5.8%	3.7%	5.9%	7.4%	6.7%	9.5%	6.5%	4.1%	4.2%	3.3%	6.2%
332919	Other Metal Valve and Pipe Fitting Manufacturing	6.0%	7.4%	6.8%	5.8%	3.7%	5.9%	7.4%	6.7%	9.5%	6.5%	4.1%	4.2%	3.3%	6.2%

Table III-22: Estimated Profit Rates for Industries Affected by the Final Standard -- (Net income from IRS Table 1 [Returns with and without net income] / Total Receipts from IRS Table 1 [Returns with and without net income]) (continued)

NAICS	Title	Average Profit Rate	Profit Rates												
			2012	2011	2010	2009	2008	2007	2006	2005	2004	2003	2002	2001	2000
332991	Ball and Roller Bearing Manufacturing	6.0%	7.4%	6.8%	5.8%	3.7%	5.9%	7.4%	6.7%	9.5%	6.5%	4.1%	4.2%	3.3%	6.2%
332996	Fabricated Pipe and Pipe Fitting Manufacturing	6.0%	7.4%	6.8%	5.8%	3.7%	5.9%	7.4%	6.7%	9.5%	6.5%	4.1%	4.2%	3.3%	6.2%
332999	All Other Miscellaneous Fabricated Metal Product Manufacturing	6.0%	7.4%	6.8%	5.8%	3.7%	5.9%	7.4%	6.7%	9.5%	6.5%	4.1%	4.2%	3.3%	6.2%
333318	Other Commercial and Service Industry Machinery Manufacturing	3.1%	3.5%	2.5%	3.6%	1.2%	1.4%	5.7%	5.6%	6.4%	1.5%	0.9%	0.9%	1.0%	5.5%
333413	Industrial and Commercial Fan and Blower and Air Purification Equipment Manufacturing	3.0%	2.8%	2.8%	1.8%	0.3%	2.1%	4.3%	5.2%	4.7%	2.6%	2.8%	3.3%	2.3%	3.9%
333414	Heating Equipment (except Warm Air Furnaces) Manufacturing	3.0%	2.8%	2.8%	1.8%	0.3%	2.1%	4.3%	5.2%	4.7%	2.6%	2.8%	3.3%	2.3%	3.9%
333511	Industrial Mold Manufacturing	3.8%	6.9%	4.7%	3.7%	2.4%	3.7%	5.2%	5.5%	11.2%	2.4%	1.3%	-0.7%	-0.4%	3.7%
333514	Special Die and Tool, Die Set, Jig, and Fixture Manufacturing	3.8%	6.9%	4.7%	3.7%	2.4%	3.7%	5.2%	5.5%	11.2%	2.4%	1.3%	-0.7%	-0.4%	3.7%
333515	Cutting Tool and Machine Tool Accessory Manufacturing	3.8%	6.9%	4.7%	3.7%	2.4%	3.7%	5.2%	5.5%	11.2%	2.4%	1.3%	-0.7%	-0.4%	3.7%
333517	Machine Tool Manufacturing	3.8%	6.9%	4.7%	3.7%	2.4%	3.7%	5.2%	5.5%	11.2%	2.4%	1.3%	-0.7%	-0.4%	3.7%
333519	Rolling Mill and Other Metalworking Machinery Manufacturing	3.8%	6.9%	4.7%	3.7%	2.4%	3.7%	5.2%	5.5%	11.2%	2.4%	1.3%	-0.7%	-0.4%	3.7%
333612	Speed Changer, Industrial High-Speed Drive, and Gear Manufacturing	2.0%	6.0%	6.1%	1.8%	0.0%	1.8%	3.9%	3.4%	3.7%	1.8%	-1.6%	1.5%	-2.0%	-0.5%
333613	Mechanical Power Transmission Equipment Manufacturing	2.0%	6.0%	6.1%	1.8%	0.0%	1.8%	3.9%	3.4%	3.7%	1.8%	-1.6%	1.5%	-2.0%	-0.5%
333911	Pump and Pumping Equipment Manufacturing	3.8%	5.2%	3.7%	4.7%	2.7%	4.4%	8.0%	4.3%	5.7%	3.6%	0.4%	0.6%	2.3%	3.8%
333912	Air and Gas Compressor Manufacturing	3.8%	5.2%	3.7%	4.7%	2.7%	4.4%	8.0%	4.3%	5.7%	3.6%	0.4%	0.6%	2.3%	3.8%

Table III-22: Estimated Profit Rates for Industries Affected by the Final Standard -- (Net income from IRS Table 1 [Returns with and without net income] / Total Receipts from IRS Table 1 [Returns with and without net income]) (continued)

NAICS	Title	Average Profit Rate	Profit Rates												
			2012	2011	2010	2009	2008	2007	2006	2005	2004	2003	2002	2001	2000
333991	Power-Driven Handtool Manufacturing	3.8%	5.2%	3.7%	4.7%	2.7%	4.4%	8.0%	4.3%	5.7%	3.6%	0.4%	0.6%	2.3%	3.8%
333992	Welding and Soldering Equipment Manufacturing	3.8%	5.2%	3.7%	4.7%	2.7%	4.4%	8.0%	4.3%	5.7%	3.6%	0.4%	0.6%	2.3%	3.8%
333993	Packaging Machinery Manufacturing	3.8%	5.2%	3.7%	4.7%	2.7%	4.4%	8.0%	4.3%	5.7%	3.6%	0.4%	0.6%	2.3%	3.8%
333994	Industrial Process Furnace and Oven Manufacturing	3.8%	5.2%	3.7%	4.7%	2.7%	4.4%	8.0%	4.3%	5.7%	3.6%	0.4%	0.6%	2.3%	3.8%
333995	Fluid Power Cylinder and Actuator Manufacturing	3.8%	5.2%	3.7%	4.7%	2.7%	4.4%	8.0%	4.3%	5.7%	3.6%	0.4%	0.6%	2.3%	3.8%
333996	Fluid Power Pump and Motor Manufacturing	3.8%	5.2%	3.7%	4.7%	2.7%	4.4%	8.0%	4.3%	5.7%	3.6%	0.4%	0.6%	2.3%	3.8%
333997	Scale and Balance Manufacturing	3.8%	5.2%	3.7%	4.7%	2.7%	4.4%	8.0%	4.3%	5.7%	3.6%	0.4%	0.6%	2.3%	3.8%
333999	All Other Miscellaneous General Purpose Machinery Manufacturing	3.8%	5.2%	3.7%	4.7%	2.7%	4.4%	8.0%	4.3%	5.7%	3.6%	0.4%	0.6%	2.3%	3.8%
334519	Other Measuring and Controlling Device Manufacturing	4.5%	7.1%	6.5%	7.6%	5.0%	5.7%	6.0%	7.8%	10.6%	2.6%	-1.4%	-2.9%	0.8%	3.0%
335210	Small Electrical Appliance Manufacturing	4.0%	4.9%	6.2%	4.5%	3.5%	4.5%	3.3%	3.8%	5.1%	5.1%	2.4%	1.8%	2.5%	4.5%
335221	Household Cooking Appliance Manufacturing	4.0%	4.9%	6.2%	4.5%	3.5%	4.5%	3.3%	3.8%	5.1%	5.1%	2.4%	1.8%	2.5%	4.5%
335222	Household Refrigerator and Home Freezer Manufacturing	4.0%	4.9%	6.2%	4.5%	3.5%	4.5%	3.3%	3.8%	5.1%	5.1%	2.4%	1.8%	2.5%	4.5%
335224	Household Laundry Equipment Manufacturing	4.0%	4.9%	6.2%	4.5%	3.5%	4.5%	3.3%	3.8%	5.1%	5.1%	2.4%	1.8%	2.5%	4.5%
335228	Other Major Household Appliance Manufacturing	4.0%	4.9%	6.2%	4.5%	3.5%	4.5%	3.3%	3.8%	5.1%	5.1%	2.4%	1.8%	2.5%	4.5%
336111	Automobile Manufacturing	-0.5%	3.6%	1.8%	0.1%	-13.1%	-4.9%	0.4%	0.3%	3.6%	0.2%	0.4%	0.5%	-0.8%	1.3%

Table III-22: Estimated Profit Rates for Industries Affected by the Final Standard -- (Net income from IRS Table 1 [Returns with and without net income] / Total Receipts from IRS Table 1 [Returns with and without net income]) (continued)

NAICS	Title	Average Profit Rate	Profit Rates												
			2012	2011	2010	2009	2008	2007	2006	2005	2004	2003	2002	2001	2000
336112	Light Truck and Utility Vehicle Manufacturing	-0.5%	3.6%	1.8%	0.1%	-13.1%	-4.9%	0.4%	0.3%	3.6%	0.2%	0.4%	0.5%	-0.8%	1.3%
336120	Heavy Duty Truck Manufacturing	-0.5%	3.6%	1.8%	0.1%	-13.1%	-4.9%	0.4%	0.3%	3.6%	0.2%	0.4%	0.5%	-0.8%	1.3%
336211	Motor Vehicle Body Manufacturing	1.3%	4.4%	3.0%	2.0%	-5.0%	-0.9%	2.5%	1.9%	4.2%	0.7%	0.4%	1.1%	0.3%	2.2%
336212	Truck Trailer Manufacturing	1.3%	4.4%	3.0%	2.0%	-5.0%	-0.9%	2.5%	1.9%	4.2%	0.7%	0.4%	1.1%	0.3%	2.2%
336213	Motor Home Manufacturing	1.3%	4.4%	3.0%	2.0%	-5.0%	-0.9%	2.5%	1.9%	4.2%	0.7%	0.4%	1.1%	0.3%	2.2%
336310	Motor Vehicle Gasoline Engine and Engine Parts Manufacturing	1.3%	4.4%	3.0%	2.0%	-5.0%	-0.9%	2.5%	1.9%	4.2%	0.7%	0.4%	1.1%	0.3%	2.2%
336320	Motor Vehicle Electrical and Electronic Equipment Manufacturing	1.3%	4.4%	3.0%	2.0%	-5.0%	-0.9%	2.5%	1.9%	4.2%	0.7%	0.4%	1.1%	0.3%	2.2%
336330	Motor Vehicle Steering and Suspension Components (except Spring) Manufacturing	1.3%	4.4%	3.0%	2.0%	-5.0%	-0.9%	2.5%	1.9%	4.2%	0.7%	0.4%	1.1%	0.3%	2.2%
336340	Motor Vehicle Brake System Manufacturing	1.3%	4.4%	3.0%	2.0%	-5.0%	-0.9%	2.5%	1.9%	4.2%	0.7%	0.4%	1.1%	0.3%	2.2%
336350	Motor Vehicle Transmission and Power Train Parts Manufacturing	1.3%	4.4%	3.0%	2.0%	-5.0%	-0.9%	2.5%	1.9%	4.2%	0.7%	0.4%	1.1%	0.3%	2.2%
336370	Motor Vehicle Metal Stamping	1.3%	4.4%	3.0%	2.0%	-5.0%	-0.9%	2.5%	1.9%	4.2%	0.7%	0.4%	1.1%	0.3%	2.2%
336390	Other Motor Vehicle Parts Manufacturing	1.3%	4.4%	3.0%	2.0%	-5.0%	-0.9%	2.5%	1.9%	4.2%	0.7%	0.4%	1.1%	0.3%	2.2%
336611	Ship Building and Repairing	6.1%	7.3%	6.8%	8.4%	6.9%	6.6%	7.6%	7.5%	5.9%	5.0%	4.0%	4.6%	4.6%	3.6%
336612	Boat Building	6.1%	7.3%	6.8%	8.4%	6.9%	6.6%	7.6%	7.5%	5.9%	5.0%	4.0%	4.6%	4.6%	3.6%
336992	Military Armored Vehicle, Tank, and Tank Component Manufacturing	4.0%	7.1%	4.0%	3.3%	1.5%	4.0%	6.5%	7.6%	5.7%	4.8%	5.2%	1.5%	-1.2%	2.5%

Table III-22: Estimated Profit Rates for Industries Affected by the Final Standard -- (Net income from IRS Table 1 [Returns with and without net income] / Total Receipts from IRS Table 1 [Returns with and without net income]) (continued)

NAICS	Title	Average Profit Rate	Profit Rates												
			2012	2011	2010	2009	2008	2007	2006	2005	2004	2003	2002	2001	2000
337110	Wood Kitchen Cabinet and Countertop Manufacturing	2.8%	3.0%	2.2%	2.6%	0.3%	0.6%	3.8%	5.0%	4.9%	3.1%	2.5%	2.6%	1.8%	3.7%
337215	Showcase, Partition, Shelving, and Locker Manufacturing	2.8%	3.0%	2.2%	2.6%	0.3%	0.6%	3.8%	5.0%	4.9%	3.1%	2.5%	2.6%	1.8%	3.7%
339114	Dental Equipment and Supplies Manufacturing	7.3%	7.4%	7.7%	7.7%	7.6%	5.6%	7.5%	11.1%	15.7%	6.1%	4.0%	5.1%	4.4%	5.2%
339116	Dental Laboratories	7.3%	7.4%	7.7%	7.7%	7.6%	5.6%	7.5%	11.1%	15.7%	6.1%	4.0%	5.1%	4.4%	5.2%
339910	Jewelry and Silverware Manufacturing	3.9%	6.4%	4.5%	4.7%	2.8%	3.6%	4.3%	5.4%	5.1%	3.2%	3.1%	2.9%	1.8%	3.3%
339950	Sign Manufacturing	3.9%	6.4%	4.5%	4.7%	2.8%	3.6%	4.3%	5.4%	5.1%	3.2%	3.1%	2.9%	1.8%	3.3%
423840	Industrial Supplies Merchant Wholesalers	3.0%	4.5%	3.7%	3.5%	2.2%	3.4%	3.9%	4.3%	4.3%	2.9%	1.6%	0.8%	1.6%	2.0%
444110	Home Centers	6.0%	7.9%	6.0%	6.5%	7.2%	5.6%	8.3%	9.5%	10.7%	8.5%	0.8%	0.9%	1.0%	5.7%
482110	Rail transportation	6.2%	12.7%	6.7%	9.7%	5.0%	7.5%	10.7%	11.7%	9.3%	2.7%	1.0%	0.7%	0.5%	2.8%
561730	Landscaping Services	3.0%	3.8%	3.3%	3.6%	2.1%	3.0%	3.6%	3.7%	5.0%	2.5%	2.3%	1.4%	2.5%	1.5%
621210	Offices of Dentists	7.8%	10.0%	8.6%	9.8%	9.3%	8.5%	9.1%	7.2%	7.5%	7.4%	6.1%	6.2%	6.3%	5.2%

Source: OSHA, Directorate of Standards and Guidance, Office of Regulatory Analysis, 2015, based on IRS, SOI Tax Stats - Corporation Source Book: U.S. Total and Sectors Listing, 2000-2011, http://www.irs.gov/uac/SOI-Tax-Stats-Corporation-Source-Book:-U.S.-Total-and-Sectors-Listing. Accessed May 2015.

SURVEY DATA AND OSHA ECONOMIC ANALYSES

As stated in the introduction to this chapter, the methodological basis for the industry and at-risk worker data presented in this chapter comes from the PEA, the ERG analysis supporting the PEA (2007a, 2007b, 2008a, and 2008b), and ERG's final supporting analysis. The actual data used in this chapter come from the rulemaking record (Docket OSHA-2010-0034), the technological feasibility analyses presented in Chapter IV of this FEA, and from OSHA (2016), which updated its earlier data to reflect the most recent industry data available.

Dr. Ronald Bird, an economic consultant to the U.S. Chamber of Commerce, suggested that OSHA's analysis would be inadequate without support from a national survey:

> The question of economic feasibility of the proposed standard cannot be answered with ***any*** degree of economic certainty without the results of a comprehensive national statistically representative survey for each affected industry of baseline exposures, current control practices, and assessment of the specific compliance engineering retrofit costs (including where applicable, complete rebuilding costs, as suggested by ERG) for each facility in the sample. **Such a survey could have been done by OSHA over the past ten years, such a survey should have been done after the 2008 ERG report alerted OSHA to the problem of compliance cost variability, and such a survey must be done before the present rulemaking moves forward** (Document ID 2368, p. 8)(emphasis in original)**.**

In response, OSHA observes that the Agency has never used surveys to ascertain the kind of detail about controls that Dr. Bird suggests should have been gathered through a survey. For past FEAs, OSHA has used surveys, and the Agency uses older surveys in this analysis for general information (such as the number of respirator types used, the presence of medical surveillance programs, and the prevalence of general safety and health practices).

Indeed, Dr. Bird's description of the key analytical inputs derived from a survey and applied to an economic analysis was for the kinds of general information about whether an occupational safety or health practice is followed, such as OSHA has used in the past and continues to use in this analysis. However, OSHA has not found surveys useful for purposes of assessing the needs for, and cost of, engineering controls. The ideal way to assess baseline data on the cost and deployment of engineering controls is to combine data on engineering controls with data on exposures. This exercise is difficult to accomplish using a survey because, in the absence of a regulation, very few firms will have exposure data, and those that do have exposure data may be reluctant to provide it to OSHA.

Combining exposure data with engineering control data can also be extremely complicated, normally requiring an on-site visit of several hours or a prolonged interview. Even given the opportunity for firms to present data anonymously, there are no instances in the record of a complete summary of engineering control data matched with exposure control data. Some commenters suggested that time constraints limited their responses,[43] but if such data could not be submitted in a multi-month process, it surely cannot be easily gathered through a survey of manageable length and reasonable response time. The basic problem with Dr. Bird's suggestion is that the kinds of data needed to assess engineering control costs are both too extensive and too hard to gather through a survey instrument.

[43] See, for example, Document ID 3580, Tr. 1407; Document ID 2348, pp. 15-16; and Document ID 4209, p. 118.

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APPENDIX III-A
Background Occupational Exposure Data Supporting OSHA's Baseline Compliance Estimate

The OSHA Information System (OIS) is OSHA's comprehensive data collection and management system for information related to OSHA programs, including workplace exposure information. OSHA maintains OIS to store information collected during compliance inspections. The OIS database contains the results of air sampling conducted to assess compliance with air contaminant standards.

The OIS dataset (Docket ID 3985) analyzed for the FEA contains personal breathing zone silica results for samples collected by OSHA between 2011 and April 17, 2014 during worksite inspections. Using the process described in the Methodology subsection of Chapter IV (Technological Feasibility), OSHA calculated airborne silica concentrations for these samples based on the measured amount of respirable dust for that sample and on the PEL for the sample (related to the percentage of silica in the respirable dust).

To determine the percentage of construction workers currently using dust controls, information on samples obtained for construction workers (identified by establishment NAICS and in some cases job/activity description) were evaluated to determine whether dust controls had been in use at the time the sample was collected (regardless of whether the control was effective or not) (Docket ID 3985).

The data presented in this appendix on exposure severity by control method support the analysis of current industry practice ("current compliance") discussed in the section CURRENT COMPLIANCE in this chapter and later in this FEA, in Chapter V, Costs of Compliance. With regard to how frequently controls are currently in use, Table III-A-1 below shows the number of measurements in the OIS dataset by control method and compliance with the current and proposed PEL.

Appendix Table III-A-2 presents by silica application group, OIS exposure data for respirable crystalline silica and information on the NAICS industry code, job title, job activity, and work environment associated with the sampling site. Furthermore, where the use of exposure controls was recorded in OIS, information on the type of control is shown in the third column in the table. According to analysis of the data, OSHA determined that controls were in use during 40 percent of the 171 construction samples taken. Of all the samples taken, 26 percent exceeded the preceding PEL (i.e. Sev.>1), and 35 percent exceeded the new PEL (RCS> 50 $\mu g/m^3$).

Moreover, of the 40 percent of the samples where controls were used, 29 percent had an RCS>50, compared with 39 percent with RCS>50 for no controls. Finally, of the 65 percent of the samples that had an RCS<50, 44 percent had controls, and 56 percent had no controls. OSHA is using this 44 percent result as the basis for its estimate of the percentage of construction workers with exposures at or below 50 μg/m^3 who are already using engineering controls in compliance with Table 1.

Table III-A-1: OSHA Information System Sampling Data for Respirable Crystalline Silica

Control Method	Total	Sev.<1 [a]	Sev.>1	%Sev.<1	RCS<=50 [b]	RCS>50	%RCS<50
Wet Method	37	31	6	84%	28	9	76%
LEV	26	20	6	77%	16	10	62%
Cab/Booth	5	3	2	60%	4	1	80%
Enclosure	3	0	3	0%	0	3	0%
None	100	70	30	70%	61	39	61%
Total	171	124	47	73%	109	62	64%

Control Method		Sev.<1	Sev.>1	%Sev.<1	RCS<=50	RCS>50	%RCS<50
Wet/LEV/Cab	68 40%	54 44%	14 32%	79%	48 44%	20 34%	71%
None	100 60%	70 56%	30 68%	70%	61 56%	39 66%	61%
Total	**168**	**124**	**44**	**74%**	**109**	**59**	**65%**

[a] Sev.<1 = Severity less than 1 (Respirable Dust less than PEL)

[b] RCS<=50 = Respirable Crystalline Silica less than or equal to 50 μg/m^3

Source: OSHA, Directorate of Standards and Guidance, Office of Technological Feasibility, 2015, based on Document ID 3958.

Table III-A-2: Personal Respirable Crystalline Silica Exposures of Workers in the Construction Industry (OIS, 2011-2014)													
Section	**Section Name**	**Controls**	**Resp. Dust (μg/m³)**	**% Silica**	**PEL (μg/m³)**	**Severity**	**RCS (μg/m³)**	**Insp ID**	**Sample Sheet**	**Exposure Assessment Number**	**Year**	**NAICS Title**	**Job Title / Job Activities / Work Environment**
21	**Refractory Repair**	None	2.300	0	5.000	0.46	0	697738	80505	27772	2012	238290 - Other Building Equipment Contractors	Refractory Supervisor (mixing and applying Morgan Thermal Ceramics Kaolite 2300 LI Monolithics)
25	**Construction - Drywall Finisher**	None	0.130	13	0.667	0.20	17	799822	108048	31266	2012	238310 - Drywall and Insulation Contractors	Line Supervisor
25	**Construction - Drywall Finisher**	None	0.250	0	5.000	0.05	0	799822	108008	31371	2012	238310 - Drywall and Insulation Contractors	Set and Feed
25	**Construction - Drywall Finisher**	None	0.080	0	5.000	0.02	0	614918	62365	24327	2012	238310 - Drywall and Insulation Contractors	Carpenter - cutting and installing ceiling panels- 2nd level south side concourse
25	**Construction - Drywall Finisher**	None	0.050	0	5.000	0.01	0	799822	107988	31369	2012	238310 - Drywall and Insulation Contractors	Packer
25	**Construction - Drywall Finisher**	None	0.047	0	5.000	0.01	0	799822	108028	31370	2012	238310 - Drywall and Insulation Contractors	Utility
26	**Heavy Equipment Operators**	Wet Method	0.380	0	5.000	0.08	0	959859	172277	70870	2014	238910 - Site Preparation Contractors	Bobcat and Excavator Operator - operating an open cab Bobcat skid steer to move bricks; and operating an open cab Komatsu tract excavator to pick up bricks and load to dump truck. Water sprayed on to bricks during pickup.

Table III-A-2: Personal Respirable Crystalline Silica Exposures of Workers in the Construction Industry (OIS, 2011-2014) (continued)													
Section	**Section Name**	**Controls**	**Resp. Dust (μg/m³)**	**% Silica**	**PEL (μg/m³)**	**Severity**	**RCS (μg/m³)**	**Insp ID**	**Sample Sheet**	**Exposure Assessment Number**	**Year**	**NAICS Title**	**Job Title / Job Activities / Work Environment**
26	**Heavy Equipment Operators**	Wet Method	0.160	0	5.000	0.03	0	959859	172371	70747	2014	238910 - Site Preparation Contractors	Same employee as sample #172275 above
26	**Heavy Equipment Operators**	Wet Method	0.110	0	5.000	0.02	0	959859	172275	70875	2014	238910 - Site Preparation Contractors	Laborer/Rough Terrain Forklift Operator
26	**Heavy Equipment Operators**	Wet Method	0.300	16	0.543	0.55	49	902143	134849	45429	2013	238910 - Site Preparation Contractors	Hoe-ram operator
26	**Heavy Equipment Operators**	Wet Method	0.676	6	1.190	0.57	43	556859	53545	18466	2012	238910 - Site Preparation Contractors	Backhoe Operator 0 demolishing concrete inside a large garage
27	**Hole Drillers Using Hand-Held Drills**	None	0.240	0	5.000	0.05	0	938231	160696	51962	2013	236220 - Commercial and Institutional Building Construction	Carpenter - hammering/drilling of concrete structure per the installation of concrete forms (installing OSB forms for the pouring of concrete)
27	**Hole Drillers Using Hand-Held Drills**	None	0.200	0	5.000	0.04	0	896810	132610	37967	2013	238220 - Plumbing, Heating, and Air-Conditioning Contractors	Sheetmetal Worker performing drilling operations; estimated drill time was between three to five seconds per hole with only 2 holes per unit hung

Table III-A-2: Personal Respirable Crystalline Silica Exposures of Workers in the Construction Industry (OIS, 2011-2014) (continued)													
Section	Section Name	Controls	Resp. Dust (μg/m³)	% Silica	PEL (μg/m³)	Severity	RCS (μg/m³)	Insp ID	Sample Sheet	Exposure Assessment Number	Year	NAICS Title	Job Title / Job Activities / Work Environment
28	**Jackhammer and Impact Drillers**	Enclosure	8.800	13	0.667	13.24	1,144	943253	162319	53889	2013	238110 - Poured Concrete Foundation and Structure Contractors	Laborer - using jackhammers to do partial demolition of damaged sections of concrete parking ramp floor
28	**Jackhammer and Impact Drillers**	Enclosure	11.000	7	1.124	9.40	759	943055	162619	55411	2013	238110 - Poured Concrete Foundation and Structure Contractors	Laborer - inside an enclosure jackhammering the concrete deck, with pneumatic jackhammers, on the north side of the parking ramp
28	**Jackhammer and Impact Drillers**	Enclosure	2.900	12	0.714	4.12	348	943253	162320	53890	2013	238110 - Poured Concrete Foundation and Structure Contractors	Laborer - using jackhammers to do partial demolition of damaged sections of concrete parking ramp floor
28	**Jackhammer and Impact Drillers**	LEV	6.300	5	1.536	4.12	284	896800	132766	38104	2013	238990 - All Other Specialty Trade Contractors	Construction Laborer - chipping operations; 4th floor of the enclosed parking garage; jackhammers
28	**Jackhammer and Impact Drillers**	LEV	5.500	5	1.488	3.72	260	896800	132757	38103	2013	238990 - All Other Specialty Trade Contractors	Construction Laborer - chipping operations; 4th floor of the enclosed parking garage; jackhammers

Table III-A-2: Personal Respirable Crystalline Silica Exposures of Workers in the Construction Industry (OIS, 2011-2014) (continued)													
Section	**Section Name**	**Controls**	**Resp. Dust (μg/m³)**	**% Silica**	**PEL (μg/m³)**	**Severity**	**RCS (μg/m³)**	**Insp ID**	**Sample Sheet**	**Exposure Assessment Number**	**Year**	**NAICS Title**	**Job Title / Job Activities / Work Environment**
28	**Jackhammer and Impact Drillers**	LEV	0.004	0	5.000	0.00	0	586818	55947	18886	2012	237110 - Water and Sewer Line and Related Structures Construction	Laborer (removing concrete with air powered jack hammers and shoveling the debris into a truck.)
28	**Jackhammer and Impact Drillers**	None	1.700	9	0.896	1.90	156	959859	172373	70746	2014	238910 - Site Preparation Contractors	Same employee as sample #172215 above
28	**Jackhammer and Impact Drillers**	None	1.900	8	1.028	1.88	147	959859	172369	70871	2014	238910 - Site Preparation Contractors	Same employee as sample #172273 above
28	**Jackhammer and Impact Drillers**	None	1.200	12	0.703	1.74	147	959859	172372	70872	2014	238910 - Site Preparation Contractors	Same employee as sample #172233 above
28	**Jackhammer and Impact Drillers**	None	1.100	8	1.041	1.03	84	959859	172370	70572	2014	238910 - Site Preparation Contractors	Same employee as sample #172253 above
28	**Jackhammer and Impact Drillers**	None	0.960	8	0.956	1.01	81	959859	172273	70715	2014	238910 - Site Preparation Contractors	Laborer/Demolition - operates hand held Dewalt demolition hammer to remove brick wall that was part of a theater building; worked from a platform of a JLG lift.
28	**Jackhammer and Impact Drillers**	None	0.310	7	1.060	0.29	23	959859	172215	70877	2014	238910 - Site Preparation Contractors	Laborer/Demolition - operates hand held Dewalt demolition hammer to remove brick wall that was part of a theater building; worked from a platform of a rough-terrain forklift.

Table III-A-2: Personal Respirable Crystalline Silica Exposures of Workers in the Construction Industry (OIS, 2011-2014) (continued)													
Section	**Section Name**	**Controls**	**Resp. Dust (µg/m³)**	**% Silica**	**PEL (µg/m³)**	**Severity**	**RCS (µg/m³)**	**Insp ID**	**Sample Sheet**	**Exposure Assessment Number**	**Year**	**NAICS Title**	**Job Title / Job Activities / Work Environment**
28	**Jackhammer and Impact Drillers**	None	0.300	0	5.000	0.06	0	959859	172253	70874	2014	238910 - Site Preparation Contractors	Laborer/Demolition - operates hand held Dewalt demolition hammer to remove brick wall that was part of a theater building; worked from a platform of a JLG lift.
28	**Jackhammer and Impact Drillers**	None	0.140	0	5.000	0.03	0	959859	172233	70876	2014	238910 - Site Preparation Contractors	Laborer/Demolition/Foreman - operates hand held Dewalt demolition hammer to remove brick wall that was part of a theater building; worked from a platform of a rough-terrain forklift.
28	**Jackhammer and Impact Drillers**	None	0.860	13	0.667	1.28	112	824782	113128	32831	2013	236220 - Commercial and Institutional Building Construction	Laborer - removing tiles from floor using a Makita demolition hammer
28	**Jackhammer and Impact Drillers**	None	0.630	15	0.588	1.08	95	824782	113168	32843	2013	236220 - Commercial and Institutional Building Construction	Laborer - removing (sweeping) the dust and debris generated by the tile removing
28	**Jackhammer and Impact Drillers**	None	1.875	23	0.400	4.69	431	557798	49705	24226	2012	237310 - Highway, Street, and Bridge Construction	Laborer (hand held jackhammers on an open bridge deck for 2-4 hours a day in the morning)

Table III-A-2: Personal Respirable Crystalline Silica Exposures of Workers in the Construction Industry (OIS, 2011-2014) (continued)													
Section	**Section Name**	**Controls**	**Resp. Dust (μg/m³)**	**% Silica**	**PEL (μg/m³)**	**Severity**	**RCS (μg/m³)**	**Insp ID**	**Sample Sheet**	**Exposure Assessment Number**	**Year**	**NAICS Title**	**Job Title / Job Activities / Work Environment**
28	**Jackhammer and Impact Drillers**	None	3.000	11	0.769	3.86	330	704518	84005	27769	2012	236220 - Commercial and Institutional Building Construction	Laborer - concrete cutting (Jackhammering)
28	**Jackhammer and Impact Drillers**	None	1.167	18	0.500	2.33	210	557798	49725	24246	2012	237310 - Highway, Street, and Bridge Construction	Laborer (hand held jackhammers on an open bridge deck for 2-4 hours a day in the morning)
28	**Jackhammer and Impact Drillers**	None	3.200	4	1.667	1.93	128	403982	13539	6976	2012	237310 - Highway, Street, and Bridge Construction	Laborer - air drilling on Interstate median
28	**Jackhammer and Impact Drillers**	None	0.329	28	0.330	1.00	93	513799	54265	15326	2012	236220 - Commercial and Institutional Building Construction	Laborer - using a jackhammer to demolish a brick wall
28	**Jackhammer and Impact Drillers**	None	0.730	0	5.000	0.15	0	403982	13439	6977	2012	237310 - Highway, Street, and Bridge Construction	Laborer - standing on Interstate median drilling holes in concrete

Table III-A-2: Personal Respirable Crystalline Silica Exposures of Workers in the Construction Industry (OIS, 2011-2014) (continued)													
Section	Section Name	Controls	Resp. Dust (μg/m³)	% Silica	PEL (μg/m³)	Severity	RCS (μg/m³)	Insp ID	Sample Sheet	Exposure Assessment Number	Year	NAICS Title	Job Title / Job Activities / Work Environment
28	**Jackhammer and Impact Drillers**	None	0.670	0	5.000	0.13	0	331823	8839	6280	2012	238110 - Poured Concrete Foundation and Structure Contractors	Jackhammering - a parking lot
28	**Jackhammer and Impact Drillers**	None	0.370	0	5.000	0.07	0	681678	78885	27095	2012	238140 - Masonry Contractors	Laborer (removing concrete with a chipping hammer for 6-8 hr per day)
28	**Jackhammer and Impact Drillers**	None	0.260	0	5.000	0.05	0	681678	78905	27096	2012	238140 - Masonry Contractors	Laborer (removing concrete with a chipping hammer for 6-8 hr per day)
28	**Jackhammer and Impact Drillers**	None	0.250	0	5.000	0.05	0	681678	78945	27099	2012	238140 - Masonry Contractors	Laborer (removing concrete with a chipping hammer for 6-8 hr per day)
28	**Jackhammer and Impact Drillers**	None	0.230	0	5.000	0.05	0	681678	78925	27100	2012	238140 - Masonry Contractors	Laborer (removing concrete with a chipping hammer for 6-8 hr per day)
28	**Jackhammer and Impact Drillers**	None	0.220	0	5.000	0.05	0	681678	78965	27090	2012	238140 - Masonry Contractors	Laborer (removing concrete with a chipping hammer for 6-8 hr per day)
28	**Jackhammer and Impact Drillers**	None	0.170	0	5.000	0.03	0	639698	68025	24437	2012	238110 - Poured Concrete Foundation and Structure Contractors	Jack Hammer

Table III-A-2: Personal Respirable Crystalline Silica Exposures of Workers in the Construction Industry (OIS, 2011-2014) (continued)													
Section	**Section Name**	**Controls**	**Resp. Dust (µg/m³)**	**% Silica**	**PEL (µg/m³)**	**Severity**	**RCS (µg/m³)**	**Insp ID**	**Sample Sheet**	**Exposure Assessment Number**	**Year**	**NAICS Title**	**Job Title / Job Activities / Work Environment**
28	**Jackhammer and Impact Drillers**	Wet Method	5.500	16	0.556	9.93	880	934746	158034	51324	2013	238990 - All Other Specialty Trade Contractors	Laborer - jackhammering to break up a concrete wheelchair ramp in a large pool area; shoveling concrete debris, placing in a wheelbarrow, and removing it from large pool area by walking up undemolished ramp
28	**Jackhammer and Impact Drillers**	Wet Method	9.900	7	1.111	8.89	693	891471	129774	36369	2013	238910 - Site Preparation Contractors	Laborer - jackhammering concrete inside of a garage
28	**Jackhammer and Impact Drillers**	Wet Method	3.900	16	0.556	7.06	624	934746	158036	51344	2013	238990 - All Other Specialty Trade Contractors	Crew Supervisor - jackhammering concrete ramp inside large pool area
28	**Jackhammer and Impact Drillers**	Wet Method	3.800	16	0.556	6.85	608	934746	157134	51336	2013	238990 - All Other Specialty Trade Contractors	Laborer - Jackhammering, shoveling concrete debris; working in a large pool area constructing a handicap ramp
28	**Jackhammer and Impact Drillers**	Wet Method	0.320	5	1.515	0.21	15	906848	137011	45391	2013	236220 - Commercial and Institutional Building Construction	Laborer - Demolition project breaking concrete

Table III-A-2: Personal Respirable Crystalline Silica Exposures of Workers in the Construction Industry (OIS, 2011-2014) (continued)													
Section	**Section Name**	**Controls**	**Resp. Dust (μg/m³)**	**% Silica**	**PEL (μg/m³)**	**Severity**	**RCS (μg/m³)**	**Insp ID**	**Sample Sheet**	**Exposure Assessment Number**	**Year**	**NAICS Title**	**Job Title / Job Activities / Work Environment**
28	**Jackhammer and Impact Drillers**	Wet Method	1.200	7	1.083	1.15	87	586818	60988	22387	2012	237110 - Water and Sewer Line and Related Structures Construction	Laborer (removing concrete with air powered jack hammers and shoveling the debris into a truck.)
28	**Jackhammer and Impact Drillers**	Wet Method	0.430	6	1.282	0.34	25	586818	61025	22386	2012	237110 - Water and Sewer Line and Related Structures Construction	Laborer (removing concrete with air powered jack hammers and shoveling the debris into a truck.)
28	**Jackhammer and Impact Drillers**	Wet Method	0.330	0	5.000	0.07	0	586818	61005	22420	2012	237110 - Water and Sewer Line and Related Structures Construction	Laborer (removing concrete with air powered jack hammers and shoveling the debris into a truck.)
29	**Masonry Cutters Using Portable Saws**	LEV	0.099	0	5.000	0.02	0	538638	45045	26426	2012	236220 - Commercial and Institutional Building Construction	Mason - toothing operation, cuts concrete block out of a wall to make room for a window
29	**Masonry Cutters Using Portable Saws**	None	2.495	4	1.667	1.50	100	957492	169456	68112	2014	237990 - Other Heavy and Civil Engineering Construction	Worker - dry cutting concrete slabs (Stihl gas-powered saw)

Table III-A-2: Personal Respirable Crystalline Silica Exposures of Workers in the Construction Industry (OIS, 2011-2014) (continued)													
Section	Section Name	Controls	Resp. Dust (µg/m³)	% Silica	PEL (µg/m³)	Severity	RCS (µg/m³)	Insp ID	Sample Sheet	Exposure Assessment Number	Year	NAICS Title	Job Title / Job Activities / Work Environment
29	Masonry Cutters Using Portable Saws	None	1.482	7	1.176	1.26	96	957492	169457	68113	2014	237990 - Other Heavy and Civil Engineering Construction	Worker - dry cutting concrete slabs (Stihl gas-powered saw)
29	Masonry Cutters Using Portable Saws	None	1.400	6	1.235	1.17	85	917916	146799	47641	2013	238110 - Poured Concrete Foundation and Structure Contractors	Laborer - removing concrete balconies by cutting, hammering and shovel debris
29	Masonry Cutters Using Portable Saws	None	0.820	5	1.493	0.55	39	917916	146797	47708	2013	238110 - Poured Concrete Foundation and Structure Contractors	Laborer - removing concrete balconies by cutting, hammering and shovel debris
29	Masonry Cutters Using Portable Saws	None	4.800	0	5.000	0.96	0	652758	69665	24443	2012	238140 - Masonry Contractors	Laborer (cutting concrete blocks; using an EDCO Masonry saw and STIHL TS 420. During the inspection the EDCO saw was used to wet cut concrete blocks on the second level. The STIHL TS 420 saw was used on the exterior lower level to dry cut concrete blocks.
29	Masonry Cutters Using Portable Saws	None	2.800	0	5.000	0.55	0	748661	94428	29204	2012	238140 - Masonry Contractors	Laborer (Dry cutting of stone sills)

Table III-A-2: Personal Respirable Crystalline Silica Exposures of Workers in the Construction Industry (OIS, 2011-2014) (continued)													
Section	Section Name	Controls	Resp. Dust (μg/m³)	% Silica	PEL (μg/m³)	Severity	RCS (μg/m³)	Insp ID	Sample Sheet	Exposure Assessment Number	Year	NAICS Title	Job Title / Job Activities / Work Environment
29	Masonry Cutters Using Portable Saws	None	0.480	7	1.075	0.44	35	652758	69645	24492	2012	238140 - Masonry Contractors	Laborer (cutting concrete blocks; using an EDCO Masonry saw and STIHL TS 420. During the inspection the EDCO saw was used to wet cut concrete blocks on the second level. The STIHL TS 420 saw was used on the exterior lower level to dry cut concrete blocks.
29	Masonry Cutters Using Portable Saws	None	1.417	0	5.000	0.28	0	748661	94408	29386	2012	238140 - Masonry Contractors	Foreman (Dry cutting of stone sills)
29	Masonry Cutters Using Portable Saws	None	0.501	10	0.850	0.59	49	92385	915	618	2011	237310 - Highway, Street, and Bridge Construction	Laborer - cuts concrete with a saber saw
29	Masonry Cutters Using Portable Saws	None	0.347	11	0.770	0.45	38	92385	916	619	2011	237310 - Highway, Street, and Bridge Construction	Laborer - cuts concrete with a saber saw
29	Masonry Cutters Using Portable Saws	None	0.175	4	2.906	0.06	6	109939	2402	1098	2011	238910 - Site Preparation Contractors	Concrete Cutter

Table III-A-2: Personal Respirable Crystalline Silica Exposures of Workers in the Construction Industry (OIS, 2011-2014) (continued)													
Section	**Section Name**	**Controls**	**Resp. Dust (μg/m³)**	**% Silica**	**PEL (μg/m³)**	**Severity**	**RCS (μg/m³)**	**Insp ID**	**Sample Sheet**	**Exposure Assessment Number**	**Year**	**NAICS Title**	**Job Title / Job Activities / Work Environment**
30	**Masonry Cutter Using Stationary Saw**	Wet Method	0.210	17	0.526	0.40	36	899044	146153	48046	2013	423320 - Brick, Stone, and Related Construction Material Merchant Wholesalers	Mason - cutting tile for a fireplace of a home
30	**Masonry Cutter Using Stationary Saw**	Wet Method	0.230	10	0.833	0.27	23	899044	146152	47999	2013	423320 - Brick, Stone, and Related Construction Material Merchant Wholesalers	Mason - cutting and placing stone on a fireplace of a home
31	**Millers Using Portable or Mobile Machines**	Cab/Booth	0.575	11	1.563	0.37	63	476798	38445	12466	2012	237310 - Highway, Street, and Bridge Construction	Bobcat Operator (milling one foot wide trench through asphalt highway. Employees would operate bobcat with sweeper attachment and remove debris or operate as flagmen.)
31	**Millers Using Portable or Mobile Machines**	Cab/Booth	0.258	8	1.908	0.14	21	476798	38465	12506	2012	237310 - Highway, Street, and Bridge Construction	Bobcat Operator (milling one foot wide trench through asphalt highway. Employees would operate bobcat with sweeper attachment and remove debris or operate as flagmen.)

Table III-A-2: Personal Respirable Crystalline Silica Exposures of Workers in the Construction Industry (OIS, 2011-2014) (continued)													
Section	**Section Name**	**Controls**	**Resp. Dust (µg/m³)**	**% Silica**	**PEL (µg/m³)**	**Severity**	**RCS (µg/m³)**	**Insp ID**	**Sample Sheet**	**Exposure Assessment Number**	**Year**	**NAICS Title**	**Job Title / Job Activities / Work Environment**
31	**Millers Using Portable or Mobile Machines**	LEV	1.400	36	0.263	5.16	504	955786	168621	65132	2014	238110 - Poured Concrete Foundation and Structure Contractors	Concrete Floor Grinding Machine Operator - operating main floor grinding machine. A large electric-powered walk-behind floor grinder with multiple rotary grinding cups on the bottom that scour the surface; removing the top layer of concrete floor. Small
31	**Millers Using Portable or Mobile Machines**	LEV	0.000	0	5.000	0.00	0	951235	167368	62951	2013	238190 - Other Foundation, Structure, and Building Exterior Contractors	Operator - operates the scarifer (initially grooves the floor to remove the paint) and floor grinder (grinder starts out with a chipping pad then goes to a diamond pad to prep floor for painting) samples 167376, 167378, 167382, 167383 are same employee
31	**Millers Using Portable or Mobile Machines**	LEV	0.000	0	5.000	0.00	0	951235	167382	62953	2013	238190 - Other Foundation, Structure, and Building Exterior Contractors	Operator - operates the scarifer (initially grooves the floor to remove the paint) and floor grinder (grinder starts out with a chipping pad then goes to a diamond pad to prep floor for painting)

Table III-A-2: Personal Respirable Crystalline Silica Exposures of Workers in the Construction Industry (OIS, 2011-2014) (continued)													
Section	Section Name	Controls	Resp. Dust (µg/m³)	% Silica	PEL (µg/m³)	Severity	RCS (µg/m³)	Insp ID	Sample Sheet	Exposure Assessment Number	Year	NAICS Title	Job Title / Job Activities / Work Environment
31	**Millers Using Portable or Mobile Machines**	LEV	0.000	0	5.000	0.00	0	951235	167383	62968	2013	238190 - Other Foundation, Structure, and Building Exterior Contractors	Operator - operates the scarifer (initially grooves the floor to remove the paint) and floor grinder (grinder starts out with a chipping pad then goes to a diamond pad to prep floor for painting)
31	**Millers Using Portable or Mobile Machines**	LEV	0.000	0	5.000	0.00	0	951235	167369	62967	2013	238190 - Other Foundation, Structure, and Building Exterior Contractors	Laborer moved hoses around while machine is operating
31	**Millers Using Portable or Mobile Machines**	LEV	0.000	0	5.000	0.00	0	951235	167373	62950	2013	238190 - Other Foundation, Structure, and Building Exterior Contractors	Laborer vacuums the floor behind the powered units
31	**Millers Using Portable or Mobile Machines**	Wet Method	0.207	0	5.000	0.04	0	191861	3520	2938	2012	238340 - Tile and Terrazzo Contractors	Precast Operator - works in precast area to hammer floors. Takes materials by milling machine to cut with laser.

Table III-A-2: Personal Respirable Crystalline Silica Exposures of Workers in the Construction Industry (OIS, 2011-2014) (continued)													
Section	Section Name	Controls	Resp. Dust (μg/m³)	% Silica	PEL (μg/m³)	Severity	RCS (μg/m³)	Insp ID	Sample Sheet	Exposure Assessment Number	Year	NAICS Title	Job Title / Job Activities / Work Environment
32	Rock and Concrete Drills	LEV	0.110	0	5.000	0.02	0	408422	13879	6973	2012	237310 - Highway, Street, and Bridge Construction	Operator - operating the EZ Drill with an attached dust collector; drilling holes in concrete
34	Grinders	LEV	0.940	24	0.385	2.46	226	955786	168615	65133	2014	238110 - Poured Concrete Foundation and Structure Contractors	Edge Grinder Floor Machine Operator - operates small electric-powered concrete floor grinder with a single rotary grinding cup used for corners/edges. Main multi-cup floor grinder operating at the same time 10-20 ft away.
34	Grinders	LEV	0.069	50	0.192	0.36	35	843303	123188	34331	2013	238160 - Roofing Contractors	Laborer - Grinding
34	Grinders	LEV	0.210	14	0.625	0.33	29	843303	123189	34332	2013	238160 - Roofing Contractors	Laborer - Grinding
34	Tuckpointers	LEV	0.450	0	5.000	0.09	0	943112	162112	53444	2013	238140 - Masonry Contractors	Foreman - grinding mortar while tuckpointing and filling in with new mortar; putting in new flashing for windows (brick office building)
34	Tuckpointers	LEV	0.300	0	5.000	0.06	0	943112	162113	53453	2013	238140 - Masonry Contractors	Laborer (foreman's assistant)

Table III-A-2: Personal Respirable Crystalline Silica Exposures of Workers in the Construction Industry (OIS, 2011-2014) (continued)													
Section	**Section Name**	**Controls**	**Resp. Dust (μg/m³)**	**% Silica**	**PEL (μg/m³)**	**Severity**	**RCS (μg/m³)**	**Insp ID**	**Sample Sheet**	**Exposure Assessment Number**	**Year**	**NAICS Title**	**Job Title / Job Activities / Work Environment**
34	**Grinders**	LEV	1.407	16	1.190	2.62	225	546878	46685	22686	2012	238190 - Other Foundation, Structure, and Building Exterior Contractors	Laborer grinding epoxy filled concrete imperfections in the floor of a shopping mall
34	**Tuckpointers**	LEV	1.630	11	1.560	1.04	180	476239	31465	12426	2012	238140 - Masonry Contractors	Laborer (tuck pointing done around windows and some of the brick.
34	**Tuckpointers**	LEV	0.710	10	1.670	0.43	71	476239	31485	12446	2012	238140 - Masonry Contractors	Laborer (tuck pointing done around windows and some of the brick.
34	**Tuckpointers**	None	21.000	13	0.667	31.12	2730	909807	138600	46144	2013	238140 - Masonry Contractors	Laborer (grinding out during tuckpointing operations)
34	**Tuckpointers**	None	23.000	8	0.980	23.29	1886	936328	158274	51345	2013	236220 - Commercial and Institutional Building Construction	Foreman - Tuckpointing
34	**Tuckpointers**	None	18.000	8	0.962	18.37	1512	906969	137925	46111	2013	238140 - Masonry Contractors	Grinder (mortar grinding in preparation for tuck-pointing)
34	**Tuckpointers**	None	8.800	10	0.848	10.33	862	906969	137924	46125	2013	238140 - Masonry Contractors	Grinder (mortar grinding in preparation for tuck-pointing)

Table III-A-2: Personal Respirable Crystalline Silica Exposures of Workers in the Construction Industry (OIS, 2011-2014) (continued)													
Section	**Section Name**	**Controls**	**Resp. Dust (µg/m³)**	**% Silica**	**PEL (µg/m³)**	**Severity**	**RCS (µg/m³)**	**Insp ID**	**Sample Sheet**	**Exposure Assessment Number**	**Year**	**NAICS Title**	**Job Title / Job Activities / Work Environment**
34	**Grinders**	None	3.300	6	1.254	2.67	197	913803	140511	46945	2013	236220 - Commercial and Institutional Building Construction	Laborer - angle grinder with steel blade to cut lines in the ceiling of the cement parking lot, while using the jackhammer, upside down to break out cement from the ceiling of the cement parking lot.
34	**Grinders**	None	0.990	7	1.104	0.90	70	913803	140551	46891	2013	236220 - Commercial and Institutional Building Construction	Laborer - angle grinder with steel blade to cut lines in the ceiling of the cement parking lot, while using the jackhammer, upside down to break out cement from the ceiling of the cement parking lot.
34	**Grinders**	None	1.300	4	1.742	0.74	49	913803	140531	46937	2013	236220 - Commercial and Institutional Building Construction	Laborer - angle grinder with steel blade to cut lines in the ceiling of the cement parking lot, while using the jackhammer, upside down to break out cement from the ceiling of the cement parking lot.
34	**Grinders**	None	0.210	0	5.000	0.04	0	918808	148537	48846	2013	236220 - Commercial and Institutional Building Construction	Mason - working on exterior of stone courthouse, finishing up the grinding stage.

Table III-A-2: Personal Respirable Crystalline Silica Exposures of Workers in the Construction Industry (OIS, 2011-2014) (continued)													
Section	**Section Name**	**Controls**	**Resp. Dust (µg/m³)**	**% Silica**	**PEL (µg/m³)**	**Severity**	**RCS (µg/m³)**	**Insp ID**	**Sample Sheet**	**Exposure Assessment Number**	**Year**	**NAICS Title**	**Job Title / Job Activities / Work Environment**
34	**Tuckpointers**	None	0.150	0	5.000	0.03	0	918808	148637	48844	2013	236220 - Commercial and Institutional Building Construction	Mason - repointing old wall; final phase of old masonry removal
34	**Grinders**	None	0.099	0	5.000	0.02	0	941642	164902	59379	2013	236220 - Commercial and Institutional Building Construction	FRP Grinder
34	**Tuckpointers**	None	3.900	13	0.689	5.70	488	782870	104008	30978	2012	238140 - Masonry Contractors	Mason - Two employees were removing and replacing old mortar of the tower by cutting using Dewalt D28110, 4 1/2 inch hand held angle grinder. No water spry was used during the cutting to control the airborne dust
34	**Tuckpointers**	None	2.700	10	0.803	3.41	282	782870	103808	30982	2012	238140 - Masonry Contractors	Mason - Two employees were removing and replacing old mortar of the tower by cutting using Dewalt D28110, 4 1/2 inch hand held angle grinder. No water spry was used during the cutting to control the airborne dust

Table III-A-2: Personal Respirable Crystalline Silica Exposures of Workers in the Construction Industry (OIS, 2011-2014) (continued)													
Section	**Section Name**	**Controls**	**Resp. Dust (µg/m³)**	**% Silica**	**PEL (µg/m³)**	**Severity**	**RCS (µg/m³)**	**Insp ID**	**Sample Sheet**	**Exposure Assessment Number**	**Year**	**NAICS Title**	**Job Title / Job Activities / Work Environment**
34	**Grinders**	None	0.640	15	1.250	1.34	96	546878	46705	22666	2012	238190 - Other Foundation, Structure, and Building Exterior Contractors	Grinder
34	**Tuckpointers**	None	0.027	0	5.000	0.01	0	456893	27385	19566	2012	238140 - Masonry Contractors	Laborer (grinding mortar out of brick work on the exterior of a building)
34	**Tuckpointers**	None	0.000	0	5.000	0.00	0	450433	24105	11306	2012	238140 - Masonry Contractors	Brick layer - chipping old mortar from a windowsill
34	**Grinders**	None	0.933	12	0.714	1.31	112	63013	704	1379	2011	237310 - Highway, Street, and Bridge Construction	Foreman/Router
34	**Tuckpointers**	None	2.487	4	2.717	0.92	105	77004	760	428	2011	236220 - Commercial and Institutional Building Construction	Foreman/Mason (6/28/2011 sampling date) - grinding brick mortar

Table III-A-2: Personal Respirable Crystalline Silica Exposures of Workers in the Construction Industry (OIS, 2011-2014) (continued)													
Section	**Section Name**	**Controls**	**Resp. Dust (μg/m³)**	**% Silica**	**PEL (μg/m³)**	**Severity**	**RCS (μg/m³)**	**Insp ID**	**Sample Sheet**	**Exposure Assessment Number**	**Year**	**NAICS Title**	**Job Title / Job Activities / Work Environment**
34	**Tuckpointers**	None	1.000	3	3.247	0.31	27	77004	820	430	2011	236220 - Commercial and Institutional Building Construction	Same employee as sample #760 above (6/23/2011 sampling date) - grinding brick mortar
34	**Grinders**	Wet Method	0.310	24	0.385	0.82	74	870683	124410	34556	2013	238990 - All Other Specialty Trade Contractors	Carpenter - grinding concrete deck
34	**Grinders**	Wet Method	0.230	30	0.313	0.74	69	870683	124415	34555	2013	238990 - All Other Specialty Trade Contractors	General Laborer - grinding concrete deck
34	**Grinders**	Wet Method	0.200	0	5.000	0.04	0	903770	135631	43628	2013	238340 - Tile and Terrazzo Contractors	Terrazzo Floor Installer/Finisher- grinding terrazzo flooring (using a wet grinder to smooth the flooring surface prior to sealing it)(hand and powered equipment to install and finish terrazzo flooring, which included both dry grinding and wet grinding.)

Table III-A-2: Personal Respirable Crystalline Silica Exposures of Workers in the Construction Industry (OIS, 2011-2014) (continued)													
Section	Section Name	Controls	Resp. Dust (µg/m³)	% Silica	PEL (µg/m³)	Severity	RCS (µg/m³)	Insp ID	Sample Sheet	Exposure Assessment Number	Year	NAICS Title	Job Title / Job Activities / Work Environment
34	**Grinders**	Wet Method	0.170	0	5.000	0.04	0	903770	135632	43646	2013	238340 - Tile and Terrazzo Contractors	Terrazzo Floor Installer/Finisher-grinding terrazzo flooring (using a wet grinder to smooth the flooring surface prior to sealing it) (hand and powered equipment to install and finish terrazzo flooring, which included both dry grinding and wet grinding.)
82	**Construction - Other**	Cab/Booth	15.000	0	5.000	2.94	0	895995	132290	37158	2013	238140 - Masonry Contractors	Construction Laborer - conducting motor mixing operations with materials containing portland inside a building
82	**Construction - Other**	Cab/Booth	5.900	0	5.000	1.18	0	895995	132292	37150	2013	238140 - Masonry Contractors	Construction Laborer - conducting motor mixing operations with materials containing portland inside a building
82	**Construction - Other**	Cab/Booth	3.900	0	5.000	0.78	0	895995	132294	37153	2013	238140 - Masonry Contractors	Construction Laborer - conducting motor mixing operations with materials containing portland inside a building
82	**Construction - Other**	LEV	0.200	30	0.313	0.63	60	923434	152584	49966	2013	238340 - Tile and Terrazzo Contractors	Lamination - gluing pieces of countertops together; located next to bridge saws
82	**Construction - Other**	LEV	0.000	0	5.000	0.00	0	843303	123168	34379	2013	238160 - Roofing Contractors	Laborer - Cutting
82	**Construction - Other**	LEV	0.000	0	5.000	0.00	0	843303	123169	34330	2013	238160 - Roofing Contractors	Laborer - Cutting

Table III-A-2: Personal Respirable Crystalline Silica Exposures of Workers in the Construction Industry (OIS, 2011-2014) (continued)													
Section	**Section Name**	**Controls**	**Resp. Dust (μg/m³)**	**% Silica**	**PEL (μg/m³)**	**Severity**	**RCS (μg/m³)**	**Insp ID**	**Sample Sheet**	**Exposure Assessment Number**	**Year**	**NAICS Title**	**Job Title / Job Activities / Work Environment**
82	**Construction - Other**	LEV	0.790	8	1.031	0.77	61	577478	54965	18668	2012	236220 - Commercial and Institutional Building Construction	Mason
82	**Construction - Other**	LEV	0.594	10	0.833	0.71	59	668120	73645	25601	2012	238140 - Masonry Contractors	Foreman
82	**Construction - Other**	LEV	0.092	0	5.000	0.02	0	408422	13899	6972	2012	237310 - Highway, Street, and Bridge Construction	Helper
82	**Construction - Other**	LEV	0.000	0	5.000	0.00	0	577478	55025	18671	2012	236220 - Commercial and Institutional Building Construction	Mason Foreman
82	**Construction - Other**	None	6.500	3	2.164	3.02	170	953584	167975	65217	2014	236220 - Commercial and Institutional Building Construction	Laborer (masonry demolition)

Table III-A-2: Personal Respirable Crystalline Silica Exposures of Workers in the Construction Industry (OIS, 2011-2014) (continued)													
Section	Section Name	Controls	Resp. Dust (μg/m³)	% Silica	PEL (μg/m³)	Severity	RCS (μg/m³)	Insp ID	Sample Sheet	Exposure Assessment Number	Year	NAICS Title	Job Title / Job Activities / Work Environment
82	**Construction - Other**	None	1.800	4	1.786	1.04	65	953584	167977	65216	2014	236220 - Commercial and Institutional Building Construction	Laborer (masonry demolition)
82	**Construction - Other**	None	0.330	8	1.000	0.33	26	963134	172737	71646	2014	238220 - Plumbing, Heating, and Air-Conditioning Contractors	Sprinkler Fitter - working adjacent to concrete floor cutting operations
82	**Construction - Other**	None	0.210	5	1.515	0.14	10	955403	168418	65215	2014	238140 - Masonry Contractors	Laborer - mixing mortar and "bank" sand in masonry mixer
82	**Construction - Other**	None	0.440	0	5.000	0.09	0	956233	168892	65141	2014	236220 - Commercial and Institutional Building Construction	Floor Cleaner
82	**Construction - Other**	None	16.000	8	0.952	17.26	1360	909807	138599	46114	2013	238140 - Masonry Contractors	Owner
82	**Construction - Other**	None	10.000	0	5.000	2.05	0	878223	126248	34431	2013	238990 - All Other Specialty Trade Contractors	Mixer/Laborer - mixing bags with some trace of silica

Table III-A-2: Personal Respirable Crystalline Silica Exposures of Workers in the Construction Industry (OIS, 2011-2014) (continued)													
Section	**Section Name**	**Controls**	**Resp. Dust (µg/m³)**	**% Silica**	**PEL (µg/m³)**	**Severity**	**RCS (µg/m³)**	**Insp ID**	**Sample Sheet**	**Exposure Assessment Number**	**Year**	**NAICS Title**	**Job Title / Job Activities / Work Environment**
82	**Construction - Other**	None	0.220	39	0.245	0.90	85	822081	115628	33292	2013	238340 - Tile and Terrazzo Contractors	Lead Tileman (vitrified ceramic tile flooring and grout) dry sweeping
82	**Construction - Other**	None	0.200	41	0.233	0.84	82	923434	152583	49967	2013	238340 - Tile and Terrazzo Contractors	Polisher - polishing granite countertops
82	**Construction - Other**	None	1.900	2	2.500	0.76	38	910558	138628	46136	2013	238220 - Plumbing, Heating, and Air-Conditioning Contractors	Fitter
82	**Construction - Other**	None	0.160	39	0.244	0.64	62	923434	152582	49963	2013	238340 - Tile and Terrazzo Contractors	Quality Control - polishing and grinding as needed for quality control
82	**Construction - Other**	None	1.900	0	5.000	0.37	0	910558	138626	46129	2013	238220 - Plumbing, Heating, and Air-Conditioning Contractors	Welder
82	**Construction - Other**	None	0.200	10	0.840	0.24	20	845903	126128	34380	2013	238120 - Structural Steel and Precast Concrete Contractors	Supervisor

Table III-A-2: Personal Respirable Crystalline Silica Exposures of Workers in the Construction Industry (OIS, 2011-2014) (continued)													
Section	**Section Name**	**Controls**	**Resp. Dust (µg/m³)**	**% Silica**	**PEL (µg/m³)**	**Severity**	**RCS (µg/m³)**	**Insp ID**	**Sample Sheet**	**Exposure Assessment Number**	**Year**	**NAICS Title**	**Job Title / Job Activities / Work Environment**
82	**Construction - Other**	None	0.150	9	0.877	0.17	14	932711	157435	50564	2013	238340 - Tile and Terrazzo Contractors	Fabricator - cutting and grinding granite
82	**Construction - Other**	None	0.440	0	5.000	0.09	0	920329	148236	48402	2013	238990 - All Other Specialty Trade Contractors	Operator
82	**Construction - Other**	None	0.210	0	5.000	0.04	0	925124	152761	49964	2013	238340 - Tile and Terrazzo Contractors	Polisher
82	**Construction - Other**	None	0.150	0	5.000	0.03	0	910558	138627	46137	2013	238220 - Plumbing, Heating, and Air-Conditioning Contractors	Laborer
82	**Construction - Other**	None	0.100	0	5.000	0.02	0	932711	157434	50565	2013	238340 - Tile and Terrazzo Contractors	Fabricator - cutting and grinding granite
82	**Construction - Other**	None	0.071	0	5.000	0.01	0	904969	136149	45402	2013	236118 - Residential Remodelers	Owner
82	**Construction - Other**	None	0.059	0	5.000	0.01	0	906671	137356	45398	2013	236118 - Residential Remodelers	Supervisor

Table III-A-2: Personal Respirable Crystalline Silica Exposures of Workers in the Construction Industry (OIS, 2011-2014) (continued)													
Section	**Section Name**	**Controls**	**Resp. Dust (μg/m³)**	**% Silica**	**PEL (μg/m³)**	**Severity**	**RCS (μg/m³)**	**Insp ID**	**Sample Sheet**	**Exposure Assessment Number**	**Year**	**NAICS Title**	**Job Title / Job Activities / Work Environment**
82	**Construction - Other**	None	0.053	0	5.000	0.01	0	941642	164898	59381	2013	236220 - Commercial and Institutional Building Construction	GRC Operator [glass reinforced cement]
82	**Construction - Other**	None	0.055	0	5.000	0.01	0	845903	126148	34381	2013	238120 - Structural Steel and Precast Concrete Contractors	Laborer (manufacture concrete structures; silica found in the concrete used to manufacture the water sewage structures)
82	**Construction - Other**	None	0.033	0	5.000	0.01	0	915995	146377	47716	2013	238320 - Painting and Wall Covering Contractors	Painter
82	**Construction - Other**	None	0.029	0	5.000	0.01	0	941642	164900	59380	2013	236220 - Commercial and Institutional Building Construction	Body man
82	**Construction - Other**	None	0.025	0	5.000	0.01	0	925124	152734	49965	2013	238340 - Tile and Terrazzo Contractors	Bridgesaw/Forklift Operator
82	**Construction - Other**	None	0.018	0	5.000	0.00	0	925124	152634	49962	2013	238340 - Tile and Terrazzo Contractors	Shop Foreman/CNC Operator - dry grinding

Table III-A-2: Personal Respirable Crystalline Silica Exposures of Workers in the Construction Industry (OIS, 2011-2014) (continued)													
Section	Section Name	Controls	Resp. Dust (μg/m³)	% Silica	PEL (μg/m³)	Severity	RCS (μg/m³)	Insp ID	Sample Sheet	Exposure Assessment Number	Year	NAICS Title	Job Title / Job Activities / Work Environment
82	**Construction - Other**	None	2.900	10	0.862	3.38	278	704518	83985	27770	2012	236220 - Commercial and Institutional Building Construction	Superintendent
82	**Construction - Other**	None	3.500	4	1.613	2.18	147	403982	13500	6974	2012	237310 - Highway, Street, and Bridge Construction	Laborer
82	**Construction - Other**	None	1.800	9	0.901	2.05	164	732761	90389	29098	2012	237310 - Highway, Street, and Bridge Construction	Laborer - saw cutting joints in pavement
82	**Construction - Other**	None	0.850	8	1.042	0.82	65	541720	48266	17586	2012	236220 - Commercial and Institutional Building Construction	Tender
82	**Construction - Other**	None	0.930	6	1.266	0.73	55	541720	48267	17589	2012	236220 - Commercial and Institutional Building Construction	Tender

Table III-A-2: Personal Respirable Crystalline Silica Exposures of Workers in the Construction Industry (OIS, 2011-2014) (continued)													
Section	**Section Name**	**Controls**	**Resp. Dust (μg/m³)**	**% Silica**	**PEL (μg/m³)**	**Severity**	**RCS (μg/m³)**	**Insp ID**	**Sample Sheet**	**Exposure Assessment Number**	**Year**	**NAICS Title**	**Job Title / Job Activities / Work Environment**
82	**Construction - Other**	None	0.990	5	1.370	0.72	52	541720	48265	17588	2012	236220 - Commercial and Institutional Building Construction	Tender
82	**Construction - Other**	None	0.500	0	5.000	0.10	0	331823	8879	6283	2012	238110 - Poured Concrete Foundation and Structure Contractors	Laborer - assists employee who is jackhammering; stands nearby filling container with black beauty
82	**Construction - Other**	None	0.310	0	5.000	0.06	0	573939	53865	18670	2012	238140 - Masonry Contractors	Laborer - cutting on concrete, brick, and black top
82	**Construction - Other**	None	0.180	0	5.000	0.04	0	646719	68945	24509	2012	238350 - Finish Carpentry Contractors	Marble Shop - casting sink countertops (removes the sink from mold, smooths out the rough edges with an angle grinder, and polishes the surface in preparation for installation.
82	**Construction - Other**	None	0.170	0	5.000	0.03	0	577478	55046	18673	2012	236220 - Commercial and Institutional Building Construction	Laborer

Table III-A-2: Personal Respirable Crystalline Silica Exposures of Workers in the Construction Industry (OIS, 2011-2014) (continued)													
Section	Section Name	Controls	Resp. Dust (µg/m³)	% Silica	PEL (µg/m³)	Severity	RCS (µg/m³)	Insp ID	Sample Sheet	Exposure Assessment Number	Year	NAICS Title	Job Title / Job Activities / Work Environment
82	Construction - Other	None	0.000	0	5.000	0.00	0	534058	67147	24439	2012	237990 - Other Heavy and Civil Engineering Construction	(This sample did not identify an employee)
82	Construction - Other	None	0.658	11	0.769	0.86	72	63013	695	1380	2011	237310 - Highway, Street, and Bridge Construction	Foreman
82	Construction - Other	None	0.160	0	5.000	0.03	0	63013	696	1383	2011	237310 - Highway, Street, and Bridge Construction	Laborer
82	Construction - Other	None	0.067	0	5.000	0.01	0	63013	705	1388	2011	237310 - Highway, Street, and Bridge Construction	Laborer - Power Blower Operator- blows the dust out of the routed groove in the pavement
82	Construction - Other	Wet Method	1.600	12	0.714	2.21	192	963110	172722	71598	2014	238910 - Site Preparation Contractors	Laborer (floor cutting operations)
82	Construction - Other	Wet Method	0.470	11	0.769	0.61	52	891772	131457	37025	2013	238140 - Masonry Contractors	Concrete Cutting Operator
82	Construction - Other	Wet Method	2.500	0	5.000	0.51	0	919531	163705	55382	2013	238340 - Tile and Terrazzo Contractors	Fabricator - performs wet polishing of stone

Table III-A-2: Personal Respirable Crystalline Silica Exposures of Workers in the Construction Industry (OIS, 2011-2014) (continued)													
Section	**Section Name**	**Controls**	**Resp. Dust (µg/m³)**	**% Silica**	**PEL (µg/m³)**	**Severity**	**RCS (µg/m³)**	**Insp ID**	**Sample Sheet**	**Exposure Assessment Number**	**Year**	**NAICS Title**	**Job Title / Job Activities / Work Environment**
82	**Construction - Other**	Wet Method	0.234	15	0.588	0.40	35	823201	130610	36702	2013	238340 - Tile and Terrazzo Contractors	Fabricator
82	**Construction - Other**	Wet Method	0.260	7	1.086	0.24	19	919531	163707	55400	2013	238340 - Tile and Terrazzo Contractors	Fabricator - performs wet polishing of stone
82	**Construction - Other**	Wet Method	0.159	10	0.833	0.19	16	823201	130594	36701	2013	238340 - Tile and Terrazzo Contractors	Fabricator
82	**Construction - Other**	Wet Method	0.260	0	5.000	0.05	0	950017	165677	59374	2013	237310 - Highway, Street, and Bridge Construction	Laborer
82	**Construction - Other**	Wet Method	0.210	0	5.000	0.04	0	919531	163704	55383	2013	238340 - Tile and Terrazzo Contractors	Fabricator - performs wet polishing of stone
82	**Construction - Other**	Wet Method	0.106	0	5.000	0.02	0	823201	130591	36700	2013	238340 - Tile and Terrazzo Contractors	Bridge Saw Operator
82	**Construction - Other**	Wet Method	0.038	0	5.000	0.01	0	950017	165675	59376	2013	237310 - Highway, Street, and Bridge Construction	Laborer
82	**Construction - Other**	Wet Method	0.000	0	5.000	0.00	0	891772	131460	36959	2013	238140 - Masonry Contractors	Concrete Cutting

Table III-A-2: Personal Respirable Crystalline Silica Exposures of Workers in the Construction Industry (OIS, 2011-2014) (continued)													
Section	**Section Name**	**Controls**	**Resp. Dust (μg/m³)**	**% Silica**	**PEL (μg/m³)**	**Severity**	**RCS (μg/m³)**	**Insp ID**	**Sample Sheet**	**Exposure Assessment Number**	**Year**	**NAICS Title**	**Job Title / Job Activities / Work Environment**
82	**Construction - Other**	Wet Method	0.590	2	2.293	0.26	14	534058	67146	24900	2012	237990 - Other Heavy and Civil Engineering Construction	Laborer
82	**Construction - Other**	Wet Method	0.693	0	5.000	0.14	0	556859	53505	18366	2012	238910 - Site Preparation Contractors	Laborer - Demolishing of concrete floor and removal of debris inside a large garage. Heavy equipment used to break up and remove concrete.
82	**Construction - Other**	Wet Method	0.570	0	5.000	0.11	0	534058	67145	24899	2012	237990 - Other Heavy and Civil Engineering Construction	Laborer
82	**Construction - Other**	Wet Method	0.330	0	5.000	0.07	0	639698	68085	24438	2012	238110 - Poured Concrete Foundation and Structure Contractors	Laborer
82	**Construction - Other**	Wet Method	0.090	0	5.000	0.02	0	192165	3599	6258	2012	238350 - Finish Carpentry Contractors	Tile Setter
82	**Construction - Other**	Wet Method	0.056	0	5.000	0.01	0	191861	3523	2939	2012	238340 - Tile and Terrazzo Contractors	Sample Maker - works in precast area to prep sample pieces. Uses milling machine to make laser cuts. Grinds and polishes sample pieces.

Table III-A-2: Personal Respirable Crystalline Silica Exposures of Workers in the Construction Industry (OIS, 2011-2014) (continued)													
Section	**Section Name**	**Controls**	**Resp. Dust (μg/m³)**	**% Silica**	**PEL (μg/m³)**	**Severity**	**RCS (μg/m³)**	**Insp ID**	**Sample Sheet**	**Exposure Assessment Number**	**Year**	**NAICS Title**	**Job Title / Job Activities / Work Environment**

Key to Abbreviations

OIS = OSHA Information System
Resp. Dust = Respirable Dust
PEL = Personal Exposure Limit
RCS = Respirable Crystalline Silica
Insp ID = OSHA's Inspection Identification Number
NAICS = North American Industry Classification System

Source: OSHA, Directorate of Standards and Guidance, Office of Technological Feasibility, 2015, based on Document ID 3958.

CHAPTER IV: TECHNOLOGICAL FEASIBILITY

1. INTRODUCTION

This chapter presents an overview of the technological feasibility assessment process for the final rule for respirable crystalline silica, including a description of the structure of the technological feasibility assessments for each individual industry sector or application group. It then addresses general comments received from stakeholders on technological feasibility; these comments are addressed here because they are applicable to the entire technological feasibility analysis or to more than one industry sector or application group. Comments pertinent to a particular sector or application group are addressed in the individual technological feasibility analyses. Comments received regarding the sampling and analysis are addressed in Section IV-3 Feasibility of Measuring Respirable Crystalline Silica Exposures at the Final Rule's PEL and Action Level.

The OSH Act requires OSHA to demonstrate that a proposed health standard is technologically feasible (29 U.S.C. § 655(b)(5)). As described in the preamble to the final rule (see Section II, Pertinent Legal Authority), technological feasibility has been interpreted broadly to mean "capable of being done" (*Am. Textile Mfrs. Inst. v. Donovan*, 452 U.S. 490, 509-510 (1981) ("*Cotton Dust*")). A standard is technologically feasible if the protective measures it requires already exist, can be brought into existence with available technology, or can be created with technology that can reasonably be expected to be developed, i.e., technology that "looms on today's horizon" (*United Steelworkers of Am., AFL-CIO-CLC v. Marshall*, 647 F.2d 1189, 1272 (D.C. Cir. 1980) ("*Lead I*"); *Amer. Iron & Steel Inst. v. OSHA*, 939 F.2d 975, 980 (D.C. Cir. 1991) ("*Lead II*"), and *American Iron and Steel Institute v. OSHA*, 577 F.2d 825 (3rd Cir. 1978)). Courts have also interpreted technological feasibility to mean that, for health standards, a typical firm in each affected industry will reasonably be able to implement engineering and work practice controls that can reduce workers' exposures to meet the permissible exposure limit in most operations most of the time without reliance on respiratory protection (see *Lead I*, 647 F.2d at 1272; *Lead II*, 939 F.2d at 990).

1.1 TECHNOLOGICAL FEASIBILITY ANALYSIS

The technological feasibility analysis is organized by industry sector in general industry and maritime and by application group in construction, with the term application group referring to a specific construction task or activity, such as abrasive blasting. General industry and maritime is mostly analyzed by job, which may incorporate more than one activity or task; construction, which comprises a single industry, is analyzed by task (e.g., hole drilling). The only maritime sector considered to have silica exposures within the range of interest warranting a feasibility analysis is the shipyard sector, which engages in substantial abrasive blasting.

For each industry sector and application group, the available exposure data is summarized by job title or activity to characterize exposures to respirable crystalline silica and to identify exposures above 50 μg/m^3 where additional engineering controls and work practices will be necessary to reduce exposures to at or below the permissible exposure limit (PEL) of 50 μg/m^3 as an 8-hour time-weighted average (TWA) that the rule sets as an enforceable maximum limit. As explained below, exposures are characterized by their median, mean, and range of values within the different job titles, application groups and industry sectors. Additional controls to further reduce exposures could include upgrading or installing engineering controls, or improving work practices such as implementing better housekeeping and routine maintenance procedures, the most common of which are the use of water to suppress dust or local exhaust ventilation to remove and collect dust. In the cases where the exposure data for a specific operation were lacking, OSHA used analogous operations to characterize these operations. OSHA finds that, with a few exceptions discussed below, employers will be able to reduce exposures to 50 μg/m^3 or below in most operations most of the time through the use of engineering and work practice controls. In many industry sectors and application groups, OSHA's analysis demonstrates that most exposures are already at or below the final PEL.

The technological feasibility assessment for each affected industry sector or application group is structured into four main parts: Description; Exposure Profile and Baseline Conditions; Additional Controls; and Feasibility Finding(s).

1.1.1 Description

The description in each section identifies the affected industry sector or application group and provides the following: 1) description of the manufacturing or industrial process or construction activity that has potential exposure to respirable crystalline silica; 2) discussion of each job category or construction task with potential exposure; and 3) major activities and sources of exposure.

1.1.2 Exposure Profile and Baseline Conditions

To establish baseline exposure levels, OSHA examined the available exposure monitoring data from OSHA inspection reports and enforcement data, site visits conducted by NIOSH and by OSHA's contractor, Eastern Research Group, Inc. (ERG), and other data and published reports submitted to the rulemaking record.

The available exposure monitoring data by job category or task within that sector or application group are presented in an exposure profile that displays the entire range and distribution of the available exposure measurements, including the median[1] and mean values. The median indicates the mid-point of a distribution, i.e., the value at which half the numbers are above and half are below, and provides a measure of central tendency for the exposure distribution. An arithmetic mean (or average) will be equal to the median if exposures are equally distributed above and below the median (e.g., a normal distribution), but will be considerably above the median where there are some very high exposures well above the median (i.e., for a distribution that is skewed toward higher exposures, such as a lognormal distribution). It is well recognized that occupational exposures to chemicals exhibit a skewed distribution such that the average exposure of a group of workers will typically exceed the median exposure (Document ID 0845). The exposure profiles are the primary basis for describing current, or baseline, exposure levels and include samples from both well-controlled and poorly controlled workplaces.

[1] In some cases, depending on the distribution of the exposure data, the geometric mean was used by OSHA or in published articles to better represent the central tendencies of the distribution. The geometric mean is the n^{th} root of the product of n samples. This type of analysis will tend to "normalize" the range and will not be overly influenced by extremely high values in non-normal distributions.

1) INTRODUCTION

OSHA used the exposure profiles to develop estimates of the percentage of workers in an industry sector or application group that are currently exposed to silica levels above the new PEL of 50 μg/m^3, and therefore require the use of additional engineering or work practice controls to achieve compliance. When the exposure profile indicates that most exposures for a particular job category are already at or below 50 μg/m^3, OSHA considers this to be evidence showing a PEL of 50 μg/m^3 to be technologically feasible for that job, because compliance is already being achieved using existing controls. When the exposure profile indicates that most exposures for a particular job category or application group exceed 50 μg/m^3, OSHA identifies additional control measures that the Agency has determined are capable of reducing exposures as needed to achieve or substantially approach compliance with the PEL.

The final exposure profiles take the exposure data that were used for the same purpose in OSHA's Preliminary Economic Analysis (PEA) and build upon them, using new data in the rulemaking record. The sampling data that were used to identify the affected industries and to develop the exposure profiles presented in the PEA were obtained from a comprehensive review of the following sources of information: OSHA compliance inspections conducted before 2011, OSHA contractor (ERG) site visits performed for this rulemaking, NIOSH site visits, NIOSH Health Hazard Evaluation reports (HHEs), published literature, submissions by individual companies or associations and, in a few cases, data from analogous operations (Document ID 1720, pp. IV-2 – IV-3). The exposure profiles presented in the PEA were updated for the Final Economic Analysis (FEA) using exposure measurements from the OSHA Information System (OIS) that were taken during compliance inspections conducted between 2011 and 2014 (Document ID 3958). In addition, exposure data submitted to the record by rulemaking participants were used to update the exposure profiles. The criteria used for determining whether to include exposure data in the exposure profiles are described in Section IV-2 – Methodology of this chapter. As explained there, some of the original data is no longer used in the exposure profiles based on those selection or screening criteria. OSHA considers the exposure data relied upon for its analysis to be the best available evidence of baseline silica exposure conditions.

OSHA considers controls to be "baseline conditions" when such controls are regularly used in an industry sector or application group. This should not be interpreted to mean that OSHA believes everyone currently uses these controls, but rather that the controls are widely available and commonly used in the industry. Thus, the baseline conditions described in OSHA's feasibility assessments can include both controlled and uncontrolled exposures; in fact, the range of exposures for a particular job category or task can provide a useful indication of how substantially exposures can be reduced using currently available controls. Information on controls used in specific industry sectors or application groups was obtained from several different sources, including site visits conducted to evaluate current exposures, NIOSH research reports, industry experts, industry associations, published literature, and submissions to the rulemaking record.

1.1.3 Additional Controls

The third section of each technological feasibility assessment describes additional controls identified by OSHA that could be implemented to reduce exposures to 50 $\mu g/m^3$ or below. OSHA often based its determination that the engineering and work practice controls can reduce exposures to or below the PEL on evidence that the additional controls are already in use at other facilities in the same application group or industry sector. Where OSHA had limited data on an industry sector or activity, OSHA evaluated the effectiveness of controls in similar industry sectors or analogous operations. In some cases, OSHA applied an estimate of the percent reduction in exposure achieved through the use of controls based on experimental studies reported in the published literature.

There were some tasks for which OSHA determined that some workers' exposures would likely remain above 50 $\mu g/m^3$, even with the implementation of additional controls. In these cases, OSHA concluded that the supplemental use of respirators is needed.

1.1.4 Feasibility Finding(s)

After describing the additional controls that can reduce exposures, OSHA includes a conclusion regarding the technological feasibility of achieving the final PEL of 50 $\mu g/m^3$ or less for each of the jobs or tasks described, along with a general finding of feasibility for the industry sector or application group where that sector or group involves more than one described and profiled job or task. OSHA considers the PEL technologically feasible when the evidence in the record, including exposure monitoring data, indicates that most operations will be able to achieve exposures at or below 50 μg/m^3 most of the time with the use of engineering and work practice controls. For these purposes, "operation" and "job or task" are equivalent terms. The feasibility findings are the result of overlaying the additional controls analysis on the exposure profiles, which are necessarily based on number of individual workers sampled rather than number of discrete operations performed.

In determining technological feasibility, OSHA reviewed the feasibility for each job category and then made an overall feasibility determination for each industry sector or application group. When OSHA anticipates that additional controls can effectively reduce exposures to below the PEL for most but not all workers in a specified job category, OSHA concludes that the PEL is technologically feasible for that job category. In general industry, OSHA used several different methods to determine feasibility for each job category depending on the available data. First, if most workers' exposures in a specific job category were already below the PEL, then OSHA determined the PEL is feasible. However, for workers above the PEL, OSHA reviewed the baseline controls and any additional controls necessary to reduce exposures to the PEL or below for these workers. For example, the exposure profile developed for the mixer operator in the paint and coating industry sector (see FEA Section IV-4.13) indicated that 75 percent of the workers already had exposures below the PEL. However, OSHA found that additional controls, including local exhaust ventilation and bag disposal systems, are necessary to achieve the PEL for the 25 percent of these workers who are exposed above the PEL (Document ID 1720, p. IV-237).

When most workers are not currently below the final PEL, OSHA described additional controls that could be applied to reduce exposures below the PEL. In some cases, OSHA applied the expected exposure reduction from use of controls to the baseline distribution of exposures to develop an estimate of the range of exposures that can be expected when controls have been implemented. For example, bag filling operations can generate high exposures to respirable dust. Four of the six samples in the exposure profile for packaging operators in the concrete products industry exceed 50 μg/m^3. However, at one facility, installing a more powerful fan motor and new filter bag for the bag-filling machine LEV and moving the hoods closer to the packaging operator's position reduced respirable dust exposure by 92 percent. After these improvements, a concrete packaging operator had a full-shift silica exposure below the limit of detection (LOD) (in this case, 11 μg/m^3) (Document ID 0126, pp. 7-8). At another facility, the installation of a ventilation system for bag-filling operations, described as an overhead air supply island system (OASIS) (Document ID 1365, p. 5-26; 1326), was shown to reduce respirable dust exposure by 98 percent and 82 percent for packaging operators at two mineral processing facilities. Thus, OSHA applied the percent effectiveness of the controls to the current exposure profile and concluded that these types of controls would reduce silica exposures of packaging operators in the concrete products industry to below the PEL.

In other cases, OSHA demonstrated that specific controls can reduce workers' exposures to the PEL or below based on direct observation in facilities that installed controls compared with facilities that had not installed controls. In the cut stone industry sector, for example, OSHA showed that a combination of engineering controls can reduce machine operator exposure substantially and under these conditions, the operator exposure level dropped from 220 μg/m^3 to 26 μg/m^3 (Document ID 1365, p. 11-25; 0178).

In the foundry industry, OSHA noted baseline conditions that covered a wide range of exposures, and included relatively well-controlled foundries with most samples already below the final PEL, and some poorly-controlled foundries with most samples above the final PEL. The relatively well-controlled facilities were more likely to have installed enclosures and local exhaust ventilation (LEV) for dusty activities, such as for sand-handling equipment, shakeout, knockout, and cleaning/finishing tasks. Relatively well-controlled foundries were also more likely to have automated processes that allow for remote operation of equipment, such as for mold making or core making, routine grinding, shot-blasting, and conveying parts into enclosures for dustier processes (e.g., shakeout, shot blast equipment). This allows workers to control these processes from control booths or behind partitions. Additionally, whether automated or not, relatively well-controlled foundries are more likely to have controls in place to reduce airborne silica dust, such as pneumatic sand transport equipment, using washed lake sand (with low respirable-sized particle content), and purchasing sand additives premixed (because the mixing process released additional dust) (Document ID 1365, pp. 2-18 – 2-19; 1409, p. 2; 0268, pp. 7-8; 0147, pp. 53, 72-75; 0082, pp. 88-89, 91, 120, 135). Thus, OSHA concluded that the same types of controls used to reduce exposure levels below the PEL at well controlled foundries could be also be used at poorly-controlled foundries.

Alternately, when OSHA did not have direct evidence that engineering controls had been implemented in a specific industry sector, the additional controls needed to reduce exposures to or below the PEL were determined based on analogous operations where effective controls have been implemented. In the pottery industry, OSHA described additional control measures to reduce exposures to or below the PEL that included covering conveyors and increasing ventilation at existing enclosed transfer points to meet the ACGIH recommended air velocity of 250 fpm/ft^2 across all openings in the enclosures (Document ID 3883, p. 13-81). OSHA did not have in the record a specific example where these controls had been implemented in the pottery industry sector; however, in several other industries that convey similar quantities of silica sand, enclosed conveying systems are an effective part of comprehensive respirable dust management programs, which results in exposure levels below the final PEL (e.g., Sections IV-4.9 – Glass Products, IV-4.13 – Paint and Coatings and IV-4.21 – Structural Clay). OSHA concluded that these controls would be equally effective in the pottery industry sector.

OSHA recognizes that for some operations exposures will exceed the final PEL even when all feasible engineering controls have been implemented. Therefore, for general industry and maritime, the individual employer is obligated to conduct exposure monitoring to identify the specific job categories and work activities during which the supplemental use of respiratory protection is required to achieve compliance. For workers in the construction industry engaged in any of the tasks listed in Table 1, employers can achieve compliance by fully and properly implementing the specified exposure controls measures and providing respiratory protection when required by Table 1. Alternatively, employers in the construction industry must assess and limit exposures in accordance with the more traditional regulatory approach of compliance with the PEL contained in paragraph (d).

1.2 GENERAL TECHNOLOGICAL FEASIBILITY COMMENTS

1.2.1 Feasibility and Variability

During the rulemaking proceeding, there were comments from various industry groups disputing the technological feasibility of achieving exposures of 50 μg/m^3 or less. The American Chemistry Council's Crystalline Silica Panel (ACC) stated that OSHA had not shown that the proposed standard would be technologically feasible in all affected industry sectors (Document ID 4209, Attachment 1, p. 97). Representatives from the American Foundry Society (AFS) and from the Asphalt Roofing Materials Association argued that, due to day-to-day variability, OSHA must demonstrate that average exposures can be reduced to 25 μg/m^3 or less in order to demonstrate that compliance with a PEL of 50 μg/m^3 is technologically feasible (see, *e.g.*, Document ID 2291, p. 5; 3584, Tr. 2654-2655; 3580, Tr. 1282-1284, 1289). The Construction Industry Safety Coalition (CISC) made a similar argument regarding the need to control exposure levels to well below the PEL due to the variability of silica exposures on construction worksites (Document ID4217, p. 11). It stated in its comments, "… if there is one piece of evidence that is virtually undisputed in the rulemaking record, it is that respirable crystalline silica exposures in the construction environment are highly unpredictable and variable" (Document ID 4217, p. 11).

OSHA recognizes that differences in exposure can occur due to workplace variables that are not under the direct control of the employer (e.g., fluctuations in environmental conditions or air movement). These factors contribute to random excursions in exposure that are often greater than variation attributable to the sampling and analytical errors. The Agency has acknowledged and discussed exposure variability in past rulemakings where the same issue was raised (*e.g.*, Benzene, 52 FR 34534; Asbestos, 53 FR 35609; Lead in Construction, 58 FR 26590; Formaldehyde, 57 FR 22290; Cadmium, 57 FR 42102; and Hexavalent Chromium, 71 FR 10099).

However, OSHA disagrees with CISC's statement that the variability in exposure necessarily means unpredictability in exposure. Several studies were submitted to the docket that used multivariate statistical models to identify factors associated with increased exposure to silica during various construction activities (Document ID 3608, 3803, 3956, 3998, Attachment 5h). These studies reported that as much as 80% of the variability in respirable quartz exposures could be attributed to various factors that were observable and controlled by the employer (e.g., location of work – indoor/outdoor, equipment used, type of controls used), clearly indicating that not all variability in exposure is due to random variation or environmental factors; rather, many high exposures are the result of known or observable factors that the employer can readily identify and address in efforts to improve exposure control. This was attested to at the hearing by Dr. Frank Mirer of the CUNY School of Public Health, representing the AFL-CIO: "[e]xposures go up and down not by magic but by particular conditions, differences in work methods, differences in control efficiency, differences in adjacent operations" (Document ID 3578, Tr. 971). Likewise, Scott Schneider of the Laborers' Health and Safety Fund of North America testified that "we know there are certain variables that are more important than others…[T]he goal of controlling exposure variability is to limit the number of variables to the most important ones and set limits or parameters on those" (Document ID 3589, Tr. 4251-4252). The International Union of Operating Engineers asserted that variables affecting silica exposure in construction are manageable because, among other reasons, many construction tasks are highly repetitive, and the variables affecting exposure are predictable (Document ID 4234, Attachment 2, pp. 31-38).

As indicated by these commenters, increasing the consistent use of engineering controls and appropriate work practices will reduce exposure variability. By implementing controls and work practices to reduce worker exposures to the final PEL or below, employers will, in addition to reducing the incidence of serious and fatal illness, substantially reduce exposure variability, reduce the number of workers needing to wear respiratory protection, and provide employers with greater confidence that they will be in compliance with the revised PEL.

OSHA does, however, acknowledge that exposure controls cannot entirely eliminate variability. Some day-to-day variability in silica exposure measurements may remain, despite an employer's conscientious application and maintenance of all feasible engineering and work practice controls. As stated above, this issue of variability in exposure levels is not new; it has been addressed in a number of other rulemakings (*e.g.*, Asbestos preamble, 51 FR 22612, 22653 (6/20/1986)). Reviewing courts have agreed that OSHA's obligation is to show that a PEL can be achieved in most operations most of the time, despite the presence of random exposure variability. In particular these courts have approved of OSHA's flexible enforcement policies, which allow the Agency to take such exposure variability into account before issuing a citation (*e.g., Building & Constr. Trades Dept. v. Brock*, 838 F.2d 1258 (D.C. Cir. 1988) ("*Asbestos II*")). In the *Asbestos II* case, for example, the D.C. Circuit approved of OSHA's policy of allowing for a possible re-inspection if OSHA measured an asbestos exposure above the PEL during an inspection. If the employer appeared to be using, to the extent feasible, work practices and engineering controls, OSHA could agree to re-inspect at a later time. Such a re-inspection would help determine if that over-exposure was typical or simply a random, uncontrollable fluctuation; OSHA could then determine whether or not to issue a citation accordingly (*Asbestos II* at 1268; see 51 FR 22653). Thus, OSHA has, in the past, adopted fair and flexible enforcement policies to deal with the issue of exposure variability and intends to do the same for enforcement of the new silica standards. Furthermore, an employer who fully and properly implements the exposure controls required by Table 1 of the final standard for construction eliminates the risk of being subject to citation for exposures that exceed the PEL.

1.2.2 OSHA's Exposure Profile and its Representation of Baseline Conditions

CISC was critical of several aspects of OSHA's feasibility analysis. CISC commented that OSHA failed to consider exposures from secondary or adjacent sources and that OSHA should factor this into its analysis (Document ID 2319, p. 30; 4217, p. 13). CISC also argued that OSHA did not account for the varying amounts of crystalline silica that could exist in materials being disturbed by workers, meaning that "the same task could be judged as being able to meet the PEL when its *real* ability to meet any PEL is contingent on the percentage of silica in the material being disturbed" (Document ID 2319, pp. 26-27).

OSHA disagrees with CISC because the sampling results relied on by OSHA to characterize silica exposures includes a wide range of silica content that is representative of the range of silica content in materials worked on by construction workers. A total of 881 samples were used in the FEA to develop the exposure profiles for construction tasks. The silica content in these samples ranged from less than 1 percent (non-detected) to 50 percent, with an average silica content of 9.1 percent (see Section IV-2 – Methodology for a description of the percent silica content of the OIS samples specifically). OSHA concludes that the exposure results obtained from these varied construction tasks, including a range of silica content, are representative of typical construction work environments, and OSHA could find no evidence in the record to suggest otherwise.

CISC also indicated that OSHA did not account for differences in exposure results "due solely to what part of the country the activity took place in" (Document ID 2319, p. 27). Similar to the discussion above about the range of quartz content, OSHA relied on exposure data taken from many different parts of the country under varying weather conditions. OSHA's construction database contains data ranging from the east coast (*e.g.*, New York, Georgia) to the Midwest (*e.g.*, Ohio, Minnesota) to the western states (*e.g.*, Arizona and Colorado). Again, OSHA believes that its large exposure database, containing results obtained from varied construction tasks in a variety of locations under different weather conditions, is representative of the broad range of conditions encountered in construction. OSHA could find no evidence in the record to prove otherwise.

Additionally, some commenters questioned whether OSHA had adequately considered the difficulties in complying with the PEL for maintenances activities. The National Association of Manufacturers (NAM), for example, quoted one of its members, which stated:

> [t]here are occasional conditions where maintenance cleaning is performed inside conveyor enclosures where the enclosure is ordinarily a part of the dust control systems. This is just one example of where a control would have to be breached in order to properly maintain it as well as the operating equipment. It is simply not technically feasible to establish engineering controls for all possible maintenance activities (Document ID 2380, Attachment 2, p. 1).

OSHA has addressed maintenance activities in each sector's technological feasibility analysis, but the standard itself acknowledges the challenges of using engineering and work practice controls in some maintenance activities. Paragraph (g)(1)(ii) of the general industry and maritime regulatory text (paragraph (e)(1)(ii) in construction) requires respiratory protection "where exposures exceed the PEL during tasks, such as certain maintenance and repair tasks, for which engineering and work practice controls are not feasible" (see the Summary and Explanation section of this preamble on Respiratory Protection for more information).

1.2.3 Operations not Covered

OSHA's technological feasibility analysis of the construction industry focused on the application groups (tasks and activities) for which OSHA found substantial evidence that, when performed without dust controls, worker exposure to respirable crystalline silica routinely exceeded the final PEL. These tasks involve the use of handheld power tools and some types of larger equipment that can generate significant levels of visible dust and lead to elevated silica exposures; these tasks include cutting, grinding, drilling, or crushing silica-containing materials. CISC submitted comments suggesting that the technological feasibility analysis was incomplete because it did not cover every construction-related task for which there is the potential for exposure to silica dust. It listed more than 20 operations, including cement mixing, cutting concrete pavers, demolishing drywall or plaster walls/ceilings, overhead drilling, demolition of concrete and masonry structures, and grouting floor and wall tiles, that it stated OSHA must examine, in addition to the application groups already covered by the Agency's analysis, in order to establish feasibility (Document ID 2319, pp. 19-21). CISC asserted that, because of the many types of silica-containing building materials used in the construction industry, as well as the presence of naturally occurring silica in soil, additional data collection and analysis by OSHA should be conducted before promulgating a final rule (Document ID 2319, pp. 25-26; 4217, p. 3).

As explained in the NPRM, OSHA's analysis for construction focuses on tasks for which the available evidence indicates that significant levels of respirable crystalline silica may be created, due primarily to the use of powered tools or large equipment that generates visible dust. OSHA notes that many of the examples of tasks for which CISC requested additional analysis are tasks involving the tools and equipment already covered in this feasibility analysis. For example, overhead drilling is addressed in Section IV-5.4 – Hole Drillers Using Handheld or Stand-Mounted Drills, and the demolition of concrete and masonry structures is addressed in Section IV-5.3 – Heavy Equipment Operators and Ground Crew Laborers. In other cases, such as for concrete mixing, there is no evidence in the record that the task is likely to result in significant exposure. OSHA discussed the use of dust controls to reduce exposures that can occur when cleaning dried concrete from mixers in Section IV-4.17 – Ready-Mixed Concrete. Other tasks listed by CISC involve working with wet or intact concrete, for which there is no evidence of significant exposure. Furthermore, CISC did not submit to the record any air monitoring data to support its assertion that these activities result in significant exposures. Therefore, OSHA has not added these additional activities to the feasibility analysis.

1.3 FEASIBILITY OF RESPIRABLE CRYSTALLINE SILICA CONTROLS

The exposure control methods described in this chapter to reduce exposures to respirable crystalline silica rely primarily on the use of water (wet methods) to suppress airborne dust at the point of generation, or on the use of local exhaust ventilation (LEV) that removes airborne dust and collects it in a baghouse or filtered dust collector. OSHA received a number of general comments on the feasibility of wet methods and LEV as well as on challenges faced when employing these dust control strategies in specific work settings.

Most of these comments addressed the use of water on construction sites; several rulemaking participants argued that it is not always possible for employers to use water for dust suppression. For example, in its post-hearing submission, CISC discussed "significant obstacles" to using wet dust suppression technologies on construction sites, including freezing weather, which contraindicates water use, and a lack of running water onsite, which requires employers to deliver water, a practice which, according to CISC, is both "costly and time consuming" (Document ID 4217, pp. 18-19). In addition, CISC stated that indoor work precludes the use of water because water could damage existing floors, drywall, or the possessions of the property owner. Use of wet methods, stated CISC, also can create excessive runoff and cause environmental problems (Document ID 4217, pp. 18-19).

However, many other participants commented that these barriers can be overcome. For example, Phillip Rice, of Fann Contracting, Inc., stated his company uses water trucks to haul water to sites and includes the cost of doing so in his bids. He added that "when someone says they can't get water on their project there is something wrong" (Document ID 2116, Attachment 1, p. 33). Representatives of the International Union of Bricklayers and Allied Craftworkers (BAC) pointed out that water is essential for work in the masonry trades and, without it, no mortar can be mixed to set materials (Document ID 3585, Tr. 3059-3060). They testified that, in their experience, it was rare to work on sites that did not have water or electricity available, but when they did, they brought in water trucks and gas-powered generators to run saws (Document ID 3585, Tr. 3061-3063). With respect to weather conditions, heated water or heated shelters can be used (Document ID 3585, Tr. 3095-3096). Water runoff can also be managed by training operators to achieve a balance between using sufficient water for effective dust control and avoiding pooling to minimize runoff (Document ID 3583, Tr. 2384).

These comments and testimony indicate that many of the barriers to wet dust suppression raised by CISC have been overcome in various construction settings. OSHA recognizes that there will be limited instances where the use of wet dust suppression is not feasible, particularly where its use can create a greater hazard. For example, water cannot be used for dust control in work settings where hot processes are present due to the potential for steam explosions (Document ID 2291, p. 13; 2298, p. 3), and it may not always be possible to use water where it can increase slip and fall hazards, such as on a roof

(Document ID 2214, p. 2). Use of water for dust suppression can also create electrical safety hazards, and therefore requires use of ground-fault circuit interrupters (GFCI) on electrical tools. Nevertheless, in the individual feasibility analyses that follow, the evidence discussed makes it clear that many employers currently use wet dust suppression, that there are many commercially available products with integrated water systems for dust suppression, and that these products can be used in most work settings to control exposures to respirable crystalline silica. OSHA understands the concerns regarding the use of wet methods and the increased risk for falls; however, OSHA also heard testimony that proper planning can enable employers to use wet methods. Therefore, OSHA is not persuaded by the arguments of CISC and others that the barriers they identify would prohibit use of wet dust suppression in most operations where it would otherwise be an effective means of dust control.

1.3.1 Commercial Availability of Effective Dust Controls

In order to demonstrate technological feasibility where current (baseline) exposures are above the final PEL, OSHA has to show that there are dust controls available or reasonably foreseeable on the horizon that are capable of reducing exposures to the PEL or below. To meet this burden, OSHA reviewed a large quantity of evidence in the record on the commercial availability of engineering controls, including wet methods and local exhaust ventilation, that can effectively reduce workers' exposures to respirable crystalline silica. For example, for construction activities, Eileen Betit, testifying on behalf of the Building and Construction Trades Department (BCTD), AFL-CIO, stated, "each year, there seem to be more and more types of tools coming out that control silica… So new innovations keep happening" (Document ID 3581, p. 1673). Chris Trahan, a certified industrial hygienist with BCTD, stated that tool manufacturers regularly work with users to create innovative solutions for industry problems. She stated, "almost all of the good tool manufacturing lines…are creating tools with integral engineering work practice controls built in" (Document ID 3581, p. 1701). She went on to describe a recent experience at a trade show where a well-known tool manufacturer presented its catalogue of options for controlling dust at the source for a variety of handheld masonry tools (Document ID 3581, pp. 1701-1702).

Several representatives of the International Union of Bricklayers and Allied Craftworkers (BAC) also spoke to the availability of engineering controls. Tommy Todd, a bricklayer with decades of experience, commented on the changing state of dust control technology, stating “new tools and equipment are coming out daily in the masonry trade and other trades as well” (Document ID 3585, p. 3073; also 3585, p. 3072). Dennis Cahill, also from BAC, testified about the introduction onto jobsites of cutoff saws, and the ways in which they have been adapted to fit with engineering controls for reducing dust. He stated, “all modern cut-off saws have a fitting to hook them up to water or to hook them up to vacuums. So they -- as these problems appear the technology tries to solve the problem. And I think we're doing a pretty good job, but if we don't apply these answers to these problems they're not going to get solved” (Document ID 3585, pp. 3073-3074).

In addition to the testimony described above, studies have demonstrated that employers and manufacturers can create their own engineering controls for use on their particular worksites or with their own products. Shepherd (2006) reported on one employer’s approach to reducing respirable dust from overhead grinding by using an extension arm equipped with a vacuum system to lift and maneuver a grinder that effectively reduced both exposure to respirable silica dust and the ergonomic stress associated with overhead grinding (Document ID 3998, Attachment 13o). Another example is the development of a circular saw equipped with a vacuum system for cutting cement-fiber board, which demonstrated one manufacturer’s ingenuity in designing tools that contain built-in dust controls with proven effectiveness specifically for use with its product (Document ID 2322, Attachment 1, pp. 9-10).

The British Health and Safety Executive (HSE) evaluated the use of on-tool controls and their effectiveness in controlling respirable dusts, based on approximately 30 studies (Document ID 3791, p. 2). The HSE stated that on-tool controls were a solution to the challenges posed by construction crews’ mobility across temporary worksites, which limits the feasibility of using stationary exhaust systems (Document ID 3791, p. i). The HSE found that:

> [a] large body of work has been carried out in the last 10 – 15 years on controls. These studies have demonstrated that significant reductions in

> exposure to workers in excess of 90% are achievable for the following activities: tuck-point grinding, surface grinding and polishing, floor sanding, drywall sanding and block, slab and tile cutting using both on-tool LEV and water suppression methods (Document ID 3791, p. iii).

The HSE noted no significant difference in the effectiveness of on-tool LEV versus water suppression methods (Document ID 3791, p. v).

Similarly, in general industry the use of enclosed and ventilated equipment is on the rise. Many industries have switched from manual transfer of raw materials to integrated bag dumping stations equipped with well-ventilated enclosures and bag compactors. For example, as discussed in the PEA, site visits indicate that the primary controls for mixer operators in the paint and coatings production industry sector are bag dumping stations equipped with well-ventilated enclosures and bag compactors (also ventilated) (Document ID 0199, pp. 9-10; 0943, p. 87; 1607 p. 10-19; 1720, p. IV-237). Neither the Society for Protective Coatings nor the American Coatings Association disputed this assertion, even though they commented on other aspects of the proposed rule (Document ID 2120; 2239). Therefore, OSHA concludes that this type of system is already being used and can be adapted to other industry sectors for use during material transfer operations (see Sections IV-4.13 – Paint and Coatings, IV-4.14 – Porcelain Enameling, IV-4.9 – Glass, and IV-4.3 – Concrete Products of this FEA for additional information).

Based on the evidence described above and in the individual sections of the technological feasibility analysis, OSHA finds that many engineering control options are currently commercially available to control respirable dust. These controls will reduce workers' exposures to respirable crystalline silica when the workers are performing the majority of tasks that create high exposures today. OSHA's finding is based on numerous studies, conducted both in experimental settings in which the tools, materials, and duration of the task are controlled by the investigator, and in observational field studies of workers performing their normal duties in the field. More than 30 studies were submitted to the docket that report substantial reductions in exposure when using controls compared with uncontrolled situations. The specific reports that OSHA relied upon to estimate the range of reductions that can be achieved through the implementation of engineering controls are discussed in greater detail in the relevant sections of the technological feasibility analyses. These studies, along with other evidence in the record, also demonstrate the responsiveness of manufacturers to industry needs in solving the problem of dust exposure. Continual technological improvements in engineering controls, which are expected to continue after promulgation of this final rule, demonstrate the effectiveness of that working relationship.

2. METHODOLOGY

The technological feasibility analysis, which is part of the Final Economic Analysis (FEA), addresses the capability of employers to implement the engineering controls and work practices necessary to comply with OSHA's new standard on occupational exposure to respirable crystalline silica (sometimes referred to as "crystalline silica" or simply "silica" throughout the preamble). Crystalline silica occurs in multiple forms (polymorphs). In the final rule, OSHA is setting the same PELs for all three of the major polymorphs of crystalline silica (quartz, cristobalite, and tridymite). The term "respirable crystalline silica" is defined in the final rule as "quartz, cristobalite, and/or tridymite contained in airborne particles that are determined to be respirable …" (see Summary and Explanation for paragraph (b) (Definitions)). The vast majority of crystalline silica encountered by workers in the United States is in the quartz form, to such an extent that investigators often use the terms crystalline silica and quartz interchangeably. Nevertheless, the data available to OSHA contain a few samples in which detectable levels of cristobalite were reported, either alone or in addition to quartz. These results, when discussed individually, are specifically identified as including detectable cristobalite. In the FEA, the concentrations of the detected forms were added together to compare against the final rule's PEL. Tridymite was not reported as a component of any of the silica samples available to OSHA.

The silica sample results included in the exposure profiles in this technological feasibility analysis are measurements of respirable crystalline silica as determined by taking personal breathing zone (PBZ) samples of respirable dust and analyzing the samples for crystalline silica. PBZ samples are taken by attaching the sampling device directly to an employee's shirt collar or lapel to measure the respirable dust in the air that the worker is breathing. This device is worn by the worker for the duration of the sampling period. (Criteria relating to duration of sampling period are discussed below). The results of other types of samples, including area samples and respirable dust samples not analyzed for silica, are also discussed when they are relevant to evaluating the effectiveness of engineering controls, but are not used in the exposure profiles. When a sample result is not a PBZ respirable crystalline silica sample, the sample type is clearly identified to avoid confusion.

2.1 SOURCES OF DATA

OSHA's technological feasibility analysis relies on information from a wide variety of sources available to the Agency, as noted in the Introduction, and described in the Preliminary Economic Analysis (PEA) and the Notice of Proposed Rulemaking (NPRM), issued September 12, 2013 (78 FR 56274). Thus, each section in this chapter includes an exposure profile that summarizes all the available exposure data for the specific industry sector or application group, including the post-1990 monitoring data previously presented in the PEA as well as the additional monitoring data obtained subsequent to publication of the PEA.

The sources of the exposure monitoring data presented in the PEA are summarized in two reports prepared by an OSHA contractor (ERG).

- Technological Feasibility Study of Regulatory Alternatives for a Proposed Crystalline Silica Standard for General Industry (Document ID 1365).
- Technological Feasibility Study of Regulatory Alternatives for a Proposed Crystalline Silica Standard for Construction (Document ID 1431).

These two reports included exposure monitoring data from the following sources, as described in greater detail in the PEA (Document 1720, p. IV-2):

- OSHA silica Special Emphasis Program (SEP) inspection reports.
- NIOSH reports, including health hazard evaluations [HHE], control technology [CT] assessments, in-depth exposure monitoring surveys with recommendations for exposure control, and studies on the effectiveness of engineering controls.
- Workplace evaluation reports related to the "sentinel event notification system for occupational risks" (SENSOR) for silica from the states of Michigan, New Jersey, and Ohio.
- ERG and OSHA site visits specifically conducted for this rulemaking.
- Published literature.

- Unpublished information (e.g., unpublished data and research obtained through personal communications, meetings, and presentations).
- Information available from other federal agencies, state agencies, labor organizations, industry associations, and other groups.

The contractor reports primarily relied on the results of air monitoring conducted between 1990 and 2001, updated with some information through 2007. In a few cases, where sources more recent than 1990 were limited and earlier information existed, sampling results from the 1980s were used.

After the NPRM was published, OSHA received comments from stakeholders that, in some cases, included additional information on exposure to respirable crystalline silica, such as exposure monitoring data and examples of engineering controls that have been implemented to reduce exposures. OSHA reviewed all comments and supporting materials submitted to the rulemaking record and incorporated additional sampling results into the exposure profiles presented in the FEA. OSHA also updated the exposure profiles using the most recent exposure monitoring data from OSHA compliance inspections from 2011 to 2014, available through the OSHA Information System (OIS) (Document ID 3958). This data set is described in greater detail below.

The exposure profiles used in the PEA were updated for the FEA by removing the most of the results of samples collected prior to 1990 (n=290), leaving a total of 2,512 of the samples from exposure profiles presented in the PEA. OSHA added to the exposure profiles presented in the FEA samples submitted by commenters during the rulemaking (n=153) and the samples obtained from the OIS database (n=699), resulting in a total of 3,364 samples (2,483 for general industry and 881 for construction) in the final exposure profiles. Table IV.2-A summarizes the number of samples in the final exposure profiles that were used in the PEA, along with the number of additional samples used in the exposure profiles that came from commenters and from the OIS database. OSHA considers these samples to be the best available information regarding current exposures to respirable crystalline silica.

Table IV.2-A
Number of Samples Included in the Final Exposure Profiles

	General Industry	Construction	Total
PEA Samples	1,877	635	2,512
Docket Comment Samples	14	139	153
OIS Database Samples	592	107	699
Grand Total	**2,483**	**881**	**3,364**

OSHA has submitted to the docket as a background document for the FEA a file that contains the results of all 3,364 samples used in the exposure profiles with the Docket ID Numbers that identifies the source document from which each of these samples was obtained.

2.2 NOTES ON DATA SOURCES, CHARACTERISTICS, AND HANDLING

2.2.1 General Data Handling and Assumptions

OSHA used several criteria to ensure that the exposure data relied on for the technological feasibility analysis were of sufficient quality and handled uniformly. The data included in the exposure profiles in the FEA met the following criteria:

The sample results are reported as either respirable crystalline silica concentrations, or as respirable dust concentrations along with percent silica content of the dust. In some cases, the percent silica content was calculated based on the reported PEL for the sample (see Section IV-2.3 – Calculation of Respirable Crystalline Silica Exposures for more detail).

- The units of measurement are either micrograms per cubic meter of air (μg/m^3), milligrams per cubic meter or air (mg/m^3), or, in some cases, millions of particles per cubic foot (mppcf). All sample results were converted to units of micrograms per cubic meter when used in the exposure profiles.
- The sample duration is reported or, where sample durations were not reported, the results are reported to be representative of 8-hour TWA exposures.

- They are samples collected in U.S. workplaces.[2]
- For sample results reported as "non-detect" or "0" in the PEA, the sample duration was 120 minutes or more, resulting in a maximum possible silica concentration below 25 μg/m^3. For the sample results from the OIS database, all samples were used regardless of duration. (see Section IV-2.3.1 – Limits of Detection for Silica Data for more detail).
- There is sufficient information to identify the sector, job category, and activity performed for general industry, or the application group and activity performed for construction.

2.2.2 Integrated Management Information System (IMIS)

To identify affected industries and application groups for the PEA, OSHA initially reviewed the silica sampling results contained in OSHA's IMIS data (1979 through mid-2002). The IMIS data identified the sector for general industry, or the application group for construction, in which OSHA performed the monitoring. The IMIS data contain sampling results from compliance inspections conducted by both Federal and State OSHA plans. The IMIS dataset contains three separate files (two in one docket entry, one in another): IMIS sampling data from 5/1/1979 through 4/29/1998 and from 1/1/1998 through 5/1/2002 (Document ID 1698), and data from 2009 through April 2014 (Document ID 4185).

The IMIS report includes the job title of the worker sampled, but does not provide information on the worker's activities or on the presence of exposure controls. Furthermore, the IMIS data do not include the sample duration. Thus, while the IMIS system is useful as a management tool for identifying industries in which OSHA has monitored silica exposures, OSHA was unable to use IMIS samples in the exposure profiles unless they were part of a more detailed Special Emphasis Program report.

[2] Information on international exposure levels is occasionally offered for perspective or in discussion of control options.

2.2.3 OSHA Special Emphasis Program (SEP) Inspection Reports

The OSHA SEP inspection reports primarily include files from inspections conducted by OSHA compliance safety and health officers (CSHOs) between 1993 and 2000 that contain silica sample results. Under this national SEP, OSHA provided extensive outreach on hazard recognition and engineering control measures for crystalline silica, and conducted inspections at randomly selected workplaces where exposures to crystalline silica were possible due to such tasks as grinding, cutting, , drilling, chipping, or polishing on granite and other stone materials containing crystalline silica. The SEP inspection reports contain silica exposure samples that are also included in the IMIS system. However, these SEP reports include substantially more information about worker activities than is available through the IMIS reports, including working conditions, sample duration, and, in some cases, post-abatement follow-up results. OSHA relied heavily on information from the 191 OSHA SEP reports from 1993 to 2000, as referenced in the ERG contractor reports (Document ID 1365; 1431).

2.2.4 OSHA Information System (OIS)

For this FEA, OSHA has updated to the exposure profiles to include the more recent data from OSHA's OIS database. The OIS is an information management system that contains information related to OSHA compliance inspections, including the results of air samples taken by CSHOs to assess employee exposures. In 2011, OSHA began a phased transition during which the OIS system replaced the IMIS; this transition was completed by 2014. When compared with the older IMIS system, the OIS database has significantly increased OSHA's ability to store and retrieve more detailed information about the results of air sampling conducted to assess compliance with air contaminant standards. The OIS system includes more detailed information on the worksite and individual exposure samples. In addition to job title, the OIS includes supplemental information recorded by the CSHO during the inspection on sampling worksheets, including the sources of exposure, worker activities, type of tools in use, and the presence or absence of exposure controls. Therefore, OSHA considers the data contained in the OIS database to be the highest quality information for characterizing baseline exposure levels in the affected industries and application groups.

2) METHODOLOGY

The samples in the OIS database were collected during workplace inspections to assess compliance with the existing PEL, and therefore the measurements are specifically collected to represent 8-hour TWA exposures for enforcement purposes. These samples were all collected by CSHOs using the same sampling procedures (OSHA Method ID-142) and all samples were analyzed using the same validated analytical methods at the OSHA Salt Lake Technical Center laboratory. These samples were all collected between 2011 and 2014, and therefore are more representative of current workplace conditions than the samples in the PEA, which were collected mostly between 1990 and 2001.

The OIS samples used in the FEA include sample results with the IMIS substance codes 9010 (Silica Crystalline Quartz, Resp. Dust), 9015 (Silica, Crystalline Cristobalite Resp. Dust), and 9017 (Silica, Crystalline Tridymite, Respirable Dust). Only samples specifically designated as PBZ were used. As a quality control measure, only samples with units “milligrams per cubic meter” or “million particles per cubic foot” were retained to ensure consistency in units. Samples with an entry of CSHO as the job title were excluded, since these were presumed to be exposures measured on the CSHO rather than an employee.

OSHA reviewed the descriptive information on the establishment, job title, and work activity for each sample in the OIS in order to identify the industry sector and specific job category for the general industry samples, and the application group and activity for the construction industry samples. OSHA also determined, when possible based on the available information, whether any exposure controls were used during the sampling period.

OSHA examined 1,097 samples that were taken after the PEA was completed for possible inclusion in the FEA (see Document ID 3958, Attachment 1). Of these, OSHA had sufficient information to calculate a respirable crystalline silica concentration for 964 samples. A smaller subset of 699 samples from 322 inspections had sufficiently detailed information to clearly identify the industry sector and job category. These samples are included in the final exposure profiles, in addition to the more recent data provided by commenters. Appendix 1 of this chapter includes a complete list of the samples from the

OIS database used in this analysis, sorted by the industry sector or application group that was assigned to the sample by OSHA during its review of the OIS database.

Summaries of the OIS silica data used in the FEA for general industry, maritime, and construction appear in Tables IV.2-B and IV.2-C. For general industry, the OIS data contains 592 samples taken during 266 inspections, including 29 samples taken during abrasive blasting operations. Among the 563 samples from general industry (not including abrasive blasting), 18 percent exceed the preceding general industry PEL for respirable dust containing crystalline silica, and 24 percent exceed the new PEL for respirable crystalline silica of 50 $\mu g/m^3$. Thus, 6 percent of OIS general industry samples (other than abrasive blasting) are between the preceding PEL and the new PEL.

Because the exposures measured during abrasive blasting operations are substantially higher than other OIS samples, the samples for abrasive blasting are summarized separately. There were 29 samples taken during abrasive blasting in general industry, of which 41 percent exceed the preceding PEL and 52 percent exceed the final PEL. The comparable OIS data for abrasive blasting in construction, where most abrasive blasting occurs, show, 67 percent (8 out of 12 samples) exceeding both the preceding and final PEL.

For the construction industry, the OIS database contains the results of 107 samples taken during 56 inspections. Among the 95 sample results other than abrasive blasting, 36 percent exceed the preceding PEL for construction, and 46 percent exceed the new PEL of 50 $\mu g/m^3$. Thus, 10 percent of OIS construction samples are below the preceding PEL but above the new PEL

The results of the OIS samples not added to the exposure profiles are presented in Table IV.2-D. These are the samples for which a silica concentration could be calculated, but the sampling information could not be matched to a specific general industry sector and job category or construction application group. Thus, OSHA could not use them in the final exposure profiles. These sample results (n=265) were, on average, lower than the results of the OIS values that were added to the profiles. For general industry other than abrasive blasting, 16 percent of the samples exceed the final PEL, compared with 24 percent of the samples that were added to the profiles. For construction, 25 percent exceed the final PEL compared with 46 percent of the samples that were added to the profile. The set of OIS samples not used in the exposure profiles also had a lower average percent silica content of 5.4 percent, compared with 7.9 percent for the samples added to the profile.

The construction industry expressed concerns regarding the large variability in the silica content of different building types of building materials (Document ID 2329, p. 31). In response, OSHA analyzed the distribution of silica content in the OIS samples. The average silica content of the OIS samples was 7.8 percent for the general industry samples and 7.9 percent for the construction samples. The distribution in the percent silica content of the respirable dust samples included in the OIS database is presented in Table IV.2-E. A silica content of less than 10 percent was detected in 71 percent of the samples from general industry, and 65 percent of samples from construction. A silica content of less than 25 percent was detected in 91 percent of the samples from general industry and 94 percent of the samples from construction. Thus, the OIS data include samples with a range of silica content, with over 90 percent of the samples containing less than 25 percent silica.

Table IV.2-B Summary of OIS Samples for General Industry and Maritime						
General Industry Sector	**N**	**Average Respirable Dust (mg/m³)**	**Average % Silica Content of Dust**	**Average Silica Conc. (μg/m³)**	**Percentage of Samples Exceeding Preceding PEL**	**Percentage of Samples Exceeding Final PEL**
Structural Clay	3	1.313	9.7%	175.3	33%	67%
Hydraulic Fracturing	30	0.371	22.8%	115.2	47%	57%
Glass Products	2	0.195	19.5%	76.2	50%	50%
Cut Stone	137	1.021	11.0%	160.3	27%	37%
Foundries - Ferrous	101	1.118	6.1%	83.2	23%	35%
Pottery	7	0.881	5.6%	59.2	14%	29%
Foundries - Captive	40	0.665	9.0%	119.1	15%	25%
Paint and Coatings	5	0.440	23.4%	64.4	20%	20%
Ready-Mix Concrete	12	1.040	2.6%	33.0	17%	17%
Foundries - Non-sand Casting	27	1.748	1.9%	53.0	15%	11%
Foundries - Nonferrous	77	0.366	4.3%	20.9	3%	8%
Refractories	12	1.291	4.8%	28.4	17%	8%
Concrete Products	73	0.940	4.0%	28.6	10%	7%
Mineral Processing	21	0.238	9.2%	21.6	0%	5%
Dental Equipment	2	0.072	0.05%	12.0	0%	0%
Dental Laboratories	5	0.089	11.4%	19.3	0%	0%
Engineered Stone	3	0.347	0.0%	12.0	0%	0%
Jewelry	3	0.490	0.0%	12.0	0%	0%
Landscaping Services	2	0.505	1.0%	14.6	0%	0%
Refractory Repair	1	2.300	0.0%	12.0	0%	0%
Subtotal	**563**	**0.864**	**7.8%**	**82.7**	**18%**	**24%**
Abrasive Blasting – General Industry						
Concrete Products	2	0.870	28.5%	301.6	50%	100%
Cut Stone	3	1.845	2.4%	64.1	33%	33%
Foundries - Captive	5	3.118	4.5%	328.6	40%	40%
Foundries - Ferrous	10	1.355	7.8%	92.1	50%	70%
Foundries - Nonferrous	2	0.240	4.5%	27.4	0%	0%
Foundries - Non-sand Casting	4	1.401	9.3%	160.0	50%	50%
Hydraulic Fracturing	1	0.420	27.0%	113.4	100%	100%
Shipyards	2	1.550	0.0%	12.0	0%	0%
Subtotal	**29**	**1.587**	**8.2%**	**144.6**	**41%**	**52%**
Grand Total	**592**	**0.900**	**7.8%**	**85.7**	**19%**	**26%**

Table IV.2-C
Summary of OIS Data for Construction

Construction Application Group	N	Average Respirable Dust (mg/m³)	Average % Silica Content of Dust	Average Resp. Crystalline Silica (μg/m³)	Percentage of Samples Exceeding Preceding PEL	Percentage of Samples Exceeding Final PEL
Demolition Workers Using Jackhammers	35	2.215	7.8%	221.9	57%	60%
Tuckpointers and Grinders	30	3.172	9.7%	314.4	30%	57%
Hole Drillers Using Hand-Held Drills	4	1.093	1.0%	41.0	25%	25%
Masonry Cutters Using Portable Saws	12	1.401	4.4%	41.4	25%	25%
Millers Using Portable or Mobile Machines	8	0.279	6.9%	81.0	13%	25%
Heavy Equipment Operators	3	0.452	7.6%	34.9	0%	0%
Masonry Cutters Using Stationary Saws	2	0.220	13.5%	29.4	0%	0%
Rock and Concrete Drillers	1	0.110	0.0%	12.0	0%	0%
Subtotal	**95**	**2.084**	**7.7%**	**196.7**	**36%**	**46%**
Abrasive Blasters – Construction	12	9.105	10.1%	1983.0	67%	67%
Grand Total	**107**	**2.872**	**7.9%**	**397.0**	**39%**	**49%**

Table IV.2-D
Summary of OIS Samples Not Included in Exposure Profiles

Sector / Application Group	N	Average Respirable Dust (mg/m³)	Average % Silica Content of Dust	Average Resp. Crystalline Silica (μg/m³)	Percentage of Samples Exceeding Preceding PEL	Percentage of Samples Exceeding Final PEL
General Industry	161	0.594	4.7%	28.8	11%	16%
General Industry - Abrasive Blasting	44	7.198	11.3%	955.3	45%	50%
Construction	60	1.421	3.1%	50.0	17%	25%
Grand Total	**265**	**1.878**	**5.4%**	**187.5**	**18%**	**24%**

Table IV.2-E Distribution of OIS Samples by Percent Silica Content				
	General Industry		**Construction**	
Percent Silica Content	**Count**	**% of Samples**	**Count**	**% of Samples**
<1	265	44.8%	36	33.6%
1-4	74	12.5%	12	11.2%
5-9	82	13.9%	22	20.6%
10-14	69	11.7%	18	16.8%
15-24	48	8.1%	13	12.1%
25-49	42	7.1%	5	4.7%
>=50	12	2.0%	1	0.9%
Total	**592**		**107**	

2.3 CALCULATION OF RESPIRABLE CRYSTALLINE SILICA EXPOSURES

In order to compare baseline exposures in the FEA to OSHA's final PEL for respirable silica, OSHA had to ensure that all exposure results were presented in the same units as the final PEL (i.e., micrograms per cubic meter of air or $\mu g/m^3$). Where the data included exposures to respirable crystalline silica in $\mu g/m^3$, OSHA used these values directly. However, most exposure values were not expressed in $\mu g/m^3$. This is because the preceding PEL for general industry was based on the air concentration of respirable dust (including but not limited to silica) expressed in units of milligrams per cubic meter of air (mg/m^3). Therefore, the results of samples in the SEP reports and the OIS database, which were taken to assess compliance with the previous PELs, were reported as the air concentration of respirable dust in units of milligrams per cubic meter of air rather than as the concentration of respirable crystalline silica.

In order for OSHA to use these results in the FEA, the air sampling results for respirable dust reported in units of mg/m^3 were converted to the equivalent respirable crystalline silica dust concentrations in units of $\mu g/m^3$. This was a two-step process. OSHA first multiplied the respirable dust concentration by the percent silica content (as reported in the sample or calculated from the reported PEL) for that sample to convert the respirable dust concentration into the respirable silica dust concentration. This value was then multiplied by 1,000 to convert from mg/m^3 to $\mu g/m^3$ to be consistent with the units for the final PEL.

In most cases, the sampling result did not report the percent silica content but rather reported the calculated PEL for silica (a level that fluctuates depending on the percentage of silica in the dust sample), from which the percent silica content could be derived. For general industry, the preceding PEL for respirable dust containing crystalline silica was calculated from the formula:

PEL = 10 ÷ (% silica + 2) (in mg/m^3);

where % silica refers to the percent silica content of the dust.

Therefore, when the PEL was provided with a sample result, OSHA calculated the percent silica content using the formula:

% silica = (10-2*PEL) ÷ PEL.

The reported respirable dust concentration was than multiplied by the percent silica content to obtain the respirable silica dust concentration, as described above (i.e., by multiplying the concentration expressed in milligrams by 1,000).

Similar to general industry, the sampling results from construction and maritime were most often reported as respirable dust concentrations. However, the concentrations were presented in units of either mg/m^3 or, in some cases, millions of particles per cubic foot of air (mppcf), for comparison with OSHA's previous PELs for the construction and maritime industry. For construction, the preceding PEL in mppcf for dust containing respirable crystalline silica was calculated using the formula:

PEL = 250 ÷ (% silica + 5) (in mppcf)

When the sample result was presented in mppcf, OSHA calculated the silica content using the formula:

% silica = (250 -5*PEL) ÷ PEL.

When the sample result was presented in mg/m^3, OSHA calculated the silica content using the formula:

% silica = (25 – 5*PEL) ÷ PEL

The reported respirable dust concentration was then multiplied by the percent silica content to calculate the respirable silica dust concentration and then by 1000 to convert to units of µg/m^3.

For SEP reports in which the original laboratory results were available, the silica concentration was calculated directly from the reported mass of silica detected on the filter in units of micrograms (µg), divided by the air volume sampled in units of cubic meters (m^3), for a result expressed in µg/m^3.

Finally, when the sample duration was less than 8 hours or multiple samples were taken on one worker during a shift, OSHA calculated the 8-hour time-weighted average using the equation contained in 29 CFR 1910.1000(d)(1)(i), which is: $(C_1*T_1 + C_2*T_2…+C_nT_n)$ ÷ 480; where C_n is the concentration for a single sample taken for time T_n in minutes.

2.3.1 Limits of Detection for Silica Data

When sample results were reported as "non-detect" or as a value of "0", this was interpreted to mean the sample result was less than the limit of detection (LOD) of the analytical method. The LOD for an analytical method refers to the smallest mass of silica that can be detected on the filter used to collect the air sample. Many laboratories currently report a LOD of 10 µg or lower for quartz samples (Document ID 0666) (see Section IV-3 – Feasibility of Measuring Respirable Crystalline Silica Exposures at the Final Rule's PEL and Action Level). For the results reported as non-detects in the PEA, OSHA calculated the maximum silica concentration that could be detected for that sample volume based on the analytical LOD. The maximum silica concentration was calculated by dividing the analytical LOD by the volume of air sampled (measured in cubic meters). For example, if the analytical LOD is 10 µg and the air volume sampled is 816 liters (0.816 m^3), the maximum silica concentration for a sample reported as a non-detect would be calculated as 10 µg/0.816 m^3 or about 12 µg/m^3.

For respirable dust samples obtained with a nylon cyclone at a fixed flow rate of 1.7 liters per minute (lpm), a shorter sampling period will result in a smaller volume of air sampled, so that a sample collected over a shorter period with a result below the analytical LOD will result in a higher calculated detection limit than a sample collected at the same flow rate over a longer period. Two results obtained on the same date at the same location, but involving different sample durations, will have different maximum silica concentrations. Table IV.2-F displays the maximum silica concentrations for silica samples analyzed using a method with an analytical LOD of 10 µg for sample durations ranging from 30 minutes to 480 minutes. The maximum silica concentration for a 120-minute air sample is 49 µg/m^3, which means that if a sample with a duration of 120 minutes is reported as a non-detect, the silica concentration must be less than 49 µg/m^3. For 480-minute samples, the maximum silica concentration for samples with no detectable silica is 12 µg/m^3.

Table IV.2-F
Maximum Silica Concentrations for Silica Results Reported as Non-Detected, Obtained Using a Method With an Analytical LOD of 10 µg

Sample Duration*	Air Volume Sampled	Maximum Silica Concentration
480 minutes (8 hours)	816 Liters (0.816 m^3)	12 µg/m^3
360 minutes (6 hours)	612 Liters (0.612 m^3)	16 µg/m^3
240 minutes (4 hours)	408 Liters (0.408 m^3)	24 µg/m^3
120 minutes (2 hours)	204 Liters (0.204 m^3)	49 µg/m^3
30 minutes (½ hour)	51 Liters (0.051 m^3)	196 µg/m^3

* Also assumes that the air sample was obtained at 1.7 lpm, the rate used for a standard nylon cyclone.

For non-detect values in the exposure profiles from the PEA, OSHA calculated the maximum silica concentration based on the analytical LOD and air volume sampled, as discussed above. These values have not been changed for the FEA. For the OIS data, which are presented as 8-hour TWAs, OSHA assigned a value of 12 µg/m^3 (the maximum silica concentration for an 8-hour sample) to all results that were reported as "0" (i.e., non-detect) regardless of the sample duration. For construction samples reported as non-detect, the maximum silica concentrations for partial shift samples were converted to corresponding 8-hour TWAs. For example, a 120-minute sample reported as non-detect has a maximum concentration of 49 µg/m^3 which, when multiplied by 120/480 minutes, corresponds to an 8-hour TWA of 12 µg/m^3. When discussing individual PBZ samples in which silica was not detected, OSHA typically includes a parenthetical notation (e.g., "(LOD)") indicating that the reported value (e.g., 12 µg/m^3) is based on a calculated silica concentration. Using the maximum silica concentration value for samples reported as non-detects slightly overestimates exposure levels because the actual exposures will always be less than the maximum silica concentration calculated under the LOD formula.

For general industry and maritime, OSHA relied primarily on sampling results having a duration of 360 minutes or greater. Because the maximum silica concentration for samples taken over at least 360 minutes is 16 μg/m^3, relying on samples of greater than 360 minutes minimized the number of results reported as LOD. For the construction industry, where task-based sampling is sometimes the most practical option, OSHA relied primarily on samples having a duration of 120 minutes or greater, for which the maximum silica concentration is 49 μg/m^3 (or 12 μg/m^3 as a 8-hour TWA). As a result of the practices described above, the values assigned to results below the LOD have only a limited impact on the technological feasibility analysis.

2.4 METHODS TO ASSESS FEASIBILITY OF CONTROL TECHNOLOGY

2.4.1 Feasibility of Control Technology

OSHA's technological feasibility analysis considers maritime (shipyards) to be 1 sector, and divides general industry into 21 sectors and the construction industry into 12 application groups. The basic division between general industry/maritime and construction is done for analytical, purposes in this FEA, it is not relevant to future enforcement practices; thus, it is possible that a sector is classified as general industry but performs some construction tasks that are covered by the standard for construction. In this respect, OSHA notes in particular that the railroad industry is one of the general industry sectors analyzed even though the primary operations within that industry that expose its employees to respirable crystalline silica (ballast dumping, associated heavy equipment operations) are construction activities (specifically, the use of heavy equipment under Table 1 of the standard for construction).

<u>Sector Analysis for General Industry and Maritime</u>

The technological feasibility analyses for general industry and maritime workplaces are grouped by industry sector based primarily on the NAICS classifications. If the sample description clearly showed that the worker’s activity is not typical of the sector, but is typical of another, the sample was in some cases assigned to a different sector based on the description of the worker’s activity, materials, or work area. Within each sector, data are further divided into job categories representing groups of workers using similar materials, work processes, equipment, and available exposure control methods. OSHA notes that these job categories are intended to represent job functions (some of which involve more than one activity); actual job titles and responsibilities might differ depending on the facility. OSHA recognizes that many other job categories exist in these sectors, but those job categories are not associated with substantial direct silica exposure and are not included in the analyses. For general industry, all samples with sufficient information to categorize the industry and job category or activity were assigned to a job category in the industry. Consequently, the exposure profiles include the job categories for which monitoring data were available, and does not include any job category for which there were no samples from that industry or from an industry performing closely analogous operations or processes. In other words, the exposure profiles only include job categories for which monitoring data were available and does not include jobs for which there was no monitoring data. The absence of any sampling data was considered by OSHA to be indicative of the absence of substantial exposures above the LOD for any job categories not included in the exposure profiles.

Application Group Analysis for Construction Industry

OSHA determined that the best method for analyzing silica exposure levels in the construction industry was to group workers by application group, with the term application group referring to a specific construction activity or task (e.g., sawing, drilling, crushing rock). By discussing individual construction industry activities, which sometimes involve more than one job function (e.g., operators and helpers), OSHA can apply the exposure profile and exposure control methods for these activities to workers who perform these activities in any segment of the construction industry. Collectively, the 12 application groups analyzed encompass the common construction tasks with substantial silica exposure, identified based primarily on compliance sampling data.

Coverage of Abrasive Blasting

As previously noted, certain activities are common to construction and some segments of general industry. Abrasive blasting is an activity that occurs in construction and across several general industry sectors, either as a routine part of the production process, or as an infrequent activity not directly related to the core business. In the FEA, abrasive blasting is included as a specific application group within the construction industry (Section IV-5.1). However, OSHA also evaluated abrasive blasting in general industry based on how abrasive blasting was used in that particular industry sector. In four general industry sectors (concrete products, cut stone, foundries, and shipyards), OSHA had sampling data for abrasive blasters and therefore included abrasive blasting as a job category. In these sectors, abrasive blasting is an integral part of the industry and the samples collected by OSHA were used in the overall exposure profile for that sector. Two other general industry technological feasibility analyses (for dental laboratories and jewelry), discuss abrasive blasting, but do not include sampling data in the exposure profile because abrasive blasting is typically carried out sporadically across the industry and then only in small-scale operations involving self-contained abrasive blasting cabinets. OSHA has also identified 44 abrasive blasting samples from other general industry sectors not covered in the FEA, but this activity more closely resembles the work described in the construction application group for abrasive blasting. Abrasive blasters in these sectors may need respiratory protection if the exposure assessments required by the standard for general industry and maritime show exposures above the PEL even with the use of available engineering and work practice controls.

Treatment of Railroads

The railroad industry is grouped with other general industry sectors for purposes of OSHA's feasibility analysis in this rulemaking, even though the railroad activities that can cause silica exposures are related to track work covered by OSHA's construction standard. The core business of this industry, operating railroads, is not construction and railroads are usually grouped with other employers in general industry for purposes of economic analysis; economic impacts on the railroad industry are traditionally distinct from economic impacts on the "construction industry." The grouping for this analysis has a distinct purpose from OSHA's enforcement policies and thus has no impact on enforcement: OSHA intends to enforce the construction standard with respect to the silica exposures that it has identified as resulting from track work.

2.4.2 Data Handling for General Industry and Maritime

When compiling the sampling data used in the exposure profiles for general industry and maritime (shipyards), OSHA relied primarily on full-shift samples with a duration of 360 minutes or longer. By using this criterion, OSHA ensured that the samples included in the analysis were collected for at least three-quarters of a typical 8-hour shift and therefore captured most if not all activities involving exposure to silica at which the worker spends a substantial amount of time (Document ID 0845, pp. 38-40). Due to the routine nature of most job activities in general industry, OSHA assumed constant exposure during the unsampled time. OSHA considers the 6-hour (360-minute) minimum sampling requirement to be a reasonable criterion for including a sample and characterizing it as "full-shift" because it limits the extent of uncertainty about general industry/maritime workers' true exposures, as no more than 25 percent of an 8-hour shift would be unsampled.

Sampling durations of 6 hours or more have less uncertainty related to maximum concentrations for samples reported as non-detects. As noted previously in the discussion of LODs, when using a nylon cyclone operated at a flow rate of 1.7 lpm, a sample with a duration of 360 minutes that is reported as a non-detect means maximum silica concentration is 16 μg/m^3. At the other end of the range, a sample taken for only 30 minutes with a reported result of "0" or "non-detect" will have a maximum silica concentration of 196 μg/m^3 (see Table IV.2-F**)**. Using the maximum silica concentration for such a sample would indicate only that the result is somewhere between 0 μg/m^3 and 196 μg/m^3, a range too large to provide meaningful information for OSHA's feasibility analysis. Thus, relying primarily on samples with a duration of 360 minutes or greater allows OSHA to draw the conclusion that any sample results reported as non-detect are below 16 μg/m^3, and well below the action level of 25 μg/m^3. This also applies to the 480-minute (full-shift) samples reported as non-detects, for which OSHA assigned a value of 12 μg/m^3.

Other than for abrasive blasting, the sampling results for the maritime industry (i.e., shipyards for purposes of this rule) have been handled in the same manner as data for general industry. For abrasive blasting in the maritime industry, OSHA concluded that this activity was similar to abrasive blasting in construction and OSHA, therefore, as explained below, assumed zero exposure during the period not sampled.

2.4.3 Data Handling for Construction

Construction workers can perform a variety of different tasks that generate respirable crystalline silica. They also perform these tasks for varying amounts of time, depending on the job. Some workers may only occasionally perform one of the construction industry tasks discussed in this technological feasibility analysis; others may perform the task daily, but for only a portion of their shift. Other workers spend their entire shifts intermittently performing the same task or a mix of several of these dusty tasks. Some construction workers more often perform tasks that continue uninterrupted over an entire work shift (e.g., heavy equipment operator). However, these workers often spend some portion of their shifts in transit between job sites, setting up or preparing to depart a site, or waiting for another construction trade to complete an activity (Document ID 0676).

The sampling results in the exposure profiles include a wide variety of construction site working conditions and worker activity patterns. The sampling results include both shorter-duration task-based samples and sampling over more extended periods, including results obtained over entire 8-hour work shifts. Furthermore, a portion of the sample results available to OSHA cover periods when the workers performed multiple activities, sometimes involving more than one of the tasks analyzed here by OSHA. For the purposes of this analysis, however, any sample collected over a period when the worker performed multiple activities was assigned to the specific construction task judged likely to have had the greatest influence on the worker's silica exposure level.

Because of the variation in the duration of the sampled exposures within the construction industry, OSHA, while relying on samples of 120 minutes or more (compared to 360 minutes or more for general industry/maritime), standardized the exposure levels to 8-hour TWAs by assuming, in general, that the sampled period in construction encompassed all of the workers' silica exposure. Thus, in calculating the 8-hour TWAs for construction tasks, OSHA assumed zero exposure to respirable crystalline silica for the unsampled portion of the shift. Among the 881 samples in the construction profiles, the sample durations exceeded 240 minutes in 70 percent of the samples, and exceeded 120 minutes in 89 percent of the samples (Table IV.2-G).

The only exception to this approach was made in cases where information associated with an exposure result clearly indicates that, although only a portion of the shift was sampled, the same exposure continued for the entire shift. In those cases, OSHA, relying upon the judgment of the CSHO who obtained the sample, calculated the 8-hour TWA assuming that exposure continued at the same concentration over the unsampled portion of the shift. When sampling duration was longer than 8 hours, the result was used to represent the 8-hour TWA.

CISC objected to using an assumption of zero exposure for the unsampled portion of the work shift when calculating 8-hour TWAs for the construction exposure profiles (Document ID 2319, pp. 21-25). It claimed this underestimated TWA exposure levels when compared with the alternative assumption that the exposure level measured during the sampled time period continued at the same exposure level during the unsampled period, as was done for general industry. CISC argued that, without further information about workers' activities after sampling ceased, OSHA's zero-exposure assumption cannot be supported (Document 2319, p. 21).

OSHA disagrees with CISC because of the widely-recognized differences in work patterns between general industry and construction operations. In general industry, most operations are at a fixed location and involve manufacturing processes that remain relatively constant over a work shift. Construction, however, is much more variable with respect to the location of the work site and the duration of tasks performed. Tasks that generate exposure to respirable crystalline silica are often performed on an intermittent basis (e.g., Document ID 0677). OSHA concludes that the variability in sample durations for the samples taken by OSHA in the construction industry more closely and accurately reflects the actual variability observed in the duration of tasks than would an assumption of continued, constant exposure. Further, as stated above, where OSHA had information indicating that silica exposure continued after the sampling stopped, OSHA adjusted the TWA for that sample accordingly.

For the construction samples, OSHA assumed no additional exposure during the unsampled period because this is consistent with the approach used for calculating 8-hour TWA for assessing compliance with the PEL. When CSHOs collect partial shift samples for comparison with a PEL, they calculate 8-hour TWA exposures using the assumption that no further exposure occurred during the unsampled period.

Support for the approach used by OSHA to calculate TWA exposures based on partial shift samples is provided by Flanagan et al. (2003), who reported the average percentage of time a worker performed dust generating tasks during the period sampled based on a large database of exposure samples from a variety of construction sites. The authors report that air sampling was conducted for the entire period of time during a work shift that a worker was engaged in a dust-generating task, and also included the time required to perform other activities such as set-up, clean-up, and other tasks in support of the task being monitored (Document ID 0676, p. 320). Based on worksite observations, they reported the percentage of time during the sampling period that the dust-generating task was performed was 31 percent for concrete cutting, 40 percent for surface grinding, and 51 percent for demolition with handheld power tools (Document ID 0676, p. 323). When applied to a 480-minute shift, these percentages result in average task durations, for the dust-generating tasks, ranging from 150 to 240 minutes. In comparison, among the 881 samples in the construction profiles, the sample durations exceeded 240 minutes in 70 percent of the samples, and exceeded 120 minutes in 89 percent of the samples (Table IV.2-G). Thus, the partial shift samples included in the construction exposure profile were of sufficient duration to include the entire portion of a work shift that a dust generating task is typically performed.

Table IV.2-G Distribution of Sampling Durations for Sample Results in FEA Exposure Profiles			
Construction			
	Duration (minutes)	**Count**	**Percent**
	120 or fewer	93	10.6%
	121-240	172	19.5%
	241-360	241	27.4%
	361 or more	375	42.6%
	Total	**881**	
General Industry			
	Duration (minutes)	**Count**	**Percent**
	120 or fewer	47	1.9%
	121-240	41	1.7%
	241-360	97	3.9%
	361 or more	2,298	92.5%
	Total	**2,483**	
Note: OSHA submitted to the rulemaking record a database of all samples used in the FEA exposure profiles.			

Information based on research at construction sites provided by the Building and Construction and Trades Department (BCTD) of the AFL-CIO, further describes the intermittent patterns of exposure when performing silica-generating tasks. The Center to Protect Workers' Rights developed a task-based exposure assessment model for the construction industry, which combines air sampling with task observations and task durations in order to assess construction workers' exposure to workplace hazards (Susi et al., 2000, Document ID 4073, Attachment 8c). This model, when applied to masonry jobsites, found that workers spent much of their shifts performing non-silica-generating tasks, both before and after the task involving silica exposure (Document ID 4223, p. 16; 4073, Attachment 3a, pp. 1-2). BCTD indicated that it was reasonable to assume these types of work patterns would be similar for other construction tasks. BCTD supported OSHA's assumptions on work patterns, stating "OSHA correctly treated the unsampled time as having 'zero exposure' in its technological feasibility assessment" (Document ID 4223, pp. 16-17).

Thus, the distribution of the durations of the samples used to develop the exposure profiles for construction tasks reflects the intermittent work patterns of construction workers performing these silica-generating tasks, and supports the assumption, relied upon in calculating the 8-hour TWA exposures for the exposure profile, that no additional exposure occurred during the unsampled portions of these work shifts.

2.4.4 Respirable Dust Properties and Use in Evaluating Control Options

In evaluating available control technologies, OSHA has considered studies of ventilation and water applications as methods for suppressing silica dust. In some cases, these researchers reported reductions in respirable dust rather than just respirable silica dust. Respirable crystalline silica particles comprise only a portion of the respirable dust in a worker's breathing zone. The remainder of the respirable dust is composed of other minerals and other types of fine particles (Document ID 0787, p. 590). When sampling for respirable dust, silica and other particles of respirable size are separated from larger particles based on aerodynamic properties. Size-selective samplers for respirable dust particles operate on the principle that the collected particles have similar aerodynamic properties and therefore have similar collection efficiencies when sampled in air. Based on this principle, OSHA concludes that the results of ventilation control measure testing, which evaluates capture of airborne respirable dust particles, will be equally applicable to the respirable silica component of respirable dust as to all other components of the dust (Document ID 3883, p. 3-2).

Researchers from Canada published a report that evaluated the effectiveness of dust control methods for reducing occupational exposures to crystalline silica at construction sites (Document ID 2287, p. iii). They reviewed studies that included both wet methods (i.e., 'spraying'), and LEV used with more than ten tools, on a variety of materials, including soil, concrete, brick, block, and joint compound (Document ID 2287, pp. 29-30). The exposure reduction using respirable dust measurements ranged from 12 percent to greater than 99 percent, and for respirable quartz measurements, exposure reductions ranged from 0 to 98 percent (Document ID 2287, pp. 29-30). The researchers observed similar percent reductions in both the respirable dust and respirable silica dust concentrations (Document ID 2287, p. 34). Respirable silica is a component of respirable dust, and therefore, OSHA concludes that reductions in respirable dust concentrations result in corresponding reductions in respirable crystalline silica concentrations.

In addition, OSHA finds that there is considerable evidence that water spray droplet size is a primary factor in the efficiency of water sprays used to control dust. The most effective spray uses a droplet size similar to the size particles that the spray is intended to control (Spray Systems, Document ID 1152). Therefore, studies of wet dust control methods applied to respirable dust will be similarly applicable to the silica portion of respirable dust.

Use of Surrogate Data

In the few instances when exposure information from a specific job category or sector was not available, OSHA based that portion of the exposure profile on “surrogate” data from one or more similar job categories in related industries. The surrogate data were selected based on strong similarities in raw materials (e.g., source of silica, percent silica, particle size), equipment, worker activities, and exposure duration in the job categories. Although other factors may differentiate the industries, the individual job categories were determined by OSHA to be sufficiently similar to represent baseline conditions in that sector or job category. When used, OSHA has clearly identified the surrogate data and the relationship between the industries or job categories. Similarly, in some cases, exposure control information from one industry was used as an example why another industry with similar process/materials/exposures should be able to achieve similar exposure results using the same methods.

Use of Short-Term Sampling Results

Short-term samples are defined by OSHA, for purposes of this technological feasibility analysis, as samples of less than 120 minutes in duration. The sample results used in the exposure profiles are representative of 8-hour TWAs; and most of them are samples of between 360 and 480 minutes. Only 2% of samples used in the exposure profiles for general industry and 10% of the samples for construction had sample durations of less than 120 minutes.

Some short-term samples taken during experimental studies were considered for the purpose of investigating the efficiency of dust controls when developing its technological feasibility analysis, but OSHA did not include these samples in the exposure profiles, which include only samples used to estimate 8-hour TWA exposures. Short-term samples can provide important information about the effectiveness of controls. Short-term samples also permit multiple trials of controlled and uncontrolled activities. In studies of this nature, investigators measure intensive periods of an activity (such as concrete sawing), without pauses in the process or supplemental activities that can complicate comparisons of airborne dust during controlled and uncontrolled conditions. Results of brief samples, even just a few minutes in duration, can provide useful comparative information, and OSHA considers these experimental results in the discussion of additional controls for specific groups of workers (e.g., Document ID 1142).

2.5 DISCLAIMER

References to specific commercial products or manufacturers in this technological feasibility analysis are included for reference or informational purposes only, and do not constitute endorsements by OSHA of such products or manufacturers.

3. FEASIBILITY OF MEASURING RESPIRABLE CRYSTALLINE SILICA EXPOSURES AT THE FINAL RULE'S PEL AND ACTION LEVEL

As explained in Pertinent Legal Authority (Section II of the preamble to the final rule), a finding that a standard is technologically feasible requires that "provisions such as exposure measurement requirements must also be technologically feasible" (see *Forging Indust. Ass'n v. Sec'y of Labor*, 773 F.2d 1436, 1453 (4th Cir. 1985), Thus, part of OSHA's technological feasibility assessment of a new or revised health standard includes examining whether available methods for measuring worker exposures have sufficient sensitivity and precision to ensure that employers can evaluate compliance with the standard and that workers have an accurate information regarding their exposure to hazardous substances. Consistent with the Supreme Court's definition of "feasibility", OSHA finds that it is feasible to measure worker exposures to a hazardous substance if achieving a reasonable degree of sensitivity and precision with sampling and analytical methods is "capable of being done" (*Am. Textile Mfrs. Inst., Inc. v. Donovan*, 452 U.S. 490, 509-510 (1981)). OSHA also notes that its analysis of the technological feasibility of the sampling and analysis of respirable crystalline silica must be performed in recognition of the fact that, as recognized by federal courts of appeals, measurement error is inherent to sampling (*Nat'l Min. Assoc. v. Sec'y, U.S. Dep't of Labor*, Nos. 14–11942, 14–12163, slip op. at 55 (11th Cir. Jan. 25, 2016); *Am. Mining Cong. v. Marshall*, 671 F.2d 1251, 1256 (10th Cir. 1982)). "Since there is no perfect sampling method, the Secretary has discretion to adopt any sampling method that approximates exposure with reasonable accuracy." *Am. Mining Cong. v. Marshall*, 671 F.2d at 1256.

Since the late 1960s, exposures to respirable crystalline silica (hereinafter referred to as "silica") have typically been measured using personal respirable dust samplers coupled with laboratory analysis of the crystalline silica content of the collected airborne dust. The laboratory analysis is usually performed using X-ray diffraction (XRD) or infrared spectroscopy (IR). A colorimetric method of analysis that was used by a few laboratories has now been phased out (Harper et al., 2014, Document ID 3998, Attachment 8, p. 1). OSHA has successfully used XRD analysis since the early 1970s to enforce its previous PELs for crystalline silica, which, for general industry, were approximately equivalent to 100 micrograms per cubic meter ($\mu g/m^3$) for quartz and 50 $\mu g/m^3$ for cristobalite and tridymite (and within the range of about 250 µg/m^3 to 500 µg/m^3 for quartz in construction). There are no other generally accepted methods for measuring worker exposure to respirable crystalline silica.

The ability of current sampling and analytical methods to accurately measure worker exposures to respirable crystalline silica was a subject of much comment in the rulemaking record. In particular, the Chamber of Commerce (Chamber) and American Chemistry Council (ACC) submitted comments and testimony maintaining that existing methods do not measure respirable crystalline silica exposures with sufficient accuracy to support OSHA's proposal in the Notice of Proposed Rulemaking to reduce the PEL to 50 µg/m^3 and establish the 25 µg/m^3 action level (Document ID 2285; 2288, pp. 17-21; 2307, Attachment A, pp. 198-227; 4209, pp. 129-155; 3436, p. 8; 3456, pp. 18-19; 3460; 3461; 3462; 4194, pp. 17-21). Similar views were expressed by several other rulemaking participants (e.g., Document ID 2056, p. 1; 2085, p. 3; 2174; 2185, pp. 5-6; 2195, Attachment 1, p. 37; 2276, pp. 4-5; 2317, p. 2; 2379, Comments, pp. 28-30; 4224, pp. 11-14; 4232, Attachment 1, pp. 3-24). Specifically, these commenters argue that, due to several asserted sources of error, current sampling and analytical methods do not meet the NIOSH accuracy criterion of ± 25 percent (NIOSH Manual of Analytical Methods, http://www.cdc.gov/niosh/docs/95-117/). Their arguments include: (1) that there is sampling error attributed to bias against the particle-size selection criteria that defines the performance of the samplers and variation in performance between sampling devices; (2) that the accuracy and precision of the analytical method at the low levels of silica that would be collected at the revised PEL and action level is less than that in the range of the previous PELs for silica, particularly in the presence of interfering substances; and (3) variation between laboratories analyzing comparable samples adds an unacceptable degree of uncertainty. After considering all of the testimony and evidence in the record, OSHA rejects these arguments and, as discussed below, concludes that it is feasible to obtain measurements of respirable crystalline silica at the final rule's PEL and action level with reasonable accuracy.

OSHA is basing its conclusions on the following findings, which are described in detail in this section. First, although there is variation in the performance of respirable dust samplers, studies have demonstrated that, for the majority of work settings, samplers will perform with an acceptable level of bias (as defined by international standards) as measured against internationally recognized particle-size selection criteria that define respirable dust samplers. This means that the respirable dust mass collected by the sampler will be reasonably close to the mass that would be collected by an ideal sampler that exactly matches the particle-size selection criteria. In addition, OSHA finds that the measure of precision of the analytical methods for samples collected at crystalline silica concentrations equal to the revised PEL and action level is only somewhat higher (i.e., somewhat less precise) than that for samples collected at concentrations equal to the previous, higher PELs. Further, the analytical methods can account for interferences such that, with few exceptions, the sensitivity and precision of the method are not significantly compromised. Studies of measurement variability between laboratories, as determined by proficiency testing, have demonstrated a significant decline in inter-laboratory variability in recent years. Improvements in inter-laboratory variability have been attributed to changes in proficiency test procedures as well as greater standardization of analytical procedures among laboratories. Finally, although measurement variability increases at low sample loads compared to sample loads in the range of the former PELs, OSHA finds, based on these studies, that the magnitude of this increase has also declined in recent years.

Several rulemaking participants commented that OSHA's analysis of the feasibility of sampling and analytical methods for crystalline silica was well supported and sound (Document ID 2080, pp. 3-4; 2244, p. 3; 2371, Attachment 1, p. 5; 3578, Tr. 941; 3586, Tr. 3284; 3577, Tr. 851-852; 4214, pp. 12-13; 4223, pp. 30-33). Gregory Siwinski, CIH, and Dr. Michael Lax, Medical Director of Upstate Medical University, an occupational health clinical center, commented that current laboratory methods can measure respirable crystalline silica at the 50 $\mu g/m^3$ PEL and 25 $\mu g/m^3$ action level, and that they have measured exposures below the action level (Document ID 2244, p. 3). Celeste Montforton of the George Washington School of Public Health testified that "[i]ndustrial hygienists, company safety personnel, consultants, and government inspectors have been conducting for decades workplace sampling for respirable silica …" and that some governments, such as Manitoba and British Columbia, are successfully collecting and analyzing samples to determine compliance with their occupational exposure limits of 25 $\mu g/m^3$ (Document ID 3577, Tr. 851-852). Frank Mirer of the CUNY School of Public Health, formerly with the UAW and on behalf of the AFL-CIO, stated that "[a]ir sampling is feasible at 25 $\mu g/m^3$ and below for [a] full shift and even for part shift. It was dealt with adequately in the OSHA proposal" (Document ID 3578, Tr. 941).

The ACC, Chamber, and others base their argument that sampling and analytical methods for respirable crystalline silica are insufficiently precise on strict adherence to NIOSH's accuracy criterion of ±25 percent at a 95-percent confidence level for chemical sampling and analysis methods (http://www.cdc.gov/niosh/docs/95-117/). The ACC pointed out that "OSHA standards typically reflect the NIOSH Accuracy Criterion by requiring employers to use a method of monitoring and analysis that has an accuracy of plus or minus 25 percent…," and cited a number of OSHA standards where the Agency has included such requirements (Benzene, 29 CFR 1910.1028; Lead (which requires a method accuracy of ±20%), 29 CFR 1910.1025; Cadmium, 29 CFR 1910.1027; Hexavalent Chromium, 29 CFR 1910.1026) (Document ID 4209, p. 129). However, the NIOSH accuracy criterion is not a hard, bright-line rule in the sense that a sampling and analytical method must be rejected if it fails to meet this level of accuracy, but is rather a goal or target to be used in methods development. Where evidence has shown that a method does not meet the accuracy criterion at the PEL or action level, OSHA has stipulated a less rigorous level of accuracy to be achieved. For example, OSHA's Acrylonitrile standard requires use of a method that is accurate to ±35 percent at the PEL and ±50 percent at the action level (29 CFR 1910.1045), and several OSHA standards require that ±35 percent accuracy be obtained at the action level (Arsenic, 29 CFR 1918; Ethylene Oxide, 29 CFR 1910.1047; Formaldehyde, 29 CFR 1910.1048; Butadiene, 29 CFR 1051; Methylene Chloride, 29 CFR 1910.1052). As discussed below, the precision of the sampling and analytical method for crystalline silica, as currently implemented using OSHA Method ID-142 for X-ray diffraction, is about ±21 percent for quartz and cristobalite.

In the remainder of this section, OSHA first describes available respirable dust sampling methods and addresses comments and testimony related to the performance and accuracy of respirable dust samplers. Following that discussion, OSHA summarizes available analytical methods for measuring crystalline silica in respirable dust samples and addresses comments and evidence regarding analytical method precision, the presence of interfering materials, and reported variability between laboratories analyzing comparable samples.

3.1 Respirable Dust Sampling Devices

Respirable dust comprises particles small enough that, when inhaled, they are capable of reaching the pulmonary region of the lung where gas exchange takes place. Measurement of respirable dusts requires the separation of particles by size to assess exposures to the respirable fraction of airborne dusts. A variety of different industrial hygiene sampling devices, such as cyclones and elutriators, have been developed to separate the respirable fraction of airborne dust from the non-respirable fraction. Cyclones are the most commonly used size-selective sampling devices, or "samplers," for assessing personal exposures to respirable dusts such as crystalline silica. The current OSHA (ID-142, revised December 1996, Document ID 0946) and NIOSH (Method 7500, Document ID 0901; Method 7602, 0903; Method 7603, http://www.cdc.gov/niosh/docs/2003-154/pdfs/7603.pdf) methods for sampling and analysis of crystalline silica specify the use of cyclones.

Although respirable dust commonly refers to dust particles having an aerodynamic diameter of 10 µm (micrometer) or less, it is more precisely defined by the collection efficiency of the respiratory system as described by a particle collection efficiency model. These models are often depicted by particle collection efficiency curves that describe, for each particle size range, the mass fraction of particles deposited in various parts of the respiratory system. These curves serve as the "yardsticks" against which the performance of cyclone samplers should be compared (Vincent, 2007, Document ID 1456). Figure IV.3-A below shows particle collection efficiency curves for two particle size selection criteria: the criteria specified in the 1968 American Conference of Governmental Industrial Hygienists (ACGIH) Threshold Limit Value (TLV) for respirable dust, which was the basis for the prior OSHA general industry silica PEL, and an international specification by the International Organization for Standardization (ISO) and the Comité

Européen de Normalisation (CEN) known as the ISO/CEN convention, which was adopted by ACGIH in 1994 and is the basis for the definition of respirable crystalline silica in the final rule. In addition to the curves, which cover the full range of particle sizes that comprise respirable dust, particle size collection criteria are also often described by their 50-percent respirable "cut size" or "cut point." This is the aerodynamic diameter at which 50 percent of the particle mass is collected, i.e., the particle size that the sampler can collect with 50-percent efficiency. Particles with a diameter smaller than the 50-percent cut point are collected with an efficiency greater than 50 percent, while larger-diameter particles are collected with an efficiency less than 50 percent. The cut point for the 1968 ACGIH specification is 3.5 µm and for the ISO/CEN convention is 4.0 µm (Lippman, 2001, Document ID 1446, pp. 107, 113).

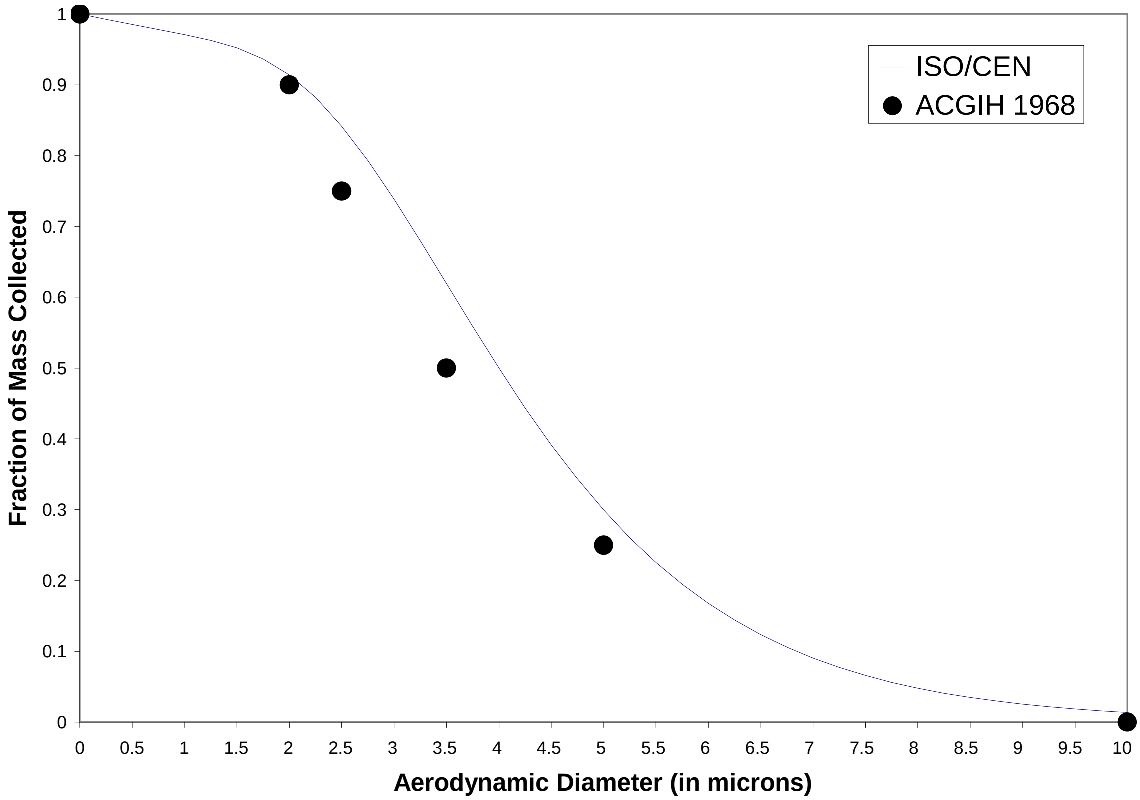

Figure IV.3.1. Comparison of the 1968 ACGIH and ISO/CEN Particle Size Collection Criteria

Source: Document ID 1720, p. IV-18

For most workplace conditions, the change in the criteria for respirable dust in the final rule would theoretically increase the mass of respirable dust collected over that measured under the previous criteria by an amount that depends on the size distribution of airborne particles in the workplace. Soderholm (1991, Document ID 1661) examined these differences based on 31 aerosol size distributions measured in various industrial workplaces (e.g., coal mine, lead smelter, brass foundry, bakery, Shielded Metal Arc [SMA] welding, spray painting, pistol range) and determined the percentage increase in the mass of respirable dust that would be collected under the ISO/CEN convention over that which would be collected under the 1968 ACGIH criteria. Soderholm concluded that, for all but three of the 31 size distributions that were evaluated, the increased respirable dust mass that would be collected using the ISO/CEN convention for respirable dust instead of the 1968 ACGIH criteria would be less than 30 percent, with most size distributions (25 out of the 31 examined, or 80%) resulting in a difference of between 0 and 20 percent (Document ID 1661, pp. 248-249, Figure 1). In the PEA, OSHA stated its belief that the magnitude of this effect does not outweigh the advantages of adopting the ISO/CEN convention. In particular, most respirable dust samplers on the market today are designed and calibrated to perform in a manner that closely conforms to the international ISO/CEN convention.

Incorporating the ISO/CEN convention in the definition of respirable crystalline silica will permit employers to use any sampling device that conforms to the ISO/CEN convention. There are a variety of these cyclone samplers on the market, such as the Dorr-Oliver, Higgins-Dewell (HD), GK2.69, SIMPEDS, and SKC aluminum. In the PEA, OSHA reviewed several studies demonstrating that these samplers collect respirable particles with efficiencies that closely match the ISO/CEN convention (Document ID 1720, pp. IV-21 - IV-24). In addition to cyclone samplers, there are also personal impactors available for use at flow rates from 2 to 8 L/min that have been shown to conform closely with the ISO/CEN convention (Document ID 1834, Attachment 1). Cyclones and impactors both separate particles by size based on inertia. When an airstream containing particles changes direction, smaller particles remain suspended in the airstream and larger ones impact a surface and are removed from the airstream. Cyclones employ a vortex to separate particles centrifugally, while impactors use a laminar airflow around a flat surface such that particles in the desired size range impact onto the surface.

3) FEASIBILITY OF MEASURING RESPIRABLE CRYSTALLINE SILICA EXPOSURES AT THE FINAL RULE'S PEL AND ACTION LEVEL

The current OSHA sampling method for crystalline silica, ID-142, is the method used by OSHA to enforce the silica PELs and is used by some employers as well. It specifies that a respirable sample be collected by drawing air at 1.7 ± 0.2 liters/minute (L/min) through a Dorr-Oliver 10 millimeter (mm) nylon cyclone attached to a cassette containing a 5-µm pore-size, 37-mm diameter polyvinyl chloride (PVC) filter (Document ID 0946). NIOSH sampling and analysis methods for crystalline silica (Method 7500, Method 7602, Method 7603) have also adopted the ISO/CEN convention with flow rate specifications of 1.7 L/min for the Dorr-Oliver 10-mm nylon cyclone and 2.2 L/min for the HD cyclone (Document ID 0901; 0903). Method 7500 also allows for the use of an aluminum cyclone at 2.5 L/min. NIOSH is revising its respirable dust method to include any sampler designed to meet the ISO/CEN criteria (Document ID 3579, Tr. 218).

The devices discussed above, when used at the appropriate flow rates, are capable of collecting a quantity of respirable crystalline silica that exceeds the quantitative detection limit for quartz (the principle form of crystalline silica) of 10 µg for OSHA's XRD method (Document ID 0946). For several scenarios based on using various devices and sampling times (8-hour, 4-hour, and 1-hour samples), OSHA calculated the amount of respirable quartz that would be collected at quartz concentrations equal to the existing general industry PEL, the proposed (and now final) rule's PEL, and the proposed (and now final) rule's action level. As seen in Table IV.3-A, computations show that the 10-mm nylon Dorr-Oliver operated at an optimized flow rate of 1.7 L/min, the aluminum cyclone operated at 2.5 L/min, the HD cyclone operated at 2.2 L/min, and the GK2.69 operated at 4.2 L/min will all collect enough quartz during an 8-hour or 4-hour sampling period to meet or exceed the 10 µg quartz limit of quantification for OSHA Method ID-142. Therefore, each of the commercially available cyclones is capable of collecting a sufficient quantity of quartz to exceed the limit of quantification when airborne concentrations are at or below the action level, provided that at least 4-hour air samples are taken. Table IV.3-A also shows that the samplers can collect enough silica to meet the limit of quantification when the airborne respirable silica concentration is below the action level of 25 µg/m^3, in one case as low as 5 µg/m^3.

Table IV.3-A
Amount of Quartz Collected by Various Personal Cyclones by Respirable Quartz Concentration and Sampling Time

Cyclone Sampler	Lowest Detectable Concentration (µg/m³)[a]		25 µg/m³ (Action Level)		50 µg/m³ (PEL)		100 µg/m³ (Previous PEL)	
	4 hr	8 hr	4 hr	8 hr	4 hr	8 hr	4 hr	8 hr
Dorr Oliver 10 mm nylon (at 1.7 L/min)	25	12	10	20	20	41	41	82
HD (at 2.2 L/min)	19	9.5	13	26	26	53	53	106
Aluminum (at 2.5 L/min)	17	8	15	30	30	60	60	120
GK2.69 (at 4.2 L/min)	10	5	25	50	50	101	101	202

[a] The lowest concentration of airborne respirable crystalline silica that will result in the collection, over the specified sampling period, of at least 10 µg, which is the limit of quantification for quartz for OSHA Method ID-142. Calculated as (1,000 L/m³ X 10 µg) / (flow rate (L/min) X Duration (min))

* Shaded boxes represent scenarios that will allow for the collection of enough quartz to meet or exceed the 10 µg limit of quantification for OSHA Method ID-142 (revised December 1996).

Source: Adapted from Document ID 1720, Table IV.B-2, pp. IV-24 - IV-25.

A comment from the National Rural Electric Cooperative Association (NRECA) stated that the current OSHA and NIOSH analytical methods require sampling to collect a minimum of 400 liters of air, and that at the flow rates specified for current samplers, sampling would have to be performed for approximately 2.5 to 4 hours; however, this is considerably longer than most construction tasks performed in electrical transmission and distribution work, which tend to last 2 hours or less (Document ID 2365, pp. 2, 6-7). OSHA does not view this discrepancy to be a problem. The minimum sampling times indicated in the OSHA and NIOSH methods contemplate that exposure occurs over most of the work shift. Construction operations frequently involve shorter-term tasks after which there is no further exposure to respirable crystalline silica. In those situations, OSHA often does not itself continue sampling during inspections and does not expect employers to continue sampling when there is no exposure to silica, and considers the sampling result that is obtained from shorter-term task sampling to be sufficient to represent a worker's 8-hour time-weighted-average (TWA) exposure, which can be calculated assuming no exposure for the period of the shift that is not sampled. If the airborne concentration of silica for the task is low, the sampling result would likely be below the limit of quantification. In that case, it would be safe for the employer to assume that the exposure is below the action level.

3.1.1 Transition to ISO-CEN Criteria for Samplers

In the final rule, OSHA is adopting the ISO/CEN particle size-selective criteria for respirable dust samplers used to measure exposures to respirable crystalline silica. Under the ISO/CEN convention, samplers should collect 50 percent of the mass of particles that are 4 µm in diameter (referred to as the cut point), with smaller particles being collected at higher efficiency and larger particles being collected at lower efficiency. Particles greater than 10 µm in diameter, which are not considered to be respirable, are to be excluded from the sample based on the ISO/CEN convention (Document ID 1446, pp. 112-113).

Several rulemaking participants supported OSHA's proposed adoption of the ISO/CEN criteria for respirable dust samplers (Document ID 1730; 1969; 3576, Tr. 290; 3579, Tr. 218-219; 4233, p. 4). For example, a representative of SKC, Inc., which manufactures samplers used to collect respirable crystalline silica, stated that:

> Adoption of the ISO/CEN performance standard for respirable dust samplers by OSHA will bring the U.S. regulatory standards in line with standards/guidelines established by other occupational health and safety agencies, regulatory bodies, and scientific consensus organizations around the world. It will also align OSHA performance criteria for respirable dust samplers to that of NIOSH (Document ID 1730, pp. 1-2).

As discussed above, OSHA's previous (and currently enforceable) general industry PEL for crystalline silica was based on a 1968 ACGIH definition, which specified a model with a cut point of 3.5 µm. Based on available studies conducted over 40 years ago, the Dorr-Oliver 10-mm cyclone was thought to perform closely to this specification. As such, it is the sampling device specified in OSHA's respirable dust sampling and analytical methods, including Method ID-142 for respirable crystalline silica (Document ID 0946). For most sizes of respirable particles, the ISO/CEN convention specifies a greater efficiency in particle collection than does the 1968 ACGIH model; consequently, samplers designed to meet the ISO/CEN convention will capture somewhat greater mass of airborne particle than would a sampler designed to the 1968 ACGIH model, with the magnitude of the increased mass dependent on the distribution of particle sizes in the air. For most particle size distributions encountered in workplaces, the increase in dust mass theoretically collected under the ISO/CEN convention compared to the ACGIH model would be 25 percent or less (Soderholm, 1991, Document ID 1661).

Several rulemaking participants commented that moving from the 1968 ACGIH model to the ISO/CEN convention effectively decreased the PEL and action level below the levels intended, since more dust would be collected by samplers that conform to the ISO/CEN convention than by those that conform to the 1968 ACGIH model (Document ID 2174; 2195, p. 30; 2285, pp. 3-4; 2307, Attachments 10, p. 19, and 12, p. 3; 2317, p. 2; 3456, p. 10; 4194, pp. 15-16). For example, the Chamber commented that adopting the ISO/CEN specification "can result in citations for over exposure to quartz dust where none would have been issued prior to the adoption of this convention" (Document ID 2288, p. 16). OSHA disagrees with this assessment because, based on more recent evaluations (Bartley et al., 1994, Document ID 1438, Attachment 2; Lee et al., 2010, 3616; 2012, 3615), the Dorr-Oliver 10-mm cyclone that has been used by the Agency for enforcement of respirable dust standards for decades has been found to perform reasonably closely (i.e., with an acceptable level of bias) to the ISO/CEN specification when operated at the 1.7 L/min flow rate specified by OSHA's existing method. Consequently, OSHA and employers can continue to use the Dorr-Oliver cyclone to evaluate compliance against the final PEL of 50 $\mu g/m^3$ without having to change equipment or procedures, and thus would not be collecting a greater quantity of dust than before. Furthermore, OSHA notes that other ISO/CEN-compliant samplers, such as the SKC 10-mm aluminum cyclone and the HD cyclone specified in the NIOSH Method 7500, are already widely used by investigators and employers to evaluate exposures to respirable crystalline silica against benchmark standards. Therefore, the change from the ACGIH convention to the ISO/CEN convention is more a continuation of the status quo than a drastic change from prior practice.

Other rulemaking participants argued that moving to the ISO/CEN convention effectively invalidates OSHA's risk and feasibility analyses since the exposure data that underlie these analyses were obtained using devices conforming to the 1968 ACGIH specification. For example, Thomas Hall, testifying for the Chamber, stated that moving to the ISO/CEN convention "would produce a difference in [current] exposure results from…historical measurements that have been used in the risk assessments" (Document ID 3576, Tr. 435). Similarly, in its pre-hearing comments, the ACC argued that:

> When OSHA conducted technological feasibility studies for attaining the proposed 50 μg/m^3 PEL, the Agency based its decisions on samples collected using the current ACGIH method, not the proposed ISO/CEN method. Thus, the switch to the ISO/CEN definition will have two impacts on feasibility. First, it will add uncertainty regarding OSHA's technological feasibility determination because greater reductions in exposure will be required to achieve a 50 μg/m^3 PEL measured by the ISO/CEN definition than by the ACGIH definition that OSHA applied. Second, OSHA's use of the ACGIH definition to estimate compliance costs causes the Agency to underestimate the costs of achieving the 50 μg/m^3 PEL because OSHA did not account for the additional workers whose exposures would exceed the proposed PEL under the ISO/CEN definition but who would be exposed below the proposed PEL if measured under the ACGIH definition (Document ID 2307, Attachment 8, p. 9).

OSHA rejects these arguments for the following reasons. First, with respect to the risk information relied on by the Agency, exposure data used in the various studies were collected from employer records reflecting use of several different methods. Some studies estimated worker exposures to silica from particle counts, for which the sampling method using impingers does not strictly conform to either the ACGIH or ISO/CEN conventions (e.g., Rice et al., Document ID 1118; Park et al., Document ID 0405; Attfield and Costello, Document ID 0285; Hughes et al., Document ID 1060). Other studies used measurements taken using cyclone samplers and modern gravimetric methods of silica analysis (e.g., Rice et al. and Park et al., data obtained from cyclone pre-separator up through 1988, Document ID 1118, 0405; Hughes et al., data from 10-mm nylon cyclone through 1998, Document ID 1060). OSHA believes it likely that exposure data collected using cyclones in these studies likely conformed to the ISO/CEN specification since flow rates recommended in the OSHA and NIOSH methods were most likely used. The studies by Miller and MacCalman (Document ID 1097) and by Buchannan et al. (Document ID

0306) used exposure measurements made with the MRE 113A dust sampler, which does conform reasonably well with the ISO/CEN specification (Gorner et al., Document ID 1457, p. 47). The studies by Chen et al. (2001, Document ID 0332; 2005, Document ID 0985) estimated worker exposures to silica from total dust measurements that were converted to respirable silica measurements from side-by-side comparisons of the total dust sampling method with samples taken using a Dorr-Oliver cyclone operated at 1.7 L/min, which is consistent with the ISO/CEN convention (see Section V, Health Effects, of the Final Rule Preamble and OSHA's Preliminary Review of Health Effects Literature and Preliminary Quantitative Risk Assessment, Document ID 1711). Thus, it is simply not the case that the exposure assessments conducted for these studies necessarily reflect results from dust samples collected with a device conforming to the 1968 ACGIH particle size-selective criteria, and OSHA finds that no adjustment of OSHA's risk estimates to reflect exposure measurements consistent with the ISO/CEN convention is warranted.

Second, with respect to the feasibility analysis, OSHA relied on exposure data and constructed exposure profiles based principally on measurements made by compliance officers using the Dorr-Oliver cyclone operated at 1.7 L/min, as the Agency has done since Method ID-142 was developed in 1981, well before the 1990 cut-off date for data used to construct the exposure profiles. As explained earlier in the section, recent research shows that the Dorr-Oliver cyclone operated at this flow rate performs in a manner consistent with the ISO/CEN specification. Other data relied on by OSHA comes from investigations and studies conducted by NIOSH and others who used various cyclones that conform to the ISO/CEN specification. Thus, OSHA finds that the exposure profiles being relied on to evaluate feasibility and costs of compliance do not reflect sample results obtained using the 1968 ACGIH model. Instead, the vast majority of sample results relied upon were collected in a manner consistent with the requirements of the final rule. NIOSH supported this assessment, stating that, given the Dorr-Oliver sampler operated at a flow rate of 1.7 L/min conforms closely to the ISO/CEN convention, "there is continuation with historic exposure data" (Document ID 4233, p. 4). For these reasons, OSHA finds that it is appropriate to rely on the feasibility and cost analyses and underlying exposure data without adjustment to account for the final rule's adoption of the ISO/CEN specification for respirable dust samplers.

3.1.2 Sampling Error

Several commenters raised issues concerning the accuracy of respirable dust samplers in relation to the ISO/CEN criteria, asserting that sampling respirable dust is uncertain and inaccurate, and that there are numerous sources of error. Chief among these were Dr. Thomas Hall of Industrial Hygiene Specialty Resources, LLC, testifying for the Chamber, and Paul K. Scott of ChemRisk, testifying for the ACC.

The Chamber's witnesses and others referenced studies showing that all samplers were biased against the ISO/CEN particle-size selection convention. This means that the sampler would collect more or less mass of respirable particulate than would an ideal sampler that exactly conforms to the ISO/CEN convention. OSHA discussed this issue in the PEA, noting that most samplers tend to over-sample smaller particles and under-sample larger particles, compared to the ISO/CEN convention, at their optimized flow rates. This means that, for particle size distributions dominated by smaller particles, the sampler will collect more mass than would be predicted from an ideal sampler that exactly conforms to the ISO/CEN convention. For particle size distributions dominated by larger particles in the respirable range, less mass would be collected than predicted. In the PEA, OSHA evaluated several studies that showed that several cyclone samplers exhibited a bias of 10 percent or less for most particle size distributions encountered in the workplace. Some of these studies found biases as high as ±20 percent but only for particle size distributions having a large mass median aerodynamic diameter (MMAD) (i.e., 20 µm or larger) and narrow distribution of particle sizes (i.e., a geometric standard deviation (GSD) of 2 or less) (Document ID 1720, pp. IV-21 – IV-24). Such particle size distributions are infrequently seen in the workplace; for well-controlled environments, Frank Hearl of NIOSH testified that the GSD for typical particle size distributions would be about 2 (Document ID 3579, Tr. 187). Dr. Hall (Document ID 3576, Tr. 502) testified, similarly, that it would be around 1.8 to 3 for well-controlled environments and higher for uncontrolled environments (see also Liden and Kenny, 1993, Document ID 1450, p. 390, Figure 5; Soderholm, 1991,1661, p. 249, Figure 1). Furthermore, a particle size distribution with a large MMAD and small GSD would contain only a very small percentage (< 10%) of respirable dust that would be collected by a sampler optimized to the ISO/CEN criteria (Soderholm, 1991, Document ID 1661, p. 249, Figure 2). According to Liden and Kenny (1993), "samplers will perform reasonably well providing the absolute bias in sampling is kept to within 10 percent… this aim can be achieved … over the majority of size distributions likely to be found in field sampling" (Document ID 1450, p. 390).

Dr. Hall commented that "sampling results differ depending on the choice of sampler used" and that published evaluations have shown that they "have different collection efficiencies, specifically with respect to particle collection in aerosol clouds with large [MMADs greater than] 10 µm" (Document ID 2285, p. 16). He cited the work of Gorner et al. (2001, Document ID 1457), who noted that the cut points achieved by different samplers varied considerably and that flow rates were optimized to bring their respective cut points closer to the ISO/CEN convention, as evidence that commercial samplers do not provide consistently similar results. However, OSHA interprets the findings of Gorner et al. as actually providing evidence of samplers' consistency with the ISO/CEN convention for most particle size distributions encountered in the workplace. This study, which was reviewed in OSHA's PEA, evaluated 15 respirable dust samplers, most of them cyclones, against 175 different aerosol size distributions and evaluated the bias and accuracy of sampler performance against the ISO/CEN convention.[3] Gorner et al. found that most of the samplers they tested met the international criteria for acceptable bias and accuracy (described by Bartley et al., 1994, Document ID 1438, Attachment 2 and Gorner et al., 2001, 1457); under those criteria, bias is not to exceed 10 percent and inaccuracy is not to exceed 30 percent for most of the size distributions tested (Document ID 1457, pp. 49, 52; Document ID 1438, Attachment 2, p. 254). Gorner et al. concluded that the samplers "are therefore suitable for sampling aerosols within a wide range of particle size distributions" (Document ID 1457, p. 52). Gorner et al. also stated that sampler performance should be evaluated by examining bias and accuracy rather than

[3] Bias means the difference in particle mass collected by a sampler as compared to the mass that would be collected by a hypothetical ideal sampler that exactly matched the ISO/CEN convention. Accuracy includes bias and other sources of error related to the testing procedure (e.g., errors in flow rate and particle mass analysis) (Document ID 1457, p. 49).

simply comparing cut points and slopes against the ISO/CEN convention (Document ID 1457, p. 50), as Dr. Hall did in his comments.

The ACC's witness, Mr. Scott, noted several potential sources of sampling error in addition to the conventional 5-percent pump flow rate error that is included in OSHA's estimate of sampling and analytical error (SAE, discussed further in Section IV-3.2.4 – Precision of Measurement). These included variation in performance of the same cyclone tested multiple times (estimated at 6%) and variation between different cyclones tested in the same environment (estimated at 5%) (Document ID 2308, Attachment 6, pp. 7-8). Based on published estimates of the magnitude of these kinds of errors, Mr. Scott estimated a total sampling error of 9.3 percent after factoring in pump flow rate error, inter-sampler error, and intra-sampler error; this would increase the SAE by 4 percent, for example, from 15 to 19 percent at 50 μg/m^3 (Document ID 2308, pp. 8-9). This means that, if all sampler error were factored into the SAE, an employer would be considered out of compliance with the PEL for an exposure exceeding 59.5 μg/m^3, rather than at 57.5 μg/m^3 if only pump error were considered, a difference of only 2 μg/m^3 in silica concentration. OSHA therefore concludes that intra- and inter-sampler error of the types described by Mr. Scott do not materially change how OSHA would enforce, or how employers should evaluate, compliance with the final rule PEL.

As described above, many different respirable dust samplers have been evaluated against the ISO/CEN convention for different particle size distributions and, in general, these biases are small for the vast majority of particle size distributions encountered in the workplace. OSHA concludes that Mr. Scott's estimate likely overstates the true total sampling error somewhat because the measurements of sampler bias against the ISO/CEN criteria involve accurately measuring and maintaining consistent pump flow rates during the testing of the samplers; therefore, adding pump flow rate error to estimates of inter- and intra-sampler measurement error is redundant. Furthermore, if an employer relies on a single type of cyclone sampler, as is OSHA's practice, there would be no inter-sampler variability between different field samples. If an employer is concerned about this magnitude of uncertainty, he or she can choose simply to use the same sampling device as OSHA (i.e., the Dorr-Oliver cyclone operated at a flow rate of

1.7 L/min, as specified in Method ID-142) and avoid any potential measurement uncertainties associated with use of different sampling devices.

The American Foundry Society (AFS) commented that the ASTM Standard D4532 for respirable dust sampling includes errors for sampling, weighing, and bias, none of which is included in OSHA's pump flow rate error (Document ID 2379, p. 29). This ASTM standard describes procedures for sampling respirable dust using a 10-mm cyclone, HD cyclone, or aluminum cyclone in a manner identical to that prescribed in the OSHA and NIOSH methods for sampling and analysis of silica. Thus, the kinds of errors identified by AFS are the same as those reflected in Mr. Scott's testimony described above, which, as OSHA has shown, do not result in substantial uncertainties in exposure measurement.

OSHA further observes that the kinds of sampling errors described by rulemaking participants are independent of where the PEL is established and are not unique to silica; these biases have existed since OSHA began using the Dorr-Oliver cyclone to enforce the previous PELs for crystalline silica, as well as many other respirable dust standards, over 40 years ago. OSHA also believes that sampling error within the range quantified by Mr. Scott would be unlikely to change how an employer makes risk management decisions based on monitoring results. One Chamber witness, Gerhard Knutson, President of Knutson Ventilation, testified that the type of cyclone used to obtain exposure measurements for crystalline silica was not typically a consideration in designing industrial ventilation systems (Document ID 3576, Tr. 521-522). Dr. Hall, another Chamber witness, also testified that he has used all three sampling devices listed in the NIOSH Method 7500 and has not historically made a distinction between them, though he might make different decisions today based on the aerosol size distribution encountered in a particular workplace (Document ID 3576, Tr. 522-523). In his pre-hearing submission, Dr. Hall cited the Gorner et al. (2001, Document ID 1457) study as recommending that "rough knowledge of the aerosol size distribution can guide the choice of an appropriate sampling technique" (Document ID 2285, p. 8). OSHA concludes it unlikely that, in most instances, it is necessary to obtain such data to minimize sampling bias for risk management purposes, given the overall magnitude of the bias as estimated by Mr. Scott (i.e., an error of less than 10%).

3.1.3 High Flow Samplers

OSHA's PEA also described high-flow samplers, in particular the GK2.69 from BGI, Inc., which is run at a flow rate of 4.2 L/min in contrast to 1.7 L/min for the Dorr-Oliver and 2.5 L/min for the aluminum cyclone. High-flow devices such as this permit a greater amount of dust to be collected in low-dust environments, thus improving sensitivity and making it more likely that the amount of silica collected will fall within the range validated by current analytical methods. For example, a Dorr-Oliver run at 1.7 L/min where the silica concentration is 50 µg/m^3 would collect 41 µg of silica over 8 hours, compared to the GK2.69 run at 4.2 L/min, which would collect 101 µg of silica (see Table IV.3-A), well within the validation range of the OSHA method (i.e., the range over which precision is determined, 50 to 160 µg) (Document ID 0946, p. 1). Several rulemaking participants supported OSHA's proposal to permit use of high-flow samplers that conform to the ISO/CEN convention (Document ID 2256, Attachment 3, p. 12; 3578, Tr. 941; 3586, Tr. 3286-3287; 4233, p. 4). For example, William Walsh, representing the American Industrial Hygiene Association (AIHA) Laboratory Accreditation Programs, stated that he could measure concentrations of silica at the 25 µg action level with sufficient precision by using a high-flow device (Document ID 3586, Tr. 3287).

The performance of high-flow samplers has been extensively studied, particularly by Lee et al. (2010, Document ID 3616; 2012, 3615), Stacey et al. (2013, Document ID 3618), and Kenny and Gussman (1997, Document ID 1444). The Kenny and Gussman study, which was reviewed in OSHA's PEA, found the GK2.69 had good agreement with the ISO/CEN convention at the 4.2 L/min flow rate, with a cut point of 4.2 µm and a collection efficiency curve that was steeper than the ISO/CEN (i.e., it was more efficient for smaller particles and less so for larger particles). For particle size distributions up to an MMAD of 25 µm and GSD of 1.5 to 3.5, bias against the ISO/CEN convention was generally between +5 and -10 percent. Bias was greater (-20%) for particle size distributions having an MMAD above 10 µm and a low GSD which, according to the authors, are not likely to be encountered (Document ID 1444, p. 687, Figure 7).

The Lee et al. (2010, Document ID 3616; 2012, 3615) and Stacey (2013, Document ID 3618) studies of high-flow sampler performance are the product of a collaborative effort between NIOSH and the United Kingdom's Health and Safety Executive (HSE) that examined the performance of three high-flow samplers; these were the GK2.69, the CIP10-R (Arelco ARC, France), and the FSP10 (GSA, Germany). The FSP10 runs at flow rates of 10 L/min and the combination of large cyclone and heavy-duty pump may be burdensome for workers to wear. The CIP-10 also runs at 10 L/min and is much smaller and lighter, but uses a collection technology different from cyclones, which may be unfamiliar to users. According to NIOSH, cyclones operating around 4 L/min "offer a current compromise" for obtaining higher flow rates without the need to use larger personal samplers that may be difficult for workers to wear (Document ID 2177, Attachment B, p. 13; 3579, Tr. 163).". For this reason, OSHA's review of these studies focuses on the performance of the GK2.69 cyclone.

Lee et al. (2010, Document ID 3616) tested the GK2.69 against 11 sizes of monodisperse aerosol and found that, at the 4.2 L/min flow rate, the estimated bias against the ISO/CEN convention was positive for all particle size distributions (i.e., the sampler collected greater mass of particulate than would be predicted from an ideal sampler that exactly conformed to ISO/CEN), with a 10-percent efficiency for collecting 10 µm particles, compared to 1 percent for the ISO/CEN convention. The authors estimated a bias of +40 percent for a particle size distribution having a MMAD of 27.5 µm. However, adjustment of the flow rate to 4.4 L/min resulted in biases of less than 20 percent for most particle size distributions and the collection efficiency for 10 µm particles was much closer to the ISO/CEN convention (2.5% compared to 1%). The authors concluded that, at the higher flow rate, the GK2.69 cyclone met the international standard for sampler conformity to relevant particle collection conventions (European Committee for Standardization, EN 13205, cited in Lee et al., 2010, Document ID 3616), and would provide relatively unbiased measurements of respirable crystalline silica (Document ID 3616, pp. 706, 708, Figure 5(a)).

Lee et al. (2012, Document ID 3615) performed a similar evaluation of the same samplers using coal dust but included analysis of crystalline silica by both XRD and IR. The GK2.69 runs at a flow rate of 4.4 L/min collected somewhat more respirable dust and crystalline silica than would be predicted from differences in flow rates, compared to the 10-mm nylon cyclone, but nearly the same as the Higgins-Dewell cyclone. The authors found that the GK2.69 "showed non-significant difference in performance compared to the low-flow rate samplers" (Document ID 3615, p. 422), and that "the increased mass of quartz collected with high-flow rate samplers would provide precise analytical results (i.e., significantly above the limit of detection and/or the limit of quantification) compared to the mass collected with low-flow rate samplers, especially in environments with low concentrations of quartz …" (Document ID 3615, p. 413). Lee et al. concluded that "[a]ll samplers met the [EN 13205] requirements for accuracy for sampling the ISO respirable convention" (Document ID 3615, p. 424).

Stacey et al. (2013, Document ID 3618) used Arizona road dust aerosols to evaluate the performance of high-flow samplers against the Safety In Mines Personal Dust Sampler (SIMPEDS), which is the low-flow sampler used to measure respirable crystalline silica in the U.K. For the GK2.69, use of a flow rate of 4.2 L/min or 4.4 L/min made little difference in the respirable mass collected, and there was closer agreement between the GK2.69 and SIMPEDS sampler when comparing respirable crystalline silica concentration than respirable dust concentration, and the difference was not statistically significant (Document ID 3618, p. 10). According to NIOSH, the findings by Stacey et al. (2013) corroborate those of Lee et al. (2010 and 2012) that the GK2.69 meets the ISO/CEN requirements for cyclone performance and that either the 4.2 L/min or 4.4 L/min flow rate "can be used to meet the ISO convention within acceptable limits" (Document ID 2177, p. 13).

Mr. Scott testified that the high-flow samplers (including the GK2.69) studied by Lee et al., (2010 and 2012), "tended to have a substantial bias towards collecting more respirable particulates than the low-flow samplers, collecting between 12 percent and 31 percent more mass" because high-flow samplers tend to collect a higher proportion of larger particles (Document ID 3582, Tr. 1984). In his written testimony, he noted that Lee et al. (2010) reported a nearly 10-fold higher collection efficiency for 10 μm particles compared to the ISO/CEN standard. However, Mr. Scott's testimony ignores Lee et al.'s findings that the oversampling of larger particles seen at a flow rate of 4.2 L/min was not apparent at the higher 4.4 L/min flow rate and that Lee et al. (2010) concluded that agreement with the ISO/CEN convention was achieved at the higher flow rate (Document ID 3616, pp. 706, 708). In addition, oversampling of larger particles at the 4.2 L/min flow rate was not reported by Lee et al. (2012, Document 3615) or Stacey et al. (2013, Document ID 3618).

Dr. Hall expressed a similar concern as Mr. Scott. He cited Lee et al. (2010) as stating that the GK2.69 would collect significantly more aerosol mass for particle size distributions having an MMAD of more than 6 µm. He also cited Lee et al. (2010 and 2012) for the finding that the GK2.69 collects from 1.8 to 3.84 times as much aerosol mass as the Dorr-Oliver or Higgins-Dewell cyclones (Document ID 2285, p. 12). In his pre-hearing comment, Dr. Hall stated that "[f]or aerosol clouds with a [MMAD] greater than 10 µm, the expected absolute bias can range be (sic) between 20 and 60%" and "the total variability for the method SAE can be as large as 85-90%" (Document ID 2285, pp. 15-16).

OSHA notes that both Dr. Hall and Mr. Scott focus their comments regarding the performance of high-flow samplers on environments where the particle size distribution is characterized by larger particles and small variance (GSD). The findings by Lee et al (2010) show that, at a flow rate of 4.2 L/min, under this experimental system, there were large positive biases (> 20%) against the ISO/CEN convention for nearly all particle size distributions having MMAD of 5 to 10 µm (Document ID 3616, pp. 704-706, Figure 3(b)). However, when the flow rate was adjusted to 4.4 L/min, bias exceeding 20 percent was found to occur primarily with particle size distributions having GSDs under 2.0 and MMAD greater than 10 µm (Document ID 3616, p. 707, Figure 5(a)). As discussed above, it is rare to encounter particle size distributions having relatively large MMADs and small GSDs, so the high variability attributed to high-flow samplers by Dr. Hall and Mr. Scott should not be of concern for most workplace settings. Further, sampler performance is considered acceptable if the bias and accuracy over at least 80 percent of the remaining portion of the bias map are within acceptable limits, which are no more than 10 and 30 percent, respectively (Document ID 1457, pp. 49, 52). The Lee et al. studies (2010 and 2012) concluded that the high-flow samplers tested met these international requirements for accuracy for sampling the ISO/CEN convention, and the

Stacey et al. (2013) study found that their results compared favorably with those of Lee et al. (2012). Therefore, OSHA finds that the uncertainties characterized by Dr. Hall and Mr. Scott are exaggerated for most workplace situations, and that there is substantial evidence that high-flow samplers, in particular the GK2.69 cyclone, can be used to collect respirable crystalline silica air samples in most workplace settings without introducing undue bias.

Mr. Scott, testifying for the ACC, was of the opinion that, although high-flow samplers have been evaluated by Gorner et al. (2001, Document ID 1457) and Lee et al. (2010, Document ID 3616; 2012, 3615) with respect to their sampling efficiencies as compared to the ISO/CEN convention and their performance compared to low-flow samplers, none of the studies evaluated the accuracy and precision using methods recommended in NIOSH’s Guidelines for Air Sampling and Analytical Method Development and Evaluation (1995, http://www.cdc.gov/niosh/docs/95-117/) (Document ID 2308, Attachment 6, p. 18). OSHA understands Mr. Scott to contend that the sampler must be tested against a generated atmosphere of respirable crystalline silica and that the precision of the sampling and analytical method must be determined overall from these generated samples.

OSHA does not agree with the implication that, until high-flow samplers have been evaluated according to the NIOSH (1995) protocol, the findings from the studies described above are not sufficient to permit an assessment of sampler performance. The NIOSH Guidelines cited by Mr. Scott state that “[a]“n experimental design for the evaluation of sampling and analytical methods has been suggested. If these experiments are not applicable to the method under study, then a revised experimental design should be prepared which is appropriate to fully evaluate the method” (http://www.cdc.gov/niosh/docs/95-117/, p. 1). These guidelines contemplate the development of entirely new sampling and analytical methods. Because the analytical portion of the sampling and analytical method for respirable crystalline silica was already fully evaluated before the GK2.69 was developed (Kenny and Gussman, 1997, Document ID 1444), it was only necessary to evaluate the performance of the GK2.69 high-flow sampler. As described above, the studies by Lee et al. (2010, Document ID 3616; 2012,

3615) and Stacey et al. (2013, Document ID 3618) reflect a collaborative effort between NIOSH in the U.S. and HSE in the U.K. to evaluate the performance of high-flow respirable dust samplers. The Lee et al. (2010, 2012) studies were conducted by NIOSH laboratories in Morgantown, West Virginia with peer review by HSE scientists, and the Stacey et al. (2013) study was conducted by HSE at the Health and Safety Laboratory at Buxton in the U.K. Both Lee et al. (2012) and Stacey et al. (2013) concluded that high-flow samplers studied, including the GK2.69, met the EN 13205 requirements for accuracy for sampling against the ISO/CEN convention, demonstrating that results from these two national laboratories compared favorably. OSHA concludes these peer-reviewed studies, performed by NIOSH and HSE scientists, meet the highest standards for effective methods evaluation and therefore does not agree with the suggestion that additional work following NIOSH's protocol is necessary. Comments submitted by NIOSH indicate that the Lee et al. (2010, 2012) and Stacy et al. (2013) studies are sufficient to establish the GK2.69 high-flow sampler as acceptable for sampling respirable crystalline silica under the ISO/CEN convention (Document ID 2177, Attachment B; 4233, p. 4).

URS Corporation, on behalf of the ACC, commented that precision will not be improved by the use of high-flow samplers because filter loadings of interferences will increase along with the amount of crystalline silica; this would, in URS's opinion, necessitate additional sample handling procedures, such as acid washing, that erode precision. URS also argued that such samples may require analysis of multiple peaks and that overall X-ray intensity may be diminished due to increased filter load (Document ID 2307, Attachment 12, p. 3). In its post-hearing brief, the ACC stated that the use of high-volume samplers "in addition to traditional Dorr-Oliver sampler" would reduce inter-laboratory precision (i.e., the extent to which different laboratories achieve similar results for the same sample) due to the use of multiple sampler types (Document ID 4209, p. 154).

OSHA finds that these arguments are unsupported. Although the high-flow sampler will collect more dust than lower-flow samplers in the same environment, the relative proportion of any interfering materials collected to the amount of crystalline silica collected would remain unchanged. Thus, there should be no increased effect from the interfering materials relative to the silica. OSHA recognizes that, to prevent undue interference or diminished X-ray intensity, it is important to keep the dust load on the filter within reasonable limits. Both OSHA and NIOSH methods stipulate a maximum sample weight to be collected (3 mg for OSHA and 2 mg for NIOSH) (Document ID 0946, p. 5; 0901, p. 3), and in the event that excess sample is collected, the sample can be split into portions and each portion analyzed separately (Document ID 0946, p. 5). In environments where using a high-flow sampler is likely to collect more than the maximum sample size, use of a lower-flow sampler is advised. In response to the concern that permitting use of high-flow samplers will affect interlaboratory variability, OSHA observes that employers are already using a variety of commercially available samplers, such as those listed in the NIOSH Method 7500, to obtain exposure samples; not everyone uses the Dorr-Oliver sampler. Thus, for the final rule, OSHA is permitting employers to use any sampling device that has been designed and calibrated to conform to the ISO/CEN convention, including higher-flow samplers such as the GK2.69. In effect, this is a continuation of well-studied current practice, not an untested departure from it.

3.2 LABORATORY ANALYSIS OF CRYSTALLINE SILICA

Crystalline silica is analyzed in the laboratory using either X-ray diffraction (XRD) or infrared spectroscopy (IR). A third method, colorimetric spectrophotometry, is no longer used (Document ID 3579, Tr. 211; Harper et al., 2014, 3998, Attachment 8, p. 1). This section describes crystalline silica analysis by XRD and IR and responds to comments and testimony on the precision and accuracy of these methods for measuring crystalline silica concentrations in the range of the final rule's PEL and action level. As discussed below, both XRD and IR methods can detect and quantify crystalline silica in amounts collected below the final rule's 25 µg action level.

3.2.1 X-Ray Diffraction

For XRD, a dust sample that has been collected by a sampler is deposited on a silver-membrane filter and scanned by the X-ray beam, where X-rays diffract at specific angles.

A sensor detects these diffracted X-ray beams and records each diffracted beam as a diffraction peak. Unique X-ray diffraction patterns are created when the diffraction peaks are plotted against the angles at which they occur. The intensity of the diffracted X-ray beams depends on the amount of crystalline silica present in the sample, which can be quantified by comparing the areas of the diffraction peaks obtained with those obtained from scanning a series of calibration standards prepared with known quantities of an appropriate reference material. Comparing multiple diffraction peaks obtained from the sample with those obtained from the calibration standards permits both quantitative and qualitative confirmation of the amount and type of crystalline silica present in the sample (i.e., quartz or cristobalite). A major advantage of XRD compared with the other techniques used to measure crystalline silica is that X-ray diffraction is specific for crystalline materials. Neither non-crystalline silica nor the amorphous silica layer that forms on crystalline silica particles affects the analysis. The ability of this technique to quantitatively discriminate between different forms of crystalline silica and other crystalline or non-crystalline materials present in the sample makes this method least prone to interferences. Sample analysis by XRD is also non-destructive, meaning that samples can be reanalyzed if necessary (Document ID 1720, pp. IV-26 - IV-27).

The OSHA Technical Manual lists the following substances as potential interferences for the analysis of crystalline silica using XRD: aluminum phosphate, feldspars (microcline, orthoclase, plagioclase), graphite, iron carbide, lead sulfate, micas (biotite, muscovite), montmorillonite, potash, sillimanite, silver chloride, talc, and zircon (https://www.osha.gov/dts/osta/otm/ otm_ii/otm_ii_1.html, Chapter 1, III.K). The interference from other minerals usually can be recognized by scanning multiple diffraction peaks quantitatively. Diffraction peak-profiling techniques can resolve and discriminate closely spaced peaks that might interfere with each other. Sometimes interferences cannot be directly resolved using these techniques. However, many interfering materials can be chemically washed away in acids that do not dissolve the crystalline silica in the sample. Properly performed, these acid washes can dissolve and remove these interferences without appreciable loss of crystalline silica (Document ID 1720, p. IV-27).

The nationally recognized analytical methods using XRD include OSHA ID-142, NIOSH 7500, and MSHA P-2 (Document ID 0946; 0901; 1458). All are based on the XRD of a redeposited thin-layered sample with comparison to standards of known concentrations (Document ID 0946, p. 1; 0901, p. 1; 1458, p. 1). These methods, however, differ on diffraction peak confirmation strategies. The OSHA and MSHA methods require at least three diffraction peaks to be scanned (Document ID 0946, p. 5; 1458, p. 13. The NIOSH method only requires that multiple peaks be qualitatively scanned on representative bulk samples to determine the presence of crystalline silica and possible interferences, and quantitative analysis of air samples is based on a single diffraction peak for each crystalline silica polymorph analyzed (Document ID 0901, pp. 3, 5).

3.2.2 Infrared Spectroscopy

Infrared spectroscopy is based on the principle that molecules of a material will absorb specific wavelengths of infrared electromagnetic energy that match the resonance frequencies of the vibrations and rotations of the electron bonds between the atoms making up the material. The absorption of IR radiation by the sample is compared with the IR absorption of calibration standards of known concentration to determine the amount of crystalline silica in the sample. Using IR can be efficient for routine analysis of samples that are well characterized with respect to mineral content, and the technique, like XRD, is non-destructive, allowing samples to be reanalyzed if necessary. The three principle IR analytical methods for crystalline silica analyses are NIOSH 7602 (Document ID 0903), NIOSH 7603 (http://www.cdc.gov/niosh/docs/2003-154/pdfs/7603.pdf), and MSHA P-7 (Document ID 1462); NIOSH Method 7603 and MSHA P-7 were both specifically developed for the analysis of quartz in respirable coal dust. OSHA does not use IR for analysis of respirable crystalline silica.

Interferences from silicates and other minerals can affect the accuracy of IR results. The electromagnetic radiation absorbed by silica in the infrared wavelengths consists of broad bands. In theory, no two compounds have the same absorption bands; however, in actuality, the IR spectra of silicate minerals contain silica tetrahedra and have absorption bands that will overlap. If interferences enhance the baseline measurement and are not taken into account, they can have a negative effect that might underestimate the amount of silica in the sample. Compared with XRD, the ability to compensate for these interferences is limited (Document ID 1720, pp. IV-29 - IV-30).

3.2.3 Sensitivity of Sampling and Analytical Methods

The sensitivity of an analytical method or instrument refers to the smallest quantity of a substance that can be measured with a specified level of accuracy, and is expressed as either the LOD or the "Limit of Quantification" (LOQ). These two terms have different meanings. The LOD is the smallest amount of an analyte that can be detected with acceptable confidence that the instrument response is due to the presence of the analyte. The LOQ is the lowest amount of analyte that can be reliably quantified in a sample and is higher than the LOD. These values can vary from laboratory to laboratory as well as within a given laboratory between batches of samples because of variation in instrumentation, sample preparation techniques, and the sample matrix, and must be confirmed periodically by laboratories.

At a concentration of 50 $\mu g/m^3$, the final rule's PEL, the mass of crystalline silica collected on a full-shift (480 minute) air sample at a flow rate of 1.7 L/min, for a total of 816 L of air, is approximately 41 µg (see Table IV.3-A). At a concentration of 25 $\mu g/m^3$, the final rule's action level, the mass collected is about 20 µg. The LOQ for quartz for OSHA's XRD method is 10 µg (Document ID 0946; 3764, p. 4), which is below the amount of quartz that would be collected from full-shift samples at the PEL and action level. Similarly, the reported LODs for quartz for the NIOSH and MSHA XRD and IR methods are lower than that which would be collected from full-shift samples taken at the PEL and action level (NIOSH Method 7500, Document ID 0901, p. 1; MSHA Method P-2, 1458, p. 2; NIOSH Method 7602, 0903, p. 1; NIOSH Method 7603, http://www.cdc.gov/niosh/docs/2003-154/pdfs/7603.pdf, p. 1; MSHA Method P-7, 1462, p. 1).

The rule's 50 $\mu g/m^3$ PEL for crystalline silica includes quartz, cristobalite, and tridymite in any combination. For cristobalite and tridymite, the previous general industry formula PEL was approximately 50 $\mu g/m^3$, so the change in the PEL for crystalline silica does not represent a substantive change in the PEL for cristobalite or tridymite when quartz is not present. OSHA Method ID-142 (Document ID 0946) lists a 30-µg LOQ for cristobalite; however, because of technological improvements in the equipment, the current LOQ for cristobalite for OSHA's XRD method as implemented by the OSHA Salt Lake Technical Center (SLTC) is about 20 µg (Document ID 3764, p. 10).

That XRD analysis of quartz from samples prepared from reference materials can achieve LODs and LOQs between 5 and 10 µg was not disputed in the record. Of greater concern to several rulemaking participants was the effect of interfering materials potentially present in a field sample on detection limits and on the accuracy of analytical methods at low filter loads when interferences are present. Although the Chamber's witness, Robert Lieckfield of Bureau Veritas Laboratories, did not dispute that laboratories could achieve this level of sensitivity (Document ID 3576, Tr. 485-486), the ACC took issue with this characterization of method sensitivity stating that "the LOQ for real world samples containing interferences is likely to be higher than the stated LOQ's for analytical methods, which are determined using pure NIST samples with no interferences" (Document ID 4209, p. 132). Both Mr. Lieckfield and Mr. Scott testified that the presence of interferences in samples can increase the LOQ and potential error of measurement at the LOQ (Document ID 2259, p. 7; 3460, p. 5).

Mr. Scott (Document ID 2308, Attachment 6, p. 5) cited a laboratory performance study by Eller et al. (1999a, Document ID 1687), in which laboratories analyzing samples with and without interfering materials present reported a range of LOD's from 5 µg to 50 µg. Mr. Scott believed that this study provided evidence that interfering materials present in crystalline silica samples adversely affected laboratories' reported LODs. OSHA disagrees with this interpretation. The Agency reviewed this study in the PEA (Document ID 1720, p. IV-33) and believes that the variability in reported LODs reflected differences in laboratory practices with respect to instrument calibration and quality control procedures. These factors led Eller et al. (1999b, Document ID 1688, p. 24; 1720, p. IV-42) to recommend changes in such practices to improve laboratory performance. Thus, OSHA finds that the variation in reported LODs referred to by Mr. Scott cannot be attributed primarily to the presence of interfering materials on the samples.

The presence of interferences can adversely affect the sensitivity and precision of the analysis, but typically only when the interference is so severe that quantification of crystalline silica must be made from secondary and tertiary diffraction peaks (Document ID 0946, p. 6). However, OSHA finds no evidence that interferences usually present serious quantification problems. First, there are standard protocols in the OSHA, NIOSH, and MSHA methods that deal with interferences. According to OSHA Method ID-142,

> Because of these broad selection criteria and the high specificity of the method for quartz, some of the listed interferences may only present a problem when a large amount of interferent is present…. Interference effects are minimized by analyzing each sample for confirmation using at least three different diffraction peaks so as to include peaks where the quartz and cristobalite results are in good agreement and where the interferent thus causes no problem. Bulk samples or a description of the process being sampled are useful in customizing a chemical cleanup procedure for any interference found difficult to resolve by software. Even so, the presence of an interference rarely jeopardizes the analysis (Document ID 0946, p. 5).

Software developed by instrument manufacturers and techniques such as acid washing of the sample when interferences are suspected to be present are also useful in resolving interferences. The Chamber's expert witness, Mr. Lieckfield, acknowledged that it was also their practice at his lab to chemically treat samples from the start to remove interfering materials and to analyze multiple diffraction peaks to resolve interferences (Document ID 3576, Tr. 533, 542). According to OSHA's representative from the SLTC, it is "nearly always possible" to eliminate interferences and is it no more difficult to obtain precise measurements when interferences are present than when they are not (Document ID 3579, Tr. 48).

ACC also cites the results of a round-robin performance study that it commissioned, in which five laboratories were provided with crystalline silica samples with and without interfering materials (Document ID 4209, p. 132). These laboratories reported non-detectable levels of silica for 34 percent of the filters having silica loadings of 20 μg or more. However, as discussed below in the section on inter-laboratory variability (Section IV-3.2.5 – Measurement Error Between Laboratories), OSHA has determined that this study is seriously flawed and, in particular, that there was systematic bias in the results, possibly due to sample loss. This could explain the high prevalence of reported non-detectable samples by the laboratories, rather than the presence of interferences *per se*.

Furthermore, OSHA's review of the several hundred inspection reports relied on to evaluate the technological feasibility of the final rule's PEL in many industry sectors does not show that investigators have particular difficulty in measuring respirable crystalline silica concentrations below the PEL. Sections IV-4 and IV-5 of this chapter contain hundreds of exposure measurement results in a wide variety of workplace settings that were detected and reported by a laboratory as being above detectable limits but below the PEL or action level. If, as ACC suggests, interferences have a profound effect on the ability to measure concentrations in this range, many of these samples might have been reported as "less than the LOD," with the reported LOD in the range of 25 μg to 50 μg. Examination of the exposure data described in Sections IV-4 and IV-5 of this chapter shows clearly that this is not the case (see, for example, exposure profiles for Concrete Products, Section IV-4.3; Cut Stone, Section IV-4.4; Foundries (Metal Casting), Section IV-4.8; Mineral Processing, Section IV-4.12; Porcelain Enameling, Section IV-4.14; Ready Mix Concrete, Section IV-4.17; Refractories, Section IV-4.18). In addition, the United Steelworkers reported receiving exposure data from 17 employers with samples in this same range, indicating that sampling of exposures below the final PEL and action level is feasible and already being utilized by employers (Document ID 4214, pp. 12-13; Document ID 4032, Attachment 3).

Therefore, OSHA finds that the presence of interfering substances on field samples will not, most of the time, preclude being able to detect concentrations of respirable crystalline silica in the range of the PEL and action level, and that such instances where this might occur are rare. Accordingly, even when the presence of interfering substances is taken into account, worker exposure is capable of being measured with a reasonable degree of sensitivity and precision.

3.2.4 Precision of Measurement

All analytical methods have some random measurement error. The statistics that describe analytical error refer to the amount of random variation in measurements of replicate sets of samples containing the same quantity of silica. This variation is expressed as a standard deviation about the mean of the measurements. The relative standard deviation (RSD), a key statistic used to describe analytical error, is calculated by dividing the standard deviation by the mean for a data set. The RSD is also known as the coefficient of variation (CV).

When random errors are normally distributed, a 95-percent confidence interval can be calculated as $\overline{X} \pm (1.96 \times CV)$, where $\overline{X}$ is the mean. This statistic is termed the "precision" of the analytical method and represents a 2-sided confidence interval in that, for a particular measurement, there is a 95-percent chance that the "true" value, which could be higher or lower than the measurement, lies within the confidence interval. The measure of analytical precision typically also includes a term to represent error in sampler pump flow, which is conventionally taken to be 5 percent. The better the precision of an analytical method, the lower its value (i.e., a method having a precision of 17% has better precision than one with a precision of 20%).

OSHA also uses a statistic called the Sampling and Analytical Error (SAE) to assist compliance safety and health officers (CSHOs) in determining compliance with an exposure limit. The estimate of the SAE is unique for each analyte and analytical method, and must be determined by each laboratory based on its own quality control practices. At OSHA's Salt Lake Technical Center (SLTC), where analytical methods are developed and air samples taken for enforcement purposes are analyzed, the SAE is based on statistical analysis of results of internally prepared quality control samples. Sampling and analytical components are assessed separately, where CV_1 reflects analytical error that is estimated from the analysis of quality control samples, and CV_2 is the sampling error, assumed to be 5 percent due to variability in sampling pump flow rates that can affect sample air volume. Analytical error is combined with sampling pump error, and the SAE is calculated as a one-sided 95-percent confidence limit with the following formula:

$$\mathrm{SAE} = 1.645 \times \sqrt{\mathrm{CV}_1^2 + \mathrm{CV}_2^2}$$

The current SLTC SAE for crystalline silica is approximately 0.17, according to testimony from a representative of SLTC (Document ID 3579, Tr. 95). OSHA uses the SAE in its enforcement of PELs, where the PEL times the SAE is added to the PEL for a substance and compared to a sample result (see Section II, Chapter 1 of the OSHA Technical Manual, https://www.osha.gov/dts/osta/otm/otm_toc.html). A sample result is considered to have definitively exceeded the PEL if the result is greater than the sum of the PEL and the PEL times the SAE. For example, with the PEL at 50 µg/m^3 and an SAE of 17 percent, an air sample result would have to be greater than 58.5 µg/m^3 (i.e., 50 + (50 x 0.17)) to be considered to have definitively exceeded the PEL. This policy gives employers the benefit of the doubt, as it assumes that the actual exposure was below the PEL even when the result is above the PEL but below the PEL plus the SAE; the effect is that OSHA does not cite an employer for an exposure above the PEL unless the Agency has obtained a sample measurement definitively above the PEL after accounting for sampling and analytical error.

OSHA's quality control samples, which were prepared and analyzed at SLTC, demonstrate that the XRD method has acceptable precision, even at the low range of filter loads (50 µg). For the period April 2012 through April 2014, SLTC's analysis of 348 quality control samples, with a range of filter loads of about 50 to 250 µg crystalline silica, showed average recovery (i.e., the measurement result as compared to the reference mean value for the sample) of 0.98 with an RSD of 0.093 and precision of 20.8 percent (Document ID 3764, Attachment 1). Among those samples, there were 114 with a target filter load of 50 µg (range of actual filter load was 50 to 51.6 µg); these samples showed an average recovery of 1.00 with an RSD of 0.093 and precision of 20.7 percent (Document ID 3764, Attachment 1). Thus, OSHA's experience with quality control standards shows that the XRD method for quartz is as precise in the low range of method validation as it is over the full range.

The ACC raised several questions regarding OSHA's Method ID-142 and its validation. First, a paper they submitted by Sandra Wroblewski, CIH, of Computer Analytical Solutions notes that OSHA's stated Overall Analytical Error is 26 percent, higher than the 25-percent level "OSHA states is necessary to ensure that a PEL can be feasibly measured," and that the method had not been validated for cristobalite (Document ID 2307, Attachment 10, pp. 13-14). In addition, the ACC stated that OSHA's method specifies a precision and accuracy validation range of 50-160 µg quartz per sample, above the quantity that would be collected at the PEL and action level (assuming use of a Dorr-Oliver sampler at 1.7 L/min) and that the method has not been tested for validation at a range corresponding to the PEL and action level (Document ID 2307, Attachment 10, p. 14). ACC also argued that OSHA's method does not comply with the Agency's Inorganic Methods Protocol, which requires the CV_1 to be 0.07 or less and the detection limit to be less than 0.1 times the PEL (Document ID 2307, Attachment A, p. 202). The Edison Electric Institute (Document ID 2357, pp. 20-21) and Ameren Corporation (Document ID 2315, p. 2) expressed similar concerns about the detection limit.

While OSHA's published Method ID-142 reports an Overall Analytical Error of 26 percent, OSHA no longer uses this statistic (it is in the process of revising Method ID-142); the Agency provides measures of precision and SAE instead. The Overall Analytical Error, which is described in Method ID-142, published in 1996, included a bias term that is now corrected for in the data used to determine method precision, so there is no longer a need to include a bias term in the estimation of analytical error. As described above, the precision of Method ID-142 is about 21 percent based on recent quality control samples[4]. OSHA's Inorganic Methods Protocol, to which the ACC referred, has been replaced by evaluation guidelines for air sampling methods using spectroscopic or chromatographic analysis, published in 2005 (https://www.osha.gov/dts/sltc/methods/spectroguide/spectroguide.html) and 2010 (https://www.osha.gov/dts/sltc/methods/chromguide/chromguide.html), respectively. These more recent publications no longer reflect the guidance contained in the Inorganic Methods Protocol, and OSHA's Method ID-142 is consistent with these more recent guidelines. Finally, although the published method did not include validation data for filter loads below 50 µg or data for cristobalite, OSHA has conducted studies to

[4] OSHA also wishes to point out that the guideline for achieving a method precision of 25 percent was never an OSHA requirement for determining method feasibility, but is drawn from the NIOSH Accuracy Criterion (http://www.cdc.gov/niosh/docs/95-117/), which was used for the purpose of developing and evaluating analytical methods. Nevertheless, OSHA's Method ID-142 now meets that guideline.

characterize the precision that is achieved at low filter loads for quartz and cristobalite; these studies are in the rulemaking record (Document ID 1670, Attachment 1; 1847, Attachment 1; 3764, pp. 15-16) and are discussed further below.

In comments submitted on behalf of the Chamber, Mr. Lieckfield cited the NIOSH Manual of Analytical Methods, Chapter R, as stating that “current analysis methods do not have sufficient accuracy to monitor below current exposure standards” (Document ID 2259, p. 1). However, this is contradicted by NIOSH’s own post-hearing submission, which stated that, although method variability was assessed based on the exposure limits at that time (i.e., 1983, see Document ID 0901, pp. 1, 7), “it was known from an intra-laboratory study that an acceptable variability would likely be at least 20 µg on-filter, and so 20 µg was given as the lower range of the analytical method” (Document ID 4233, p. 3). Furthermore, in Chapter R of NIOSH’s Manual, NIOSH goes on to say that the GK2.69 high-flow sampler “has promise for potentially lowering the levels of silica that can be measured and still meet the required accuracy” (http://www.cdc.gov/niosh/docs/2003-154/pdfs/chapter-r.pdf, p. 265). This chapter was published in 2003, well before the studies by Lee et al. (2010, 2012) and Stacey et al. (2013), discussed above, which demonstrate that the GK2.69 sampler has acceptable performance. NIOSH concluded in its post-hearing comment that “current methods of sampling and analysis for respirable crystalline silica have variability that is acceptable to demonstrate compliance with the proposed PEL and action level” (Document ID 4233, p. 4).

At the time of the proposal, there was little data characterizing the precision of analytical methods for crystalline silica at filter loads in the range of the PEL and action level (i.e., with prepared samples of 40 µg and 20 µg crystalline silica, which are the amounts of silica that would be collected from full-shift sampling at the PEL and action level, respectively, assuming samples are collected with a Dorr-Oliver cyclone at a flow rate of 1.7 L/min). To characterize the precision of OSHA’s Method ID-142 at low filter loads, SLTC conducted studies in 2010 and again in 2013 (the latter of which was presented in the PEA; see Document ID 1720, p. IV-35). For these studies, the lab prepared 10 replicate samples each of quartz and cristobalite from NIST standard reference material and determined the precision of the analytical method; a term representing pump flow rate error was included in the precision estimate. In the 2010 test (Document ID 1670, Attachment 1), the precision for quartz loads equating to the PEL and action level was 27 and 33 percent, respectively. For cristobalite loads equating to the PEL and action level, the precision was 23 and 27 percent, respectively. The results from the 2013 test (Document ID 1847, Attachment 1; 3764, pp. 15-16; Document ID 1720, p. IV-35) showed improvement in the precision; for quartz, precision at loads equating to the PEL and action level was 17 and 19 percent, respectively, and for cristobalite, precision at loads equating to the PEL and action level was 19 and 19 percent, respectively. Both the 2010 and 2013 tests were conducted using the same NIST standards, same instrumentation, and same sample preparation method (OSHA Method ID-142) with the exception that the 2013 test used automatic pipetting rather than manual pipetting to prepare the samples (Document ID 1847). OSHA believes it likely that this change in sample preparation reduced variation in the amount of silica loaded onto the filters, which would account for at least some of the increased precision seen between 2010 and 2013 (i.e., imprecision in preparing the samples would make the analytical precision for 2010 appear worse than it actually was). Based on these studies, particularly the 2013 study, OSHA preliminarily determined that the XRD method was capable of accurately measuring crystalline silica concentrations at the PEL and action level.

The ACC believed that OSHA's reliance on the 2013 study was "misplaced" because the results were not representative of "real world" samples that contain interfering minerals that could increase analytical error, and because the studies did not account for inter-laboratory variability (Document ID 4209, pp. 135-137; 2308, Attachment 6, p. 10). The ACC also believed that variability would have been depressed in this study because the samples were analyzed in close temporal proximity by the same analyst and using the same instrument calibration, and the study involved only 10 samples at each filter load (Document ID 4209, pp. 137-138; 2308, Attachment 6, p. 10). The ACC's witness, Mr. Scott, also commented that the study failed to take into account the effect of particle sizes on the analysis of crystalline silica and believed that SLTC's evaluation could not reflect differences in precision between the XRD and IR methods (Document ID 2308, Attachment 6, p. 10).

3) FEASIBILITY OF MEASURING RESPIRABLE CRYSTALLINE SILICA EXPOSURES AT THE FINAL RULE'S PEL AND ACTION LEVEL

Despite the criticism that OSHA's investigation involved a small number of samples analyzed at the same time, the results obtained were comparable to OSHA's analysis of quality control samples at somewhat higher filter loads (between 50 and 51.6 μg) analyzed over a two-year period (Document ID 3764, Attachment 1). These results, described above, showed a precision of 20.7 percent, compared to 17 and 19 percent for quartz filter loads of 40 and 20 μg, respectively (Document ID 1847, Attachment 1; Document ID 3764). From these results, OSHA concludes that any effect on analytical error from performing a single study using the same analyst and instrument calibration is modest.

OSHA also concludes that Mr. Scott's argument that particle size effects were not taken into account is without merit. The samples prepared and analyzed in OSHA's study, like any laboratory's quality control samples, use standard materials that have a narrow range in particle size. Although large (non-respirable) size particles can result in an overestimate of crystalline silica content, in practice this is not typically a serious problem with air samples and is more of a concern with analyzing bulk samples. First, as discussed above, respirable dust samplers calibrated to conform to the ISO/CEN convention are collecting respirable particulate and excluding larger particles (Document ID 3579, Tr. 219). In analyzing field samples, OSHA uses microscopy to identify whether larger particles are present and, if they are, the results are reported as a bulk sample result so as not to be interpreted as an airborne exposure (Document ID 3579, Tr. 213). Additionally, OSHA's Method ID-142 calls for grinding and sieving bulk samples to minimize particle size effects in the analysis (Document ID 0946, p. 13). OSHA also notes that the Chamber's witness, Mr. Lieckfield, testified that his laboratory does not check for oversized particles (Document ID 3576, p. 483).

With regard to interferences, as discussed above, there are procedures that have been in place for many years to reduce the effect of interfering materials in the analysis. The presence of interferences does not typically prevent an analyst from quantifying crystalline silica in a sample with reasonable precision. As to the claim regarding XRD versus IR, a recent study of proficiency test data, in which multiple laboratories are provided comparable silica samples, both with and without interfering materials added, did not find a meaningful difference in precision between laboratories using XRD and those using IR (Harper et al., 2014, Document ID 3998, Attachment 8). In addition, as discussed above, NIOSH's and OSHA's measures of precision of the XRD method at low filter loads were comparable, despite differences in equipment and sample preparation procedures. Therefore, OSHA finds that the studies it carried out to evaluate the precision of OSHA Method ID-142 at low filter loads provide a reasonable characterization of the precision of the method for analyzing air samples taken at concentrations equal to the final PEL and action level under the respirable crystalline silica rule.

With respect to the ACC's and Mr. Scott's reference to inter-laboratory variation in silica sample results, OSHA discusses data and studies that have evaluated inter-laboratory variance in analytical results in the next section.

3.2.5 Measurement Error Between Laboratories

The sources of random and systematic error described above reflect the variation in sample measurement experienced by a single laboratory; this is termed intra-laboratory variability. Another source of error that affects the reliability of results obtained from sampling and analytical methods is inter-laboratory variability, which describes the extent to which different laboratories may obtain disparate results from analyzing the same sample. Inter-laboratory variability can be characterized by using data from proficiency testing, where laboratories analyze similarly-prepared samples and their results are compared. In practice, however, it is difficult to separate intra- and inter-laboratory variability because each laboratory participating in a proficiency test provides analytical results that reflect their own degree of intra-laboratory variability. Thus, use of proficiency test data to compare performance of laboratories in implementing an analytical method is really a measure of total laboratory variability.

The best available source of data for characterizing total variability (which includes an inter-laboratory variability component) of crystalline silica analytical methods is the AIHA Industrial Hygiene Proficiency Analytical Testing (PAT) Program. The AIHA PAT Program is a comprehensive testing program that provides an opportunity for laboratories to demonstrate competence in their ability to accurately analyze air samples through comparisons with other labs. The PAT program is designed to help consumers identify laboratories that are deemed proficient in crystalline silica analysis.

Crystalline silica (using quartz only) is one of the analytes included in the proficiency testing program. The AIHA PAT program evaluates the total variability among participating laboratories based on proficiency testing of specially prepared silica samples. The AIHA contracts the preparation of its crystalline silica PAT samples to an independent laboratory that prepares four PAT samples in the range of about 50 to 225 μg (Document ID 3586, Tr. 3279-3280) and one blank sample for each participating laboratory per round. Each set of PAT samples with the same sample number is prepared with as close to the same mass of crystalline silica deposited on the filter as possible. However, some variability occurs within each numbered PAT sample set because of small amounts of random error during sample preparation. Before the contract laboratory distributes the round, it analyzes a representative lot of each numbered set of samples to ensure that prepared samples are within ±10 percent (Document ID 3586, Tr. 3276). The samples are distributed to the participating laboratories on a quarterly basis (Document ID 1720, p. IV-36). The PAT program does not specify the particular analytical method to be used. However, the laboratory is expected to analyze the PAT samples using the methods and procedures it would use for normal operations.

The results of the PAT sample analysis are reported to the AIHA by the participating laboratories. For each PAT round, AIHA compiles the results and establishes upper and lower performance limits for each of the four sample results based on the mean and RSD of the sample results. For each of the four samples, a reference value is defined as the mean value from a selected set of reference laboratories. The RSD for each of the four samples is determined from the results reported by the reference labs after correcting for outliers (generally clear mistakes in analysis or reporting, particularly those that are order-of-magnitude errors) (Document ID 4188, p. 2). A participating laboratory receives a passing score if at least three out of the four sample results reported are within 20 percent of the reference mean for the sample (Document ID 3586, Tr. 3291). Two or more results reported by a lab in a given round that are outside the limits results in the lab receiving an unsatisfactory rating. An unsatisfactory rating in 2 of the last 3 rounds results in revocation of the lab's AIHA accreditation for the analysis of crystalline silica. Participation in the PAT program is a prerequisite for accreditation through the AIHA Industrial Hygiene Laboratory Accreditation Program (IHLAP).

In the PEA, OSHA presented PAT results from its SLTC for the period June 2005 through February 2010 (PAT Rounds 160-180) (Document ID 1720, pp. IV-40-41). The mean recovery was 99 percent, with a range of 55 to 165 percent. Eighty-one percent of the samples analyzed over this period were within ±25 percent of the reference mean and the RSD for this set of samples was 19 percent, showing reasonable agreement with the reference mean. OSHA also evaluated PAT data from all participating laboratories for the period April 2004 through June 2006 (PAT Rounds 156-165) (Document ID 1720, pp. IV-37 - IV-40). Overall, the mean lab RSD was 19.5 percent for the sample range of 49 to 165 μg. Beginning with Round 161, PAT samples were prepared by liquid deposition rather than by sampling a generated silica aerosol, in order to improve consistency and reduce errors in sample preparation. The improvement was reflected in the results, with the mean lab RSD declining from 21.5 percent to 17.2 percent after the change to liquid deposition, demonstrating the improved consistency between PAT samples.

In the time since OSHA analyzed the PAT data, Harper et al. (2014, Document ID 3998, Attachment 8) evaluated more recent data. Specifically, Harper et al. (2014, Document ID 3998, Attachment 8, p. 3) evaluated PAT test results for the period 2003-2014 (Rounds 152 through 194) and found that variation in respirable crystalline silica analysis has improved substantially since the earlier data from 1990 to 1998 was studied by Eller et al. (1999a, Document ID 1687). A total of 9,449 sample results were analyzed after removing re-test results, results where the method of analysis was not identified, and results that were more than three standard deviations from the reference mean. There was a clear improvement in overall variation in the newer data set compared with that of Eller et al. (1999a, Document ID 1687), with the mean laboratory RSD declining from about 28.7 percent to 20.9 percent (Document ID 3998, Attachment 8, Figure 1). Both the older and newer data sets showed that analytical variation increased with lower filter loadings, but the more recent data set showed a much smaller increase than did the older. At a filter load of 50 μg, the mean lab RSD of the more recent data was less than 25 percent, whereas it was almost 35 percent with the older data set (Document ID 3998, Attachment 8, Figure 1). It was also clear that the change in sample preparation procedure (i.e., from aerosol deposition to liquid deposition starting in Round 161) explained at least some of the improvement seen in the more recent PAT results, with the mean lab RSD declining from 23.6 percent for all rounds combined to 19.9 percent for Rounds 162-194.

Despite the improvement seen with the change in deposition method, it is important to understand that the observed variation in PAT results between labs still reflects some sample preparation error (limited to ±10 percent as explained above), a source of error not reflected in the analysis of field samples. Other factors identified by the investigators that account for the improved performance include the phasing out of the colorimetric method among participating labs, use of more appropriate calibration materials (i.e., NIST standard reference material), calibration to lower mass loadings, stricter adherence to published method procedures, and possible improvements in analytical equipment. There was also only a small difference (2%) in mean lab RSD between labs using XRD and those using IR (Document ID 3998, Attachment 8, p. 9). The increase in variance seen with lower filter loads was not affected either by analytical method (XRD vs. IR) or by the composition of interfering minerals added to the matrix (Document ID 3998, Attachment 8, p. 4).

OSHA finds that this study provides substantial evidence that employers will obtain reliable results from analysis of respirable crystalline silica most of the time for the purpose of evaluating compliance with the PEL. From Round 162 through 194 (after the deposition method was changed), and over the full range of PAT data, only about 7 out of the 128 (5%) lab RSD values reported were above 25 percent (Document ID 3404, Figure 2). For filter loads of 75 µg or less, only 3 lab RSD values out of about 30 reported, were above 25 percent. As stated above, the mean RSD at a filter load of 50 µg was less than 25 percent and agreement between labs improved substantially compared to earlier PAT data.

Summary data for PAT samples having a target load of less than 62.5 µg were provided by AIHA in a post-hearing comment (Document ID 4188) and compared with the findings reported by Harper et al. (2014, Document ID 3998, Attachment 8). For PAT rounds 155-193 (from 1999 to 2013), there were 15 sets of samples in the range of 41.4 to 61.8 μg distributed to participating laboratories. Lab RSDs from results reported for these samples ranged from 11.2 to 26.4 percent, with an average RSD of 17.1 percent, just slightly above the average RSD of 15.9 percent for all samples across the entire range of filter loads from those rounds. Taken together, the results of the analysis performed by Harper et al. (2014, Document ID 3998, Attachment 8) and the summary data provided by AIHA (Document ID 4188) suggest that sample results from participating labs will be within 25 percent of the crystalline silica filter load most of the time.

In its post hearing comments, the National Stone, Sand & Gravel Association (NSSGA) contended that analytical laboratories cannot provide adequately precise and accurate results of silica samples (Document ID 4232). NSSGA provided a detailed analysis of low-load samples from the same 15 PAT rounds as examined by AIHA (Document ID 4188) and concluded that "employers and employees cannot rely on today's silica sampling and analytical industry for consistently accurate sample results necessary to achieve or surpass compliance requirements" (Document ID 4232, p. 26). The NSSGA compared individual labs' sample results to the reference mean for each sample and found, from the AIHA PAT data, that 76-84 percent of the results were within 25 percent of the reference mean, and the range of results reported by laboratories included clear outliers, ranging from zero to several-fold above the target filter load (Document ID 4232, p. 8, Table 1, rows 1-6). NSSGA concluded from this that "[i]t is of little value to employers that a given lab's results meet the NIOSH Accuracy Criterion while other labs' results cannot, particularly since employers almost certainly won't know which labs fall into which category" (Document ID 4232, p. 10). NSSGA's point appears to be that the outliers in the PAT data erode an employer's ability to determine if they are receiving accurate analytical results, without which they have little ability to determine their compliance status with respect to the PEL or action level. Further, NSSGA suggests that OSHA's analysis of the PAT data, discussed above, is not adequate to demonstrate the performance of an individual laboratory that may be chosen by an employer.

3) FEASIBILITY OF MEASURING RESPIRABLE CRYSTALLINE SILICA EXPOSURES AT THE FINAL RULE'S PEL AND ACTION LEVEL

In response to NSSGA's criticism, OSHA points out that its analysis of the PAT data was part of its analysis of technological feasibility in which the Agency's legal burden is to show that employers can achieve compliance in most operations most of the time. It may be an unavoidable fact that lab results may be inaccurate some of the time, but that does not render the standard infeasible or unenforceable. OSHA contends that its analysis has satisfied that burden and nothing in the NSSGA's comments suggests otherwise.

NSSGA further suggests that employers have no means of determining, based on a laboratory's PAT proficiency rating alone, whether that individual laboratory is likely to produce erroneously high or low results. OSHA concurs that selecting a laboratory based on accreditation, price, and turnaround time, as NSSGA suggests (Document ID 4232, p. 5), is common but may be inadequate to determine whether an individual laboratory is capable of producing results of consistently high quality. Employers and their industrial hygiene consultants can, and should, ask additional questions and request additional assurances of quality from the laboratories they consider using. For example, employers can ask to review the laboratory's individual PAT results over time, focusing on and questioning any significant outliers in the laboratory's results. While NSSGA suggests that the PAT results are treated as confidential by the AIHA-PAT program (Document ID 4232, p. 6), there is nothing stopping a laboratory from sharing its PAT data or any other information related to its accreditation with their clients or prospective clients.

Further, laboratories routinely perform statistical analyses of their performance in the context of analyzing known samples they use for equipment calibration, and often perform statistical comparisons among the various technicians they employ. Review of these statistics can shed light on the laboratory's ability to provide consistent analysis. Finally, as employers conduct exposure monitoring over time, and come to understand what results are typically seen in their workplaces, clear outliers should become more identifiable; for example, if employee exposures are usually between the action level and PEL, and a sample result shows an exposure significantly above the PEL without any clear change in workplace conditions or operations, employers should question the result and ask for a reanalysis of the sample. Employers could also request gravimetric analysis for respirable dust against which to compare the silica result to confirm that the silica content of the dust is consistent with past experience. For example, if, over time, an employer's consistent results are that the silica content of respirable dust generated in its workplace is 20 percent silica, and subsequently receives a sample result that indicates a significantly higher or lower silica content, it would be appropriate for the employer to question the result and request reanalysis. Therefore, OSHA rejects the idea that employers are at the mercy of random chance and have to simply accept a high degree of uncertainty in exposure measurements; rather, there are positive steps they can take to reduce that uncertainty.

Results from the AIHA PAT program were discussed at considerable length during the rulemaking proceeding. After considering all of the analyses of PAT data presented by Eller et al. (1999a, Document ID 1687), OSHA in its PEA, and Harper et al. (2014, Document ID 3404), the ACC concluded that "PAT program results indicate that analytical variability as measured by precision is unacceptably high for silica loadings in the range of 50-250 µg" and that the PAT data "provide strong evidence that commercial laboratories will not be able to provide reliable measurements of…[respirable crystalline silica] exposures at the levels of the proposed PEL and action level" (Document ID 4209, p. 144). OSHA disagrees with this assessment. First, OSHA's experience over the last forty years in enforcing the preceding PEL that this standard supersedes is that analytical variability has not been an impediment to successful enforcement of the superseded PEL, and there have been few, if any, challenges to such enforcement actions based on variability. Nor has OSHA been made aware of concerns from employers that they have been unable to evaluate their own compliance with the former PEL or make reasonable risk management decisions to protect workers. In fact, the Chamber's expert, Mr. Lieckfield, admitted that analytical variability for asbestos, another substance that has been regulated by OSHA over the Agency's entire history, "is worse" than that for crystalline silica (Document ID 3576, Tr. 531).

To support its contention that reliably measuring silica at the final rule's PEL and action level is not possible, the ACC cited Harper et al. (2014, Document ID 3998, Attachment 8) as stating that further increases in laboratory variance below the 40-50 µg range would have "implications for the [working] range of the analytical methods," and that excessive variance might "make it difficult to address for either method" (Document ID 4209, p. 144). However, it is clear from Harper et al. (2014) that this is the basis for the authors' recommendation that the PAT program consider producing samples with filter loads as low as 20 µg to "support the analysis of lower target concentration levels" (Document ID 3404, p. 5). They also identify use of currently available higher-flow-rate sampling devices (discussed above) to increase the collected mass of silica, which would generate field samples in the filter load range currently used in the PAT program.

Finally, the ACC sponsored a performance testing study to assess inter-laboratory variability at crystalline silica filter loads at 40 and 20 µg (i.e., the amount of silica collected at final rule's PEL and action level, respectively, assuming use of a Dorr-Oliver cyclone operated at a flow rate of 1.7 L/min) as well as at 80 µg (i.e., the amount collected at the preceding PEL) (Document ID 2307, Attachment 14; 3461; 3462). The study was blinded in that participating laboratories were not aware that they were receiving prepared samples, nor were they aware that they were involved in a performance study. For this study, each of five laboratories was sent three replicate rounds of samples; each round consisted of three filters prepared with respirable crystalline silica (Min-U-Sil 5) alone, three of silica mixed with kaolin, three of silica mixed with soda-feldspar, and one blank filter. The samples were prepared by RJ Lee Group and sent by a third party to the laboratories as if they were field samples. All laboratories were accredited by AIHA and analyzed the samples by XRD.

The samples were initially prepared on 5 µm PVC filters; however, due to sample loss during preparation, RJ Lee changed to 0.8 µm PVC filters. It should be noted that the 2-propanol used to suspend the Min-U Sil sample for deposition onto the 0.8 µm filter dissolved between 50 and 100 µg of filter material, such that the amount of minerals deposited on the filter could not be verified from the post-deposition filter weights. In addition, two of the labs had difficulty dissolving these filters in tetrahydrofuran, a standard method used to dissolve PVC filters in order to redeposit the sample onto silver membrane filters for XRD analysis. These labs were replaced by two laboratories that used muffle furnaces to ash the filters before redeposition, as did the other three labs originally selected.

Results reported from the labs showed a high degree of both intra-and inter-laboratory variability as well as a systematic negative bias in measured vs. applied silica levels, with mean reported silica values more than 30 percent lower than the deposited amount. Across all laboratories, mean results reported for filter loads of 20, 40, and 80 µg were 13.36, 22.93, and 46.91 µg, respectively (Document ID 2307, Attachment 14, pp. 5-6). In addition, laboratories reported non-detectable results for about one-third of the silica samples (Document ID 2307, Attachment 14, p. 7) and two blank filters sent to the labs were reported to have silica present, in one case an amount of 52 µg (Document ID 2307, Attachment 14, pp. 9-10; 3582, Tr. 1995). Individual CVs for the labs ranged from 20 to 66 percent, up to more than 3 times higher than the CVs reported by OSHA or NIOSH for their respective methods. After examining variability in reported results, the investigators concluded that two-fold differences in filter load could not be reliably distinguished in the concentration range of 25 to 100 $\mu g/m^3$ (Document ID 2307, Attachment 14, p. 14).

OSHA identifies several deficiencies in this study; these deficiencies are sufficient to discredit the finding that high variability in silica results can be attributed to the inability of the analytical method to accurately measure crystalline silica at filter loads representative of concentrations at the action level and PEL set by this rule. Principally, the loss of filter material during deposition of the samples, combined with the lack of any verification of the actual amount of silica loaded onto the filters, makes it impossible to use the laboratory results to assess lab performance since the amount of silica on the filters analyzed by the labs cannot be known. The large negative bias in lab results compared to the target filter load implies that there was significant sample loss. In addition, the quality control employed by RJ Lee to ensure that filter loads were accurately known consisted only of an analysis of six separately prepared samples to evaluate the recovery from the 0.8 µm PVC filter and two sets of filters to evaluate recovery and test for shipping loss (Document ID 3461, Slides 8, 15, 16; 3582, Tr. 2090-2091). This is in stark contrast to the procedures used by the AIHA PAT program, which verifies its sample preparation by analyzing a statistically adequate number of samples prepared each quarter to ensure that sample variation does not exceed ±10 percent (Document ID 3586, Tr. 3276-3277). RJ Lee's use of the 0.8 µm PVC copolymer filter

(Document ID 4001, Attachment 1) is also contrary to the NIOSH Method 7500 (Document ID 0901), which specifies use of the 5 μm PVC filter, and may have introduced bias. As stated at the hearing by Mary Ann Latko of the AIHA Proficiency Analytical Testing Programs, "[a]ny variance from the NIOSH method should not be considered valid unless there's a sufficient quality control data provided to demonstrate the reliability of the modified method" (Document ID 3586, Tr. 3278).

OSHA finds that the AIHA PAT data are a far more credible measure of inter-laboratory variation in crystalline silica measurement than the ACC-sponsored RJ Lee study. Strict procedures are used to prepare and validate sample preparation in accordance with ISO requirements for conformity assessment and competence of testing in calibration laboratories (Document ID 3586, Tr. 3275) and the database includes 200 rounds of silica testing since 2004, with 55 laboratories participating in each round (Document ID 3586, Tr. 3264-3265). By comparison, the RJ Lee study consisted of three rounds of testing among five laboratories.

One of the goals of the RJ Lee study was to conduct a double-blind test so that laboratories would not know they were analyzing prepared samples for proficiency testing; according to Mr. Bailey, a laboratory's knowledge that they are participating in a performance study, such as is the case with the AIHA PAT program, "can introduce bias into the evaluation from the very beginning" (Document ID 3582, Tr. 1989; Document ID 4209, p. 147). However, OSHA doubts that such knowledge has a profound effect on laboratory performance. Accredited laboratories participating in the PAT program undergo audits to ensure that analytical procedures are applied consistently whether samples are received from the field or from the PAT program. According to testimony from Mr. Walsh:

> [S]ite assessors [for the AIHA accreditation program] are very sensitive to how PAT samples are processed in the lab. It's a specific area that's examined, and if the samples are processed in any way other than a normal sample, the laboratory is cited as a deficiency (Document ID 3586, Tr. 3299-3300).

Therefore, after considering the evidence and testimony on the RJ Lee study and AIHA PAT Program data, OSHA concludes that the AIHA PAT data are the best available data on which to evaluate inter-laboratory variability in measuring respirable crystalline silica. The data evaluated by Harper et al. (2014) showed that laboratory performance has improved in recent years resulting in greater agreement between labs; mean RSD for the period 2003-2013 was 20.9 percent (Document ID 3998, Attachment 8, Figure 1). In addition, across the range of PAT filter loadings, only about 5 percent of the samples resulted in lab RSDs above 25 percent. At lower filter loads, 75 µg or less, about 10 percent of samples resulted in RSDs above 25 percent Document ID 3998, Attachment 8, Figure 2). OSHA concludes that these findings indicate general agreement between laboratories analyzing PAT samples.

Although laboratory performance has not been broadly evaluated at filter loads below 40 µg, particularly when interferences are present, OSHA's investigations show that the XRD method is capable of measuring crystalline silica at filter loads of 40 µg or less without appreciable loss of precision. The analysis of recent PAT data by Harper et al. (2014, Document ID 3998, Attachment 8) shows that the increase seen in inter-laboratory variation with lower filter loads (e.g., about 50 and 70 µg) is modest compared to the increase in variation seen in the past from earlier PAT data, and the summary data provided by AIHA (Document ID 4188) show that the average lab RSD for samples with low filter loads is only a few percentage points above average lab RSD across the full range of filter loads used in the PAT program since 1999. OSHA finds that the studies of recent PAT data demonstrate that laboratories have improved their performance in recent years, most likely as a result of improving quality control procedures such as were first proposed by Eller et al. (1999b, Document ID 1688, pp. 23-24). Such procedures, including procedures concerning equipment calibration, use of NIST standard reference material for calibration, and strict adherence to published analytical methods, are required by Appendix A of the final rule. According to Dr. Rosa Key-Schwartz, NIOSH's expert in crystalline silica analysis, NIOSH worked closely with the AIHA laboratory accreditation program to implement a silica emphasis program for site visitors who audit accredited laboratories to ensure that these quality control procedures are being followed (Document ID 3579, Tr. 153). With such renewed emphasis being placed on tighter procedures for crystalline silica analysis, OSHA finds that exposure monitoring results being received from laboratories are more reliable than was the case in years past and thus are deserving of greater confidence from employers and workers.

3.3 CONCLUSION

Based on the record evidence reviewed in this section, OSHA finds that current methods to sample respirable dust and analyze samples for respirable crystalline silica by XRD and IR methods are capable of reliably measuring silica concentrations in the range of the final rule's PEL and action level. This finding is based on the following considerations, which were discussed in more detail above: (1) several sampling devices are available that conform to the ISO/CEN specification for particle-size selective samplers with a level of bias and accuracy deemed acceptable by international convention, and moving to the ISO/CEN convention will maintain continuity with past practice, (2) both the XRD and IR methods can measure respirable crystalline silica with acceptable precision at amounts that would be collected by samplers when airborne concentrations are at or around the PEL and action level, and (3) laboratory proficiency data demonstrate that there is reasonable agreement between laboratories analyzing comparable samples most of the time.

There are several sampling devices that can collect respirable crystalline silica in sufficient quantity to be measured by laboratory analysis; some of these include the Dorr-Oliver nylon cyclone operated at 1.7 L/min air flow rate, the Higgins-Dewell cyclones (2.2 L/min), the SKC aluminum cyclone (2.5 L/min), and the GK2.69, which is a high-flow sampler (4.2 L/min). Each of these cyclones can collect the minimum amount of silica necessary, at the PEL and action level, for laboratories to measure when operated at their respective flow rates for at least four hours. In addition, each of these devices (as well as a number of others) has been shown to conform to the ISO/CEN convention with an acceptable bias and accuracy for a wide range of particle-size distributions encountered in the workplace. OSHA used the Dorr-Oliver at a flow rate of 1.7 L/min to enforce the previous PELs for respirable crystalline silica, so specifying the use of sampling devices conforming to the ISO/CEN convention does not reflect a change in enforcement practice. The modest error that is associated with using respirable dust samplers is independent of where the PEL is set, and these samplers have been used for decades both by OSHA, to enforce the preceding silica PEL (and other respirable dust PELs), and by employers in managing silica-related risks. Therefore, OSHA finds that these samplers are capable of and remain suitable for collecting respirable dust samples for crystalline silica analysis.

Both XRD and IR analytical methods are capable of quantifying crystalline silica with acceptable precision when air samples are taken in environments where silica concentrations are around the PEL and action level. OSHA's quality control samples analyzed by XRD over the past few years show the precision to be about 20 percent over the range of filter loads tested (about one-half to twice the former PEL). OSHA conducted studies to characterize the precision of its Method ID-142 at low filter loads representing the amounts that would be captured using the Dorr-Oliver cyclone at the action level and PEL (i.e., 20 and 40 μg, respectively), and found the precision, for quartz and cristobalite, at both 20 and 40 μg to be comparable to the precision at the higher range of filter loads.

Evaluation of data from AIHA's Proficiency Analytical Testing Program shows that results from participating laboratories are in agreement (i.e., within 25%) most of the time. Performance between laboratories has improved significantly in recent years, most likely due to adoption of many of the quality control practices required by Appendix A of the final rule. Although precision declines as the amount of crystalline silica in samples declines, the rate of decline in precision with declining mass is less today than for prior years. OSHA expects that increasing emphasis on improved quality control procedures by the AIHA laboratory accreditation program (Document ID 3579, Tr. 153), the requirement in the final rule for employers to use laboratories that use XRD or IR analysis (not colorimetric) and that are accredited and conform to the quality control procedures of Appendix A of the final rule, and increased market pressure for laboratories to provide reliable results are likely to improve agreement in results obtained by laboratories in the future.

Inter-laboratory variability has not been well characterized at filter loads below 50 μg, which is slightly more than would be collected by a Dorr-Oliver cyclone sampling a silica concentration at the PEL over a full shift. However, OSHA concludes that the studies conducted by SLTC show that acceptable precision can be achieved by the XRD method for filter loads obtained by collecting samples with the Dorr-Oliver and similar devices at the action level and PEL. If employers are concerned about the accuracy that their laboratory would achieve at filter loads this low, samplers with higher flow rates could be used to collect an amount of silica that falls within the working range of the OSHA method and within the range of filter loads currently used by the PAT program (i.e., 50 μg or more). For example, either the aluminum cyclone or HD will collect at least 50 μg or more of silica where concentrations are around the PEL, and the GK2.69 will collect a sufficient quantity of crystalline silica where concentrations are at least at the action level.

Based on the information and evidence presented in this section, OSHA is confident that current sampling and analytical methods for respirable crystalline silica provide reasonable estimates of measured exposures. Employers should be able to rely on sampling results from laboratories meeting the requirements in Appendix A of the final rule to analyze their compliance with the PEL and action level under the new silica rule; employers can obtain assurances from laboratories or their industrial hygiene service providers that such requirements are met. Similarly, employees should be confident that those exposure results provide them with reasonable estimates of their exposures to respirable crystalline silica. Thus, OSHA finds that the sampling and analysis requirements under the final rule are technologically feasible.

4. TECHNOLOGICAL FEASIBILITY FOR GENERAL INDUSTRY

4.1 ASPHALT PAVING PRODUCTS

4.1.1 Description

Asphalt paving product manufacturing facilities are primarily classified in the six-digit North American Industry Classification System (NAICS) code 324121, Asphalt Paving Mixture and Block Manufacturing. Silica-containing materials are commonly used as aggregate to add bulk and durability to asphalt mixtures and blocks (unit pavers) used for pavement construction, rehabilitation, and/or maintenance. Common aggregates for asphalt paving products include sand, gravel, crushed stone, and reclaimed asphalt pavement (RAP) and account for about 95 percent of the total mixture by weight. Additionally, virgin Portland cement is sometimes added as a stabilizer (Document ID 1365, p. 19-1).

There are two types of central mix plants broadly classified as batch mix plants and drum mix (continuous) plants, depending on the process by which the raw materials are mixed. There are two commonly used types of asphalt paving mixtures that are produced at mix plants: hot mix and cold mix. In addition, some asphalt plants have begun using a warm mix asphalt technology as an alternative to hot mixes to decrease fumes and odors (Document ID 0674, p. 1). Hot mix plants require drying (heating) and screening of aggregate, presenting additional sources of silica dust not present at cold mix plants (Document ID 1365, p. 19-3).

Asphalt paving product workers can be exposed to silica-containing dusts when handling loose, dry aggregate; during crushing, drying, and screening activities; and when mixing aggregate with asphalt cement (Document ID 1365, pp. 19-2 – 19-3). The job categories with potential for exposure to silica include facility operator, front-end loader operator, and maintenance worker. Table IV.4.1-A summarizes the major activities and sources of exposure in this industry.

There is potential for further exposure in facilities with recycling activities that include crushing and screening of recovered concrete and/or RAP. These workers have job titles such as crusher operator and tender (belt picker, laborer), and their activities might involve the use of mobile rubble crushing plants, lump breakers, and screeners. For a discussion of crusher operators and tenders, refer to Section IV-5.10 – Mobile Crushing Machine Operators and Tenders.

Table IV.4.1-A
Job Categories, Major Activities, and Sources of Exposure of Workers in the Asphalt Paving Products Industry (NAICS 324121)

Job Category*	Major Activities and Sources of Exposure
Facility Operator	Controls and monitors production of asphalt paving products with an automated computer-controlled process. Operates conveyors, elevators, dryers, and mixing equipment, and dispenses product into trucks or storage silos from a control room/booth. Most control rooms are fully enclosed and ventilated with little potential for exposure to silica-containing dusts. • Dust from "manually" operating production operations (when necessary). • Dust from material handling activities and the plant yard/haul road (when control rooms are not fully enclosed).
Front-End Loader Operator	Transports raw materials using a front-end loader. Might oversee receipt of raw materials via truck or rail car. • Dust from manually transporting sacks of specialty materials (when necessary). • Dust from material handling activities (when the front-end loader is not equipped with a fully enclosed and ventilated cab). • Dust from the plant yard/haul road.
Maintenance Worker (Laborers)	Inspects, services, repairs, and adjusts equipment. Cleans up around the facility. • Dust from the plant yard/haul road, raw material storage piles, conveyors, weight scales, and process equipment (such as dust collectors).

*Job categories are intended to represent job functions; actual job titles might differ, and responsibilities might be allocated differently, depending on the facility.
Source: Document ID 1365, p. 19-7.

Table IV.4.1-B summarizes the available exposure information for the affected job categories. For each of the job categories listed in Table IV.4.1-B and for the asphalt paving industry as a whole, OSHA concludes that Table IV.4.1-B represents baseline conditions.

4.1.2 Exposure Profile and Baseline Conditions

The exposure profile in Table IV.4.1-B includes 5 full-shift personal breathing zone (PBZ) samples of respirable crystalline silica for workers in the asphalt paving industry. The median is 20 μg/m^3, the mean is 27 μg/m^3, and the range is 20 μg/m^3 (limit of detection (LOD)) to 53 μg/m^3. Table IV.4.1-B shows that, of the 5 samples, 1 (20 percent) is at or above 50 μg/m^3 and none exceed 100 μg/m^3. The following sections describe the exposure profile and baseline conditions for each affected job category based on two OSHA Special Emphasis Program (SEP) inspection reports from hot mix plants (Document ID 1365, p. 19-8; 0186; 0077).[5] In the absence of information specific to cold mix plants, OSHA considers the available exposure data relevant to both hot and cold mix production. OSHA noted in its preliminary analysis that the data may overestimate the exposure of some workers at plants using cold mix techniques (Document ID 1720, p. IV-50). This is because cold mix plants might be somewhat less dusty than hot mix plants as they lack dryers and screens. OSHA received no comments regarding this conclusion.

As noted above, the available exposure data for the Asphalt Paving Products industry includes only five samples obtained from two OSHA SEP reports. Four of these samples are between 4 and 5 hours duration and are below the limits of detection [LOD] of 20 to 21 μg/m^3. The U.S. Chamber of Commerce commented that this small number of samples does not provide a representative sample of exposures at Asphalt Paving Products manufacturing facilities (Document ID 2368, p. 19). OSHA acknowledges that these data are limited; however, OSHA requested – but did not receive – additional exposure data for this industry, and therefore considers the samples to represent the best available evidence regarding exposures to respirable crystalline silica in the asphalt paving products industry.[6]

Exposure Profile and Baseline Conditions for Facility Operators

The exposure profile in Table IV.4.1-B includes 1 sample for facility operators in the asphalt paving industry, with a value of 21 μg/m^3. This single exposure result available for facility operators is from an OSHA inspection at an asphalt plant. The exposure result is below the LOD, which in this case is less than or equal to 21 μg/m^3 (290-minute sample). This value was obtained for an operator working in an air-conditioned room at a

[5]Due to the limited exposure data available for the asphalt paving industry, OSHA has considered data from four samples greater than 4 hours duration. In this case, 8-hour time-weighted averages (8-hour TWAs) were derived from samples of 4-hours or longer by assuming the exposure concentration during any unsampled portion of the shift was the same as the concentration during the period sampled.

[6] In the PEA, OSHA included as supporting information a discussion of sampling results from the Ready-Mix industry in that the processes and range of exposures are similar to the Asphalt Paving Products industry. However, OSHA has not relied on the sampling information from the Ready-Mix operations as the basis for the conclusions in the FEA because the sample results did not significantly alter the exposure profile and therefore did not impact the related conclusions.

continuous feed asphalt plant where visible dust had been greatly reduced by maintenance and adjustments to an existing ventilation system on the blending equipment and water spray in the sand/aggregate drier exhaust system (Document ID 1365, p. 19-15; 0077). The inspection report prepared by the compliance officer stated:

> High dust levels were noted during the initial walk-around, based in large part on dust being discharged from the blender overflows. When sampling could be conducted, the employees had had the opportunity to perform a large amount of maintenance work and experiment with dust control measures in the operation of the blender. The operator was successful in controlling dust overflows from the blender quite well, making the dust levels measured by sampling quite low. Dust emissions from the drier were controlled by a water spray scrubber that had been installed on the air exhaust from the drier. Bulk sample results showed silica levels of about 8%, with none being detected in the personal air monitoring samples (Document ID 0077, p. 13).

OSHA received no additional exposure data for facility operators. OSHA also reviewed the OSHA inspection data from OSHA's Information System (OIS) submitted to the rulemaking record (Document ID 3958); however, no additional data were identified for facility operators. Based on the information in the docket, OSHA considers 21 μg/m^3 to be the baseline exposure level for facility operators.

Exposure Profile and Baseline Conditions for Front-End Loader Operators

The exposure profile in Table IV.4.1-B includes 2 samples for front-end loader operators in the asphalt paving industry. The median is 37 μg/m^3, the mean is 37 μg/m^3, and the range is 20 μg/m^3 (limit of detection (LOD)) to 53 μg/m^3. Table IV.4.1-B shows that, of the 2 samples, 1 (50 percent) is at or above 50 μg/m^3 and none exceed 100 μg/m^3. These two PBZ silica samples were obtained during two inspections at asphalt plants. One sample measured an exposure below the LOD of 20 μg/m^3 during a 290-minute sampling period, and a second sample measured 53 μg/m^3 over a 435-minute sampling period (Document ID 1365, p. 19-16; 0186; 0077). At both plants, the front-end loader operators scooped sand, aggregate, and other filler materials and dumped them into hoppers (Document ID 0186, p. 63; 0077, p. 30). At the plant where the sampling result was below the LOD, the front-end loader operator worked in a ventilated cab and maintenance work on existing dust controls had substantially reduced visible dust on the sampling date (Document ID 0077, p. 13).

OSHA also reviewed the OIS sampling data submitted to the rulemaking record (Document ID 3958); however, no additional data were identified, nor were any comments received related to front-end loader operator exposure. Based on this best available (but limited) data, OSHA concludes that half of front-end loader operators are currently exposed to silica levels below 50 μg/m^3, and the median exposure is below 50 μg/m^3 (37 μg/m^3), with the highest exposure only slightly above the PEL.

Exposure Profile and Baseline Conditions for Maintenance Workers (Laborers)

The exposure profile in Table IV.4.1-B includes 2 samples for maintenance workers (laborers) in the asphalt paving industry. These maintenance workers serviced machinery, picked trash from the belt carrying aggregate to the blender, and assisted plant operators with trucks. The sample durations were 282 minutes and 297 minutes, and both samples were below the reported LOD of 20 μg/m^3 (Document ID 1365, p. 19-17; 0077).

OSHA received no additional exposure data for maintenance workers. OSHA also reviewed its inspection data recorded in OIS and submitted to the rulemaking record (Document ID 3958); however, there were no additional data for maintenance workers in the asphalt paving products sector. Based on this best available (but limited) information, OSHA considers 20 μg/m^3 to be the baseline exposure level for maintenance workers.

Table IV.4.1-B Respirable Crystalline Silica Exposure Range and Distribution of Results for Workers in the Asphalt Paving Products Industry (NAICS 324121)											
	Exposure Summary			Exposure Range			Exposure Profile				
Job Category	N	Mean (µg/m³)	Median (µg/m³)	Min (µg/m³)	Max (µg/m³)		<25 (µg/m³)	≥25 and ≤50 (µg/m³)	>50 and ≤100 (µg/m³)	>100 and ≤250 (µg/m³)	>250 (µg/m³)
Facility Operator	1	21	21	21	21		1 (100%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)
Front-End Loader Operator	2	37	37	20	53		1 (50%)	0 (0%)	1 (50%)	0 (0%)	0 (0%)
Maintenance Worker	2	20	20	20	20		2 (100%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)
Total	**5**	**27**	**20**	**20**	**53**		**4 (80%)**	**0 (0%)**	**1 (20%)**	**0 (0%)**	**0 (0%)**

Notes: All samples summarized are personal breathing zone (PBZ) results representing 8-hour time-weighted average exposures. Job categories are intended to represent job functions; actual job titles might differ, and responsibilities might be allocated differently, depending on the facility. Percentages may not add to 100 percent due to rounding.

Sources: Document ID 1720; 0077; 0186

4.1.3 Additional Controls

Additional Controls for Facility Operators

The exposure profile in Table IV.4.1-B shows that zero percent (0 out of 1 sample) of facility operators have exposures above the final PEL of 50 μg/m^3. Therefore, no additional controls are required. As noted above, based on the best available exposure data, OSHA concludes that the baseline exposure level for facility operators performing routine activities is 21 μg/m^3. In those instances where elevated exposure might occur, silica levels can be reduced through the use of fully enclosed and ventilated operator control rooms and/or by controlling adjacent sources of silica-containing dust through local exhaust ventilation (LEV) and dust suppression methods (Document ID 1365, p. 19-19).

Although few data are available regarding exposure reduction through LEV or dust suppression methods, these methods are generally effective in controlling silica dust. In a 272-minute sample, OSHA measured a PBZ concentration less than the LOD (21 μg/m^3 in this case) for a facility operator who worked in an air-conditioned booth at the previously discussed hot-mix asphalt plant where maintenance and adjustments to existing LEV (on the blender) and wet scrubber (aggregate drier exhaust) had greatly reduced visible dust (Document ID 1365, p. 19-15; 0077).

Related studies involving exposures from similar types of materials, with the use of dust suppressants suggest that a significant reduction in silica exposure can be achieved with the proper use of dust suppressants to control fugitive dust emissions associated with haul roads, and aggregate storage and handling. For example, a study by Addo and Sanders compared the performance of three dust suppressants (lignosulfonate, calcium chloride, magnesium chloride) to no treatment on an unpaved roadway over four and a half months (Document ID 0516). The dust suppressants reduced fugitive dust emissions by 50 to 70 percent when compared with the untreated section (Document ID 0516, p. 106).

OSHA received no comments questioning its conclusion that no additional exposure controls are required for this job category.

Additional Controls for Front-End Loader Operators

The exposure profile in Table IV.4.1-B shows that 50 percent (1 out of 2 samples) of front-end loader operators have exposure above the final PEL of 50 μg/m^3. Therefore, OSHA finds that additional controls will be necessary to achieve the PEL for these overexposed workers. However, since the only sample in the record above 50 μg/m^3 was a 53 μg/m^3 sample, and the other sample in the record was at the LOD of 20 μg/m^3, the median exposure level for front-end loader operators is 37 μg/m^3. Therefore, OSHA believes that approximately half of front-end loader operators will require some additional controls to achieve the PEL of 50 μg/m^3. In those instances where an exposure above the PEL would still occur, the silica exposure of front-end loader operators will be reduced through improved maintenance of existing dust control systems. Furthermore, silica levels can be reduced through the use of fully enclosed, sealed, ventilated, and maintained operator cabs, and/or by controlling adjacent sources of silica-containing dust through LEV and wet or other dust suppression methods (Document ID 1365, p. 19-21).

In its preliminary analysis, OSHA concluded that dust suppression methods are particularly beneficial for work with sand and aggregates, such as those that are handled by front-end loader operators. Simple foams provide dust control benefits similar to water spray, but offer increased dust control capacity compared with the same volume of water (Document ID 1720, pp. IV-53 –54). OSHA received no comments questioning the effectiveness of foam as a dust control method for front-end loader operators in this industry, and therefore reaffirms its conclusion here.

For facilities where elevated exposures persist, well-sealed, air-conditioned cabs maintained under positive pressure with filtered air provide an additional control option for loader operators. While cabs are available, the cabs are not consistently used as a dust control measure. Cab interiors can contain a notable amount of silica-containing dust (Document ID 0839, p. 1). Additionally, the National Institute for Occupational Safety and Health (NIOSH) and the Mine Safety and Health Administration (MSHA) report that, in general, heavy equipment cabs are poorly sealed and that original-equipment ventilation design does not necessarily provide positive pressure or appropriately filter air

(Document ID 0839, pp. 1-2; 0888, p. 1; 0822, pp. 3-4; 0824, pp. 3-4). To effectively reduce the silica exposure of loader operators, cabs may need to be modified.

Although data documenting the effectiveness of such enclosures (i.e., equipment cabs) at asphalt paving product facilities are not available, other sources suggest a 94 to 99.5 percent reduction in respirable dust (inside compared with outside the cab) with well-sealed, air-conditioned, and filtered cabs (Document ID 0719, p. 51). The precise reduction depends on dust size and the ventilation system. Operators working in heavy equipment cabs that are sealed and pressurized with filtered intake air should experience exposure reductions in this general range. Although these cabs require regular maintenance to function properly, OSHA estimates and concludes that appropriately fitted and maintained cabs would offer a similar reduction in silica exposure for front-end loader operators in the asphalt paving products industry (Document ID 1365, p. 4-20).

Additional Controls for Maintenance Workers (Laborers)

The exposure profile in Table IV.4.1-B shows that none of the (0 out of 2 samples) maintenance workers (laborers) have exposure above the final PEL of 50 μg/m^3. Therefore, additional controls are not required for this job category. As noted above, the best available information indicates that the baseline exposure level for maintenance workers is less than 20 μg/m^3, well below the final PEL of 50 μg/m^3. In those instances where elevated exposure occurs, silica levels can be reduced by: 1) controlling adjacent sources of silica-containing dust (e.g., yard dust and dust associated with aggregate storage and handling activities) through wet or other dust suppression methods (discussed above); 2) installing enclosures and exhaust ventilation; and/or 3) using wet cleaning methods and high-efficiency particulate air (HEPA)-filtered vacuuming (Document ID 1365, p. 19-22; 0717, pp. 8-11; 1413, p. 854).

NIOSH recommends vacuuming with an approved HEPA-filtered vacuum or the use of wet cleaning methods to minimize worker exposure to hazardous air contaminants such as asbestos, silica, and heavy metals during housekeeping activities (Document ID 0881, p. 8; 0883, p. 5; 0873, p. 11). For some maintenance and repair activities (e.g., servicing the inside of a dust collector/bag house), engineering controls might not be feasible. In these cases, respiratory protection might be necessary to control worker exposure to silica.

4.1.4 Feasibility Finding

Feasibility Finding for Facility Operators

Based on the exposure profile in Table IV.4.1-B and other record evidence discussed above, OSHA finds that most facility operators are likely to have silica exposures below 50 μg/m^3 because they are usually isolated from production operations in a control room or booth. Additional exposure controls are not anticipated for this job category. In instances where elevated exposures might occur, OSHA reasonably expects that silica levels can be reduced to 50 μg/m^3 or less through the use of fully enclosed and ventilated operator control rooms and/or by controlling adjacent sources of silica-containing dust through LEV.

Feasibility Finding for Front-End Loader Operators

Based on the exposure profile in Table IV.4.1-B and other record evidence discussed above, OSHA finds that the exposures for 50 percent of front-end loader operators are less than 50 μg/m^3. Where elevated exposures occur, OSHA estimates silica levels can be reduced to 50 μg/m^3 or less through the use of fully enclosed, sealed, ventilated, and maintained operator cabs and/or by controlling adjacent sources of silica-containing dust through LEV or dust suppression methods.

Feasibility Finding for Maintenance Workers (Laborers)

Based on the exposure profile in Table IV.4.1-B and other record evidence discussed above, OSHA finds that exposure levels for most maintenance workers are less than 25 μg/m^3. While the need for additional controls is not anticipated, in instances where elevated exposures might occur, OSHA estimates silica levels can be reduced to 50 μg/m^3 or less by: 1) utilizing wet or other dust suppression methods, 2) installing engineering controls such as enclosures and LEV, and 3) using wet cleaning methods and HEPA-filtered vacuuming.

Overall Feasibility Finding for Asphalt Paving Products Facilities

Based on the exposure profile in Table IV.4.1-B and other record evidence discussed above, OSHA concludes that after implementing additional controls for front-end loader operators, most asphalt paving product manufacturing facilities can achieve exposure levels of 50 $\mu g/m^3$ or less in most operations, most of the time. Accordingly, OSHA concludes that the final PEL of 50 $\mu g/m^3$ is technologically feasible for the Asphalt Paving Products industry.

4.2 ASPHALT ROOFING MATERIALS

4.2.1 Description

Manufacturers of asphalt roofing materials produce roofing products that can be classified in three broad categories: shingles, surfaced and smooth roll roofing, and asphalt-saturated felt rolls. Shingles and roll roofing are outer roof coverings, while saturated felts are used as inner roof materials or underlayment. Shingles and roll roofing consist of three basic components: 1) a base material of organic felt or fiberglass mat, 2) an asphalt coating, and 3) a surfacing of mineral granules. Saturated felts consist of dry felt saturated with asphalt. These manufacturers are classified in the six-digit North American Industry Classification System (NAICS) 324122, Asphalt Shingle and Coating Materials Manufacturing (Document ID 1365, pp. 22-1 – 22-2; 1720, p. IV-58).

The production of asphalt roofing materials is a highly automated, stationary continuous process. The principal steps begin with unwinding a roll of base material and saturating it with asphalt by passing it through a series of hot asphalt tanks, and ending with a coater unit that applies a final layer of mineral-stabilized asphalt. For shingles and roll roofing, an additional step is mineral application during which minerals are pressed into both sides of the hot, coated surface (Document ID 1365, p. 22-1). Silica-containing minerals are incorporated into asphalt coatings and used as front and back surfacing granules to increase weather and fire resistance; back surfacing agents like talc and mica (commonly known as “partying agents”) also act to prevent asphalt products from sticking to each other in the manufacturer’s packaging (Document ID 1365, pp. 22-1, 22-3, 22-18; 0889, p. 3). Minerals typically used include slate (5 to 15 percent silica), limestone (up to 67 percent silica), dolomite (0 to 3 percent silica), granite (9-60 percent silica), trap rock (up to 12 percent silica), talc (up to 5 percent silica), silica sand (75 – 98 percent silica), mica (up to 10 percent silica), and or ceramic granules. After application of the mineral surfacing, the coated sheet is rapidly cooled and air dried, and then cut and packaged (Document ID 1365, pp. 22-1 – 22-4).

Mineral stabilizer material is delivered by truck, conveyed to storage bins, heated, and then mixed with the coating asphalt. Granules and back surfacing materials are brought by rail or truck and mechanically or pneumatically conveyed to storage bins and hoppers (Document ID 1365, p. 22-4; 1720, p. IV-58).

Workers attend each step of the process, including the receiving, handling, transfer, storage, and mineral surfacing, and their exposures occur primarily when silica-containing materials are added during the process (Document ID 1365, pp. 22-1, 22-4). Workers with potential silica exposure are production operators and material (mineral) handlers. Production operators monitor production line areas, which include the coater, the press, and the cooling section. These workers' major sources of silica exposure are from dust released during drying, preheating the mineral stabilizer, and mineral surfacing, as well as from mineral storage hoppers and bins located near the coater. Material handlers are responsible for handling and monitoring the use of granules and other minerals, and loading these materials into hoppers. Major sources of silica exposure for material handlers are dust from manually loading hoppers, from the mineral transfer systems, and from mixing silica-containing materials with asphalt coating (Document ID 1365, pp. 22-4 – 22-5). The major activities and sources of exposure for these job categories are summarized below in Table IV.4.2-A.

Table IV.4.2-A
Job Categories, Major Activities, and Sources of Exposure of Workers in the Asphalt Roofing Materials Industry (NAICS 324122)

Job Category*	Major Activities and Sources of Exposure
Production Operator (coater, press, cooling section, and relief operator)	Monitoring production line operations. • Dust from drying and preheating mineral stabilizer. • Dust from mineral surfacing (pressing minerals such as mica or talc into both sides of the base material). • Dust from mineral storage hoppers and bins in close proximity to the coater.
Material Handler (slate assistant, granule assistant)	Handling and monitoring the use of granules and other minerals and loading the materials into hoppers. • Dust from manually loading materials into hoppers. • Dust from the mineral transfer system. • Dust from mixing silica-containing minerals with coating asphalt.

*Job categories are intended to represent job functions; actual job titles may differ and responsibilities may be allocated differently, depending on the facility.
Source: Document ID 1720, p. IV-59.

Table IV.4.2-B summarizes the available exposure information for the affected job categories. For each of the job categories listed in Table IV.4.2-B and for the asphalt roofing materials industry as a whole, OSHA concludes that Table IV.4.2-B represents baseline conditions.

4.2.2 Exposure Profile and Baseline Conditions

In preparing the Preliminary Economic Analysis (PEA), OSHA reviewed exposure monitoring data from 12 samples from five NIOSH health hazard evaluations (HHE) conducted during the late 1970s.[7] Due to the small numbers of available samples, two samples of less than 360 minutes duration were included in the exposure profile (these samples had durations of 300 and 312 minutes). Approximately 42 percent of samples were below the PEL of 50 μg/m^3, with a median of 59 μg/m^3, a mean of 71 μg/m^3, and a range from below the limit of detection (LOD, in this case 28 μg/m^3) to 188 μg/m^3(Document ID 1720, pp. IV-59 - IV-60).

Due to the age of the NIOSH evaluations and to provide additional insight into exposures, OSHA also reviewed sample results from inspections recorded in OSHA's Integrated Management Information System (IMIS) for the years 1983 through 2001. The majority of the highest exposure samples were collected before 1985 (Document ID 1365, p. 22-8). These IMIS data were not added to the exposure profile due to the lack of information regarding sample duration and worker activities, workplace conditions, and engineering controls during the sampling period. Over 40 percent of IMIS sample results were below the limit of detection (Document ID 1720, pp. IV-59 – IV-62 (reviewing Document ID 1698 [IMIS data])). OSHA also reviewed inspection data recorded in the OSHA Information System (OIS) and submitted to the rulemaking record but identified no additional pertinent data (Document ID 3958).

Controls typically used in this industry include process enclosures with local exhaust ventilation (LEV) to control worker exposures associated with mineral handling and storage operations, and bag-type dust collectors with LEV to control exposures during mineral surfacing in the mineral application and cooling process areas of the plant. General dilution ventilation in the cooling sections of the manufacturing line also

[7] Exposure data collected prior to 1990 was retained in this exposure profile because more recent data were not available for this sector. (see Section IV-2–Methodology within this chapter)

contributes to lower contaminant exposures, although its effectiveness may vary within the industry (Document ID 0837, pp. 23, 28).

Information That Silica Exposures Have Declined in the Industry

Information on exposure data for other air contaminants from the asphalt roofing materials industry suggests that more recent silica exposure values are likely significantly lower than those reflected in the NIOSH HHE and IMIS data. The data at 53 U.S. plants of four companies indicated that, after 1990, exposures to total particulates, benzene, and cyclohexane-soluble samples declined for three companies. It is likely that the engineering controls implemented to control these exposures, including the improved capture efficiency of exhaust hoods, and reduction of fugitive emissions in order to meet the requirements of the Clean Air Act Amendment of 1990, would also be effective in reducing silica exposures (Document ID 0837, p. 17).

In Germany, bitumen roofing products manufacturing (i.e., asphalt roofing materials manufacture) saw a marked decline in respirable quartz exposure from a mean of 150 $\mu g/m^3$ for the period from 1983 through 1989 to a mean of 40 $\mu g/m^3$ for the period from 1995 through 2004 (Document ID 0553, p. 129). Over the same periods, the median (reported as the 50th percentile) silica result was reduced from 40 $\mu g/m^3$ to 10 $\mu g/m^3$, and the 90th percentile value, representing the higher individual exposures, was cut by slightly less than 63 percent to 100 $\mu g/m^3$ (Document ID 0553, p. 129).[8] These reductions indicate that improvements in equipment, materials, control technology, and work practices have effectively reduced exposure levels in this industry.

Similarly, Anttila et al. (2009) noted a 61 percent decline in arithmetic mean silica exposures in Finland between the periods from 1975 through 1979 and from 2000 through 2005, and a 66 percent decline in geometric mean (i.e., median) exposures for the same time periods. The authors credit improvements in dust control and work methods

[8] The difference between the 1983-1989 time frame (0.27 mg/m^3) and the most recent period 1995 to 2004 (0.10 mg/m^3) is 0.27-0.10=0.17 mg/m^3. 0.17/0.27= 62.9 percent (rounds to 63 percent) difference (Document ID 0553, p. 129).

implemented in the mid-1980s for reducing average exposures (Document ID 0529, pp. 147 - 148).

Mr. John Ferraro, General Manager of the Asphalt Roofing Manufacturers Association (ARMA), provided extensive exposure data for ARMA members that included newer data from 70 plants representing 81 percent of ARMA members and approximately 31 percent of the overall industry (Document ID 2291, p. A-3). Mr. Ferraro noted that “silica exposures are well controlled in ARMA member plants (Document ID 2291, p. A-6). For routine manufacturing operations, 91 percent of samples were less than 50 µg/m^3 (Document ID 2291, p. B-4).

The ARMA data reflect median exposures substantially lower than the values in OSHA’s exposure profile (Table IV.2-B). The data provided by ARMA could not be included in the exposure profile for this industry since only summary data by job category were provided with no individual sample results or descriptions of working conditions.

Given the implementation of more efficient technology and updated work practices since the late 1970s, the U.S. trends reflected in the ARMA data, and the international experience in reducing silica levels, OSHA concludes that silica exposures in the U.S. are likely lower in the asphalt roofing materials industry than reflected by the NIOSH HHE and IMIS data.

Exposure Profile and Baseline Conditions for Production Operators

The exposure profile in Table IV.4.2-B includes 5 samples for production operators in the asphalt roofing materials industry. The median is 29 µg/m^3, the mean is 56 µg/m^3, and the range is 28 µg/m^3 (limit of detection (LOD)) to 131 µg/m^3. Table IV.4.2-B shows that, of the 5 samples, 2 (40 percent) are above 50 µg/m^3 and 1 (20 percent) exceeds 100 µg/m^3. The exposure profile for production operators is based on five PBZ silica samples obtained by NIOSH at four different asphalt roofing manufacturing facilities in the 1970s. Sixty percent of the samples were below the PEL of 50 µg/m^3.

The ARMA data referenced above, which include positions equivalent to Production Operator, reflect a median exposure of 13 µg/m^3, a mean exposure of 33 µg/m^3, and reports that 91 percent of samples were below the PEL of 50 μg/m^3 (Document ID 2291, p. B-4, Table B-2). These data, considered with the German and Finnish studies discussed above, strongly indicate that the exposure profile based on the older NIOSH HHE evaluations, as shown in Table IV.4.2-B, likely significantly overstates the exposure levels of production operators. In the PEA, OSHA estimated that "current silica exposure levels are lower by half than those reported in the NIOSH HHE reports of the 1970s" for production operators (Document ID 1720, p. IV-62). OSHA's estimate was not questioned and, indeed, was shown to be conservative by the ARMA data. Therefore, OSHA is retaining the estimate that current silica exposure levels are likely 50 percent lower than those reported in Table IV.4.2-B. Therefore, OSHA has revised the exposure profile in Table IV.4.2-C to reflect this reduction.

In addition, OSHA notes that the proportion of workers in each job category is not accurately reflected by the number of samples in each job category as presented in Table IV.4.2-B. The ARMA data reflect a greater percentage of Production Operators (86 percent) than Material Handlers (Document ID 2291, p. B-2, Table B-1). In light of this information, OSHA prepared a revised estimated exposure distribution for the workers to better reflect the industry in Table IV.4.2-C.

Therefore, Table IV.4.2-C shows the revised exposure profile, presenting an updated exposure profile reflecting the reduction in the estimate of exposures for each job category as well as a revised exposure distribution for the total workers.

Exposure Profile and Baseline Conditions for Material Handlers

The exposure profile in Table IV.4.2-B includes 7 samples for material handlers in the asphalt roofing materials industry. The median is 67 μg/m^3, the mean is 82 μg/m^3, and the range is 29 μg/m^3 (limit of detection (LOD)) to 188 μg/m^3. Table IV.4.2-B shows that, of the 7 samples, 5 (71.4 percent) are above 50 μg/m^3 and 2 (28.6 percent) exceed 100 μg/m^3. These seven PBZ silica samples were collected by NIOSH investigators during HHEs at five different roofing manufacturing facilities as shown in Table IV.4.2-B. Even in the 1970s, when these data were collected, 28.6 percent of workers sampled had exposures below 50 μg/m^3. These samples had a median of 67 μg/m^3, a mean of 82 μg/m^3, and a range from less than 29 μg/m^3 (below the sample limit of detection) to 188 μg/m^3. Three of the seven samples were below the limit of detection, with LODs of 29 μg/m^3, 39 μg/m^3, and 57 μg/m^3 (Document ID 1365, pp. 22-11 – 22-14).

The ARMA data submitted into the record provide summary statistics for a number of job categories (Document ID 2291, p. B-4, Table B-2). The job description for “Slate/Granule/Bulk Materials Attendant” matches the description “material handler” (Document ID 2291, p. B-3; 1720, p. IV-59). The 180 PBZ silica exposure samples reported by the ARMA for this job category show a mean of 51 μg/m^3, a median of 14 μg/m^3, and a third quartile of 28 μg/m^3, with 85 percent of samples below 50 μg/m^3 (Document ID 2291, p. B-4, Table B-2). These data are consistent with the conclusion that the exposure profile overestimates the baseline exposure level for material handlers.

For the reasons discussed above for production operators, OSHA has concluded that the exposure profile for material handlers generated from the NIOSH HHE evaluations likely overestimates median exposure levels for this job category. In the PEA, OSHA estimated that “the NIOSH data might overestimate the baseline exposure level for [material handlers] * * * by greater than half” (Document ID 1720, pp. IV-62 – IV-63). OSHA’s estimate was not questioned and, indeed, was shown to be conservative by the ARMA data. Therefore, OSHA is retaining the estimate and concludes that the revised exposure profile (Table IV.4.2-C) accurately reflects the distribution of exposures for workers in the asphalt roofing materials industry.

Table IV.4.2-B
Preliminary Exposure Profile
Personal Respirable Crystalline Silica Exposure Range and Distribution of Results for Workers in the Asphalt Roofing Materials Industry (NAICS 324122)

	Exposure Summary			Exposure Range			Exposure Profile				
Asphalt Roofing Materials Industry	**N**	**Mean (μg/m^3)**	**Median (μg/m^3)**	**Min (μg/m^3)**	**Max (μg/m^3)**		**<25 (μg/m^3)**	**≥25 and ≤50 (μg/m^3)**	**>50 and ≤100 (μg/m^3)**	**>100 and ≤250 (μg/m^3)**	**>250 (μg/m^3)**
Production Operator	5	56	29	28	131		0 (0%)	3 (60%)	1 (20%)	1 (20%)	0 (0%)
Material Handler	7	82	67	29	188		0 (0%)	2 (28.6%)	3 (42.9%)	2 (28.6%)	0 (0%)
Asphalt Roofing Materials Industry Total	**12**	**71**	**59**	**28**	**188**		**0 (0%)**	**5 (41.7%)**	**4 (33.3%)**	**3 (25%)**	**0 (0%)**

Notes: All samples summarized are personal breathing zone (PBZ) results representing 8-hour time-weighted average exposures.
Job categories are intended to represent job functions; actual job titles might differ, and responsibilities might be allocated differently, depending on the facility.
Percentages may not add to 100 percent due to rounding.

Sources: Document ID 1720, IV-61; 1365, pp. 22-13 – 22-14; 0889; 0890; 0891; 0892; 0893.

Table IV.4.2-C
Revised Exposure Profile
Distribution of Exposures for Workers in the Asphalt Roofing Materials Industry (NAICS 324122)

Asphalt Roofing Materials Industry	**Proportion of workers in Job Category**	**<25 (μg/m3)**	**≥25 and ≤50 (μg/m3)**	**>50 and ≤100 (μg/m3)**	**>100 and ≤250 (μg/m3)**	**>250 (μg/m3)**
Production Operator	86.0%	0.0%	80.0%	10.0%	10.0%	0.0%
Material Handler	14.0%	0.0%	64.2%	21.5%	14.3%	0.0%
Asphalt Roofing Materials Industry Total	100%	0.0%	77.8%	11.6%	10.6%	0.0%

Notes: This table estimates the proportion of industry workers in each of the two job categories using information submitted by ARMA (86% of workers in this industry are Production Operators, 14% Material Handlers).
Sources: Document ID 1720, IV-61; 1365, pp. 22-13 – 22-14; 0889; 0890; 0891; 0892; 0893; 2291, p. B-2.

4.2.3 Additional Controls

<u>*Additional Controls for Production Operators*</u>

The preliminary exposure profile in Table IV.4.2-B shows that 40 percent (2 out of 5 samples) of production operators in the asphalt roofing materials industry have exposures above the final PEL of 50 μg/m^3. As shown in Table IV.4.2-C, revised exposure profile, OSHA estimates that only 20 percent of production operators will require additional controls.

As discussed above, OSHA estimated in the PEA that the profile likely overstated exposures "by half," that is, only 20 percent of production operators would require additional controls, as compared to the 40 percent indicated by the profile (Document ID 1720, pp. IV-62 – IV-63). OSHA's estimate was not questioned and, indeed, borne out by the ARMA data showing that only approximately eight percent of production operators would need additional controls.

In those instances where elevated exposures occur (e.g., at the coater, cooling, and press areas), as described further below, manufacturers will need to use a combination of improvements or upgrades in existing LEV systems and process enclosures, and improved housekeeping methods (e.g., HEPA vacuums) to reduce silica levels to 50 μg/m^3 or less. In addition, the use of washed sand has been shown to reduce exposure. In an analysis of respirable quartz exposures obtained at two Finnish roofing membrane plants from 1975 to 2005, worker exposure was significantly lower when washed quartz sand was used compared with unwashed quartz sand (Document ID 0529, p. 148).

Ventilation and Process Enclosures for Production Operators

In assessments of facilities manufacturing asphalt roofing materials, NIOSH investigators recommended installation of LEV over the coater and press areas, enclosure of the coating process, and/or repair and servicing of existing process enclosures and ventilation systems to eliminate leaks and poor hood capture (Document ID 0889, pp. 12-13; 0891, pp. 3, 11; 0890, p. 14; 0893, p. 12).

OSHA does not have data specifically measuring the exposure reductions achieved with adequate ventilation and enclosures in this industry. However, in OSHA inspections of similar mineral powders handling operations in the pottery industry, OSHA measured an exposure level of 29 μg/m^3 for a worker operating mixers equipped with LEV and fed by ventilated, automated conveyance equipment, and 23 μg/m^3 for a worker charging mixers using enclosed, automated equipment (Document ID 1365, p. 22-20; 1436, pp. 1, 27, 28-29; 0143, pp. 128, 130-131).[9] At a site where workers produced batches of paint by emptying 50-pound bags of quartz and cristobalite powder into hoppers, the OSHA contractor Eastern Research Group (ERG) reported exposures of less than 12 μg/m^3 and 13 μg/m^3 (the sample limits of detection) when the combined exhaust ventilation and local exhaust ventilation on bag disposal systems were working properly. These values are 95 percent lower than the result obtained during another shift at the same plant when these controls malfunctioned (Document ID 0199, p. 9). OSHA expects that these same types of controls would be effective in controlling exposures for production operators and material handlers in asphalt roofing materials manufacturing because the materials handled have similar characteristics.

Further, the levels of silica exposure control reported by the ARMA, with median exposures of 13 μg/m^3 and mean exposures of 31 μg/m^3 for process operators (excluding bulk materials attendant, which corresponds to the OSHA job function of materials handler discussed below), indicate that adequate controls can be achieved to reduce exposures to levels well below the PEL most of the time (Document ID 2291, p. B-4).[10]

[9] OSHA calculated silica exposure results using the weight of respirable dust measured by the laboratory on the sample filter, multiplied by the percent crystalline silica in the dust sample to obtain the weight of silica on the sample filter. The weight of silica was divided by the air volume sampled. For example, 460 μg of respirable dust on the filter, times 0.036 (the fractional value of 3.6 percent silica), divided by 0.706 m^3 volume of air sampled = 23 μg/m^3.

[10] OSHA estimated the revised mean for data summarized in AMRA's comments. For each row (except the group of 180 samples including the bulk materials attendants), OSHA created proxy sample results by assigning the average value for the row to the number of samples represented in the row, then recalculating the average for these 1,000 proxy sample results for workers performing production operator activities (Document ID 2291, p. B-4). OSHA's estimate of the mean for the 1,000 production worker samples is 31 μg/m^3. [Note on total number of samples: the correct total sum of the "No. of Samples" column is 1,180, including the bulk material attendants. The total is incorrectly listed as 1,320 in Table 2B of Document ID 2291. Based on the information presented in the table, OSHA finds that the number of samples associated with production operator duties is 1,180 minus the 180 Bulk Material attendant samples = 1,000 samples.]

Additional Controls for Material Handlers

The preliminary exposure profile in Table IV.4.2-B shows that 71.4 percent (5 out of 7 samples) of material handlers have exposures above the final PEL of 50 μg/m^3. As shown in Table IV.4.2-C, revised exposure profile, OSHA estimates that only 36 percent of material handlers experience exposures above 50 μg/m^3. OSHA finds that additional controls will be necessary to achieve the PEL for these overexposed workers.

The preliminary exposure profile (Table IV.4.2-B) reflected that the exposure level for at least 28.6 percent of mineral material handlers is less than 50 μg/m^3, indicating that additional controls would be required for the remaining 71.5 percent of material handlers. As discussed above, however, more recent data reported by ARMA reflect that for more recent periods, 85 percent of material handlers had exposures below 50 μg/m^3, indicating that as few as 15 percent may require additional controls. Because the companies that submitted exposure data to ARMA represent only thirty-one percent of the industry, the actual percentage of material handlers working in plants without effective controls is likely higher. OSHA has more conservatively estimated that the exposure profile based on the NIOSH data from the 1970s overstate current exposures by 50 percent. Based on these considerations, OSHA estimates that approximately 36 percent (half of the 71.4 percent in the preliminary profile) of material handlers would require additional controls to limit their exposures to below the PEL. Controls to address exposures for these material handlers include improvements in local exhaust ventilation, preventive maintenance, and housekeeping methods such as HEPA-filtered vacuuming, which are discussed in more detail below.

Local Exhaust Ventilation for Material Handlers

Adequate exhaust ventilation and process enclosures for the manufacture of asphalt roofing materials as described above for the production operator job category are also applicable to mineral handling systems.

Material handlers in this industry work with raw material and dust collection drums, transfer equipment, hoppers, and similar points of material handling and distribution. The NIOSH reports indicate that LEV is already installed at slate and dust drums, granule and backdust applicators, transfer rolls, and the majority of mineral products hoppers, although leaks or inadequate hood capture efficiency were noted in some cases. NIOSH recommended providing LEV at all mineral transfer points, providing LEV for mineral products hoppers, and repairing leaks or improving hood capture efficiency (Document ID 0837, p. 28; 1365, p. 22-22). The highest exposures in the exposure profile (78 µg/m^3, 120 µg/m^3, and 188 µg/m^3) were associated with two facilities that either did not have LEV at slate transfer points, or had leaks in the slate transfer system (Document ID 1365, pp. 22-13 – 22-14; 0889, p. 4, 15; 0893, pp. 12, 18). The silica exposures reported by the ARMA for a bulk materials attendant, which corresponds to the job category of materials handler, indicated a median exposure of 14 µg/m^3, with 85 percent of exposed workers below 50 µg/m^3 (Document ID 2291, p. B-4). This more recent data suggest that improvements in LEV and maintenance to prevent leaks can lower silica levels significantly below the values reflected in the exposure profile.

Additional Controls for Both Production Operators and Materials Handlers

Housekeeping

NIOSH and OSHA have recommended cleaning using either vacuuming with a HEPA-filtered vacuum or wet cleaning methods in order to minimize worker exposure to silica (Document ID 0895, p. 10). In a study of Finnish construction workers, worker exposures were approximately five times lower when workers used vacuums as compared with dry sweeping (Document ID 1163, p. 217).

Although Mr. John Ferraro of the ARMA agreed that wet methods “are effective for dust suppression,” they were not always safe or feasible. He stated:

> Wet methods * * * cannot be used in many settings in asphalt roofing plants because of safety and feasibility constraints * * * The mineralization area * * * is directly adjacent to the hot asphalt coater * * * introduction of water to the coater pan * * * may result in serious burn hazard * * * [that] expose[s] workers to splashes of hot asphalt” (Document ID 2291, p. 13).

Regarding HEPA-filtered vacuuming, Mr. Ferraro stated that portable HEPA vacuums would not be feasible in many cases due to the "practical limitation * * * [that] include cumbersome hoses with often inadequate reach, limited or problematic mobility, and inadequate collection capacities." Mr. Ferraro concluded that central, HEPA-filtered vacuum systems would need to be installed at great expense (Document ID 2291, p. 13).

Mr. Ferraro further stated that:

> While ARMA members support the use of HEPA vacuuming and wet methods in all settings in which they are feasible and effective * * * the standard must recognize that compressed air, dry sweeping and dry brushing represent the only feasible methods of housekeeping in a number of important settings in asphalt roofing plants * * * Specifically * * * certain pieces of equipment on the production line require use of compressed air to clean out small compartments and crevices. We know from long experience that vacuums cannot reach many of these dust and debris accumulations, and that wet methods are also infeasible as water will foul the production process * * * In addition, experience shows that * * * during scheduled housekeeping campaigns, shoveling or sweeping of bulk material is required because there is no feasible alternative (Document ID 2291, p. 19).

Mr. Ferraro further noted that scheduled housekeeping campaigns are typically conducted during plant "down days" when few workers are present (Document ID 2291, p. 14).

As previously stated, OSHA recognizes that the complete elimination of compressed air cleaning or dry sweeping may not be feasible. The ARMA comments, however, do indicate that wet methods and HEPA vacuums can and are used in many, if not all, situations to reduce exposures.

Preventive Maintenance

Properly maintained mineral handling systems are necessary to ensure low exposures to silica-containing dusts during material transfer and other process-related operations. NIOSH investigators noted process leaks in and around enclosures and less-than-optimal LEV in a facility manufacturing roofing granules. NIOSH recommendations included: 1) implementing a preventive maintenance program, 2) designing and testing LEV systems according to recognized guidelines, and 3) replacing process enclosures that are removed for inspection or maintenance purposes as soon as the work is completed (Document ID 0889, pp. 12-13; 0890, p. 14-15; 0891, pp. 3, 11; 1377, pp. 15-16). OSHA made similar recommendations for controlling the exposure of workers performing similar duties at a facility where airborne clay dust was prevalent (Document ID 0108, pp. 7, 45, 47).

Non-routine Tasks

Comments submitted to the docket regarding the feasibility of engineering controls in the asphalt roofing materials sector related to non-routine tasks and compliance deadlines. Mr. Ferraro of the ARMA described areas of a plant where "workers are not routinely present," that are entered only occasionally for activities "such as housekeeping during extended scheduled maintenance down time * * * once or twice a year" (Document ID 2291, pp. 17-18). The Agency has acknowledged that respiratory protection is appropriately used for short-term intermittent activities such as maintenance tasks where it is not feasible to implement permanent engineering solutions.

4.2.4 Feasibility Finding

Comments on Feasibility

Except for comments on the infeasibility of using wet methods near the hot asphalt coater and HEPA-filtered vacuuming in certain areas with limited access, there were no industry comments that it was technologically infeasible to reduce exposure levels below the PEL for most operations, most of the time (Document ID 2291, pp. 13, 14, and *passim*). ARMA stated that it was infeasible to implement controls that would assure that exposures did not exceed the PEL 100 percent of the time (or with a 95 percent certainty), and that OSHA had not therefore demonstrated that the standard's requirements of engineering and administrative controls were technologically feasible (Document ID 2291, pp. 5-15, 27, and *passim*).

As reflected in Section IV-1 – Introduction: Technological Feasibility of this FEA, courts do not require OSHA to demonstrate that an employer can comply 95 percent of the time or with a 95 percent certainty to show that the requirements are feasible. Based on careful reading of the studies and inspection documents, it appears that the causes for exposures above the PEL are predictable and that there will be few to no instances where an employee will be exposed above the PEL if the employer has implemented adequate engineering and administrative controls for normal manufacturing operations, including LEV, hopper and process enclosures, general ventilation, and regular housekeeping using methods that do not re-suspend settled dust.

Nevertheless, the ARMA exposure data indicate that the PEL is feasible for routine operations in asphalt roofing manufacture because 91 percent of the sample results associated with routine operations were below 50 μg/m^3 TWA.

Ms. Peg Seminario of the AFL-CIO supported this conclusion, stating:

> [T]he exposure information provided by the ARMA shows that the mean exposure in all but one of the jobs in routine manufacturing in that industry are already below the proposed 50 μg/m^3 exposure level (Document ID 2291, p. B-4, Table B-2). The information also shows that 91 percent of the samples in these jobs were below 50 μg/m^3, with a median exposure less than 15 μg/m^3 (Document ID 4204, p. 29).

Feasibility Finding for Production Operators

Based on the exposure profiles in Tables IV.4.2-B and IV.4.2-C and other record evidence discussed above, OSHA estimates that the current exposure level for most production operators is below 50 μg/m^3. This finding is based on information presented in Table IV.4.2-B indicating that 60 percent of these workers had exposure levels of 29 μg/m^3 or below during the 1970s. In light of the German and ARMA data, OSHA estimates that approximately 20 percent of production operators may require additional controls to reduce exposures to 50 μg/m^3 or less, as shown in Table IV.4.2-C. In those instances where elevated exposure might occur, silica levels can be reduced to 50 μg/m^3 or less through the use of adequate LEV, process enclosures, and the use of low dust producing cleaning methods such as HEPA-filtered vacuuming. As discussed above, other industries with similar dust producing processes have been shown to achieve dust levels below the PEL where process equipment is enclosed and ventilated (Document ID 1436, pp. 1, 27, 28-29; 0143, pp. 128, 130-131).

Feasibility Finding for Material Handlers

Based on the exposure profiles in Tables IV.4.2-B and IV.4.2-C and other record evidence discussed above, OSHA concludes that the PEL of 50 μg/m^3 is feasible for material handlers. Approximately 28.6 percent of material handlers already had exposures below 50 μg/m^3 in the 1970s, as shown in Table IV.4.2-B. However, as shown the revised profile in Table IV.4.2-C, OSHA estimates that currently only approximately 36 percent of material handlers may require additional controls to reduce exposures to 50 μg/m^3 or less. Control options include properly enclosed, ventilated, and maintained mineral handling systems and the use of low dust-producing cleaning methods such as HEPA-filtered vacuuming. Although OSHA does not have data demonstrating the effectiveness of engineering controls in the asphalt roofing materials industry, as discussed above, other industries with similar dust producing processes, have been shown to achieve dust levels below the PEL where process equipment is enclosed and ventilated. As NIOSH has stressed and is obvious, preventive maintenance at asphalt roofing materials facilities is necessary to ensure that exposure control systems function properly and are effective (Document ID 0837, p. 26).

Overall Feasibility Finding for Asphalt Roofing Materials Manufacturers

Based on the exposure profiles in Tables IV.4.2-B and IV.4.2-C and other record evidence discussed above, OSHA believes that in the United States exposure levels in this industry have declined since the 1970s, when data used in the exposure profile were obtained by NIOSH, and therefore, the exposure profile (Table IV.4.2-B) likely overestimates current exposures in the asphalt roofing materials industry. Exposure monitoring data submitted to the record by the ARMA indicate that among the facilities that are members of their organization, 91 percent of production operators and 85 percent of material handlers already have exposures below 50 μg/m^3. In Table IV.4.2-C, OSHA presents revised estimates of the distribution of exposures in the asphalt roofing materials manufacturing sector, which lowers the preliminary exposure profile results by 50 percent. In summary, OSHA concludes that most asphalt roofing materials manufacturing facilities currently achieve exposure levels of 50 μg/m^3 or less in most operations most of the time. Accordingly, OSHA finds a PEL of 50 μg/m^3 is technologically feasible for the Asphalt Roofing Materials industry.

4.3 CONCRETE PRODUCTS

4.3.1 Description

Silica-containing materials are the main ingredients in the manufacture of concrete products, such as blocks, bricks, tanks, pipes, and dry mixes. Facilities manufacturing concrete products are classified in six-digit North American Industry Classification System (NAICS) codes 327331, Concrete Block and Brick Manufacturing; 327332, Concrete Pipe Manufacturing; 327390, Other Concrete Product Manufacturing; and 327999, All Other Miscellaneous Nonmetallic Mineral Product Manufacturing. OSHA has grouped together facilities in these industries based on the similarity of raw materials, processes, and worker activities associated with potential silica exposure. A similar industry, NAICS 327320 – Ready-Mix Concrete Manufacturing, differs from those addressed here in many of the processes and job categories associated with silica exposure, and thus OSHA has created a separate section for it (see Section IV-4.17 – Ready-Mix Concrete).

OSHA reviewed the available NIOSH studies, OSHA Special Emphasis Program (SEP) reports, hearing testimony and information submitted to the rule making record, to identify job categories in the concrete industry with the potential for exposure to crystalline silica. OSHA has determined that workers in all phases of the production of concrete products have the potential for silica exposure. Industry agrees with this determination. Robert Thomas of the National Concrete Masonry Association (NCMA) commented that "the manufacturing of concrete products inherently exposes employees to respirable crystalline silica as this material is present in all phases of the operation" (Document ID 2279, p. 3).

Concrete products are typically made by mixing cement, usually Portland cement made from calcined lime and clay, with sand, and aggregate materials (such as gravel or crushed stone) with water in varying proportions depending on the final product (NIOSH, 1984 as cited in Document ID 1365, p. 5-2). Cement does not contain silica, so the crystalline silica content of concrete will vary based on the amount of sand and aggregate mixed into the product. The mixed concrete is poured into forms or molding machines.

The formed products are then allowed to harden (cure), and the forms are removed.[11] Certain products are finished by sawing, grinding, drilling, or abrasive blasting. Dry-mixed concrete is normally produced by drying the raw materials (cement, sand, and aggregate), mixing the dried materials, and then packaging the dry mixture (Document ID 1365, p. 5-2; 0602).

The primary job categories with potential for exposure are: material handler, mixer operator, forming operator, finishing operator, and packaging operator. Certain workers regularly perform tasks associated with multiple job categories. Table IV.4.3-A presents a summary of the primary activities associated with silica exposure of workers in each job category.

Material Handler

As discussed below in Section IV-4.3.2 – Exposure Profile and Baseline Conditions, material handlers oversee the transfer of raw materials such as cement, sand, and aggregate to on-site storage locations. Facilities typically receive raw materials by railcar or bulk truck. At some facilities, material handlers operate pneumatic conveyors that transfer raw materials into storage silos. At other facilities, raw materials are dumped into outdoor piles, and material handlers use front-end loaders to transfer materials to storage silos or bins. Material handlers may also use forklifts to transport bagged raw materials. After forming and curing, material handlers use lift trucks to transport products to finishing lines, storage areas, and shipping areas. Material handlers may transfer products by manually placing them onto conveyors. At some facilities, material handlers manually stack and palletize products (Document ID 1365, p. 5-3; 0039; 0220; 0236).

Mixer Operator

Mixer operators oversee the weighing and transfer of raw materials and water (if required) to concrete mixers. Batching and mixing operations are typically automated and do not require mixer operators to handle raw materials. At some facilities, however,

[11] "Curing" is the term for the chemical reaction that causes hardening of cement-based materials, such as concrete. Within hours of casting, most concrete products become firm enough to handle without the mold, but it can take days or weeks for the concrete to reach its full strength. "Uncured" concrete has recently become firm, but has not yet completed the hardening process (Document ID 1720, p. IV-68).

mixer operators may manually weigh and transfer ingredients, such as silica sand, into mixers by shoveling or emptying bags into mixer hoppers. Mixer operators typically operate mixers using control panels adjacent to the mixer or in isolated control booths. Mixer operators also clean mixers daily. Typically, they are cleaned immediately following each production run while the concrete residue is still wet. Mixer operators spray mixer interiors with high-pressure water hoses, rotate the mixers with the wash water inside, and then pour the water out. However, sometimes the operator has to enter the mixers to manually hammer or chip away dried concrete deposits (Concrete Product Industry Representative A, 2000, as cited in Document ID 1365, pp. 5-3 – 5-4).

Forming Operator

Forming line operators transfer the mixed concrete into forms or automatic molding machines that shape the mixture. Depending on the facility, forming line operators pour wet concrete into forms manually or by operating computer-controlled equipment. At some facilities, forming line operators use trowels or other hand tools to ensure that the concrete has completely filled the forms. After products have set sufficiently, forming line operators remove the forms. Forms are typically removed manually. Depending on the facility and product, forming line operators remove forms while products are still wet or after they have cured. After removing forms, forming line operators clean the forms by removing any concrete residue. Sometimes, forming line operators might be required to manually hammer or chip away deposits of dried concrete. More typically, workers clean forms by scraping off the concrete residue while still wet and then spraying with water (Concrete Product Industry Representative A, 2000, as cited in Document ID 1365, p. 5-4).

Finishing Operator

After forming, finishing operators perform various processes such as grinding, patching, coring, drilling, sanding, blasting, and sawing of concrete products. Finishing operators perform these tasks to enhance product appearance, to cut or drill products to required specifications, and to repair defects. Finishing activities are most frequently associated with architectural product facilities (Concrete Products Industry Representative A, 2000 as cited in Document ID 1365, p. 5-4). However, OSHA SEP, NIOSH reports, and industry contacts indicate that at least some finishing processes (grinding, chipping, and coring) are performed at approximately two-thirds of the facilities making concrete blocks and bricks (NAICS 327331), but at only a few establishments in the other concrete industries (NAICS 327332, 327390, and 327999). Although finishing operators typically work on cured products, an increasing number of facilities have altered their processes so finishing operators are working on uncured (still wet) products. Finishing operators usually use manually-operated dry tools, such as handheld grinders. Automated equipment, such as enclosed grinding machines, is sometimes used for repetitive finishing tasks, such as finishing the faces of blocks. Finishing work with automated equipment often uses wet processes or LEV (Document ID 1365, p. 5-5; 0039; 0603; 0606). For patching products, finishing operators manually mix small batches of concrete in buckets and apply concrete by hand. Finishing operators may also perform abrasive blasting, typically outdoors (Document ID 1365, p. 5-5; 0055; 0898). The increasing popularity of retarders (which slow curing and allow the outer layer of concrete to be removed by brushing or pressure washing) is rapidly reducing the need for abrasive blasting in this industry (Concrete Products Industry Representative A, 2000, as cited in Document ID 1365, p. 5-5). While abrasive blasting is normally an activity performed by the finishing operator, OSHA is handling this activity separately to more accurately describe the exposure profile and additional controls.

Packaging Operator

Packaging operators transfer dry, powdered concrete mix into bags or boxes at facilities producing dry-mixed concrete products. At some facilities, packaging operators might operate bagging equipment requiring them to manually position empty bags against fill nozzles that dispense dry concrete mix in the bags, which the machine then seals. Some bagging machines automatically discharge filled bags to a conveyor, but others require manual removal of filled bags. To package dry-mixed concrete in super sacks, packaging operators may use forklifts to hold the super sacks in place while being filled. Packaging operators may also handle filled bags during manual stacking or palletizing tasks (Document ID 1365, p. 5-5; 0602; 0604).

Table IV.4.3-A Job Categories, Major Activities, and Sources of Exposure of Workers in the Concrete Products Industry (NAICS 327331, 327332, 327390, 327999)	
Job Category*	**Major Activities and Sources of Exposure**
Material Handler	Transferring silica-containing raw materials from storage silos to weigh hoppers via front-end loader; transferring product via fork lift or travel lift; manually stacking and palletizing product. • Dust generated during transfer and dumping of raw material. • Dust resuspended by heavy equipment operations. • Dust from adjacent operations.
Mixer Operator	Weighing and transferring silica-containing raw materials into mixing machines; operating and cleaning mixing machines. • Dust generated during manual weighing and ingredient transfer. • Dust generated during manual cleaning of mixers, especially dried concrete deposits.
Forming Operator	Transferring concrete into forms or molding machines manually or automatically; removing formed products; preparing and cleaning forms. • Dust generated while removing forms from cast product and during cleaning of forms, especially dried concrete deposits. • Dust from adjacent operations.
Finishing Operator: Abrasive Blasting	Abrasive blasting on cured products. • Dust from silica abrasive blasting media and concrete surface being abrasively blasted.
Finishing Operator (Other than Abrasive blasting)	Grinding, chipping, coring, sawing, patching, or sanding on formed products. • Dust generated during finishing activities on cured products.
Packaging Operator	Packaging dry, powdered concrete mixture. • Dust released at bag nozzle. • Dust in air displaced during filling or expelled when the bag is released from filling nozzle and drops to conveyor. • Dust from bags breaking.
*Job categories are intended to represent job functions; actual job titles might differ and responsibilities might be allocated differently, depending on the facility. Source: Document ID 1365, pp. 5-2 – 5-17.	

Table IV.4.3-B summarizes the available exposure information for the affected job categories. For each of the job categories listed in Table IV.4.3-B and included in the exposure profile and for the concrete products industry as a whole, OSHA concludes that Table IV.4.3-B represents baseline conditions.

4.3.2 Exposure Profile and Baseline Conditions

The exposure profile in Table IV.4.3-B includes 219 full-shift personal breathing zone (PBZ) samples of respirable crystalline silica for workers in concrete products industry. The median is 15 μg/m^3, the mean is 219 μg/m^3, and the range is 10 μg/m^3 (limit of detection (LOD)) to 26,826 μg/m^3. Table IV.4.3-B shows that, of the 219 samples, 57 are above 50 μg/m^3 and 36 exceed 100 μg/m^3. To assess current exposure levels and develop the exposure profile for workers in concrete product manufacturing facilities, OSHA reviewed exposure monitoring data from 17 OSHA SEP inspection reports, five NIOSH case studies of concrete manufacturing, one contractor site visit, and two articles in the published literature. The facilities covered by these inspections, case studies, and articles produced a wide variety of concrete products ranging from precast concrete wall cladding and decorative concrete architectural elements, to water pipes and sacks of dry concrete and mortar mixes. OSHA restricted its analysis to observations obtained for workers performing single, well-defined tasks during the sampling period, thereby permitting a better characterization of the exposures associated with each job category. Based on a comprehensive review of the available information, OSHA identified a total of 144 TWA exposures measurements covering six job categories that were presented in the PEA.

Following the publication of the PEA, OSHA reviewed the compliance monitoring data from its OIS system for air sampling data. An additional 90 measurements taken in the concrete products industry between 2011 and 2014 were identified, but 15 were not included in the exposure profile due to insufficient information.[12] The remaining 75 measurements were added to the exposure profile, increasing the number of exposure measurements available for the exposure profile to a total of 219. These measurement results are summarized by job title in Table IV.4.3-B.

Exposure Profile and Baseline Conditions for Material Handlers

The exposure profile in Table IV.4.3-B includes 46 sample results for material handlers in the concrete products industry. The median is 21 μg/m^3, the mean is 62 μg/m^3, and the range is 11 μg/m^3 (limit of detection (LOD)) to 620 μg/m^3. Table IV.4.3-B shows that, of the 46 samples, 12 (26 percent) are above 50 μg/m^3 and 6 (13 percent) exceed 100 μg/m^3.

All of the sample readings for material handlers exceeding 50 μg/m^3 were obtained in facilities where the majority of exposure readings for workers in all job categories also

[12] The 15 sample results that were excluded: Document ID 3958, Rows 426, 427, 429, 430, 432, 436, 438, 477, 479, 495, 596, 597, 598, 605, and 606.

exceeded 50 μg/m^3, suggesting poor dust control throughout these facilities. For example, OSHA obtained a sample of 116 μg/m^3 for a material handler who operated a forklift to transport cast concrete products between various surface finishing stations at a facility that manufactured precast concrete siding. The report indicated that dust generated by various other processes in the facility was a contributing factor (Document ID 1365, p. 5-9; 0039). This conclusion was supported by the fact that 9 of the 10 samples collected for workers in four job categories at the facility also exceeded 100 μg/m^3. The OSHA inspector noted that there were leaks in the silo bin chute as well as some controls were not being fully utilized. These circumstances suggest that material handlers at some facilities experience elevated silica exposure simply from passing through or working in areas where other workers' activities generate high concentrations of silica. If dust from these activities is permitted to accumulate, silica particles resuspended in the air by passing forklifts can exacerbate the situation. The exposures for this industry also suggest that when dust is controlled for all job categories, material handler exposure levels are also reduced. In fact, most of the concrete products industry material handler exposure readings below 50 μg/m^3 were obtained in facilities where the majority of exposure values for workers in all job categories also were less than 50 μg/m^3.

At another concrete products facility, four samples for two material handlers evaluated on two consecutive days resulted in values of 48 μg/m^3, 54 μg/m^3, 57 μg/m^3, and 73 μg/m^3. The workers inspected and prepared to palletize concrete blocks exiting an automated de-hacking machine used to unload blocks from a curing kiln and also performed a variety of other tasks, which included dry sweeping (Document ID 0220, p. 6). During the evaluation, NIOSH noted that "most of the facility has 1/8-inch dust on the floor." The investigators concluded that the dry sweeping might have had a notable effect on worker exposure and that as an alternative the facility could eliminate dry sweeping by switching to either a centralized or portable High-Efficiency Particulate Air (HEPA)-filtered vacuum system.

Although the exposure of many material handlers appears to have been influenced by the activities of other job categories, in a few cases material handlers were performing tasks that generated substantial dust. The two highest sample results available to OSHA for this job category, 610 μg/m^3 and 620 μg/m^3, were obtained in a packaging area with ineffective ventilation where one material handler palletized sacks of dry concrete mix and the other used a front-end loader to transfer sand to a hopper feeding the dry mix blending equipment (Document ID 0013, pp. 95, 97). Exposures of 60 μg/m^3 (palletizing job) and 193 μg/m^3 (loader operator moving sand and gravel) were observed in the same part of the plant the previous year (the report provides no explanation for the difference in exposure levels from one year to the next). OSHA did note that forced-air jets, intended to slightly levitate 80-pound sacks of dry mix concrete as the worker slid the sacks off the conveyor, blew dust (emitted from the bags during the transfer) into the workers' breathing zone. These samples comprise three of the four values above 100 μg/m^3 (among a total of 45 results for this job category), indicating that most material handlers at other concrete product facilities work under less extreme conditions. Brian Ogle with Nation Shale commented that "[i]n the packaging end, the finished product, we don't have any problem. The local exhaust ventilation normally suffices" (Document ID 3586, Tr. 3450). In this facility, however, both material handlers and packaging operators contributed to the substantial airborne silica in the area, where the material handlers were usually the most highly exposed workers (Document ID 0013, pp. 7, 36-60).[13]

For material handlers operating in outdoor work areas and product storage yards, thirteen results (42 percent) are associated with some variety of yard maintenance to control dust (not necessarily effectively), including the use of water spray, dust suppressants, crushed aggregate ground cover, or regular power-sweeping of paved surface. These results range from 11 μg/m^3 to 110 μg/m^3 and have a median of 24 μg/m^3 and a mean of 34 μg/m^3. The highest of these outdoor readings, 110 μg/m^3, is associated with a yard that had been previously watered but let dry. Other watered yards (presumably not dried) and yards using a dust suppressant are associated with very low exposure readings, including five

[13] The packaging operator working in the same area also had elevated exposures (370 μg/m^3 and 142 μg/m^3 in the two respective years) (Document ID 0013).

readings at or below the LOD and one reading of 21 µg/m^3.[14] (Document ID 0087, p. 258; 0220, p. 7-8; 0234, pp. 5-6; 0236, p. 7-9; 0898, p. 7-8).

OSHA has determined that the baseline conditions are best represented by the range of working conditions associated with the use of some engineering controls (e.g., LEV or wetting) that may not be operating optimally. The results are summarized in Table IV.4.3-B. Therefore, OSHA concludes that the median value for all material handlers (21 µg/m^3), shown in Table IV.4.3-B, is also the median baseline value.

Exposure Profile and Baseline Conditions for Mixer Operators

The exposure profile in Table IV.4.3-B includes 35 sample results for mixer operators in the concrete products industry. The median is 12 µg/m^3, the mean is 40 µg/m^3, and the range is 10 µg/m^3 (limit of detection (LOD)) to 281 µg/m^3. Table IV.4.3-B shows that, of the 35 samples, 7 (20 percent) are above 50 µg/m^3 and 6 (17.2 percent) exceed 100 µg/m^3. Two of the highest readings, 281 µg/m^3 and 122 µg/m^3, were obtained for mixer operators who cleaned the interior of a concrete mixer using handheld jackhammers to chip dried concrete residue (Document ID 0067, pp. 159-160). Other elevated readings – 134 µg/m^3, 108 µg/m^3, and 107 µg/m^3 – were obtained for operators manually dumping bags of silica-containing materials at hoppers equipped with ineffective LEV systems (Document ID 1365, pp. 5-10 – 5-11; 0039).

Several low sample readings were taken on operators controlling enclosed mixers from ventilated control rooms. One low exposure result, 24 µg/m^3, is for an operator who used a pneumatic chipping hammer and a compressed air wand to remove dried concrete from the interior of the mixer (Document ID 0898, pp. 12, 15). This result, along with the two high exposure levels described in the previous paragraph, indicates a wide variability in exposure for operators removing concrete from mixing drums, possibly due to variations

[14] Exposures reported as “none detected” are assigned a value equal to the LOD. The LOD is determined individually for each sample based on the volume of air sampled and the method used to analyze the sample, therefore, the limit of detection varies between samples. See Section IV-2–Methodology.

in work practices, the amount of concrete being removed, and the amount of time spent on the task (a function of how frequently cleaning is performed).

Information from industry contacts suggests that common controls for mixer operators include enclosed mixers, automated weighing and charging or loading of raw materials into the mixing equipment, and wet methods to clean mixing equipment. Facilities in this industry commonly use at least one of these controls, but no single control is consistently used throughout the industry (i.e., the baseline condition includes use of any one of several controls). Examples of exposures associated with these conditions include 12 μg/m^3, 24 μg/m^3, and 25 μg/m^3 (Document ID 0236, p. 11; 0898, p. 15). Mixer operators at some facilities, however, continue to manually charge mixers and clean mixing equipment using dry methods, yielding higher exposure levels (Document ID 1365, p. 5-16; 0039; 0067; 0898).

OSHA has determined that the baseline conditions for this job category are best represented by the wide range of exposure situations under which exposures summarized in Table IV.4.3-B were obtained. Thus, the median value for mixer operators in the Table IV.4.3-B exposure profile (12 μg/m^3) represents the median value for this job category under baseline conditions.

Exposure Profile and Baseline Conditions for Forming Operators

The exposure profile in Table IV.4.3-B includes 65 sample results for forming operators in the concrete products industry. The median is 13 μg/m^3, the mean is 20 μg/m^3, and the range is 11 μg/m^3 (limit of detection (LOD)) to 107 μg/m^3. Table IV.4.3-B shows that, of the 65 samples, 5 (7.7 percent) are above 50 μg/m^3 and 1 (1.5 percent) exceeds 100 μg/m^3.

The highest sample reading, 107 μg/m^3, was associated with a forming operator removing concrete siding from forms and palletizing it at an unventilated workstation. At this facility, 9 of 10 respirable silica readings for workers in four job categories exceeded 100 μg/m^3, indicating poor control of silica throughout (Document ID 1365, p. 5-11; 0039). This was confirmed by the OSHA inspector, who noted that there were leaks in the silo bin chute as well as some controls were not being fully utilized. OSHA notes that secondary exposure from activities of other workers most likely contributed to the silica exposure of this forming operator.

Other samples in excess of 50 μg/m^3 were associated with similar, widespread dust control problems (Document ID 0220, pp. 6, 10). Two such samples were obtained at a facility for a worker controlling a concrete block-making machine. The worker stood near activities which generated high volumes of dust, including a block making machine that generated dust and dry sweeping activities. Additionally, this worker was 20 feet from a mixing machine, which emitted dust during hopper loading (Document ID 1365, p. 5-12; 0220, p. 8).

In contrast, facilities that properly implemented dust controls had lower exposures. Among the lowest exposure results are six readings, ranging from less than or equal to 12 μg/m^3 (LOD) to less than or equal to 14 μg/m^3 (LOD), which were obtained for four operators at a facility visited by NIOSH. Three of the operators formed concrete products using computer-controlled molding machines. The operators used water spray, shovels, and mold vibrators to evenly distribute the wet concrete in the molds. The fourth operator manually assembled forms and then cleaned them by brushing and grinding (Document ID 1365, p. 5-12; 0234).

Based on OSHA SEP and NIOSH reports and discussions with concrete product manufacturers, OSHA finds that current or baseline conditions for forming operators involve the same range of working conditions represented by the results for this job category summarized in Table IV.4.3-B, all of which were below the detectible limit.

Exposure Profile and Baseline Conditions for Finishing Operators (Abrasive Blasting)

The exposure profile in Table IV.4.3-B includes 17 sample results for finishing operators (Abrasive Blasting) in the concrete products industry. The median is 126 μg/m^3, the mean is 2,227 μg/m^3, and the range is 10 μg/m^3 limit of detection (LOD) to 26,826 μg/m^3. Table IV.4.3-B shows that, of the 17 samples, 14 (82.3 percent) are above 50 μg/m^3 and 10 (58.8 percent) exceed 100 μg/m^3.

These values, much higher than other job categories, are based on 17 samples for abrasive blasters in this concrete products industry reported by OSHA, NIOSH, and the OSHA contractor ERG (Document ID 0011, p. 40; 0012, pp. 145-147; 0053, pp. 128, 130; 0055, pp. 128, 144, 155; 0204, p. 18; 0733, p. 26; 0898, p. 15; 3958, Rows 306, 366). 82.3 percent of the abrasive blaster results exceed 50 μg/m^3. These samples are in the same range as other similar abrasive blasting operations (see Section IV-5.1 – Abrasive Blasting).

The three highest sample readings (26,826 μg/m^3, 6,482 μg/m^3, and 2,303 μg/m^3) were obtained at two facilities, where operators performed abrasive blasting of concrete panels in unenclosed, outdoor workstations.[15] The operators at both facilities used silica sand blast media containing 87 percent to 99.9 percent quartz, according to the media manufacturer's material safety data sheets (Document ID 1365, p. 5-13; 0012; 0053). Among the workers performing abrasive blasting, some of the lowest samples were associated with outdoor blasting on concrete panels using coal slag blast media[16] (20 μg/m^3, 30 μg/m^3, and 54 μg/m^3), although values as high as 473 μg/m^3 were also reported (Document ID 1365, p. 5-14; 0011; 0055; 0204, p. 18). Results of 10 μg/m^3 and 154 μg/m^3 were obtained at a facility using silica sand blasting media with a dust suppressant additive (Document ID 1365, p. 5-14; 0898). A study described by Heitbrink (2007) used silica sand media with less than 3 percent fines[17] by weight (screened with 100-mesh) in conjunction with a water induction nozzle using water at a rate of 13 pounds per minute (approximately 1.5 gallons per minute). The wet abrasive blasting was performed outdoors and exposed the underlying aggregate of precast concrete building

[15] OSHA's requirements for respirators and exhaust ventilation for abrasive blasting are codified at 29 CFR §§ 1910.94 – Ventilation for general industry and 1910.134 – Respiratory Protection. During abrasive blasting, airline helmet-style respirators would be required under 29 CFR § 1910.94.

[16] Coal slag is a low-silica abrasive blasting media, but may contain other toxic materials such as toxic metals.

[17] "Fines" is a general term referring to very small particles in a mixture of varying sizes. A 100-mesh screen is defined as having 100 openings per linear inch, meaning that the screen openings are 149 microns in size and will separate out particles of smaller size (Document ID 1720, p. IV-75).

panels. Under these working conditions, the investigator obtained two full-shift silica exposures of 75 μg/m^3 and 124 μg/m^3 (Document ID 0733, p. 26).

Manual abrasive blasting of concrete products is most often conducted outdoors as a dry process; however, as indicated previously in this section, some concrete product manufacturers are attempting alternate methods such as retarders, which slow the rate of curing and therefore minimize the need for abrasive blasting altogether. OSHA has determined that there are a variety of working conditions ranging from no or minimum controls to the use of alternate media and/or engineering controls such as wet methods or dust suppressants. OSHA finds that the samples summarized for finishing operators (abrasive blasting) in Table IV.4.3-B best describe the baseline conditions for all abrasive blasting operators in this industry. Thus, the median value for this job category shown in Table IV.4.3-B (126 μg/m^3) also represents the median baseline silica exposure level for abrasive blasting operators.

Exposure Profile and Baseline Conditions for Finishing Operators (Other Than Abrasive Blasting)

The exposure profile in Table IV.4.3-B includes 50 sample results for finishing operators (Other than Abrasive Blasting) in the concrete products industry. The median is 19 μg/m^3, the mean is 78 μg/m^3, and the range is 11 μg/m^3 limit of detection (LOD) to 660 μg/m^3. Table IV.4.3-B shows that, of the 50 samples, 15 (30 percent) are above 50 μg/m^3 and 11 (22 percent) exceed 100 μg/m^3.

Elevated exposures for workers performing finishing activities other than abrasive blasting are associated with workers using poorly controlled processes or general dust control issues. For example, at one facility, surfacing machines were associated with results of 210 μg/m^3, 240 μg/m^3, 281 μg/m^3, and 318 μg/m^3, and a punch press operator experienced an exposure of 96 μg/m^3 (Document ID 1365, p. 5-14; 0039, pp. 80, 86, 93, 99, 155).[18] Even though the punch press and surfacing machines were all equipped with LEV, the OSHA inspector attributed the elevated sample results to inadequate LEV on

[18] The surfacing machine action is not specified but presumably involves automated grinding to level the surface or modify texture based on the job description of feeding and removing boards (Document ID 0110, p. 24).

the surface grinders and to dust which entered the punch press workstation through holes in the floor (Document ID 0039, pp. 151-153). Ninety percent of the exposure readings taken were above 100 μg/m^3 indicating a general problem with dust control throughout the facility (Document ID 0039, pp. 23-26). High exposures were also experienced at another facility where workers using handheld power tools to grind concrete panels had results of 308 μg/m^3 and 69 μg/m^3 and an exposure level of 347 μg/m^3 was recorded for a finishing operator performing patching of finished panels in the sandblasting area (Document ID 1365, p. 5-14; 0067, pp. 119, 129, 135). OSHA noted during the inspection that abrasive blasting had occurred on the day the sample was taken (Document ID 1365, p. 5-14; 0067, pp. 119, 129, 135).

Some of the lowest exposures for hand tool workers include two exposure readings of less than or equal to 12 μg/m^3 (LOD) for finishing operators who cut or scored uncured precast concrete products. This cutting was performed using non-powered hand tools while the "zero-slump" concrete was still wet, thus eliminating the need for power tools, which are required after the concrete has dried (Document ID 1365, p. 5-14; 0234). Zero-slump concrete lacks any fluidity and retains its shape prior to curing, thus enabling finishing operations to be performed on still-damp concrete. At this site, none of the 17 results for three of the other job categories exceeded 21 μg/m^3, indicating that dust was well controlled throughout the facility (Document ID 0234).

Activities and associated conditions vary greatly for finishing operators. Based on a review of OSHA SEP and NIOSH reports, OSHA has determined that baseline conditions for manual finishing operations involve outdoor, dry work performed on cured concrete, while automated finishing operations are typically conducted indoors with some form of control such as wet methods or LEV. Nevertheless, OSHA has determined that together the various working conditions represented by data summarized for finishing operators in Table IV.4.3-B best describe the baseline conditions for all finishing operators in this industry. Thus, the median value for this job category shown in Table IV.4.3-B (19 μg/m^3) represents baseline silica exposures level for finishing operators.

Exposure Profile and Baseline Conditions for Packaging Operators

The exposure profile in Table IV.4.3-B includes 6 sample results for packaging operators in the concrete products industry. The median is 84 µg/m^3, the mean is 117 µg/m^3, and the range is 11 µg/m^3 (limit of detection (LOD)) to 370 µg/m^3. Table IV.4.3-B shows that, of the 6 samples, 4 (66.7 percent) are above 50 µg/m^3 and 2 (33.4 percent) exceed 100 µg/m^3.

These six readings for packaging operators were obtained from four OSHA SEP inspection reports for facilities where workers used bag-packing machines to fill sacks with dry concrete mix (Document ID 1365, p. 5-15; 0013; 0073; 0126; 0158).

The two highest sample readings were obtained for packaging operators at a facility inspected by OSHA. OSHA obtained a sample reading of 142 µg/m^3 for a worker who used a bag-filling machine to load 80-pound bags of dry-mix concrete, with general exhaust ventilation fans located near the workstation. After the inspection, the facility installed an LEV system for the packaging operation, but an industrial hygiene consultant later obtained a reading of 370 µg/m^3 for the packaging operator even with the new ventilation system in place. The consultant found that the system did not effectively remove dust generated by the packaging operation, but offered no explanation (Document ID 1365, p. 5-15; 0013).[19]

The lowest sample reading for this job category, less than or equal to 11 µg/m^3 (the reported LOD), was obtained for a packaging operator at a facility that had upgraded its dust controls following an OSHA SEP inspection. The facility had improved the LEV system for the packaging operation by relocating hoods closer to the operator's position while filling bags. The facility also had rebuilt the LEV system to generate greater airflow and installed a new filter bag. In addition, daily housekeeping for the workstation had been implemented after the inspection (Document ID 1365, p. 5-15; 0126, p. 10).

[19] The inspection report associates the exposure readings with cement packaging. OSHA, however, described the facility as a concrete packaging plant, and the percentage of quartz (6 percent) found in the sample suggests that the reading is associated with concrete packaging.

Based on the available reports, typical conditions for packaging operators include manual insertion of empty bags into bag-filling machines equipped with LEV; however, the exhaust ventilation systems often are poorly maintained or function inefficiently. Dust is generated when filled bags expel product as they are released from bag-filling machines and when filled bags covered with spilled product are dropped onto conveyors (Document ID 1365, pp. 5-17 – 5-18; 0013; 0073; 0126). OSHA finds that the samples summarized for packaging in Table IV.4.3-B best describe the baseline conditions for all packing operators in this industry. Thus, the median value for this job category shown in Table IV.4.3-B (84 μg/m^3) also represents the median baseline silica exposure level for packaging operators.

Table IV.4.3-B
Personal Respirable Crystalline Silica Exposure Range and Distribution of Results for Workers in the Concrete Products Industry (NAICS 327331, 327332, 327390, 327999)

	Exposure Summary			Exposure Range			Exposure Profile				
Concrete Products Industry	**N**	**Mean ($\mu g/m^3$)**	**Median ($\mu g/m^3$)**	**Min ($\mu g/m^3$)**	**Max ($\mu g/m^3$)**		**< 25 ($\mu g/m^3$)**	**≥ 25 and ≤ 50 ($\mu g/m^3$)**	**> 50 and ≤ 100 ($\mu g/m^3$)**	**> 100 and ≤ 250 ($\mu g/m^3$)**	**> 250 ($\mu g/m^3$)**
Material Handlers	46	62	21	11	620		26 (56.5%)	8 (17.4%)	6 (13%)	4 (8.7%)	2 (4.3%)
Mixer Operators	35	40	12	10	281		26 (74.3%)	2 (5.7%)	1 (2.9%)	5 (14.3%)	1 (2.9%)
Forming Operators	65	20	13	11	107		56 (86.2%)	4 (6.2%)	4 (6.2%)	1 (1.5%)	0 (0%)
Finishing Operators (Abrasive Blasting)	17	2,227	126	10	26,826		2 (11.8%)	1 (5.9%)	4 (23.5%)	4 (23.5%)	6 (35.3%)
Finishing Operators (Other than Abrasive Blasting)	50	78	19	11	660		26 (52%)	9 (18%)	4 (8%)	6 (12%)	5 (10%)
Packaging Operators	6	117	84	11	370		2 (33.3%)	0 (0%)	2 (33.3%)	1 (16.7%)	1 (16.7%)
Concrete Products Industry Total	**219**	**219**	**15**	**10**	**26,826**		**138 (63%)**	**24 (11%)**	**21 (9.6%)**	**21 (9.6%)**	**15 (6.8%)**

Notes: All samples summarized are personal breathing zone (PBZ) results representing 8-hour time-weighted average exposures.
Job categories are intended to represent job functions; actual job titles might differ, and responsibilities might be allocated differently, depending on the facility.
Percentages may not add to 100 percent due to rounding.

Sources: Document ID 1720; 3958; 0011; 0012; 0013; 0024; 0039; 0053; 0055; 0067; 0073; 0075; 0087; 0126; 0158; 0160; 0175; 0184; 0185; 0204; 0220; 0022; 0234; 0236; 0733; 0898.

4.3.3 Additional Controls

There are many commonly used control methods and work practices that can significantly reduce exposures in this application group. According to Robert Whitmore from the National Precast Concrete Association (NPCA), ongoing efforts to reduce dust at concrete manufacturing plants include:

> wet sawing; water sprays and misting before sweeping concrete dust; dust collectors on tools; and enclosed cabs on equipment. In addition, the [NPCA] SHE Committee supports continuing education among plant personnel on the proper use of respirators and other personal protective equipment (Document ID 2067, p. 2).

Several commenters argued that there have been significant trends in the concrete products industry to reduce exposures to respirable silica including LEV. These systems were initially installed to control the dust associated with charging the mixer with dry cement. However, even with investing in the use of LEV, there can still be significant exposures for some operations (Document ID 2114; 2384; 2388; 3300). In the discussion below, OSHA emphasizes that when reducing worker exposures, the employer must minimize exposures from all sources and in many cases will need a combination of controls including LEV, wet methods, and improved housekeeping.

Additional Controls for Material Handlers

The exposure profile in Table IV.4.3-B shows that 26 percent (12 out of 46 samples) of material handlers have exposures above the final PEL of 50 μg/m^3. Therefore, OSHA finds that additional controls will be necessary to achieve the PEL for these overexposed workers. Appropriate control measures include adding or improving LEV at raw material receiving hoppers (particularly in the dry bagged concrete mixing area), making changes to the area where material handlers transfer finished sacks from conveyors onto pallets, suppressing dust in storage yards, and using enclosed cabs on front-end loaders when transferring raw materials where exposures continue to be elevated. Adjacent operations also need to be controlled in order to reduce most material handler exposures. Specifically, changes described later under additional controls for packaging operators (e.g., improved LEV for bag-filling machines and switching to bags designed to emit less dust) will also help reduce the exposure of material handlers who work in the area or eventually handle the same bags.

Local Exhaust Ventilation (LEV)

LEV should be installed to provide appropriate air flow. The American Conference of Governmental Industrial Hygienists (ACGIH) provides design recommendations for ventilated hoppers receiving dusty materials (Document ID 0515). The designs will vary depending on the method the facility uses for loading the hopper. ACGIH recommends a minimum air flow of 150 feet per minute (fpm) across bin and hopper openings for manual loading operations. However, for other loading methods that cause material to enter the hopper in a manner different than manual loading (e.g., using a front-end loader, or during high-speed automated loading operations), ACGIH recommends an air rate of one-and-a-half to two times that minimum air flow rate of 150 fpm. The recommended velocity depends on the material flow rate (a front-end loader adds materials at a much greater material flow rate than manual transfers), dustiness (the material at this site was apparently very dusty), and the height the material falls (influenced by either hopper design or by material handler work practices). Furthermore, ACGIH also recommends that the enclosure be "*large enough to accommodate the 'splash' effect*" that occurs when a load is dumped into the hopper (Document ID 0515, p. 13-78) (italics in original).

Exposure to material handlers who operate front end loaders can be reduced by using a redesigned hopper enclosure of adequate size to accommodate the loader scoop and resulting "splash" effect. Air must be exhausted from the enclosure at a rate commensurate with the material flow rate and dustiness (potentially up to two times the minimum recommended rate of 150 fpm, equal to a rate of 300 fpm across the enclosure opening). Information from the pottery industry indicates that, when material transfer stations have functional LEV, worker exposures are markedly lower (median exposure level 27 $\mu g/m^3$) than when material transfer stations operations are associated with LEV that is clearly inadequate or missing (median exposure level 530 $\mu g/m^3$). Based on the similarity of hoppers, conveyors, and mixing equipment used to blend the similar mineral powders used by both industries, OSHA expects that LEV at material transfer stations in pottery operations would also be effective in the concrete product industry.

Yard Dust Management

Facilities that implemented yard dust management controls show that exposure levels at or below 50 µg/m^3 are achieved in almost all cases (85 percent of the samples). These observations include four readings of less than 21 µg/m^3 for facilities using dust suppressants, two readings of less than 19 µg/m^3 for those that consistently wetted yard dust, a reading of less than 40 µg/m^3 for a facility using an aggregate bed, and four readings of less than 57 µg/m^3 for facilities using power sweeping of a paved yard (Document ID 1365, p. 5-18; 0220; 0234). In contrast, exposures greater than 110 µg/m^3 were observed at a facility where wetted yards were allowed to dry (Document ID 1365, p. 5-18; 0087). Additional support for the application of dust suppressants includes a study by Addo and Sanders (1995) that examined three chemical dust suppressants (lignosulfate, calcium chloride, and magnesium chloride) applied to an unpaved roadway for four and a half months. The study found that compared to an untreated roadway, the suppressants reduced fugitive dust emissions by 50 to 70 percent (Document ID 1720, p. IV-78; 0516, p. 106).

Wet dust suppression methods can also be used to minimize exposure during raw materials transfer. One industry contact reported use of dampened aggregate to minimize dust release as materials are dumped into hoppers (Document ID 1365, p. 5-18; 0605). Although the effectiveness of this control has not been quantified for use in loading operations, other operations in this application group have shown that wetting the material effectively prevents fine particles mixed with the aggregate from becoming airborne (see the discussions below in this section, under the headings Additional Controls for Mixer Operators and Additional Controls for Finishing Operators).

Control of yard dust offers the best results when used in conjunction with other efforts to control silica dust. One facility, for example, controlled exposures through the use of worker training and regularly applied dust suppressants, enclosed equipment, wet methods, and rigorous housekeeping as elements of a comprehensive dust control program. The three exposure readings for the material handlers at this facility were all less than 13 µg/m^3 (Document ID 1365, p. 5-18; 0234).

Improved Housekeeping

Poor housekeeping contributes substantially to worker exposure levels in material handling areas. A thorough initial cleaning to remove dust that has accumulated in combination with improved dust controls and daily housekeeping procedures to maintain cleanliness can reduce exposures in areas where dust has been allowed to accumulate. Exposure levels ranged from 48 to 73 μg/m^3 for concrete product material handlers who performed dry sweeping during their shifts where "most of the facility has 1/8-inch of dust on the floor," which NIOSH indicated could have been a significant source of their exposure (Document ID 0220, pp. 9-10).

In the structural clay industry, another application group with similar material handling requirements, thorough, professional-quality cleaning of a brick manufacturing facility dramatically reduced exposure levels (by 90 percent or more in some cases) for workers in areas where raw materials were transported or handled (raw material storage, near grinding equipment and conveyors, during bag dumping, and at raw material hoppers) (see Section IV-4.21–Structural Clay) (Document ID 1365, p. 3-20; 0571).

Enclosed Operator Cabs

Enclosed operator cabs offer another option for reducing the exposure of material handlers. In the PEA, OSHA estimated that only a quarter of concrete product manufacturing facilities use well-enclosed cabs equipped with air filtration and air conditioning to effectively control exposures of material handlers operating mobile equipment in dusty areas (Document ID 1365, p. 5-18). While there were no specific comments on the percentage of companies using enclosed cabs, several commenters indicated that the use of enclosed cabs was difficult due to communication issues (Document ID 4217, PDF p. 93) while others indicated that they have solved this problem by using mobile devices (Document ID 2262, p. 28). An exposure level of 21 μg/m^3 was obtained at a precast concrete facility for a material handler who used a front-end loader with an air-conditioned cab enclosure to transport raw materials across a water and dust suppressant-treated yard (Document ID 1365, p. 5-19; 0898).

NIOSH recommends several cab design features (enclosed positive-pressured cabs with air conditioning and filtered air supply) and emphasizes the importance of maintenance and cleanliness (Document ID 0839, p. 2). Cabs employing several of these recommended features regularly achieve exposure reductions (inside versus outside the cab) exceeding 90 percent[20] (Document ID 0590, p. 59; 0844, p. 2).

Multiple silica exposure control strategies (e.g., enclosed cab, plus dust suppressant on the ground as described in the example above) can be used simultaneously if a single method is inadequate to reduce the exposure levels.

Additional Controls for Mixer Operators

The exposure profile in Table IV.4.3-B shows that 20.1 percent (7 out of 35 samples) of mixer operators have exposures above the final PEL of 50 µg/m^3. Therefore, OSHA finds that additional controls will be necessary to achieve the PEL for overexposed workers. Operators in the group requiring additional controls experience elevated exposure while performing two activities: chipping residual concrete from mixing barrels and emptying bags of raw materials into the mixer during manual mixer charging.

In the concrete products industry, the chipping activity is usually performed once daily (and at least weekly), typically for brief periods. While these operations may only last for brief periods of time, worker exposure is generally substantial and warrants control. Controls include wet methods for cleaning mixing equipment before residual concrete has dried, as well as use of wet methods and LEV when chipping is required.

Other control measures are necessary when mixer operators are exposed to elevated levels of silica during manual mixer charging and raw material mixing. Use of ventilated bag dumping stations or automated mixer charging, and operator isolation in a control room or booth, can reduce mixer operators' silica exposures to levels below 50 µg/m^3 for these operations.

[20] The Cecala study (Document ID 0590, p. 59) reported reductions in levels of respirable dust between 97.8 to 98.7 percent.

Controls for Chipping Operations

As previously discussed, mixer operators must clean the mixing drum daily. OSHA has determined that the best control for reducing silica dust exposures when cleaning drums is to clean the mixer while the concrete residue is still wet (Document ID 1365, pp. 5-3 – 5-4).

Lynn Burchfield from Acme Brick commented on mixer cleaning. Cleaning normally involves the uses of compressed air and chipping hammers to break free hardened material. This activity generally takes 30 minutes or less. Ms. Burchfield has identified some difficulties associated with recommended controls, such as using water to clean mixers which can create sludge or color contamination on future batches. She also indicated that ventilation and dust collection systems have proven to be problematic. Ms. Burchfield indicated that the peak levels of exposure typically ranged from 25 to 125 $\mu g/m^3$ (Document ID 2023, pp. 3-4). OSHA appreciates the difficulty in implementing controls; however, as discussed below, these difficulties have been overcome in other industries with similar activities with the use of a combination of controls.

OSHA has determined that the chipping activity to clean hardened concrete from in-plant mixing drums is essentially the same task that workers perform to remove hardened concrete from ready-mixed concrete truck drums. As described in Section IV-4.17 – Ready-Mix Concrete, this activity occurs in a more challenging (more enclosed) environment, takes longer (several hours compared to several minutes), and usually involves a notably heavier concrete buildup on the mixer drum walls because, according to the National Ready Mixed Concrete Association, truck drums are typically only cleaned twice per year compared with the daily or weekly cleaning schedule for in-plant mixer barrels (Document ID 0922, p. 9). Therefore, OSHA has determined that work on truck drums represents the worst-case scenario. Based on the similarities between the two processes, OSHA concludes that exposure controls for ready-mixed concrete truck drum cleaning will be at least as effective for cleaning in-plant mixer barrels.

Investigators have found that the following control methods used for ready-mixed concrete truck drum cleaning offer exposure reductions of at least 70 percent compared with uncontrolled levels (typically up to approximately 1,000 μg/m^3).[21] For a more detailed discussion on the engineering controls for controlling worker exposure during ready-mixed truck drum cleaning please see Section IV-4.17 – Ready-Mix Concrete in this technological feasibility analysis.

- *LEV-equipped chipping tool plus general exhaust ventilation:* Silica levels reduced to a mean of 220 μg/m^3 (Document ID 1365, p. 13-22; 0245, p. 12).
- *Water misting device and push/pull ventilation system:* Silica levels reduced to 128 μg/m^3 (Document ID 1157, p. D123).[22]
- *Periodic spraying of the interior surface of the drum and directing continuous water spray at the chisel point during chipping:* Silica levels reduced to "less than the PEL" (100 μg/m^3 or somewhat less, calculated using OSHA's general industry standard for respirable dust containing silica) (Document ID 3732, Attachment 3, pp. 14-16).

In the exposure profile for mixer operators, the two highest sample results are 281 μg/m^3 and 122 μg/m^3 are associated with barrel cleaning. A 70 percent reduction would lower the second highest result to a level of 37 μg/m^3 and reduce all the other results in the mixer operator exposure profile summarized in Table IV.4.3-B to levels less than 37 μg/m^3; only the highest value of 281 μg/m^3 would not be reduced to below the 50 μg/m^3 PEL. OSHA's exposure profile is consistent with industries' experience of typical exposures for mixer cleaning ranging from 25 to 125 μg/m^3 (Document ID 2023, p. 4). OSHA also notes, as discussed above, that it is often a combination of controls including work practices, minimizing the amount of time an employee may spend in a drum, and engineering controls, which could include both LEV and wet methods, that is needed to adequately control exposures (Document ID 1157, p. D123; 3732, Attachment 3, pp. 9-20). However, OSHA also notes that there may be some circumstances where the use of respirators may be necessary for cleaning in-plant mixer barrels.

[21] The exposure levels shown in the bulleted list are for workers who spent at least half of the sampling period (and usually the entire period) chipping concrete from inside truck mixing drums (the worst-case scenario).

[22] The respirable crystalline silica levels were calculated by multiplying the respirable dust concentration (1.69) mg/m^3 by the percent of silica in the sample (7.6 percent): 1.69 mg/m^3 x 0.076 = 128 μg/m^3.

Controls for Mixer Charging

Manual mixer charging is another source of mixer operator exposure in non-automated plants. Control options include ventilated bag dumping stations, automatic mixer charging systems, and operator control booths.

Bag Dumping Stations

Bag dumping stations can potentially control dust generated by bag emptying and disposal. While data from concrete product facilities using ventilated bag dumping stations are not available, a bag dumping station with fully functioning LEV was found to reduce silica exposure by at least 95 percent in a paint manufacturing facility where workers emptied 50-pound bags of silica-containing materials (Document ID 1365, pp. 5-20 – 5-21; 0199). The stations consist of hoppers topped with grates enclosed by LEV hoods. After each bag is emptied, the worker releases it and suction automatically pulls the bag into the ventilation system and transfers it to an enclosed storage area. Ventilated bag dumping and disposal stations are readily available from commercial sources (Document ID 0581; 0594; 0680; 1212; 1224).

Automatic Mixer Charging

Automatic mixer charging equipment reduces operator exposure by allowing the worker to stand at a distance from the mixer while controlling the flow of raw materials into the mixer. Automated systems are widely used in many industries and are readily available from commercial sources (Document ID 0680; 1212; 1224). Exposures of less than or equal to 12 μg/m^3 (the LOD) were reported for a mixer operator using an automated charging system at a precast concrete architectural panel facility (Document ID 1365, p. 5-21; 0204, p. 10-11). An 86 percent reduction in respirable silica exposure readings occurred at a structural clay product facility after a manual bag dumping station was replaced with an enclosed, automated sand transfer system (Document ID 1365, p. 5-21; 0161). Like mixer operators in the concrete products industry, workers in the structural clay industry handle silica-containing dry ingredients (clay, sand, and other ground minerals), which they mix with water to create wet clay to form into products. OSHA expects at least similar reductions in exposures if not greater in this application group, since the structural clay industry workers use a wider range of silica-containing materials, potentially milled to smaller particle sizes. OSHA therefore concludes that control measures that are effective in controlling dust in the structural clay application group will also be effective in the concrete products industry.

Operator Control Booths

When exposures continue to be elevated during automated mixer charging, the charging system controls can be placed in an enclosed operator booth. To effectively control silica exposure, the operator booth must be maintained to exclude dust through tight seals at doors and windows and must provide clean air that keeps the booth under slight positive pressure to help exclude dust. At a structural clay facility visited twice by OSHA, an area sample collected inside a poorly sealed ventilated control room resulted in an average silica concentration of 111 μg/m^3. Before OSHA's next visit, the facility sealed gaps around the main entrance door to the control room. This modification reduced airborne silica levels inside the room to 11 μg/m^3, a 90 percent reduction compared to the earlier sample (Document ID 1365, pp. 3-17 – 3-18; 0161). OSHA notes that low silica levels inside the control room suggest that the room provides a substantial level of protection for any worker inside.

Additional Controls for Forming Operators

The exposure profile in Table IV.4.3-B shows that 7.7 percent (5 out of 65 samples) of forming operators have exposures above the final PEL of 50 μg/m^3. Therefore, OSHA finds that additional controls will be necessary to achieve the PEL for overexposed workers. The data summarized in Table IV.4.3-B show that 86 percent of forming operators' exposures are 25 μg/m^3 or less, and 92 percent have exposures of 50 μg/m^3 or less, indicating that routine activities of forming operators do not normally generate silica concentrations that exceed 50 μg/m^3. Controlling adjacent sources of silica dust (e.g., chipping in mixer barrels, finishing processes that are performed near the forming area) will reduce the exposure levels of those few forming operators (10 percent) that have elevated exposures. As noted previously, the highest result (107 μg/m^3) was associated with a worker who emptied and palletized forms at a facility where 9 out of 10 silica results in four job categories exceeded 100 µg/m^3.

In the event that additional controls are needed after adjacent sources of exposure have been controlled, concrete product facilities can improve housekeeping and add LEV to work stations, particularly those stations associated with automated processes. Two of the results between 50 µg/m^3 and 100 µg/m^3 were associated with adjacent sources of exposure and a nearby block making machine that emitted dust (Document ID 1365, pp. 5-11 – 5-12; 0220).

Forming operators can also use cleaning techniques that limit dust released when they clean forms and work areas. HEPA-filtered vacuums used in place of dry brushing or sweeping will minimize worker exposure to silica during these activities. A thorough initial cleaning in conjunction with regularly scheduled housekeeping will help reduce exposure from settled dust that might have accumulated in the work area. Disturbed dust is another likely contributor to the silica exposure for all three of the workers with results above 50 µg/m^3 discussed in the previous paragraphs.

Additional Controls for Finishing Operators (Abrasive Blasting)

The exposure profile in Table IV.4.3-B shows that 82.3 percent (14 out of 17) samples of finishing operators (Abrasive Blasting) have exposures above the final PEL 50 µg/m^3. Therefore, OSHA finds that additional controls will be necessary to achieve the PEL for these overexposed workers. One alternative to abrasive blasting, surface retarding, can eliminate exposure to silica, while exposing aggregate on concrete surfaces (a primary objective of some abrasive blasting tasks). Other exposure control methods do not reduce silica exposure to the same extent but do provide some benefit. Wet abrasive blasting can suppress dust considerably, provided sufficient water is added to the abrasive media. Additionally, compared to abrasive blasting with silica sand, use of low-silica abrasive blasting media that are less toxic than quartz sand also reduce worker silica exposure. The concrete surfaces that workers abrasively blast contribute to the silica dust released during abrasive blasting, so some exposure can occur even if the media contains no silica (Concrete Product Industry Representative A, 2000; APA, 2000; Master Builders, 2000, as cited in Document ID 1365, pp. 5-23 – 5-24). For a more in-depth discussion of alternatives to abrasive blasting, see Section IV-5.1 – Abrasive Blasters in this technological feasibility analysis, which covers abrasive blasting in the construction industry.

Alternatives to Abrasive Blasting – Surface Retarding

Operators creating certain product finishes can use a surface retarder to inhibit curing and allow an outer layer of concrete to be washed or brushed away as an alternative to abrasive blasting. The chemical retarder applied to the mold for concrete panels allow finishing operators to remove the outer layer of concrete by pressure-washing the surface with water. Use of the retarder reduces the need for abrasive blasting by as much as 40 percent (Document ID 1365, p. 5-23; 0898, p. 9). An industry representative indicated that use of retarders is rapidly becoming the preferred method of finishing concrete (Concrete Products Industry Representative A, 2000, as cited in Document ID 1365, p. 5-5). A wide range of finishes can be achieved using different surface retarder and acid wash products, ranging from the look of exposed aggregate to the appearance of a smooth sand-blasted surface (Concrete Product Industry Representative A, 2000; APA, 2000; Master Builders, 2000, as cited in Document ID 1365, pp. 5-23 – 5-24).

Wet Methods

Wet abrasive blasting and hydro-blasting are effective controls in some situations. During outdoor abrasive blasting of a parking garage to remove the outer layer of cured concrete (e.g., to expose the aggregate), workers using a mix of 80 percent dry sand and 20 percent water had a geometric mean (a mathematical representation of the median) silica exposure of 200 $\mu g/m^3$ (Document ID 0795, pp. D26 – D28). Another facility that produced precast concrete used a water induction nozzle to control silica exposure (Document ID 0733). The nozzle combines water with the abrasive-media-and-air mixture so that atomized liquid droplets are added to the abrasive blasting stream. Operators performed three different activities outdoors: light blasting of wall units to even the color, light blasting of fire stairs to roughen the texture, and heavier blasting of building panels to expose the aggregate. The geometric mean for 10 samples of personal silica exposure was 62 μg/m^3, with a range of 20 μg/m^3 to 130 μg/m^3 (Document ID 0733, pp. 14-15). OSHA notes that in addition to the water nozzle, this facility also used pre-screened silica sand media from which most of the fines had been removed (rendering the new abrasive media less dusty). The author of the study found that restricting the fines content of the sand in combination with wet blasting was effective in reducing silica exposures but the effect of the pre-screened media could not be separated from the effect of the water induction nozzle in this study. Although many exposures reported in Mazzuckelli et al. (2004) and Heitbrink (2007) still exceed the proposed PEL of 50 μg/m^3, they are much lower than the highest exposures reported in the exposure profile for uncontrolled, outdoor abrasive blasting with sand in this industry (e.g., 26,826 μg/m^3, 6,482 μg/m^3, and 2,303 μg/m^3) (Document ID 0012, p. 146; 0053, pp. 128, 130).

While wet methods can substantially reduce worker exposures to silica, they need to be appropriately applied. An OSHA contractor-provided study evaluated wet abrasive blasting at the precast concrete architectural panel manufacturing facility that used coal slag abrasive blasting media (Document ID 0204).[23] Water flow rate measurements showed that the rate of water application (one-half fluid ounce per minute) was less than 2 percent of the amount recommended by the water-fed abrasive blasting nozzle manufacturer (24 ounces to 192 ounces per minute) (Document ID 0204, p. 12).[24] Split-shift results for dry and wet abrasive blasting showed that this low-moisture wet method did not consistently provide lower silica exposure results compared to the same worker performing dry abrasive blasting with the same media, indicating that wet methods were not adequately implemented to reduce exposures.

Another alternative is hydroblasting, which uses high-pressure water without added abrasive media. After reviewing other published and unpublished work, Lahiri et al. (2005) estimated that silica exposure associated with sand blasting can be eliminated by using hydroblasting, even when the surface being hydroblasted contains silica, such as

[23] Results are provided in the paragraphs that follow in the discussion on alternate abrasive blasting media.

[24] The nozzle is fitted with a water hose that provides low pressure tap water. The compressed air and media stream creates negative pressure at the nozzle, which causes water from the hose to be sucked into and distributed through the blast media stream (Document ID 0204, p. 8).

with concrete (Document ID 0776, pp. 505-506). OSHA recognizes, however, that this method cannot replace the use of silica media in abrasive blasting under all circumstances.

Alternate Abrasive Blast Media

Using alternate types of abrasives that are low in silica or silica-free will reduce abrasive blasting operator silica exposure levels but not eliminate exposure when blasting is performed on silica-containing substrates, such as concrete. Outdoor abrasive blasting at two concrete product facilities using silica sand media was associated with exposure readings of 26,826 $\mu g/m^3$, 6,482 $\mu g/m^3$, 2,303 $\mu g/m^3$, 371 $\mu g/m^3$, and 56 $\mu g/m^3$ (Document ID 1365, p. 5-24; 0012; 0053). By contrast, outdoor abrasive blasting at a concrete product facility using coal slag blast grit (a low-silica media mixed with a small amount of water) was associated with exposure readings of 54 $\mu g/m^3$ and 30 $\mu g/m^3$ (Document ID 1365, p. 5-24; 0055). Outdoor abrasive blasting with coal slag media in a strong wind at another facility was associated with a reading of 20 $\mu g/m^3$ (Document ID 1365, p. 5-24; 0011).

At a third facility that produced concrete architectural panels, silica levels of 133 $\mu g/m^3$ (a less-than full-shift sample of 319 minutes), 149 $\mu g/m^3$ and 473 $\mu g/m^3$ were measured during a combination of wet and dry abrasive blasting using coal slag blasting media (Document ID 1365, p. 5-14; 0204, pp. 10, 12-14, 18, and 27). Company exposure data indicated that prior to switching to coal slag media, silica exposure levels during dry abrasive blasting ranged from 430 $\mu g/m^3$ to 5,400 $\mu g/m^3$ with three of four silica results above 2,000 $\mu g/m^3$ (Document ID 0204, pp. 24-25).[25]

Use of a ventilated booth for abrasive blasting of granite monuments (another silica-containing substrate) using alternate low-silica media was associated with a median exposure reading of 51 $\mu g/m^3$ (Document ID 1365, p. 5-24; 0218). Employers will need to consider the possible hazards of abrasive media substitutes when switching from silica to an alternate blast media. For example, depending on the abrasive, alternative media can result in elevated levels of other hazardous air contaminants such as metals

[25] The less-than-full-shift and company-reported results are not included in the exposure profile.

(Document ID 0773, p. 91). For further discussion on abrasive blasting in the construction industry, see Section IV-5.1 – Abrasive Blasters.

Enclosure and Local Exhaust Ventilation

Complete isolation of the operator from the blasting operation (i.e., use of a glove box-type ventilated blasting cabinet) can reduce silica exposure during abrasive blasting of smaller pieces. For example, ventilated blasting cabinets used by three operators in granite sheds (using either silica sand or an alternate media) generated exposure results of 15 µg/m^3 to 77 µg/m^3 with a mean of 41 µg/m^3 (Document ID 1225, pp. 427 - 428). OSHA estimates that exposure levels associated with blasting cabinets can be reduced to levels consistently below 50 µg/m^3 by using silica-free blast media that is less toxic than sand and a combination of other engineering and work practice controls. These controls include enclosed and ventilated media recycling systems, interlocks to prevent operators from opening doors before the cabinet has been exhausted, and use of HEPA-filtered vacuums instead of dry sweeping or compressed air to clean in and around the cabinet. Ventilated abrasive blasting enclosures (booths) also are effective in limiting the exposure of adjacent workers where blasting must be performed. Large, glove box-style cabinets for abrasive blasting oversize or awkwardly shaped objects are available commercially (Document ID 0953; 1693). For example, one manufacturer produces ventilated cabinets that have reportedly been used for abrasive blasting of granite tombstones (Document ID 0953; 1693). This size box is interlocked, to prevent operation unless the unit is sealed, and ventilated at 840 cubic feet per minute (cfm). In addition, the boxes are fitted with a dust collector for high efficiency filtering and a completely enclosed, ventilated media reclamation system. A larger ventilation system will be needed when two or more of these cabinets are linked together to provide a larger internal workspace (Document ID 0953).

Large items that cannot fit in a blast cabinet might be better controlled by another commercially available option: a gauntlet glove panel and window that can be inserted into the wall of a walk-in sized sealed and ventilated abrasive blast booth (Document ID 0954).

Combination of Controls

As noted previously, workers used a combination of wet and dry abrasive blasting methods outdoors with coal slag abrasive blasting media at a facility that produced precast concrete architectural panels. The wet methods, however, used a fraction of the water flow rate recommended by the wet abrasive blasting nozzle manufacturer. Under these conditions, silica levels of 133 μg/m^3 (less-than full-shift sample of 319 minutes), 149 μg/m^3, and 473 μg/m^3 were measured during a combination of wet and dry abrasive blasting using coal slag blasting media (Document ID 1365, p. 5-14; 0204, pp. 10, 12-14, 18, and 27). Based on results reported by Heitbrink (2007), described in the discussion of the exposure profile, OSHA concludes that using a greater flow rate would have resulted in somewhat lower silica levels (Document ID 0733).

Similar results were realized at German concrete products and precast component manufacturing plants where abrasive blasting operator exposures were reduced through a combination of abrasive blasting in enclosed, recirculating systems with dust collection and using conditioned abrasive blasting media. Exposure levels were approximately 100 μg/m^3 using these methods (Document ID 0553, p. 73).

Additional Controls for Finishing Operators (Other Than Abrasive Blasting)

The exposure profile in Table IV.4.3-B shows that 30 percent (15 out of 50 samples) of finishing operators (Other Than Abrasive Blasting) have exposures above the final PEL of 50 μg/m^3. Therefore, OSHA finds that additional controls will be necessary to achieve the PEL for these overexposed workers. Available controls include the use of wet finishing methods, LEV, non-silica blast media, and changes in work practices to perform more finishing operations on uncured concrete. Workers can use a combination of control measures for most activities.

Robert Thomas, President of the National Concrete Masonry Association, indicated that finishing operations presented significant challenges with regard to dust control and that it would be difficult if not impossible to comply with a PEL of 50 μg/m^3 for these finishing operations (Document ID 3585, Tr. 2894-2895). Conversely, Bayou Concrete, LLC acknowledged that dust can be controlled to the previous PEL when engineering controls and work practices are strictly adhered to, stating that “OSHA has underestimated the feasibility, achievability and economics associated with the proposed rule.” (Document ID 2075, p. 3). OSHA acknowledges that some circumstances may prove more challenging to control than others; however, through implementation of the controls described below, compliance with the PEL can be achieved.

Wet Methods

A number of finishing tools use wet methods to help control dust, including water-fed drilling, grinding, cutting, and chipping equipment and automated wet process finishing equipment (Concrete Product Industry Representative A, 2000, as cited in Document ID 1365, p. 5-23; 0898; 1146). For example, at a facility that manufactured precast concrete structural and utility products, workers used a horizontal coring machine (for holes 2 to 31 inches in diameter) with a water-fed bit. The measured silica exposures of these workers were less than or equal to 12 μg/m^3 (LOD) and 31 μg/m^3 (Document ID 0898, pp. 6, 15).

In one experiment at an indoor field laboratory, the use of a wet grinder (a water hose attached to the grinder providing water at 3 liters per minute [L/min]) reduced the geometric mean silica exposure by 98.2 percent during brief periods of intensive concrete surface grinding compared to uncontrolled grinding (Document ID 0522, pp. 770, 774, and 778). During this test, however, the mean silica exposure during wet grinding was still extremely high: 896 μg/m^3. An additional study examined the exposures associated with the use of a handheld abrasive cutter to make cuts through concrete blocks (Document ID 0868, pp. v, 11-12, and 17-18). The use of a water spray attachment (providing water at 1.4 L/min) reduced silica exposures by an average of 90 percent compared to uncontrolled cutting. Again, however, silica exposures were still extremely high, ranging from 1,000 μg/m^3 to 2,400 μg/m^3. In both of these studies, test periods were extremely brief (4 to 11 minutes), during which intensive grinding took place without the normal frequent pauses to change the work angle, change concrete blocks, take measurements, or reposition materials (Document ID 0868, pp. 4, 17). The conditions in this environment are much different from those during typical grinding operations. Samples collected during these conditions typically produce higher exposures. They are valuable for evaluating control methods, but do not represent 8-hour TWA exposure levels.

Lahiri et al. (2005) described unpublished data reporting reductions of 81 and 82 percent during chipping and sawing concrete using wet methods (Document ID 0776, p. 506). The exact details on the wet method used and data collected are not available, however. OSHA notes that many electric grinder housings might not be sufficiently sealed to permit safe use in wet environments. To minimize the hazard of electric shock, the stone and stone products industry uses pneumatic handheld grinding tools to grind high-silica stone such as granite (Document ID 1146, pp. 579-581).

While using wet methods can effectively reduce worker exposures, this method may not be appropriate for all applications. It is important to note that wet grinding can create safety hazards, such as slippage and electrocution, and might be unsuitable for indoor or freezing environments. In addition, wet methods can cause aesthetic problems (e.g., water marks) if appearance is an important component of the final product (e.g., architectural elements) (Document ID 1365, p. 5-23; 4029, p. 3).

Local Exhaust Ventilation

LEV or ventilated enclosures might be necessary for facilities finishing architectural concrete products particularly where wet methods are infeasible for surface finishing. Handheld grinders equipped with LEV are widely available and can help control operator and bystander exposures. While no data are available quantifying the effectiveness of LEV or ventilated enclosures for reducing exposures associated with finishing operations in the concrete products application group, studies of concrete finishers in the construction industry provide substantial data on analogous activities. The use of vacuum dust collection systems for concrete grinders reduced workers' silica exposures by 74 to 93 percent (Document ID 1365, p. 5-23; 0521; 0613, p. 5; 1385, pp. 4-8). Another comparative study evaluating an abrasive cutter (on concrete) found an average reduction in silica of 95 percent with an LEV shroud and vacuum cleaner (Document ID 0868, p. 10). Finally, the use of four different hood-vacuum combinations on a hammer-drill being used to drill concrete reduced silica concentrations from 308 $\mu g/m^3$ (no LEV) to between

6 µg/m^3 and 28 µg/m^3 (overall reduction of 94 percent) (Document ID 1142, pp. 42, 46). Even when substantial exposure reductions are reported with LEV shrouds and vacuum attachments, however, worker exposure levels often still exceed 100 µg/m^3 and are sometimes several times higher (Document ID 0522; 0632; 0681; 0868). These levels can result from inadequate air flow rates.

Although investigators in the cited studies considered vacuum capacity when matching suction equipment to grinding shrouds, OSHA estimates that actual vacuum cleaner air flows were likely less than the published, nominal air flows (specified with zero static pressure at the air inlet) due to pressure losses attributed to the hood, hose, bends in the hose, vacuum cleaner body, vacuum cleaner filters, and debris accumulation on filters. Echt and Sieber (2002) reported that 36 pounds of debris were collected in a vacuum cleaner during one day of concrete grinding (Document ID 0632, p. 460). In addition, the vacuum cleaners used for dust control during concrete grinding and cutting might have been undersized. In Akbar-Khanzadeh et al. (2007), the grinder used with LEV had a diameter of 6 inches (Document ID 0522, p. 772). The vacuum cleaner model used in Akbar-Khanzadeh et al. (2007) had a free air flow rating of only 106 cfm (Document ID 0522, p. 776). [26] Considering system pressure losses, the actual air flow was likely substantially lower for the reasons discussed previously. To optimize performance, a vacuum system should include cyclonic pre-separation, large (2-inch) diameter hoses, a gauge indicating filter pressure, a high-efficiency filter with a large surface area, and a powerful motor (sufficient to move the required air flow even as filter loading begins to occur) (Document ID 0600, pp. 884-886; 0731, pp. 382-384). For additional discussion of issues surrounding air flow rates and vacuums, see Section IV-4.11 – Tuckpointers and Grinders.

Finishing Uncured Concrete

Silica exposures can be reduced if operators perform finishing operations on uncured concrete. Some facilities in the concrete products industry currently use a retarder to slow

[26] "Free air flow" is air flow without accounting for various pressure losses including debris accumulation on the filters, resistance in the vacuum hose, and static pressure losses throughout the vacuum (Document ID 1720, p. IV-86).

the rate at which concrete cures (Concrete Product Industry Representative A, 2000, as cited in Document ID 1365, p. 5-5). Workers cutting, scoring, and adjusting the finish on uncured concrete products eliminated the need for power-grinding and air-hammering (which typically produce large quantities of dust). This work on uncured concrete was associated with two silica readings of less than or equal to 12 μg/m^3 (LOD) (Document ID 1365, p. 5-24; 0234).

Combination of Controls

OSHA notes that, in Germany's concrete products industries, finishing operator's respirable dust and silica exposure levels have decreased as the facilities have implemented targeted controls, often in combination (Document ID 0553). Examples include:

- Abrasive blasting in enclosed, recirculating systems with dust collection and conditioned abrasive blasting media (exposure levels around 100 μg/m^3).
- Wet grinding.
- Dry grinding with dust collection (exposure levels around 50 μg/m^3).
- Sawing wet or dry with LEV (which reduces exposure levels by at least 50 percent below wet sawing alone).
- Using clean water for wet sawing to minimize silica aerosols generated by dust bearing recirculated water.

Although these German facilities encounter exposures above 150 μg/m^3 during certain tasks, the median silica value obtained during finishing and treating of concrete products was 20 μg/m^3 (Document ID 0553).

Additional Controls for Packaging Operators

The exposure profile in Table IV.4.3-B shows that 67 percent (4 out of 6 samples) of packaging operators have exposures above the final PEL of 50 μg/m^3. Therefore, OSHA finds that additional controls will be necessary to achieve the PEL for these overexposed workers.

Dust is generated during several parts of the packaging process: when bags are filled, when filled bags drop from the filling equipment onto the conveyor, and when workers use compressed air for cleaning (Document ID 1365, p. 5-25; 1689). Control options include installing or adding effective ventilation systems, improving existing ventilation equipment, and using alternate bag and bag valve designs to minimize dust release.

Local Exhaust Ventilation

OSHA SEP inspection report exposure results illustrate the effectiveness of well-designed LEV for concrete packaging tasks. At one facility, installing a more powerful fan motor and new filter bag for the bag-filling machine LEV and moving the hoods closer to the packaging operator's position reduced respirable dust exposure by 92 percent.[27] After these improvements, a concrete packaging operator had a full-shift silica exposure below the LOD (in this case, 11 µg/m^3) (Document ID 0126, pp. 7-8). Similar exposures were observed (12 µg/m^3, the LOD) at another facility that also had installed dust collection equipment on the concrete bagging equipment (Document ID 0073, pp. 109-111). Another type of ventilation for bag-filling operations, an overhead air supply island system (OASIS) (Document ID 1365, p. 5-26; 1326), has been shown to reduce respirable dust exposure by 98 percent and 82 percent for packaging operators at two mineral processing facilities. OSHA finds that OASIS would be similarly effective at reducing silica exposures of packaging operators in the concrete products industry because dry concrete is a form of mineral dust.

A dual concentric nozzle system for bag-filling machines also can reduce exposures for packaging operators. This system consists of an inner-fill nozzle (to load the bag with material) surrounded by an outer nozzle (to depressurize the filled bag and remove dust from bag valve, thereby preventing dust release). A study conducted by Cecala et al. (2000) at a mineral processing facility (described in more detail in the OSHA contractor

[27] Total respirable dust was reduced by 92 percent from an initial level of 15,500 µg/m^3 to 1,150 µg/m^3 after these modifications (Document ID 0126, pp. 7-8). Silica was only evaluated after the modifications were made, at which point the worker exposure level was 11 µg/m^3.

report (ERG-G, 2008)) found that this type of system reduced respirable dust levels by 83 percent compared to unvented nozzles (Document ID 1365, p. 5-26; 1326).

Bag Design and Quality

The use of bags with valves that seal effectively and prevent product leakage from filled bags is another way to control exposure. In addition to studying nozzles, Cecala et al. (2000) found that the use of 6-inch extended polyethylene valves reduced respirable dust exposures by more than 60 percent compared with standard paper valves, and the use of 4-inch foam valves reduced exposures by more than 45 percent (Document ID 1326, pp. 759, 764). Because the concrete products industry, like the mineral processing industry, packs mineral powders, OSHA expects that a dual-nozzle system and effective bag valves can be easily adopted and will be as effective in the concrete products industry as these studies have shown it is in the mineral processing industry.

Alternate bag designs that minimize breakage, spillage, and leaks reduce levels of airborne silica in the workplace. Bags that break during filling can be a notable source of silica dust and can contribute to operator exposures in the 200 to 300 $\mu g/m^3$ range (Document ID 0587, p. 1). On a busy production line, improperly handled or low-quality bags might break frequently, 10 to 20 times per two hours, releasing dust in the air as the contents spill and while workers clean up spilled material (Document ID 1365, p. 5-27; 0587, p. 2). Another major source of exposure is during leakage from bags that do not fully contain the product during filling. Additionally, workers should be trained on proper techniques for filling and handling bags and subsequent handling requirements that together minimize dust release (Document ID 1365, p. 5-27; 0587, p. 2). One dry concrete bagging facility reduced worker respirable dust and silica exposure levels by changing product packaging from a three-ply bag perforated throughout, to a two-ply bag perforated only on the inner layer. This change alone reduced respirable dust by 83 percent and caused silica levels to fall from 180 $\mu g/m^3$ to 83 $\mu g/m^3$ (Document ID 0766, pp. 1-2).[28] A subsequent adjustment to the ventilation system (temporarily repositioning the ductwork directly over the filling area) further reduced respirable dust by an additional 48 percent. Worker silica exposures associated with the last two changes ranged from 10 µg/m^3 to 23 µg/m^3, representing an 87 to 94 percent reduction compared to the original silica level of 180 µg/m^3. The samples for which durations are available were obtained over 4-hour periods (morning, afternoon) before and after modifications (midday) and so are not of sufficient duration to include in the exposure profile (Document ID 0766). However, this study demonstrates that these controls and work practices can significantly reduce worker exposure.

Combination of Controls

If the exposures of all packaging operators with currently elevated exposures were reduced by 83 percent (achieved by changing the type of bag being filled), then the percentage of packaging operators with results above 50 µg/m^3 in Table IV.4.3-B would be reduced from 66 percent to 17 percent. If the highest result for a packaging operator from Table IV.4.3-B (370 µg/m^3) were reduced by 87 to 94 percent by modifying bags and improving LEV, this worker's silica exposure level would be reduced to a value between 22 µg/m^3 and 48 µg/m^3.

4.3.4 Feasibility Findings

Feasibility Finding for Material Handlers

Based on the exposure profile in Table IV.4.3-B and other record evidence discussed above, OSHA has determined that it is feasible for most material handlers to achieve exposure levels of 50 µg/m^3 most of the time. Exposures for the vast majority of material handlers are already well below 50 µg/m^3. Exposures presented in Table IV.4.3-B, show that 73.9 percent of the material handlers in this industry currently experience silica exposures of 50 µg/m^3 or less. OSHA has determined that exposure levels of 50 µg/m^3 or

[28] Dusty displaced air from the filling process was released from points all over the sack through the perforations in the three-ply bags. In contrast, only the inner layer of the two-ply bags was perforated and displaced air passed inside the solid outer layer to a single relief point at the sack opening (i.e., nozzle entry point). Dusty air exiting from between layers at the relief point was captured by LEV associated with the filling nozzle.

less can be achieved for most of the remaining workers in this job category by using appropriately designed, well-maintained ventilation systems, implementing more consistent housekeeping and yard dust management programs, and reducing the exposures of workers in other job categories to levels of 50 µg/m^3 or less. All of these control measures may be necessary for the most highly exposed workers.

Exposures above 100 µg/m^3 were associated with material handlers for whom adjacent operations contributed to worker exposure. Additionally, most of these exposures were dramatically affected by ineffective LEV. Exposures for material handlers were drastically reduced in the pottery industry when workers had access to functional LEV (median exposure level 27 µg/m^3) versus when workers used material transfer stations where LEV was clearly inadequate or missing (median exposure level 530 µg/m^3). Based on the similarity of front-end loaders, hoppers, and mixing equipment used to blend mineral powders in both industries, OSHA has determined that LEV at material transfer stations will be as effective in the concrete product industry as in pottery operations. Therefore, OSHA concludes that installing or upgrading LEV to meet ACGIH (2010) recommendations, particularly at blender hoppers charged by material handlers operating front-end loaders, will reduce even the highest exposures reported for material handlers in the concrete products industry to levels in the range of 100 µg/m^3.[29]

OSHA projects, however, that controlling adjacent operations to levels of 50 µg/m^3, in addition to upgrading the LEV, could reduce exposure levels to even lower levels (e.g., the median of 27 µg/m^3 calculated for the pottery industry), providing that yards and floors do not contribute airborne silica. Therefore, in order to further reduce exposures and achieve levels of 50 µg/m^3 or less for all material handlers, silica emissions from yard dust and poor housekeeping practices (e.g., dry sweeping and disturbing dust settled in the plant) also need to be controlled. Exposures at facilities that implemented yard dust management controls include four readings of less than 21 µg/m^3 for facilities using dust suppressants and two readings of less than 19 µg/m^3 for those that consistently wetted

[29] This conclusion is based on the apparent prevalence of secondary exposure for this job category noted above (improved ventilation will reduce exposure levels, but will continue to be elevated until adjacent sources of exposure are also controlled).

yard dust (see discussion under the heading Yard Dust Management, later in this subsection). In contrast, a material handler result of 110 μg/m^3 was associated with a yard that had been previously watered, but allowed to get dry. Furthermore, material handler exposure levels ranged from 48 to 73 for material handlers who performed dry sweeping during their shifts where "[m]ost of the facility has 1/8-inch of dust on the floor" (Document ID 0220, p. 6). In the structural clay industry, another industry with similar material handling requirements, professional-quality, thorough cleaning of a brick manufacturing facility dramatically reduced exposure levels (by 90 percent or more in some cases). In material handling areas where such cleaning was performed, most worker exposures were reduced to less than 50 μg/m^3 without other abatement efforts (Document ID 1365, p. 3-20; 0571). Where dust does accumulate, facilities should switch from brooms to HEPA-filtered vacuums to eliminate dry sweeping as a source of exposure.

Where material handlers continue to experience elevated exposure, other control options are also available, such as enclosed, sealed, filtered and air-conditioned cabs, which can reduce the driver's exposure level by more than 90 percent when this control is combined with the benefits of LEV, dust suppressing yard maintenance, and reduced exposures from controlling job categories causing silica dust in adjacent areas. For example, NIOSH measured an exposure of 21 μg/m^3 for an operator who used a front-end loader with an air-conditioned cab to transport raw materials across a water and dust suppressant-treated yard (Document ID 1365, p. 5-19; 0898). Therefore, based on the information presented above, OSHA has determined that an exposure level of 50 μg/m^3 can be achieved for material handlers, with few exceptions.

Feasibility Finding for Mixer Operators

Based on the exposure profile in Table IV.4.3-B and other record evidence discussed above, OSHA has determined that it is feasible for mixer operators in all operations to achieve exposure levels of 50 μg/m^3 or less through a combination of controls, with few exceptions. Exposures for the vast majority of mixer operators are already 50 μg/m^3 or less. Exposures presented in Table IV.4.3-B, show that 80 percent of all mixer operators currently have exposures of 50 μg/m^3 or less, with 74.3 percent having exposures less than 25 μg/m^3. To achieve that level, the remaining 20 percent of operators will need additional controls during mixer drum chipping and manual bag dumping. Appropriate controls include frequent and conscientious rinsing of mixing equipment before residual concrete hardens on the barrel and using wet methods with chipping equipment when it becomes necessary to remove hardened concrete. During mixing activity, exposures can be controlled through ventilated bag dumping stations or automated mixer charging. In the event that results remain elevated, ventilated control rooms or booths can offer additional protection.

In the few instances where mixer operators must perform chipping operations, based on the similar activities in the ready-mix industry (see discussion under the heading Combination of Controls, above in Section IV-4.3.3 – Additional Controls for Finishing Operators), the use of a combination of controls has shown to significantly reduce worker exposures. Investigators have found that the following combinations of control methods offer exposure reductions of *at least* 70 percent compared with uncontrolled levels typically.

- LEV-equipped chipping tool plus general exhaust ventilation (Document ID 1365, p. 13-22; 0245, p. 12); or
- Water misting device and push/pull ventilation system (Document ID 1157, p. D123); or
- Periodic spraying of the interior surface of the drum and directing continuous water spray at the chisel point during chipping (Document ID 3732, Attachment 3, pp. 14-16).

A 70 percent reduction would have the effect of reducing exposures for most mixer operators who are currently above 50 µg/m^3 to below the PEL.[30] In chipping operations where mixer operators would experience higher than normal exposures due to the duration of the job or the amount of material built up prior to cleaning, supplemental use of respirators may be necessary.

[30] OSHA multiplied 70 percent by the second highest result available to OSHA for this job category (as identified in the discussion of the exposure profile for mixer operators performing barrel chipping in this industry), reducing exposures from 122 µg/m^3 (the second highest exposure value) to a level of 37 µg/m^3.

OSHA has also determined that mixer operators can achieve an exposure level of 50 μg/m^3 or less when charging the mixing vessel. For those mixer operators who experience elevated exposure while manually charging mixers, OSHA concludes that ventilated bag dumping stations will reduce even the highest exposures associated with manual mixer charging to levels of 50 μg/m^3 or less. OSHA bases this conclusion on the effectiveness of controls used in analogous operations at a paint manufacturer, which also charged mixers with high-silica powdered mineral products that used a bag dumping station with fully functioning LEV, leading to a reduction in silica exposure of at least 95 percent (Document ID 1365, pp. 5-20 – 5-21; 0199).

Exposures can be further reduced by the use of automated mixer charging. An exposure of less than or equal to 12 μg/m^3 (LOD) was reported for a mixer operator using an automated charging system at a precast concrete panel facility (Document ID 1365, p. 5-21; 0204). In the event that mixer operators continue to experience elevated exposures during automated mixer charging, ventilated control rooms are also effective in maintaining a low exposure. For example, exposure of 23 μg/m^3 was achieved for a worker who operated a computer-controlled mixer and charging equipment from an enclosed booth (Document ID 1365, p. 5-21; 0161).

Therefore, based on the information presented above, OSHA has determined that an exposure level of 50 μg/m^3 can be achieved for mixer operators with few exceptions (e.g., long duration of chipping operations or a high build-up of dried concrete).

Feasibility Finding for Forming Operators

Based on the exposure profile in Table IV.4.3-B and other record evidence discussed above, OSHA has determined that, through a combination of controls, it is feasible for forming operators to achieve exposure levels of 50 μg/m^3 or less, with few exceptions. As shown in Table IV.4.3-B, 92.4 percent of exposures for forming operators are 50 μg/m^3 or less. OSHA has determined that this is accomplished primarily by minimizing forming operators' exposure to silica produced by adjacent workers.

OSHA bases this conclusion on information that the forming operators with silica values exceeding 50 μg/m^3 were subject to silica dust from adjacent sources and from the activities of other workers who had exposure levels above 100 μg/m^3 (Document ID 1365, pp. 5-11 – 5-12; 0220, pp. 6, 8, 10). A forming operator with exposures exceeding 50 μg/m^3 on two consecutive days controlled a concrete block-forming machine that emitted dust. That forming operator's location was near the mixing area, from which dust was emitted during mixer charging. Another worker performed dry sweeping nearby (Document ID 1365, pp. 5-11 – 5-12; 0220). Additionally, the highest sample in Table IV.4.3-B for this job category (107 μg/m^3) was obtained at a facility at which 9 of 10 exposures exceeded 100 μg/m^3 and the inspector noted there were leaks in the material handling system, as well as some not-fully-used controls (Document ID 1365, p. 5-11; 0039). Therefore, OSHA concludes that controlling these sources of exposure will reduce forming operators' overall exposure.

In the event that additional controls are necessary for forming operators where exposures remain above 50 μg/m^3 (after the exposures of other job categories are controlled to levels of 50 μg/m^3 or less), other measures are available to reduce exposures. These measures include adding LEV to forming operator workstations, particularly those with automated processes, and improving housekeeping, starting with a one-time thorough cleaning to remove accumulated dust and continuing with the benefit of HEPA-filtered vacuums to clean forms and the facility. These control measures have effectively reduced exposures for workers in this job category.

Therefore, based on the information presented above, OSHA has determined that an exposure level of 50 μg/m^3 can be achieved for most forming operators, most of the time.

<u>*Feasibility Finding for Finishing Operators (Abrasive Blasting)*</u>

Based on the exposure profile in Table IV.4.3-B and other record evidence discussed above, the majority of the workers in this job category (approximately 82 percent) experience exposure levels that exceed 100 μg/m^3, and many exposures are extremely high. Therefore, OSHA has determined that additional controls or alternate production processes will be necessary to reduce exposures. Abrasive blasting has historically been associated with very high silica levels. OSHA has determined that these exposure levels can be reduced (although not eliminated) by using alternative abrasive blasting media that is less toxic than silica or by switching to wet abrasive blasting (or a combination of both). While exposures can be significantly reduced, if facilities cannot substitute a process that avoids abrasive blasting then respirator use may be necessary, particularly for abrasive blasting outdoors where isolation of the blasting operation is less common (Document ID 0553; 0733). The primary method for reducing the exposure of those abrasive blasters with the highest exposures is using retarders and water sprays to wash away incompletely-cured concrete and to expose aggregate. This completely eliminates the need for abrasive blasting. Where abrasive blasting must be performed, wet methods used outdoors or in a ventilated environment will substantially reduce silica exposure levels. Restricting the fines content of the sand in combination with wet blasting is also effective in reducing silica exposures. However, the use of appropriate respiratory protection and proper ventilation, especially within enclosures, will still be needed to protect workers from hazardous levels of contaminants that can be generated during abrasive blasting from the abrasive, the substrate, or both. To ensure protection, ventilation and respiratory protection must meet the requirements of 29 Code of Federal Regulations (CFR) 1910.94 and 1910.134, respectively (Document ID 1351).

As an alternative exposure reduction method, low-silica abrasive blast media that is less toxic than silica sand can also reduce exposure levels for abrasive blasting operators in this industry. Although concrete surfaces remain a source of silica dust during abrasive blasting even when low- or non-silica media are used, these levels are often notably lower than silica concentrations measured during abrasive blasting with quartz sand. For example, three readings, 54 $\mu g/m^3$, 30 $\mu g/m^3$, and 20 $\mu g/m^3$, were obtained from two facilities at which finishing operators performed abrasive blasting of concrete products outdoors with coal slag media (Document ID 1365, p. 5-14; 0011, p. 40; 0055, pp. 144, 155). Employers must consider the possible hazards of substitutes if switching from silica sand. For example, depending on the abrasive, alternative media can result in elevated levels of other hazardous air contaminants such as toxic metals (Document ID 0772; 0773; 0774). Furthermore, total and respirable dust levels will continue to be a concern even with alternate abrasive blasting media because of the silica content in the substrate.

OSHA has reviewed the information contained in the rulemaking record for abrasive blasting operators in this industry and in the related abrasive blasting in the construction industry (Section IV-5.1 – Abrasive Blasters). Based on this information, OSHA has determined that for those instances where abrasive blasting cannot be completely eliminated by the use of alternate processes, such as retarders, the use of wet methods or alternative abrasive blasting media can reduce the exposures of abrasive blasting operators working outdoors to levels consistently below 50 μg/m^3 (Document ID 1365, p. 5-14; 0011; 0055). However, when blasting indoors, in enclosed spaces, or in cases where wet methods cannot be implemented, respirator use may still be necessary for abrasive blasting operations.

Feasibility Finding for Finishing Operators (Other Than Abrasive Blasting)

Based on the exposure profile in Table IV.4.3-B and other record evidence discussed above, OSHA has determined that, through a combination of controls, it is feasible with few exceptions to achieve exposure levels of 50 μg/m^3 or less for finishing operations, other than abrasive blasting, which is treated here as a separate job category. As shown in Table IV.4.3-B, 70 percent of finishing operators have exposure levels at or below 50 μg/m^3. The exposure levels of the remaining 30 percent of finishing operators can be brought below 50 μg/m^3 most of the time by using controls or work practices that are commonly used in this application group, including the use of water-fed equipment, LEV, and modified work practices (e.g., finishing of uncured products). This finding is based on exposure levels ranging from less than or equal to 12 μg/m^3 (LOD) to 31 μg/m^3 obtained for finishing operators who were either working on uncured concrete products or using water-fed hand tools. Exposures obtained for finishing operators who used hand and power tools to work on uncured concrete products, were less than or equal to 12 μg/m^3 (LOD) (Document ID 1365, p. 5-24; 0234), while finishing operators who used a water-fed coring machine to drill concrete products had exposures at or below 31 μg/m^3 (Document ID 1365, p. 5-24; 0898). Therefore, OSHA has determined that finishing operators can obtain exposure at 50 μg/m^3 or less with the use of either alternate manufacturing processes or engineering controls.

Feasibility Finding for Packaging Operators

Based on the exposure profile in Table IV.4.3-B and other record evidence discussed above, Exposures for packaging operators can be controlled to 50 μg/m^3 or less through a variety of controls, either separately or in combination. By switching to package (bag) designs that release less dust and by improving or adding adequate workstation ventilation, exposure levels can be reduced to at or below 12 μg/m^3 (LOD) (Document ID 1365, p. 5-25; 0073). Additionally, a packaging operator who loaded bags of dry-mixed concrete using a bag-filling machine equipped with effective LEV experienced an exposure below the LOD (11 μg/m^3) (Document ID 1365, p. 5-25; 0126). A third concrete products facility reduced silica exposure levels from an initial reading of 180 μg/m^3 to multiple readings below 25 μg/m^3 (10 μg/m^3 and 23 μg/m^3) by changing the bag design (to reduce dust emissions) and improving LEV to capture residual dust (Document ID 0766). Therefore, OSHA has determined that, by improving LEV and bag quality and design, it is feasible to achieve exposure levels of 50 μg/m^3 or less for packaging operators.

Overall Feasibility Finding

Based on the exposure profile in Table IV.4.3-B and other record evidence discussed above, OSHA concludes that most workers at concrete products facilities are currently exposed to silica levels below 50 μg/m^3. For workers who are currently exposed above 50 μg/m^3, the engineering and work practice controls described in this section can be implemented to reduce silica exposure levels to 50 μg/m^3 or less in most operations, most of the time, with exceptions in some cases for mixer operators during tank cleaning and workers performing abrasive blasting operations. These workers may need to continue to use supplemental respiratory protection in compliance with the existing respirator standard to achieve the PEL. Accordingly, OSHA concludes that the final PEL of 50 μg/m^3 is technologically feasible for the Concrete Products industry.

4.4 CUT STONE AND STONE PRODUCTS

4.4.1 Description

Fabricating facilities that produce cut stone and stone products are classified in the six-digit North American Industry Classification System (NAICS) as 327991, Cut Stone and Stone Products Manufacturing. The manufacture of man-made stone (engineered stone) is classified separately as NAICS 327999, All Other Miscellaneous Nonmetallic Mineral Product Manufacturing, and is discussed in Section IV-4.7 – Engineered Stone Products, in this technological feasibility analysis. Once manufactured, however, these engineered stones are cut to shape and finished by the stone and cut stone products industry. Similar processes involving the cutting, grinding, and polishing of stone products occurs infrequently in other industries. Although OSHA anticipates that these types of activities are limited in occurrence, exposure controls used in the Cut Stone industry could also be applied to reduce any potential for exposure to respirable crystalline silica in these industries.[31]

Silica exposures in this application group occur when slabs of silica-containing stones are cut, shaped, and often polished to form a diverse range of products including floor tile, countertops, roofing slates, building cladding, and funeral monuments. The most commonly used dimension stones with the highest percentage of free quartz are granite (up to 45 percent quartz), sandstone (42 to 95 percent quartz), high-silica limestone (9 to 67 percent quartz), and slate (31 to 45 percent quartz) (Document ID 1365, p. 11-1). In 2003, the U.S. Geological Survey reported that granite comprised 41 percent of the dimension stone used in the United States; sandstone contributed another 9 percent; slate comprised 6 percent (Document ID 1365, p. 11-1). Although many other stones contain silica, most have less desirable physical characteristics and are not cut for commercial purposes. Two of the other most commonly used dimension stones, marble and low-silica

[31] Samples from four NAICS codes other than 327991-Cut Stone have been included in the exposure profile for this application group. Samples from the following NAICS codes were included where OSHA determined that, at the time of sampling, the workers were performing tasks that were very similar to the tasks performed in the cut stone industry. OSHA also included samples from NAICS codes: 423320 - Brick, Stone, and Related Construction Material Merchant Wholesalers, 444110 - Home Centers 337110 - Wood Kitchen Cabinet and Countertop Manufacturing 238340 - Tile and Terrazzo Contractors (Document ID 3958).

limestone, occasionally contain low levels of silica as impurities, but do not contribute significantly to worker exposure (Document ID 1365, p. 11-1; 0098; 0154).

The process begins with the delivery from the mine of either natural or engineered stone as blocks that workers cut into slabs or, more frequently, stone is delivered as slabs precut to the approximate thickness of the ultimate product. Sawyers cut the blocks or slabs to appropriate dimensions for the product. Fabricators change the contours and finish and assemble the pieces. Additional specialized steps can include manual chipping or splitting, mechanical trimming or milling, and abrasive blasting (Document ID 1365, p. 11-1).

4.4.2 Exposure Profile and Baseline Conditions

The exposure profile in Table IV.4.4-B includes 240 full-shift personal breathing zone (PBZ) samples of respirable crystalline silica for workers in the cut stone and stone products industry. The median is 41 μg/m^3, the mean is 165 μg/m^3, and the range is 12 μg/m^3 (the limit of detection (LOD)) to 7,439 μg/m^3. Of the 240 samples, 113 (47 percent) exceed 50 μg/m^3.

Stone industry workers can be exposed to silica when they saw large blocks and slabs of stone; grind or chip the stone; finish the pieces by smoothing, polishing, or abrasive blasting the surface; handle or transport stone; and during housekeeping activities (Document ID 1365, p. 11-1). Workers who work with cut-stone and adjacent to the above activities risk significant silica exposure at each step in the process. Exposures depend on the silica content of the stone, the work practices, and the equipment used. Table IV.4.4-A identifies and describes the five job categories with sources of exposure for workers in the cut stone industry.

Table IV.4.4-A Job Categories, Major Activities, and Sources of Exposure of Workers in the Cut Stone Industry (NAICS 327991)	
Job Category*	**Major Activities and Sources of Exposure**
Sawyer	Operates large water-fed stationary bridge or gantry-type saws. • Dust from wet-sawing stone. • Dust disturbed from stone and work surfaces. • Dust from housekeeping and adjacent activities.
Fabricator	Produces finished stone products from slabs. • Dust from dry grinding, edging, milling, contouring, and polishing stone. • Dust disturbed from stone and work surfaces. • Dust from housekeeping and adjacent activities.
Splitter/Chipper (Splitter, Stone Cutter, Sculptor)	Uses handheld equipment to change the shape of the stone. • Dust from dry chipping, splitting, and cleaving stone using hammer and chisel. • Dust generated while operating power tools for drilling and chipping. • Dust disturbed from stone and work surfaces. • Dust from housekeeping and adjacent activities.
Machine Operator (Trimmer, Gouger, Puncher, Planer)	Operates trimming, punching, gauging, or planing machines. • Dust emitted from unventilated, unenclosed trimming, punching, gauging, or planning machines. • Dust disturbed from stone and work surfaces. • Dust from housekeeping and adjacent activities.
Abrasive Blasting Operator	Operates blasting equipment. • Dust generated during blasting with silica sand or alternative media on silica-containing stone. • Dust from using compressed air for cleaning stone. • Dust disturbed from stone and work surfaces.
*Job categories are intended to represent job functions; actual job titles might differ, and responsibilities might be allocated differently, depending on the facility. Source: Document ID 1365, p. 11-3.	

The following sections describe the exposure data and baseline conditions for each affected job category based on more than one dozen OSHA Special Emphasis Program (SEP) inspection reports and several NIOSH reports, previously described in ERG-G (Document ID 1365). In addition, for this analysis, OSHA identified exposure data collected by OSHA during compliance inspections that were entered into the OSHA Information System (OIS) from 2011 through April 17, 2014 (Document ID 3958).

For each of the job categories listed in Table IV.4.4-B and included in the exposure profile and for the cut stone and stone products paving industry as a whole, OSHA concludes that Table IV.4.4-B represents baseline conditions.

Exposure Profile and Baseline Conditions for Sawyers

The exposure profile in Table IV.4.4-B includes 48 sample results for sawyers in the cut stone and stone products industry. The median is 49 µg/m^3, the mean is 93 µg/m^3, and the range is 12 µg/m^3 (LOD) to 843 µg/m^3. Table IV.4.4-B shows that, of the 48 samples, 24 (50 percent) are above 50 µg/m^3 and 13 (27 percent) exceed 100 µg/m^3. Sawyers typically operate large, powerful stationary bridge or gantry-type saws, with single or multiple heads (Document ID 1365, p. 11-3). All of the results included in the exposure profile are associated with water-fed saws of these general varieties. OSHA reviewed 48 personal breathing zone (PBZ) results for sawyers from 10 OSHA SEP Inspection reports, one NIOSH report, and OIS data (Document ID 0042; 0180; 0187; 0157; 0240; 0178; 0046; 0176; 0061; 0153; 0240; 3958). The highest results were associated with cutting granite with respirable samples containing greater than 35 percent silica.

A local survey conducted by Phillips and Johnson (2012) found that 91 percent of area granite countertop fabrication shops surveyed always performed initial granite cutting using wet methods, with an additional 6 percent reporting that the task was usually performed using such wet methods (Document ID 3957, pp. 3-4).

OSHA inspection reports indicate that sawyers generally cut stone from 30 minutes to 4 hours per day, but might work at the task up to 8 hours per day. A typical shop will employ approximately 25 percent of the production work force as saw operators, although the percentage might be higher in mass production shops, such as floor tile or slate roof manufacturing facilities (Document ID 1365, p. 11-4; 0153; 0046; 0180).

An extremely high-pressure water jet, often containing abrasives, can also be used to cut stone. A small but growing number of facilities are using water jet equipment to cut specialty shapes (e.g., sink openings in countertops) in smaller pieces of stone (Document ID 1365, p. 11-4). The operator programs the automated equipment and positions the stone inside an enclosed space, and a fine, high-pressure water spray (computer controlled) is directed along the cutting line (Document ID 1365, p. 11-4). OSHA expects exposures to sawyers would be lower with this automated process since this process isolates a worker from the dust generated inside. This determination is based on similar controls used for abrasive blasters in this application group which showed significant reductions in exposures (see discussion later in this section under the heading Exposure Profile and Baseline Conditions for Abrasive Blasting Operators). Additionally, no silica was detected in two OIS samples collected on operators using computer numerical control (CNC) saws (Document ID 3958).

Exposure Profile and Baseline Conditions for Fabricators

The exposure profile in Table IV.4.4-B includes 135 sample results for fabricators in the cut stone and stone products industry. The median is 28 $\mu g/m^3$, the mean is 216 $\mu g/m^3$, and the range is 12 $\mu g/m^3$ (LOD) to 7,439 $\mu g/m^3$. Table IV.4.4-B shows that, of the 135 samples, 52 (38.6 percent) are above 50 $\mu g/m^3$ and 36 (26.7 percent) exceed 100 $\mu g/m^3$. These results were obtained from seven OSHA SEP inspection reports, two NIOSH reports, and OIS data (Document ID 0098; 0153; 0156; 0061; 0046; 0063; 1826; 0240; 0856; 3958). Fabricators produce finished stone products from the sawn slabs or shapes (Document ID 1365, p. 11-4). Fabricators use both electric and pneumatic tools, including handheld dry circular saws and angle-grinders, handheld or hand-guided grinders and routers, and higher speed polishing tools (Document ID 1365, p. 11-4).

Grinding and polishing can be performed as a wet or dry process (Document ID 1365, p. 11-4). A study conducted in the state of Washington found that fabricators in one-third of the facilities evaluated were primarily using wet methods at the time of the initial visit (Document ID 1146, pp. 578-579). A study conducted in Oklahoma on granite countertop fabricators found that 21 percent of shops surveyed reported performing all fabrication steps wet, while only one shop reported performing all fabrication steps dry. The remainder of the shops reported using a combination of wet and dry methods some or all of the time when completing various steps (Document ID 3957, p. 4).

Sixty to 100 percent of production workers in typical custom architectural component (e.g., kitchen countertop) manufacturing facilities are classified as fabricators (Document ID 1365, p. 11-5). Workers typically grind stone 20 minutes to 4 hours per day, and spend the balance of the day polishing, filling defects, waxing, inspecting work, and performing housekeeping activities (Document ID 1365, p. 11-5; 0061; 0063; 0153; 1826).

Exposure Profile Baseline Conditions for Splitters/Chippers

The exposure profile in Table IV.4.4-B includes 29 sample results for splitters/chippers in the cut stone and stone products industry. The median is 98 μg/m^3, the mean is 90 μg/m^3, and the range is 13 μg/m^3 (LOD) to 208 μg/m^3. Table IV.4.4-B shows that, of the 29 samples, 20 (69 percent) are above 50 μg/m^3 and 14 (48.3 percent) exceed 100 μg/m^3. Splitters/chippers typically use handheld hammers and chisels, working within arm's length of their breathing zones, to change the shape of stone. These results are obtained from eight OSHA SEP inspection reports, two NIOSH reports, and OIS data (Document ID 0042; 0180; 0115; 0046; 0176; 0157; 0187; 0178; 0240; 0856; 1365; 3958). Four of the highest results, ranging from 134 μg/m^3 to 181 μg/m^3, are associated with dry splitting of slate (a high silica stone, therefore a worst case condition). No dust controls or in some cases poorly implemented dust controls were typical of the slate-splitting work areas inspected by OSHA. Splitters/chippers typically work at this task for the full shift but might rotate to other tasks if the need arises. Typical slate tile manufacturing facilities employ approximately 30 percent of their production force as splitters (Document ID 1365, p. 11-5; 0046; 0178; 0157).

Exposure Profile and Baseline Conditions for Machine Operators

The exposure profile in Table IV.4.4-B includes 18 sample results for machine operators in the cut stone and stone products industry. The median is 69 μg/m^3, the mean is 118 μg/m^3, and the range is 12 μg/m^3 (LOD) to 314 μg/m^3. Table IV.4.4-B shows that, of the 18 samples, 12 (67 percent) are above 50 μg/m^3 and 8 (44 percent) exceed 100 μg/m^3. Machine operators are typically employed in facilities that mass produce large quantities of identical stone products (e.g., tiles). They operate stationary equipment. The stone is conveyed through the machine, processed, and conveyed out the back or side of the machine to be manually or automatically stacked on a pallet (Document ID 1365, p. 11-6; 0042). Typical machine functions include trimming, gouging, punching, and planing.

These results for machine operators were obtained from six OSHA SEP inspection reports, one NIOSH report, and OIS data (Document ID 0042; 0187; 0178; 0157; 0176, 0180; 0240; 3958). Three of the highest results were collected from two slate trimming machine operators and a punching machine operator where controls (e.g., ventilation) were absent or ineffective or equipment was malfunctioning. These higher results (and the associated controls) are representative of those typically seen in facilities prior to abatement efforts instigated by an OSHA inspection (Document ID 1365, p. 11-13). At facilities described in OSHA inspection reports, these processes were performed dry without any local exhaust ventilation. In these facilities, machine operators make up 20 to 30 percent of the production workforce and work at their tasks approximately 8 hours per day (Document ID 1365, p. 11-6).

Exposure Profile and Baseline Conditions for Abrasive Blasting Operators

The exposure profile in Table IV.4.4-B includes 10 sample results for abrasive blasting workers in the cut stone and stone products industry. The median is 51 μg/m^3, the mean is 115 μg/m^3, and the range is 12 μg/m^3 (LOD) to 309 μg/m^3. Table IV.4.4-B shows that, of the 10 samples, 5 (50 percent) are above 50 μg/m^3 and 4 (40 percent) exceed 100 μg/m^3. Abrasive blasting operators in this application group typically use traditional dry abrasive blasting methods to etch patterns, such as lettering or decorations, into stone (Document ID 1365, p. 11-6). These results were obtained from one OSHA SEP Inspection Report, three NIOSH reports, and OIS data (Document ID 0115; 0218; 0240; 0856; 3958).

At all six facilities considered in the exposure profile, the abrasive blasting media consisted of various grit sizes of aluminum oxide or bauxite. Aluminum oxide contains little or no silica, and bauxite can contain 2 to 9 percent quartz. Some operators also use silica sand to finish or “whiten” the blasted surface (Document ID 1365, pp. 11-6-11-7; 0218; 0240; 0856; 0115).

Abrasive blasting operators might spend 1 to 7 hours per 8-hour shift operating blasting equipment. In addition to blasting, operators normally spend substantial amounts of time applying masking materials to protect portions of the stone from the effects of blasting. Operators’ other activities include cleaning dust from stone, usually with compressed air, and removing spent media and stone dust from the blasting area using shovels and brooms. In memorial production facilities, 10 to 30 percent of production workers are abrasive blasting operators (Document ID 1365, p. 11-7).

NIOSH evaluated blasting booths at two of the three establishments it visited and found that the ventilation rate measured less than half of the face velocity rate recommended by the American Conference of Industrial Hygienists (ACGIH): 100 cubic feet per minute per square foot (cfm/ft^2) (Document ID 0240; 0218; 0515, p. 10-119). TWA respirable silica exposures for the abrasive blasters at one facility ranged from <12 to 309 μg/m^3, with a mean of 190 μg/m^3 (Document ID 0240, p. 5), and at the other facility ranged from 22 to 25 μg/m^3, with a mean of 51 μg/m^3 (Document ID 0218, p. 4).

OSHA also reviewed the results of four less than full-shift PBZ samples collected by NIOSH for abrasive blasting operators at a stone monument manufacturer. Although these data are less than full shift and thus are not included in Table IV.4.4-B, they provide additional insight on the effectiveness of the controls used by these workers. The sample times range from 4 to nearly 6 hours, and all sample results are below 50 μg/m^3 for the periods sampled (mean of 29 μg/m^3). Three of the operators performed automated blasting in ventilated abrasive blasting booths, and one used both the ventilated blasting booth and a manual blasting cabinet contained within an enclosure with a rubber curtain that acted as a barrier for dust. Although the type of media used was not reported, the percent of silica in total respirable dust for these samples ranged from 14 percent to 33 percent. The measured face velocity at the screen was 160 feet per minute (fpm) for the automated blasting operation, and 100 fpm at the curtain for the manual blasting operation (Document ID 1361, p. 4).

Table IV.4.4-B Personal Respirable Crystalline Silica Exposure Range and Distribution of Results for Workers in the Cut Stone Industry (NAICS 327122, 327991, 337110, 423320, 444110)											
	Exposure Summary			Exposure Range			Exposure Profile				
Cut Stone Industry	**N**	**Mean (µg/m³)**	**Median (µg/m³)**	**Min (µg/m³)**	**Max (µg/m³)**		**<25 (µg/m³)**	**≥25 and ≤50 (µg/m³)**	**>50 and ≤100 (µg/m³)**	**>100 and ≤250 (µg/m³)**	**>250 (µg/m³)**
Sawyer	48	93	49	12	843		16 (33.3%)	8 (16.7%)	11 (22.9%)	10 (20.8%)	3 (6.2%)
Fabricator	135	216	28	12	7,439		66 (48.9%)	17 (12.6%)	16 (11.9%)	18 (13.3%)	18 (13.3%)
Splitter/Chipper	29	90	98	13	208		5 (17.2%)	4 (13.8%)	6 (20.7%)	14 (48.3%)	0 (0%)
Machine Operator	18	118	69	12	314		3 (16.7%)	3 (16.7%)	4 (22.2%)	6 (33.3%)	2 (11.1%)
Abrasive Blaster	10	115	51	12	309		2 (20%)	3 (30%)	1 (10%)	2 (20%)	2 (20%)
Cut Stone Industry Total	**240**	**165**	**41**	**12**	**7,439**		**92 (38.3%)**	**35 (14.6%)**	**38 (15.8%)**	**50 (20.8%)**	**25 (10.4%)**

Notes: All samples summarized are personal breathing zone (PBZ) results representing 8-hour time-weighted average exposures.
Job categories are intended to represent job functions; actual job titles might differ, and responsibilities might be allocated differently, depending on the facility.
Percentages may not add to 100 percent due to rounding.

Sources: Document ID 1720; 3958; 0042; 0046; 0061; 0098; 0115; 0129; 0153; 0156; 0157; 0176; 0178; 0180; 0187; 0218; 0240; 0856;1826.

4.4.3 Additional Controls

Throughout this application group, workers exposures have seen significant reductions over the last 40 years. Yassin et al. (2005) analyzed OSHA's Integrated Management Information System (IMIS) data for the period 1988 – 2003 and found a downward trend in exposure levels for cut stone and stone products workers compared with earlier IMIS data (Document ID 1236, pp. 255, 258-259). This industry had geometric mean silica exposure levels approximately 10 times higher in 1979 – 1987 than in 1988 – 2003 (619 micrograms per cubic meter [$\mu g/m^3$] compared to 63 $\mu g/m^3$, respectively), suggesting modern equipment and work practices have reduced exposures substantially (Document ID 1236, p. 258).

Attfield and Costello (2004) evaluated older data for Vermont granite workers and found average measured personal and area silica levels were lower after 1950 compared with earlier years for several job categories applicable to the stone and stone products industry (Document ID 0285, p. 131). This could have been due to either improved dust control (including increased automation) or increased use of lower silica stone (e.g., marble).

Additional Controls for Sawyers

The exposure profile in Table IV.4.4-B shows that 50 percent (24 out of 48 samples) of sawyers have exposures above the final PEL of 50 $\mu g/m^3$. Therefore, OSHA finds that additional controls will be necessary to achieve the PEL for these overexposed workers. These controls include wet methods, LEV, and thorough housekeeping to prevent the accumulation of dried slurry and other settled dust that can be re-entrained into the air. Increased water flow to the saw and saw or operator enclosures with remote control saws might be required in some facilities.

OSHA SEP inspection reports suggest that a combination of housekeeping and other measures can reduce silica levels. For example, the median full-shift PBZ silica exposure level was 30 $\mu g/m^3$ for eight sawyers at four facilities that implemented housekeeping in combination with other control measures, such as enclosing the saw in a booth with a fan, pre-wetting stone, managing slurry, increasing water flow for wet processes, and controlling dust from adjacent processes (Document ID 1365, p. 11-17; 0046; 0176;

0180; 0157). This level is more than 40 percent lower than the median result for all sawyers reported in the exposure profile (49 µg/m^3), which includes exposures for well-controlled as well as uncontrolled processes. It is also lower than the median of 100 µg/m^3 for sawyers in three facilities using some form of additional controls, but where rigorous housekeeping was not reported (Document ID 1365, p. 11-17; 0042; 0178; 0157).

Housekeeping activities at the four low-exposure facilities included steps that minimized dust accumulation on surfaces and kept floors damp. In the event that recirculating water for saws is becoming laden with stone dust, changing the water more frequently could also reduce the amount of silica in mist and dried slurry. Comments received from Linda Stelmaszyk, on behalf of a small fabrication business, indicated that recent installation of a water filtration system, which cleaned the water that was recirculated onto the blade, was beneficial in controlling dust exposures when using wet methods. She stated her belief that many shops in the cut stone industry continue to cut dry and have not invested in dust controls: “Regarding silica dust, we operate a wet cutting shop with a brand new state of the art water filtration system which puts us well below current OSHA requirements” (Document ID 1775, p. 1). The OSHA SEP inspections reports indicated that the median exposure for workers that used both engineering controls and housekeeping were significantly lower than exposures for workers at facilities that only used engineering controls (30 µg/m^3 versus 100 µg/m^3, respectively) (Document ID 1365, p. 11-17; 0046; 0176; 0180; 0157; 0042; 0178). For example, housekeeping, in combination with any other control measures, such as enclosing the saw in a booth with a fan, pre-washing stone, managing slurry, and controlling dust from adjacent processes reduced the PBZ respirable silica level for eight sawyers (Document ID 0046; 0176; 0180; 0157; 0042; 0178).

The value of combining LEV with whole-shop exposure control efforts is illustrated by exposure monitoring data obtained by OSHA at a facility where efforts to augment housekeeping, enclose the saw, and control other sources of silica dust in the shop had already reduced the sawyers’ median exposure from 84 µg/m^3 to 49 µg/m^3 (Document ID 1365, pp. 11-17; 0180). After modification of the ventilation to exhaust directly from the top of the saw, the silica median exposure for sawyers was further reduced to 22 μg/m^3 (Document ID 1365, pp. 11-18; 0180).

Stand-alone fan-powered dust collectors are a feasible method to lower dust levels in small dimension stone processing shops. Air cleaning units, however, must be properly sized to clean dust loads and keep acceptable dust levels low. Chekan et al. (2008) demonstrate that a 2.24 kilowatt (kW) motor cleaning unit cleaned 19 percent more air and captured 32 percent more respirable dust than the 0.56 kW unit (Document ID 0593, p. 5). The study also discussed cost-effective retrofit options. Although dust collectors are practical means to reduce respirable dust, reliable data do not exist to determine their effectiveness (Document ID 0593).

Additional Controls for Fabricators

The exposure profile in Table IV.4.4-B shows that 39 percent (52 out of 135 samples) of fabricators have exposures above the final PEL of 50 μg/m^3. Therefore, OSHA finds that additional controls will be necessary to achieve the PEL for these overexposed workers.

The primary controls for fabricators include both wet methods and LEV when polishing and grinding stone and rigorous housekeeping in work areas where dust accumulates.

The exposure level for fabricators can be reduced substantially by converting to water-fed equipment and switching to wet methods. According to Simcox et al. (1999), exposures of fabricators at granite handling facilities were reduced from a mean of 490 μg/m^3 to 60 μg/m^3 (88 percent) when all dry grinding tools used on granite were either replaced or modified to be water fed. The same study reported similar reductions in exposure at other fabricating facilities when wet grinding, polishing, and cutting methods were adopted (Document ID 1365, p. 11-20; 1146, p. 3). Phillips and Johnson (2012) surveyed granite countertop fabrication shops of various sizes throughout Oklahoma and concluded, “The self-reported use by some shops of exclusively wet methods indicated that this means of exposure control is feasible” (Document ID 1365, p. 11-20; 3957, p. 7).

Results obtained from NIOSH and OSHA SEP inspection reports showed a substantial reduction in fabricator exposure levels associated with wet methods. All 7 full-shift PBZ silica results for fabricators using water-fed equipment exclusively were 51 μg/m^3 or less (Document ID 1365, p. 11-20; 0061; 1826; 0156; 0240; 0856). In six of these instances of wet-method use, the fabricator was polishing granite; in one case, the fabricator was working with marble in a facility that also handled granite (Document ID 1365, p. 11-20).

Rigorous control of dust-laden water from wet processes prevents dust from depositing on surfaces where, after evaporation of the water, the dry dust can be disturbed and become airborne. The following methods, combined with water-fed equipment, are associated with reduced exposure levels for fabricators: frequent replacement or filtration of recirculated water for milling machines, adequate collection of used water from handheld equipment, and frequent washing of floors and surfaces where dust-laden water might evaporate or dust might accumulate (Document ID 1365, p. 11-21).

Stand-alone fan-powered dust collectors, discussed previously as an additional control for sawyers, also are a feasible method to lower dust levels in small-dimension stone processing shops (Document ID 0593, p. 6).

Additional Controls for Splitters/Chippers

The exposure profile in Table IV.4.4-B shows that 69 percent (20 out of 29 samples) of splitters/chippers have exposures above the final PEL of 50 μg/m^3. Therefore, OSHA finds that additional controls will be necessary to achieve the PEL for these overexposed workers.

Available controls include LEV at workstations, rigorous housekeeping, and wet methods. Based on the similarity of tools and exposures, OSHA anticipates that splitters and chippers benefit similarly from the controls discussed under sawyers, fabricators, and abrasive blasters in this section.

OSHA has only limited data to quantify the reductions in exposure that can be anticipated through the use of LEV and water-fed tool attachments in the stone products industry. However, there is evidence that demonstrates that a combination of LEV, wet methods, and other efforts can be very effective in reducing exposures. For example, at a facility visited by OSHA, workers also used a combination of housekeeping, LEV, and wet methods to control splitter/chipper exposure. In this case, workers washed stone with a constant stream of water (rather than a spray). The single full-shift PBZ splitter/chipper exposure result was 31 µg/m^3. Previous silica results for chippers/splitters at the facility had been 132 µg/m^3, 124 µg/m^3, and less than 13 µg/m^3 (no quartz detected in the 13 µg/m^3 sample) (Document ID 1365, p. 11-22; 0187).

At another facility OSHA visited, the workers wet stone with a hose before and between each operation, washed floors daily with a fire hose and kept them damp at all times, and controlled dust from the saws by modifying ventilation to exhaust directly from the top of the saws. Additionally, the facility retrofitted splitting stations with LEV (Document ID 1365, p. 11-22; 0180**)**. Under these conditions, the full-shift respirable silica exposures for splitters were reduced from 104 µg/m^3, 109 µg/m^3, and 137 µg/m^3 (a mean of 117 µg/m^3) to levels of 17 and 19 µg/m^3 (a mean of 18 µg/m^3), a 66 percent reduction rate (Document ID 1365, p. 11-22; 0180). A combination of controls to reduce all source of potential exposure was needed to adequately reduce exposures. At these facilities, individual exposure reduction efforts (e.g., LEV alone) failed to maintain exposures below 100 µg/m^3, but were successful when used in combination (e.g., wet methods and LEV) (Document ID 1365, p. 11-22).

Other dust control options for power chipping tools include LEV fitted directly to the chipping bit and water feeds that spray mist at the chipping point. In short-duration tests, both LEV and water-fed attachments reduced the silica exposure of workers removing hardened concrete from the interior of concrete-mixer drums. For example, NIOSH reported a 69 percent reduction in worker exposure levels when the LEV fitting was used with jack hammers. During controlled, short-duration tests, the geometric mean PBZ silica concentration was 300 µg/m^3 with the LEV, compared with 970 µg/m^3 when no controls were used (Document ID 0245, pp. 10-11). Silica levels decreased further when general exhaust ventilation was used in addition to LEV. The combined controls provided a net reduction of 78 percent (from 970 µg/m^3 to 213 µg/m^3). Although neither control is commercially available, shop-made versions have been assembled from materials available at hardware stores (Document ID 0741).

Sampling results submitted to the docket by NIOSH showed wet suppression when using jackhammers to split or chip stone can produce respirable dust reductions of 81-95 percent and silica reductions of 86-98 percent resulting in silica exposure levels of 48-65 μg/m^3 (Document ID 2177, Attachment D, p. 19).

Stand-alone fan-powered dust collectors, discussed previously as an additional control for sawyers, also are a feasible method to lower dust levels in small dimension stone processing shops (Document ID 0593).

Additional Controls for Machine Operators

The exposure profile in Table IV.4.4-B shows that 67 percent (12 out of 18 samples) of machine operators have exposures above the final PEL of 50 μg/m^3. Therefore, OSHA finds that additional controls will be necessary to achieve the PEL for these overexposed workers.

Appropriate controls include converting to water-fed equipment, enclosing machines, adding exhaust ventilation close to the point where dust is generated, employing rigorous housekeeping, and frequently washing stone and floors (Document ID 1365, p. 11-24).

The respirable silica exposures of machine operators can be reduced significantly by the use of wet process rather than dry process machines and by manufacturer-designed, adequately exhausted machine housing (Document 1365, p. 11-25). Stone Working Equipment Distributor A (2000) indicated that most new machines sold to high-volume production facilities come with LEV dust collectors and/or enclosures as standard equipment (Document ID 1156).

Facilities that use a combination of these controls can reduce machine operator exposure substantially. For example, a slate-working establishment exhausted the machine at the point where dust was generated, pre-wet the stone, installed spray mister nozzles to keep the stone wet, and took steps to reduce dust released from the adjacent saws. Under these conditions, the operator exposure level dropped from 220 μg/m^3 to 26 μg/m^3 (Document ID 1365, p. 11-25; 0178). At another facility, OSHA reported 2 full-shift PBZ silica results of 44 μg/m^3 and 314 μg/m^3 around the time of the initial compliance inspection.

The facility implemented procedures to pre-wash stone, controlled dust from other operations, and enclosed trimmers in exhausted plastic housing. After the modifications, full-shift silica results for operators were more consistent, at 60 $\mu g/m^3$ and 69 $\mu g/m^3$ (Document ID 1365, p. 11-25; 0187). Although these results are more consistent and have a much lower average (65 $\mu g/m^3$ vs. 179 $\mu g/m^3$) than those collected before the modifications, they are still above 50 $\mu g/m^3$ (Document ID 1365, p. 11-25). Machine operators with exposures currently greater than 100 $\mu g/m^3$ will require the entire range of controls described previously to increase the likelihood of maintaining exposure values below 50 $\mu g/m^3$. There is one example from an OSHA inspection report of a machine operator whose exposure dropped from 220 $\mu g/m^3$ to 26 $\mu g/m^3$ after a combination of controls were implemented However, the available data are not sufficient to demonstrate that exposures to all machine operators can be reduced below 50 $\mu g/m^3$ with any subset of the controls (Document ID 0178, pp. 61, 185).

Additional Controls for Abrasive Blasting Operators

The exposure profile in Table IV.4.4-B shows that 50 percent (5 out of 10 samples) of abrasive blasting operators have exposures above the final PEL of 50 $\mu g/m^3$. Therefore, OSHA finds that additional controls will be necessary to achieve the PEL for these overexposed workers.

Additional controls for those over-exposed workers include improved maintenance of blasting cabinets, adequate ventilation, and alternative low-silica or silica-free blasting media that is less toxic than silica sand.

Isolation of the operator from the blasting operation can reduce silica exposure during abrasive blasting as demonstrated in a study of silica exposure in granite sheds (Document ID 1225, p. 428). In this study, ventilated blasting cabinets used by three operators in the granite sheds (using either silica sand or an alternate media) generated exposure results of 15 $\mu g/m^3$ to 77 $\mu g/m^3$ with a mean of 41 $\mu g/m^3$ (Document ID 1225, p. 428). These data provide evidence that silica exposure levels associated with granite work in blasting cabinets can be reduced to levels consistently below 50 $\mu g/m^3$ by using silica-free blast media and a combination of other engineering and work practice controls.

These controls include enclosed and ventilated media recycling systems, interlocks to prevent operators from opening doors before the cabinet has been exhausted, and use of high-efficiency particulate air (HEPA)-filtered vacuums instead of dry sweeping or compressed air to clean in and around the cabinet. A well-sealed blast cabinet (a type of containment) isolates a worker from the dust generated inside and the interlock and ventilation systems ensure that the cabinet is free of airborne dust before the operator opens it. Large, glovebox style cabinets for abrasive blasting oversized or awkward shaped objects are available commercially (Document ID 0801, p. 12). Glove boxes/cabinets are enclosed compartments with long, usually elbow-length gloves attached to them, which allow the user to reach inside and manipulate the contents while remaining outside of the sealed cabinet. One manufacturer produces ventilated cabinets that have reportedly been used for abrasive blasting of granite tombstones (Document ID 1693; 0953, p. 1). This size box is interlocked, to prevent operation unless the unit is sealed, and ventilated at 840 cfm. In addition, the boxes are fitted with a dust collector (99.9 percent filter efficiency for 0.3 micron particles available for some models) and a completely enclosed, ventilated media reclamation system. A larger ventilation system is required when two or more of these cabinets are linked together to provide a larger internal workspace (Document ID 0953, p. 3).

For large items that cannot fit in a blast cabinet, improving ventilation to at least the ACGIH-recommended air flow rate of 100 cfm per square foot of face area (equivalent to 5,000 cfm for a 7-by-7-foot booth) have been shown to decrease the exposure to blasting operators to less than 50 μg/m^3 (Document ID 1361, p. 5). Alternatively, using an abrasive blasting booth that includes a partition to separate the operator from the blasting activity (for example roll-up doors with an access slot and window) may provide an additional level of protection, if negative pressure is maintained in the blasting enclosures. For example, ventilated blasting booths used by three operators at a stone monument manufacturer resulted in exposures of less than 50 μg/m^3 (mean of 29 μg/m^3) for all three workers. Silica content ranged from 14 percent to 20 percent. Although the 4- to 6-hour sample times for these exposures are less than full shift, these durations are typical of the industry (Document ID 1361, pp. 3, 5).

In addition, this type of equipment (abrasive blasting booth that includes a partition) was used by two of the three granite working facilities in which NIOSH conducted control technology assessments (Document ID 0218, p. 3; 0240, p. 4). Exposure monitoring data associated with these partitions at one of the sites, however, showed mixed results, with full-shift PBZ exposures of 22 μg/m^3 and 252 μg/m^3 (Document ID 0218, pp. 4, 8). Although investigators indicated that the ventilation system was not operating for part of the sampling period, the available documentation is inadequate to correlate worker exposure and properly operating equipment. This is because the partitions were not evaluated at the other site. Moreover, air pressure and turbulence introduced during blasting might limit the reliability of this control option. Also, the intermittent elevated exposure evident with this style of enclosure (access slot in door) might be better controlled by another commercially available option: a gauntlet glove panel and window that can be inserted into the wall of a walk-in size sealed and ventilated abrasive blast booth (Document ID 0954).

More extensive use of silica-free blast media also might reduce operator exposures. Bauxite can contain up to 10 percent silica and might contribute to worker exposure (Document ID 1365, p. 11-27; 0207, p. 403). Aluminum oxide and steel shot, which also are used as blast media, contain little to no silica (Document ID 3747, p. 14; 2212, p. 4).

Wet abrasive blasting methods are widely available and work well on all structural and most decorative concrete surfaces (Document ID 0733, p. 22). OSHA concludes that wet abrasive blasting is an effective method of controlling dust during abrasive blasting operations. This conclusion is based on a NIOSH study and an OSHA SEP inspection that show a marked decrease in dust levels when compared to uncontrolled, dry abrasive blasting (Document ID 0230; 0497). Wet abrasive blasting would be similarly effective on stone (stone aggregate is a major component of concrete). Abrasive blasters in this application group can use wet methods as an alternative to ventilated process enclosures that separate workers from the abrasive blasting area.

Although the silica exposure levels for abrasive blasting operators performing open-air blasting can exceed OSHA's final permissible exposure limit (PEL), OSHA has existing requirements for abrasive blasting under the Ventilation standard for General Industry (1910.94). The standard requires abrasive blasting operators to wear abrasive blasting respirators approved by NIOSH for protection from dusts produced during abrasive blasting operations. The standard also includes specifications for blast-cleaning enclosures, exhaust ventilation systems, air supply and air compressors, and operational procedures.

4.4.4 Feasibility Finding

Feasibility Finding for Sawyers

Based on the exposure profile in Table IV.4.4-B and other record evidence discussed above, OSHA concludes that the respirable silica exposures of most sawyers can be controlled to levels of 50 μg/m^3 or less most of the time by implementing a combination of engineering and work practice controls. For example, the median full-shift PBZ silica exposure level for sawyers was 30 μg/m^3 at facilities that implemented housekeeping as well as other control measures (enclosing the saw, pre-washing stone, managing slurry, and controlling dust from adjacent processes) (Document ID 1365, p. 11-18; 0042; 0178; 0157). Although these examples are from slate product manufacturers, OSHA concludes that the same controls would be similarly effective in facilities that process granite and other stone since the silica percentage content is similar.

Feasibility Finding for Fabricators

Based on the exposure profile in Table IV.4.4-B and other record evidence discussed above, OSHA concludes that the exposure of most fabricators can be reduced below 50 μg/m^3 most of the time since 61 percent of the fabricators exposures are already below 50 μg/m^3. Silica exposures below 50 μg/m^3 are associated with the use of wet processes and rigorous housekeeping, such as washing or HEPA vacuuming rather than dry sweeping and work surfaces (Document ID 1365, p. 11-21). The sample results for fabricators using water-fed equipment exclusively ranged from less than or equal to 12 to 51 μg/m^3 with a median of 16 μg/m^3 (Document ID 1365, p. 11-20; 0061; 1826; 0156; 0240; 0856). OSHA expects that improved housekeeping will reduce exposures to levels below 50 μg/m^3 since resettled dust contributes significantly to worker exposures in this application group. The most successful exposure reductions have all originated from efforts to complement engineering controls with housekeeping measures, as discussed above (Document ID 1365, p. 11-17; 0046; 0176; 0180; 0157). Controlling water from wet processes prevents dust left by evaporated water from being disturbed and becoming airborne. Managing dust from adjacent operations also helps maintain exposures of fabricators below 50 µg/m^3.

Feasibility Finding for Splitters/Chippers

Based on the exposure profile in Table IV.4.4-B and other record evidence discussed above, OSHA concludes that the silica exposure of most splitters/chippers can be controlled to levels below 50 µg/m^3 most of the time by implementing a combination of engineering and work practice controls similar to those used for sawyers. The combination of rigorous housekeeping, daily floor washing, wetting of the stone before and between operations, and controlling dust from adjacent operations has been shown to be effective for splitters (note the full shift mean respirable silica reduction from 137 µg/m^3 to 19 µg/m^3 at a facility visited by OSHA (Document ID 1365, p. 11-22; 0180, p. 13).

More rigorous controls will also be necessary for some workers, including the 48 percent of splitters/chippers who are currently exposed at levels exceeding 100 µg/m^3. These workers are typically employed at slate facilities and some facilities manufacturing memorials, which will need to install LEV at splitter/chipper stations. A facility using a combination of housekeeping, LEV, and wet methods (constant water flow) to control splitter/chipper exposures reduced the splitter/chipper exposure level to 31 µg/m^3 (Document ID 1365, p. 11-22; 0187). Facilities also might need to improve drainage to allow frequent washing of stone and floors (Document ID 1365, p. 11-24).

Exposure results for splitters/chippers suggest that memorial manufacturers might require supplemental flexible exhaust trunks to ensure that LEV is readily accessible to all points around large three-dimensional products (Document ID 1365, pp. 11-23 - 11-24). Furthermore, those establishments where chipper/splitters use power tools (e.g., pneumatic chipping equipment) will need to implement task-specific controls. Options include tool-mounted water-fed or tool-mounted LEV devices as described by NIOSH

(Document ID 0838, p. 2; 0865, pp. 2-4). These controls are discussed in more detail in Section IV-5.5 – Jackhammers and Other Powered Handheld Chipping Tools in this technological feasibility analysis.

Feasibility Finding for Machine Operators

Based on the exposure profile in Table IV.4.4-B and other record evidence discussed above, OSHA concludes that stone product facilities can achieve silica exposure levels of 50 μg/m^3 or less for most machine operators in this application group most of the time. Thirty percent of machine operators already experience exposures below this level. OSHA finds that by using a combination of controls the exposures for the remaining 70 percent of workers in this job category can also be reduced to 50 μg/m^3 or less (Document ID 1365, p. 11-17; 0042; 0178; 0157). Appropriate controls include enclosing machines, adding exhaust ventilation close to the point where dust is generated, converting to water-fed equipment, and rigorous housekeeping, as well as frequently washing stone and floors (Document ID 1365, p. 11-25).

Incremental improvements will reduce exposures sufficiently for some workers; however, to consistently achieve levels of 50 μg/m^3 or less, OSHA anticipates that a facility may have to employ the full extent of available controls. For example, a facility visited by OSHA implemented procedures to pre-wash stone, controlled dust from other operations, and enclosed trimmers in exhausted plastic housing. After the modifications, exposures were reduced from a mean of 179 μg/m^3 to 65 μg/m^3. The facility did not modify the equipment to include a water delivery system, and the Agency has determined that exposures could have been further reduced if dust originating from the machine was suppressed by water. This determination is based on the exposure reduction obtained at a slate-working establishment, which exhausted the machine at the point where dust was generated, pre-wet the stone, installed spray mister nozzles to keep the stone wet, and took steps to reduce dust released from the adjacent saws. Under these conditions, the operator exposure level dropped from 220 μg/m^3 to 26 μg/m^3 (Document ID 1365, p. 11-25; 0178; 0187). OSHA expects that similar reductions in exposures to machine operators can be replicated in other stone product facilities if similar combinations of controls are also used.

Feasibility Finding for Abrasive Blasting Operators

Based on the exposure profile in Table IV.4.4-B and other record evidence discussed above, OSHA concludes that the exposure of most abrasive blasting operators can be controlled to levels of 50 μg/m^3 or less most of the time through the use of HEPA-filtered vacuum cleaning and sealed, ventilated, and interlocked blasting cabinets. These controls are appropriate for small to medium-size stone objects, including all modestly sized memorials. Properly maintained blast cabinets can offer complete isolation from exposures and are commonly used for this purpose. For example, ventilated blasting cabinets used by three operators in granite sheds (using either silica sand or an alternate media) generated a mean exposure result of 41 μg/m^3 (Document ID 1365, p. 11-26; 1225, p. 428). Although a high result of 77 μg/m^3 was recorded by these investigators, OSHA expects that exposure levels associated with blasting cabinets can be reduced to levels consistently below 50 μg/m^3 by using silica-free blast media that is less toxic than silica sand or a combination of other engineering and work practice controls. These controls include enclosed and ventilated media recycling systems, interlocks to prevent operators from opening doors before the cabinet has been exhausted once blasting is complete, and use of HEPA-filtered vacuums instead of dry sweeping or compressed air to clean in and around the blasting cabinet (Document ID 1365, pp. 11-26 - 11-27).

For larger stone objects, OSHA believes that ventilated blasting booths (with partitions) might be used to control exposures to levels of 50 μg/m^3 and below. For example, ventilated blasting booths used by three operators at a stone monument manufacturer resulted in exposures of less than 50 μg/m^3 (mean of 29 μg/m^3) for all three workers. Although the 4- to 6-hour sample times for these exposures are less than full shift, these durations are typical of the time spent performing abrasive blasting in this application group (Document ID 1361, pp. 5-6). Although the silica exposure levels for abrasive blasting operators performing open-air blasting can exceed OSHA's new PEL, OSHA's has existing requirements for abrasive blasting under the Ventilation standard for General Industry (1910.94). The standard requires abrasive blasting operators to wear abrasive blasting respirators approved by NIOSH for protection from dusts produced during abrasive blasting operations. The standard also includes specifications for blast-cleaning enclosures, exhaust ventilation systems, air supply and air compressors, and operational procedures.

Overall Feasibility Finding

Based on the best available information in the record, including submitted comments, testimony, and exposure data, OSHA concludes that most cut stone product manufacturers can achieve exposure levels of 50 μg/m^3 or less for most operations, most of the time, using the engineering controls and improved housekeeping methods described in this section. Where exposure currently exceeds 50 μg/m^3, additional controls include wet methods, including water delivery systems at the point of operation along with slurry management, LEV, enclosures, and rigorous housekeeping. In sum, OSHA concludes that the final PEL of 50 μg/m^3 is technologically feasible for the Cut Stone and Stone Products industry.

4.5 DENTAL EQUIPMENT AND SUPPLIES

4.5.1 Description

Some manufacturers of dental equipment and supplies produce silica-containing restorative materials, porcelains, plasters, and refractory investment (ceramic molding) materials[32] for use by dentists or dental labs. These materials can contain up to 100 percent silica in the form of quartz, cristobalite, or both. Some dental supply manufacturers also operate small sand casting foundries, using silica sand to produce ingots of dental metal alloys (Document ID 1365, pp. 17-1 – 17-2). Producers of supplies and equipment for dental offices and laboratories are classified in the six-digit North American Industry Classification System (NAICS) code 339114, Dental Equipment and Supplies Manufacturing.

Workers at dental equipment and supply manufacturers (production operators) receive, blend, and package silica-containing restorative materials, porcelains, plasters, and refractory investment materials. Dry, powdered quartz or cristobalite is typically received in bulk (50-pound bags up to tanker trucks), ready for blending. Large scale operations use automated processes such as pneumatic materials transfer systems, while workers in low-volume operations manually empty sacks of materials into hoppers or use handheld scoops to transfer materials from bags to weighing equipment. Production operators add silica-containing ingredients and other dry, viscous, or liquid ingredients from hoppers or weighing equipment to mixing tanks where the products are blended. Once blended, the materials move to filling and packaging operations, where worker activities vary from monitoring fully automated, mostly enclosed machinery to manual dispensing. Manual dispensing involves placing buckets under spouts or putting bags on filling nozzles, with workers standing within arm’s length of the packaging equipment (Document ID 1720, p. IV-114).

[32] Investment molding material are used in investment casting which is a form of metal casting that involves enclosing a three-dimensional pattern in a heat-resistant ceramic mold called investment material. Lost-wax casting is an example of a type of investment casting commonly used in the dental laboratory industry (Document ID 0201).

4.5) Dental Equipment and Supplies

Production operators may be exposed to silica at different points in the manufacturing process, including when dust is released during the transfer of raw materials from delivery vehicles to storage areas or from storage to mixing areas, and during the weighing or metering of raw materials into mixers. Silica exposures may also occur when dust escapes during operation of mixing and filling equipment and when powdered product is compacted into containers. Housekeeping activities, such as dry sweeping and vacuuming of silica-containing materials, can also generate exposures to silica (Document ID 1365, pp. 17-3-17-4).

Workers in dental equipment facilities that produce metal alloys might encounter silica if they use sand molds to cast ingots as part of a small foundry operation. Although the extent of foundry work in the dental equipment and supply industry is unknown, it is likely insignificant (Document ID 1365, pp. 17-2-17-3). For a complete discussion of sand casting foundries, see Section IV-4.8 – Foundries (Metal Casting).

Table IV.4.5-A summarizes the major activities and primary sources of silica exposure for this industry.

Table IV.4.5-A
Job Categories, Major Activities, and Sources of Exposure of Workers in the Dental Equipment and Supplies Manufacturing Industry (NAICS 339114)

Job Category*	Major Activities and Sources of Exposure
Production Operator (blender, compounder, packaging operator)	Preparing and packaging batches of silica-containing restorative materials, porcelains, plasters, and refractory investment materials. • Dust released during transfer of raw materials from delivery vehicles to storage areas and from storage to mixing areas. • Dust released during weighing or metering of raw materials into mixers (from hoppers, by dumping bags, or pouring by hand). Operating mixing and filling equipment, including manual placement of containers on filling equipment. • Dust escaping from mixing/blending equipment. • Dust escaping from packaging equipment used to fill product containers (envelopes, bags, barrels). • Dust disturbed during use of vibrating equipment used to compact powdered product in containers. Housekeeping • Dry sweeping and vacuuming silica-containing materials.

* Job categories are intended to represent job functions; actual job titles might differ, and responsibilities might be allocated differently, depending on the facility.
Source: Document ID 1720, p. IV-115.

For each of the job categories listed in Table IV.4.5-B and for dental equipment and supplies industry as a whole, OSHA concludes that Table IV.4.5-B represents baseline conditions.

4.5.2 Exposure Profile and Baseline Conditions

The exposure profile in Table IV.4.5-B includes 5 full-shift personal breathing zone (PBZ) samples of respirable crystalline silica for workers in the dental equipment and supplies manufacturing industry. The median is 12 μg/m^3, the mean is 68 μg/m^3, and the range is 10 μg/m^3 (the limit of detection (LOD)) to 214 μg/m^3. Table IV.4.5-B shows that, of the 5 samples, 2 (40 percent) exceed 50 μg/m^3 and 1 (20 percent) exceeds 100 μg/m^3. Available exposure information from the PEA for production operators was limited to only three personal breathing zone (PBZ) samples: two obtained from an OSHA Special Emphasis Program (SEP) inspection report of a dental materials supplier that blends and packages dental investment powders used for casting, and one from an interview with a manufacturer of silica-containing dental restorative material (Document ID 0043, pp. 43-44, 52-53; 0620). The rulemaking record provides two additional sample results, from OSHA Information System (OIS) inspection data, that OSHA has added to this analysis. The additional samples were from a single inspection, and both silica exposures were below the LOD (Document ID 3958, Rows 274, 275).

Sixty percent (3 out of 5) of the sample results are less than the final rules permissible exposure limit (PEL) of 50 μg/m^3.

Interviews conducted by OSHA and ERG, OSHA's contractor, with three dental equipment and supplies facilities indicate that local exhaust ventilation (LEV) was available on mixing and packaging equipment at all three facilities (Document ID 1720, p. IV-116). The manufacturer of silica-containing dental restorative material, discussed earlier, blends a silica-containing powder with other ingredients to form a paste product. This manufacturer has already achieved consistently low silica exposures, including a full-shift exposure level of 10 μg/m^3, through a combination of careful work practices, LEV at the weighing station, an air-tight cover on the mixer, and a hood/enclosure and conical exhaust trunk for hand-scooping of material from a raw materials bag to a weigh bucket (Document ID 1720, p. IV-116; 0620).

The two exposure sample results in the exposure profile (Table IV.4.5-B) that exceeded the new PEL of 50 µg/m^3 were collected in October 1994 at a dental investment materials supplier that had poorly designed LEV and inadequate work practices. LEV was positioned so the worker was between the LEV and dust generated by mixer charging, exhaust hoses had excessively sharp bends that potentially restricted exhaust airflow, and workers reportedly routinely spilled material. The respirable quartz levels associated with these conditions were 90 µg/m^3 and 214 µg/m^3 (Document ID 1720, p. IV-116; 0043, pp. 43-44, 52-53).

This facility made improvements in LEV, work station design, and work practices. Short-term samples taken before and after implementation of the improvements showed a dramatic reduction in exposures (Document ID 1720, pp. IV-115, IV-118). Since these samples were all less than 360 minutes in duration, OSHA did not include them in this exposure profile (see Sections IV-1 – Introduction and IV-2 – Methodology of this FEA). The improvements, however, and the resulting decreases in exposure, are described below in the discussion of additional controls.

For the two samples added to the profile from OIS, no description of work activities is available and the ventilation described is general dilution ventilation (Document ID 3958, Rows 274, 275).

Supplemental Data

The UAW, which represents workers at dental equipment and supplies manufacturing facilities, provided comments that included 519 exposure sample results from a plant that produced refractory materials for the dental industry. The UAW described the data in its comments, noting that 481 of the results (approximately 94 percent) were below the final rule's action level of 25 µg/m^3, and fewer than 4 percent of samples exceeded the PEL of 50 µg/m^3 (Document ID 2282, Attachment 1, pp. 1-14; Attachment 3, pp. 7-8). The UAW concluded that the evidence "shows that 25 µg is feasible in dental equipment manufacturing" (Document ID 3582, Tr. 1874; 2282, Attachment 3, p. 12). OSHA reviewed the data submitted by the UAW and agrees that the job descriptions are consistent with dental equipment manufacturing operations related to refractory handling. The Agency also agrees that the data appear to show a trend toward lower exposure levels, with exposures exceeding 50 $\mu g/m^3$ reported less frequently over the years covered by this dataset (1994-1997).

The data submitted by the UAW, however, are of limited use for the purposes of incorporating this data into the exposure profile. The 519 data values appear to represent a smaller number of air samples, each analyzed for three silica “hazard” types, labeled Q, C, and T, with the result for each hazard type reported separately rather than as total crystalline silica for each sample number. (OSHA notes that Q, C, and T could be interpreted as quartz, cristobalite, tridymite, although OSHA is unable to confirm this from the available documentation) (Document ID 2282, Attachment 1). These data could not be incorporated into the exposure profile because certain key data descriptors, including sampling duration and whether the exposure values present the concentrations for each “hazard” as 8-hour TWAs or in another form, were lacking. Nevertheless, OSHA concludes that the data provided by the UAW appear to support OSHA’s exposure profile with the vast majority of the exposures below the action level and shows that silica exposures are routinely at low levels in dental equipment and supplies manufacturing facility.

In fact, these data from the UAW suggest that OSHA’s exposure profile (Table IV.4.5-B) might overestimate silica exposures for workers in this industry. OSHA notes that four of the five samples in the exposure profile were drawn from OSHA inspections, which tend to measure the most highly exposed workers and are likely to overestimate median and mean exposures. Flanagan et al. (2006) illustrated this trend in a large set of silica data from the construction industry (Document ID 0677, p. 146). OSHA concludes that current worker exposures in this industry are no higher than those presented in the exposure profile (Table IV.4.5-B) and likely are routinely lower.

Table IV.4.5-B
Respirable Crystalline Silica Exposure Range and Distribution of Results for Workers in the Dental Equipment and Supplies Industry (NAICS 339114)

	Exposure Summary			**Exposure Range**		**Exposure Profile**				
Job Category	**N**	**Mean (μg/m³)**	**Median (μg/m³)**	**Min (μg/m³)**	**Max (μg/m³)**	**<25 (μg/m³)**	**≥25 and ≤50 (μg/m³)**	**>50 and ≤100 (μg/m³)**	**>100 and ≤250 (μg/m³)**	**>250 (μg/m³)**
Production Operator	5	68	12	10	214	3 (60%)	0 (0%)	1 (20%)	1 (20%)	0 (0%)
Total	**5**	**68**	**12**	**10**	**214**	**3 (60%)**	**0 (0%)**	**1 (20%)**	**1 (20%)**	**0 (0%)**

Notes: All samples summarized are personal breathing zone (PBZ) results and represent 8-hour time-weighted average exposures.
Job categories are intended to represent job functions; actual job titles might differ, and responsibilities might be allocated differently, depending on the facility.
Percentages may not add to 100 percent due to rounding.

Sources: Document ID 1720, p. IV-117; 3958; 0043; 0620.

4.5.3 Additional Controls

The exposure profile in Table IV.4.5-B shows that 40 percent (2 out of 5 samples) of production operators have exposures above the final PEL of 50 μg/m^3. Therefore, OSHA finds that additional controls will be necessary to achieve the PEL for these overexposed workers.

The exposure profile indicates that silica exposure levels for 60 percent (and, according to the UAW, up to 96 percent) of all production operators are already 50 μg/m^3 or less. To achieve this level for the remainder of production operators, dental supply manufacturers will need to use a combination of improvements or upgrades in existing LEV systems and improved work practices to reduce the amount of silica dust that becomes airborne.

Controls such as those used effectively by the manufacturer of silica-containing dental restorative material, described in the preceding section on baseline conditions, could be implemented by those facilities that have not yet achieved exposures below 50 μg/m^3. This dental restorative material facility achieved consistently low silica exposures, including a full-shift exposure level of 10 μg/m^3, through a combination of careful work practices, LEV at the weighing station, an air-tight cover on the mixer, and a hood/enclosure and conical exhaust trunk for hand-scooping of material from a raw materials bag to a weigh bucket (Document ID 0620).

The investment materials manufacturing facility described earlier, which was evaluated by OSHA compliance and consultation officers, achieved a reduction in median exposures from 430 μg/m^3 to 31 μg/m^3, with maximum exposures reduced from 885 μg/m^3 to 66 μg/m^3 based on short-term results. Prior to the improvements, OSHA obtained three short-term results of 885 μg/m^3, 430 μg/m^3, and 372 μg/m^3. After the facility implemented the improvements listed below, OSHA obtained five more short-term silica samples results below the LOD (24 μg/m^3, 26 μg/m^3, 29 μg/m^3, 32 μg/m^3, and 40 μg/m^3) and one short-term result of 66 μg/m^3 during two visits to the facility. The median for these final six results is 31 μg/m^3. Although these data represent samples collected over less than four hours, and the samples therefore were not included in the exposure profile, OSHA believes that the data demonstrate the success of the improvements in exposure controls (Document ID 1720, p. IV-118; 0043). Worker exposures dropped dramatically when the facility:

- Improved LEV systems, including:
  - Use of enhanced hood designs;
  - Realigned ventilation exhaust points to improve capture;
  - Improved duct angles and upgraded exhaust fans;
  - Reduced leaks in the mixer and packaging systems and enclosed a portion of the packaging operation;
  - Added High-Efficiency Particulate Air (HEPA)-filtered exhaust to a bag dumping station;
  - Added a partially enclosed and ventilated sleeve at the mixer charging port (to contain ingredients during mixer charging);
- Changed workstation designs to limit the drop distance for empty raw material bags (a source of dust) and reduce product overflow from packaging activities;
- Encouraged work practices that minimized spilled material and maintained the LEV between the workers' breathing zone and the point where dust was released; and
- Improved housekeeping, using a sweeping compound to reduce dust during all clean-up activities (Document ID 1720, p. IV-118; 0043).

The two exposures above the new PEL of 50 μg/m^3 in Table IV.4.5-B are from a dental material blending operation that involved dumping bags of silica-containing material into a mixing machine. Blending and mixing operations in this industry are typical of mixing operations in any manufacturing industry that require powdered raw materials to be handled and mixed prior to processing. These operations may require properly designed bag dumping stations with LEV to control silica dust. The effectiveness of ventilated bag dumping stations, equipped with integrated bag disposal and compaction, in reducing exposures to below the new PEL has been demonstrated in a paint manufacturing facility's mixing process (Document ID 0199, pp. 4, 6, 7, 11), and in a NIOSH engineering assessment of a bag dumping station (Document ID 1369, p. 1). OSHA expects such ventilated bag dumping stations to be equally effective in the dental equipment and supplies industry, which uses similar equipment for similar tasks. Such systems are commercially available (Document ID 1224).

4.5.4 Feasibility Finding

Based on the exposure profile in Table IV.4.5-B and other record evidence discussed above, OSHA concludes that, by implementing a combination of controls that reduce the amount of dust that becomes airborne and using LEV to capture dust that is released, manufacturers of silica-containing dental equipment and supplies can achieve the final PEL of 50 $\mu g/m^3$ or less for most workers, most of the time.

Such controls include installing ventilation systems or improving existing systems (at bag dumping stations, weighing and mixing equipment, and packaging machinery) and designing workstations to minimize opportunities for silica-containing materials to spill, fall, or drop (*e.g.*, adding a sleeve to guide raw materials into an open mixer). Additionally, it will be necessary for facilities to ensure that workers properly use the LEV systems and to encourage work practices that minimize spills and release of airborne silica dust. Accordingly, OSHA finds a PEL of 50 $\mu g/m^3$ is technologically feasible for the Dental Equipment and Supplies industry.

4.6 DENTAL LABORATORIES

4.6.1 Description

Dental laboratories use silica-containing materials as a component of dental appliances (crowns, bridges, orthodontic appliances, and dental prostheses), in mold materials for casting dental appliances, and as an abrasive material for finishing these products. Dental laboratories are classified in the six-digit North American Industry Classification System (NAICS) 339116, Dental Laboratories.

Dental technicians produce custom dental appliances, first by constructing plaster models from dental impressions, and then using these models as templates to make molded metal, plastic, or ceramic castings. The major tasks in dental product manufacture that involve potential silica exposure include plaster model and mold production, investment casting[33] using ceramic mold materials, and finishing of metal castings and coating dental appliances with porcelain enamel. Table IV.4.6-A summarizes the major activities and primary sources of silica exposure in this industry.

[33] Investment casting is a form of metal casting that involves enclosing a three-dimensional pattern in a heat-resistant ceramic mold called investment material. Lost-wax casting is an example of a type of investment casting commonly used in the dental laboratory industry (Document ID 0201).

Table IV.4.6-A Job Categories, Major Activities, and Sources of Exposure of Workers in Dental Laboratories (NAICS 33911)	
Job Category*	**Major Activities and Sources of Exposure**
Dental Technician	Constructing plaster models of dental impressions. • Manual mixing of plasters, some of which can contain silica (e.g., 30% quartz). • Molding and grinding of dry plaster models. • Casting of dental products using plaster models. • Dry sweeping or using compressed air to clean work areas. Using investment casting techniques to produce metal dental appliances. • Manual mixing of powdered investment material containing up to 70% silica as quartz and cristobalite. • Breaking investment materials to release metal castings. Finishing cast metal appliances. • Grinding metal castings to remove adhered investment material. • Abrasive blasting of castings to remove embedded investment material (typically in a ventilated glove box). Applying and finishing porcelain coatings on dental appliances. • Grinding and polishing porcelain coatings. • Abrasive blasting of porcelain coatings (typically in a ventilated glove box).
*Job categories are intended to represent job functions; actual job titles may differ and responsibilities may be allocated differently, depending on the facility. Source: Document ID 1365, p. 6-2.	

For each of the job categories listed in Table IV.4.6-A and for dental laboratories as a whole, OSHA concludes that Table IV.4.6-B represents baseline conditions.

4.6.2 Exposure Profile and Baseline Conditions

The exposure profile in Table IV.4.6-B includes 36 full-shift personal breathing zone (PBZ) samples of respirable crystalline silica for workers in the dental laboratory industry. The median is 10 μg/m^3, the mean is 14 μg/m^3, and the range is 5 μg/m^3 (the limit of detection (LOD)) to 58 μg/m^3. Table IV.4.6-B shows that, of the 36 samples, 1 (3 percent) exceed 50 μg/m^3 and none exceed 100 μg/m^3. Available exposure information for dental technicians used in preparing the PEA consisted of 31 full-shift personal breathing zone (PBZ) silica results from 14 dental labs; one was provided by the OSHA contractor ERG, and the other 13 by the New Jersey Department of Health and Senior Services (NJDHSS) (Document ID 0201, pp. 11-12; 0913, pp. 3-15). The rulemaking record provides five additional sample results, from OSHA Information System (OIS) inspection data, that OSHA has added to this analysis. The samples were from two inspections – four exposures were below the LOD,[34] while a fifth, at 48 μg/m^3, was below the new permissible exposure limit (PEL) of 50 μg/m^3 (Document ID 3958, Rows 140, 141, 142, 143, 313). The controls in the sampled activities were all described as using general dilution ventilation and local exhaust or “process enclosed/ventilated cab or booth.” The highest exposure of 48 μg/m^3 was taken on a technician during activities described as a “Grind in / Contour Tech” performing shaping and contouring bridge and crown work using a micropencil air abrasive unit, lathe with guard and air suction, enclosed/ventilated process, and general dilution ventilation. Sampling results for the “Grind in/Contour Supervisor” performing grinding and contouring work in the same facility and using the same controls were below the limit of detection. The supervisor’s respirable dust exposure was slightly higher; however, no silica was detected in the sample. Activities described in the other samples included, but were not limited to, casting, grinding, polishing, and metal finishing.

Ninety-seven percent of the sample results are less than the revised PEL of 50 μg/m^3, with 21 (58 percent) below the LOD. While silica continues to be present in dental laboratories, the work practices and controls currently in use produce exposures less than 50 μg/m^3 the vast majority of the time.

The baseline conditions for this group of workers typically include the use of local exhaust ventilation (LEV) such as positionable ventilated hoods and enclosures on work benches; enclosed, ventilated equipment for abrasive blasting (i.e., a ventilated glovebox); and ventilated or water-fed grinders (Document ID 0201, pp. 12-14; 3958). These controls, together with the small amounts[35] of silica-containing materials handled and the short duration of use, result in exposures below the final rule’s action level of 25 μg/m^3 for 83 percent of workers. This finding is consistent with a Korean study by Kim et al. (2002) that showed sample means less than 25 μg/m^3, with a sample maximum of

[34] Results reported as “none detected” are assigned a value equal to the LOD. The LOD is determined individually for each sample based on the volume of air sampled and the method used to analyze the sample; therefore, the limit of detection varies among samples. See Section IV-2–Methodology for additional information on LODs. For OIS data, a value of 12 μg/m^3 is used as the LOD.

[35] Since dental laboratories produce custom dental appliances, technicians handle and process small work pieces on an individual basis.

51 μg/m^3, for dental technicians working in laboratories equipped with LEV systems (Document ID 0763).

No additional data was submitted to the docket by stakeholders that relate to the feasibility of achieving the revised PEL in dental laboratories. Based on the best available information, OSHA concludes that the vast majority of dental laboratory technicians are currently exposed to silica at levels well below 50 μg/m^3.

Table IV.4.6-B
Respirable Crystalline Silica Exposure Range and Distribution of Results for Dental Laboratories (NAICS 339116, 621210)

	Exposure Summary			Exposure Range			Exposure Profile				
Job Category	**N**	**Mean (μg/m³)**	**Median (μg/m³)**	**Min (μg/m³)**	**Max (μg/m³)**		**<25 (μg/m³)**	**≥25 and ≤50 (μg/m³)**	**>50 and ≤100 (μg/m³)**	**>100 and ≤250 (μg/m³)**	**>250 (μg/m³)**
Dental Technicians	36	14	10	5	58		30 (83%)	5 (14%)	1 (3%)	0 (0%)	0 (0%)
Total	**36**	**14**	**10**	**5**	**58**		**30 (83%)**	**5 (14%)**	**1 (3%)**	**0 (0%)**	**0 (0%)**

Notes: All samples summarized are personal breathing zone (PBZ) results and represent 8-hour time-weighted average exposures.
Job categories are intended to represent job functions; actual job titles might differ, and responsibilities might be allocated differently, depending on the facility.
Percentages may not add to 100 percent due to rounding.

Sources: Document ID 1720, p. IV-124; 3958; 0201; 0913.

4.6.3 Additional Controls

The exposure profile in Table IV.4.6-B shows that 3 percent (1 out of 36 samples) of dental technicians have exposures above the final PEL of 50 μg/m^3. Therefore, OSHA finds that additional controls will be necessary to achieve the PEL for these overexposed workers.

OSHA's contractor report noted the potential for dental technicians to be exposed to elevated levels of silica at least occasionally (Document ID 1365, p. 6-4). For that worker and other similarly overexposed dental technicians, improved engineering controls and work practices would be necessary to reduce exposure to below the new PEL. Examples of available controls include installing and using properly designed and operated LEV and enclosures, such as abrasive blasting cabinets and laboratory hoods. For these systems, an important feature is effective filtration of the air discharged from the hoods and blasting cabinets (if not exhausted outdoors) (Document ID 0201, pp. 12-13). The feasibility of implementing improvements to ventilation systems in dental labs was corroborated in hearing testimony by Ms. Diane Matthew Brown of the American Federation of State, County and Municipal Employees (AFSCME), representing workers in dental facilities in public health and university settings, who noted that dental laboratories "are not settings that move.… You can put controls in place" (Document ID 3585, Tr. 3128-3129). Likewise, Mr. John Adams, Vice President of the American Federation of Government Employees (AFGE) Local 2778, representing dental laboratory workers at the Atlanta Veterans Administration hospital, noted that in dental laboratories "when there are not good [silica-free] substitutes, exposure can be reduced by the use of ventilation systems…. used to remove work dust from the work area" (Document ID 1763, p. 3). Mr. Adams also noted that exposures may occur when abrasive blasting cabinets are not installed, maintained, or used properly:

> Leaks in a blasting box can cause exposure. Exposure is also caused by opening the door to the blasting box before the dust had settled. Dust in a blasting box must be removed by a dust collection system to prevent dental lab workers from being exposed to silica (Document ID 1763, p. 2).

ERG (2000) described the effective controls in place in a facility where all five exposure samples were below the LOD (12 μg/m^3), even with use of modeling plaster containing 30 percent silica, and investment casting material containing 70 percent silica (Document ID 0201, pp. 12-15). The controls at this dental laboratory included LEV for mixing, abrasive blasting, and finishing operations, and enclosures and ventilation for mixing dry ingredients, and use of clean blast media for each abrasive blasting session. Other controls used for some tasks in this same facility, which could be used to control elevated exposures that may occur in some dental laboratories, include wet methods for grinding and divesting castings (investment mold breaking), and silica-free abrasive blasting agents (e.g., glass beads, aluminum oxide, walnut shells) (Document ID 0201, pp. 5, 13). Further substitution of non-silica or low silica materials may be possible for abrasive blasting or casting (plaster and investment materials). Mr. Adams of AFGE noted that "materials that contain crystalline silica should be replaced with materials that do not … [such as] aluminum oxide" (Document ID 1763, p. 2). Other silica-free abrasive blasting media used in dental laboratories include walnut shells and glass beads (Document ID 0201, p. 5). In addition to silica-free abrasive blasting media, ERG noted that no silica was detected in the porcelain or die stone materials used at Dental Laboratory A, and stated that "in some cases it may be possible to substitute non-silica or low silica plaster and investment materials for casting" (Document ID 0201, p. 12; 1365, p. 6-10).

Improved housekeeping practices, (i.e., elimination of dry sweeping and compressed air cleaning, and use of high-efficiency particulate air (HEPA) filter-equipped vacuums, daily where necessary) have proven successful in other industries (Document ID 1720, pp. IV-155, IV-157, IV-165). Mr. Adams of AFGE noted the importance of good housekeeping, i.e., that "work areas in the Dental Lab should be kept as free of dust as possible" (Document ID 1763, p. 3).

Based on the best available evidence in the record, OSHA estimates that facilities will need to add or improve controls at the workstations of approximately 3 percent of dental technicians. Where exposures exceed 50 μg/m^3, options for reducing exposure include improved housekeeping (particularly in the areas where refractory molding materials are mixed and the resulting molds broken, and where silica-containing plasters are handled) and work practices, enhanced LEV, use of wet methods, and use of silica-free abrasive blasting agents and non-silica or low silica materials for casting.

4.6.4 Feasibility Finding

Based on the exposure profile in Table IV.4.6-B and other record evidence discussed above, OSHA concludes that dental laboratories can limit the silica exposure during most operations, most of the time, to 50 μg/m^3 or less using currently available technology. The vast majority of dental laboratories currently have effective exposure controls, in that almost all technicians (97 percent) are currently exposed to silica at levels less than 50 μg/m^3, and 83 percent are exposed to levels less than 25 μg/m^3. Accordingly, OSHA finds that a PEL of 50 μg/m^3 is technologically feasible for Dental Laboratories.

4.7 ENGINEERED STONE PRODUCTS

4.7.1 Description

Engineered stone (also called quartz surfaces) is a man-made, composite material comprised mainly of mineral aggregate and resin. Engineered stone products are primarily used as an alternative to granite and other natural rocks for custom countertops although they may be used in other applications such as interior and exterior cladding, table tops, and flooring (Document ID 1365, p. 23-1; 0569, p. 10). Engineered stone product manufacturing is classified under the six-digit North American Industry Classification System (NAICS) code 327999, All Other Miscellaneous Nonmetallic Mineral Product Manufacturing.

The engineered stone discussed in this section is differentiated from other related products, such as manufactured precast concrete, by its very high concentration of silica aggregates and distinctively different production process. The primary component of engineered stone products is ground quartz (usually 93 percent) along with resin, pigments, and other additives (Document ID 0759, p. 2). Other formulations may contain recycled glass or other aggregates and less quartz.

In addition to engineered stone, there are other products made in the United States using a combination of plastic resin and natural stone materials. Cultured marble is an example of a manufactured product that mimics natural stone. OSHA contractors investigated these related industries and found no evidence of silica exposure because these industries use low- or non-silica-containing mineral fillers such as calcium carbonate (Document ID 1365, p. 23-2). Concrete-based products commonly used in outdoor applications are discussed in Section IV-4.3 – Concrete Products.

Instead of the poured mold and curing process utilized for concrete products, engineered stone uses an automated, patented process of vibration, compression under vacuum, and heat to produce engineered stone slabs (Document ID 1365, pp. 23-3-23-4; 0570). Through 2012, only one manufacturer of engineered stone (natural quartz surfaces) operated in the United States under an exclusive rights agreement with the owner of the processing technology (Document ID 1248, p. 1). This is an emerging industry in the

U.S. and OSHA expects that it will continue to grow domestically as engineered stone products grow in popularity among residential and commercial builders and home owners[36] (Document ID 1248, p. 2).

The engineered stone production process begins with receipt of bulk raw materials, primarily ground quartz, bonding resin, and other additives (Document ID 1365, p. 23-2). The raw materials are mixed and processed in a vibro-compression vacuum machine and cured in a constant temperature kiln to produce engineered stone slabs (Document ID 1365, pp. 23-1, 23-3). The slab finishing process includes machine grinding and polishing using wet methods to achieve the desired uniform width and surface finish (Document ID 1365, p. 23-3). The finished engineered stone slabs are shipped to fabrication facilities (covered under Section IV-4.4 – Cut Stone) where they are cut, shaped, and installed (Document ID 1365, p. 23-3).

Workers who might be exposed to silica during the slab production process include production workers who operate automated equipment and perform related activities to support production (e.g., moving bulk materials, collecting samples, cleaning the machines and work areas) (Document ID 1365, p. 23-2; 0650, pp. 1-2).

Material handling and mixing operations are comparable to similar operations in the paint and coatings industry (see Section IV-13 of this technological feasibility analysis) although the engineered stone batch process is more highly automated (Document ID 0650, p. 1; 1365, p. 23-2). Slab finishing is similar to grinding and polishing operations in the cut stone industry (see Section IV-4.4) when wet methods are used. The primary job category, major activities, and sources of exposure for engineered stone products are summarized in Table IV.4.7-A.

[36] The engineered stone industry is well established in other countries, where the product is distributed as a functional substitute for granite. The United States imports more engineered stone than it produces.

Table IV.4.7-A
Job Categories, Major Activities, and Sources of Exposure of Workers in the Engineered Stone Products Industry (NAICS 327999)

Job Category*	Major Activities and Sources of Exposure
Production Worker (equipment operators, (includes material handling. mixing operations, inspections, quality control, maintenance, housekeeping)	Performing intermittent manual production and maintenance tasks (e.g., receiving and storing raw materials, transferring silica-containing raw materials (e.g., ground quartz) from storage to mixing station, performing housekeeping and maintenance). • Dust from manually opening sacks of ground quartz and moving bulk raw materials. • Dust from cleaning and scraping the mixers. • Dust from cleaning baghouse filters, dry sweeping, or using compressed air for cleaning. Monitoring automated processes or engaging in manual process support activities (weighing, dispensing, mixing raw materials; slab finishing). • Dust from raw material transfer stations, hoppers, and mixing stations. • Dust from finishing operations (e.g., cutting, grinding, polishing). • Dust associated with leaks and spills from raw material conveyance ductwork and dust collection systems.

*Job categories are intended to represent job functions; actual job titles might differ, and responsibilities might be allocated differently, depending on the facility.
Source: Document ID 1720, p. IV-128.

4.7.2 Exposure Profile and Baseline Conditions

As indicated in Table IV.4.7-A, potential silica exposure occurs among most plant production workers from a variety of work activities that involve possible exposure sources. A review of the OSHA Information System (OIS) database contained silica sampling data for cut stone and concrete products but no specific data on engineered stone (Document ID 3958). In addition, OSHA received no comments or testimony regarding specific exposures in the engineered stone industry. In the absence of silica exposure data and comments on this application group, OSHA relied on the following descriptive information on engineered stone manufacturing and then extrapolated exposure information from analogous operations to estimate exposures for plant production workers. The descriptive information includes personal communications in 2008 between the OSHA contractor Eastern Research Group (ERG) and an individual familiar with a domestic engineered stone manufacturing facility (Document ID 0650). The interview provided information on the production process, various work activities, controls, and worker exposure conditions (Document ID 0650). Additional information on the same facility was obtained from a 2008 interview and follow-up interview of an individual involved in an OSHA compliance inspection at the facility in 2007 (Document

ID 0816; 0817). The company's silica exposure database was reviewed at the time of the inspection and was described as extensive. The individual results, however, are not available for review (Document ID 1365, p. 23-4; 0817, p. 1). OSHA also relies upon silica sample results from analogous material handling and mixing operations, under the production worker category, in the paint and coatings industry (Section IV-4.13) and slab finishing operations in the cut stone industry (Section IV-4.4) to estimate silica exposures in the engineered stone industry. Engineered stone slabs are further processed by fabrication and installation contractors for end users. Fabrication of finished products from engineered stone and natural stone slabs is covered in Section IV-4.4 – Cut Stone.

Information obtained during the interviews and personal communications describes a highly automated production process where many potential silica exposure points are isolated, fully enclosed, or ventilated (Document ID 1365, pp. 23-2-23-4; 0650, p. 1; 0816, p. 1). Ground quartz is received either in bulk by tanker truck or in large sacks and stored in silos or on racks in the material storage room. Bulk quartz is pneumatically transferred to the mixing hoppers while the sacks of quartz must be opened manually before the contents are dumped by crane into mixing hoppers. The hoppers deliver the raw materials to the mixing room and are equipped with manually activated local exhaust ventilation (LEV) systems, which exhaust to a baghouse. The automated mixing and slab production process is isolated in a separate, ventilated room. Workers only enter this room to perform maintenance between run cycles (Document ID 0650, p. 1). The cured slabs undergo automated wet grinding in an enclosed area to produce a uniform slab width (Document ID 0816, pp. 1-2; 0650, p. 2). The slab surface is polished also using wet methods (Document ID 1365, 23-3; 0650, p. 2). Observations during the OSHA compliance inspection indicated that all processing steps are automated, with very little worker interaction (Document ID 0816, p. 1). One commenter supported these observations, stating that the process used in this engineered stone facility is "among the most automated" of the processes used to make these and similar types of products (Document ID 1769).

John Schweitzer of the American Composite Manufacturers Association testified during the silica hearings that manufacturers of highly-silica filled polymer products such as engineered stones have very few employees potentially exposed to silica, and that this exposure usually occurs when workers handle bags of dry silica material (Document ID 3588, Tr. 3932). Based on the information in the record, discussed further below, OSHA concludes that exposures in the engineered stone industry occur when workers manually open bags containing silica, but that exposures can also occur during machine cleaning, housekeeping, and maintenance activities.

Information obtained from the interview of the individual involved in the OSHA inspection indicated that the facility was free of visible dust (Document ID 0816, p. 1). The interviewee stated that the company knew where the few exposure points were that required respirators (Document ID 0816, p. 1). In the follow-up interview, the interviewee stated that employees with silica exposure were limited but that the facility had some overexposures (i.e., above 100 μg/m^3) to silica (Document ID 0817, p. 1). However, in response to an interview question about tasks where silica exposures exceeded the OSHA PEL, the interviewee answered that there were many overexposures but there were also many engineering controls to reduce exposure and respirator use was required in certain areas of the facility (Document ID 0817, p. 2). There is no additional material in the rulemaking record that would permit OSHA to account for this conflicting information, from the same source, on exposure levels.

All of the information about this facility, however, indicated that the company's air monitoring program was extensive and that it identified some silica exposures that exceeded the previous permissible exposure limit (PEL) (Document ID 0650, pp. 1-2; 0817, p. 1). Silica exposures were said to slightly exceed the 100 μg/m^3 PEL in the material storage room (silo storage and baghouse area) (Document ID 0650, p. 1). The company did require workers to wear respirators in the material storage room and when cleaning the baghouse filters (Document ID 0650, p. 1). Workers also wore respirators when performing maintenance and cleaning in the mixing process room (Document ID 0650, p. 1). The number of employees required to wear respiratory protection was estimated to be 10 percent or less of the workforce (Document ID 0817, p. 1). Housekeeping included the use of HEPA vacuums and compressed air and was routinely performed by most production workers. Wet methods were not used for housekeeping

(Document ID 0650, pp. 1-2). Poor maintenance and condition of the baghouse (located inside the material storage room) and ductwork, due in part to the abrasive nature of the quartz, were described and likely contributed to the silica exposures in the material storage room (Document ID 0650, p. 2). Inappropriate housekeeping methods, such as the use of compressed air, also likely contributed to silica exposures in the plant (Document ID 0650, p. 1).

In the Engineered Stone Products section of the Preliminary Economic Analysis, OSHA estimated the median silica exposure level in this industry to be approximately 98 $\mu g/m^3$ respirable dust, or slightly below the then-applicable PEL (Document ID 1720, p. IV-129). This number was based on the percentage of quartz in the product and a general statement that the company's exposure levels were close to the previous PEL. OSHA has concluded that the information in the rulemaking record on silica exposures in this facility is inadequate to support broad conclusions about the company's, much less the industry's, overall exposure levels. In this FEA, OSHA instead draws conclusions about silica exposures based on sampling data from related industries. OSHA concludes that these new estimates represent a more reliable picture of exposures in the engineered stone industry.

To estimate silica exposures of production workers in the engineered stone industry when they are handling and mixing quartz material, silica sampling data on material handlers and mixer operators from the paint and coatings industry were evaluated. The paint and coatings industry was chosen because of the similar practice of adding bulk silica material to the product (see Section IV-4.13 – Paint and Coatings). The percent silica content of engineered stone is likely higher than in paint and coating products and thus may contribute to higher silica exposures in engineered stone workers. However, the percent silica concentrations in samples from the paint and coatings application group were some of the highest – including one sample containing 67 percent silica – in the OIS database (Document ID 3958, Row 238). In addition, information from ERG's visit to a different manufacturer in the paint and coatings industry indicated that up to half the bags of raw materials being handled by workers contained 70 to 93 percent silica (in the form of cristobalite) (Document ID 0199, p. 4). OSHA expects that any underestimate of exposures due to the higher percentage of silica in engineered stone products is offset by the highly automated material handling and mixing operations in engineered stone manufacturing relative to paint and coatings.

The paint and coatings exposure data for material handlers and mixer operators is based on a total of 23 samples derived from two OSHA Special Emphasis Program (SEP) inspection reports, samples taken at two companies in the paint and coatings industry and contained in the OIS database, and an OSHA contractor site visit (Document ID 0105; 0943; 3958; 0199). Material handlers typically perform tasks involving the transfer, weighing, and dispensing of silica-containing raw material. Eleven samples from four paint and coatings facilities were used to characterize material handler exposure. All 11 samples for material handlers are below 25 μg/m^3 (Document ID 3958, Row 532, 533, 534; 0199, pp. 7, 11; 0105). Since material handling in the engineered stone industry is mostly automated, and there is considerable manual handling in the paint and coatings facilities, OSHA concludes that worker exposure to silica would similarly be at or below 25 μg/m^3 in the engineered stone industry.

Mixer operators perform tasks involving the transfer of raw material to mixing stations and machines. This may involve opening bags of material, weighing material, mixing raw material, and pouring material into hoppers. Twelve personal exposure samples from four facilities are used in OSHA's characterization of mixer operator exposure in the paint and coatings industry. Eight of these samples for mixer operators were below 25 μg/m^3, 1 sample was between 25 μg/m^3 and 50 μg/m^3, and 3 samples exceeded the new PEL of 50 μg/m^3 (Document ID 3958, Rows 238, 239; 0199, p. 7, 11; 0943; 0105). While the median exposure level for all 12 mixer operator samples is 13 μg/m^3 (the LOD), all three samples over the new PEL exceeded 200 μg/m^3 (Document ID 3958, Row 238; 0943; 0199, p. 11).

OSHA determined that exposures among material handlers and mixer operators in the paint and coatings industry are due primarily to airborne dust generated as: 1) bags are opened, 2) materials are transferred into hoppers, and 3) empty bags are compressed for disposal. The Agency also determined from a site visit to a paint manufacturer that exposures are higher when LEV is not available (Document ID 0199, pp. 9-10). Sampling data from the OSHA contractor (ERG) site visit in the paint and coatings industry provide clear evidence of how LEV is instrumental in preventing silica exposure in material handling and mixing operations. At this paint manufacturer, material handlers and mixer operators were handling bags of silica-containing material. As many as half the bags contained 70 to 93 percent cristobalite (a form of crystalline silica) and many of the other bags contained up to 30 percent quartz (Document ID 0199, p. 4). Fourteen of fifteen full-shift TWA PBZ samples indicated no measurable levels of respirable quartz or respirable cristobalite (Document ID 0199, pp. 7, 11).[37] Most of the sample results represent a typical, routine work shift, during which the local exhaust ventilation systems were operating (Document ID 0199, pp. 8-9). One sample on a mixer operator, however, found a respirable quartz level of 263 μg/m³ (Document ID 0199, p. 11). The LEV system was not operating for approximately two hours in the morning while this mixer operator added raw materials to the dispersion tanks while producing a paint batch (Document ID 0199, p. 9). The resulting high level of exposure demonstrates how exposure levels can spike when the LEV is not operating and, by negative inference, illustrates the effectiveness of LEV in controlling exposures for material handlers and mixer operators. In another example from the paint and coatings industry of the importance of LEV in controlling silica exposure, an OSHA inspection found a silica exposure of 237 μg/m³ in a sample taken on a mixer operator during a period in which the OSHA compliance officer noted only general dilution ventilation was being used (Document ID 3958, Row 238). Since the mixing area in the engineered stone industry is automated and the mixing hoppers are equipped with LEV, OSHA concludes that the exposures greater than 200 μg/m³ are not representative of the engineered stone manufacturing process; the samples above 200 μg/m³ from a paint manufacturer were taken while workers manually charged an unventilated (or poorly ventilated) mixer (Document 0199, pp. 9-10; 3958, Row 238; 0943). OSHA expects that the exposure levels for mixer operators in engineering stone facilities will ordinarily be below the new

[37] OSHA excluded one of the fifteen samples from its exposure profile, as the laboratory technician does not fall under one of the relevant job classifications of material handler and mixer operator.

PEL of 50 µg/m³, similar to exposure levels for most mixer operators using LEV in the paint and coatings industry.

A number of limitations exist in comparing exposure levels in the engineered stone and paint and coatings industries. An important difference is that the engineered stone industry is a relatively new industry with modern plants that use highly automated material handling and mixing processes, including integrated LEV. The results from the paint and coatings industry reflect considerable manual handling of packaged and bulk raw materials, which increases the exposure risk to material handlers (Document ID 1365, p. 9-9; 0943; 0105). Another difference between these two industries is that because of the highly automated process in engineered stone manufacturing, production workers in this industry do not operate as material handlers or mixer operators on a full time basis. The workers perform a variety of tasks across the production process, including housekeeping (which contributes to the production operators overall exposure). This variety of tasks which results in less time spent in material handling and mixing (Document ID 0650, pp. 1-2).

Slab finishing processes in the engineered stone industry, such as grinding and polishing slabs, can result in worker exposure to silica. These operations are part of the production process and are done by machine using wet methods. The cut stone industry (Section IV-4.4 – Cut Stone) also processes natural stone (granite, etc.) slabs using cutting, grinding, and polishing procedures. The silica content of engineered stone is likely higher than natural stone products and may contribute to higher silica exposures in engineered stone workers. However, the highest percent silica concentration sample in the OSHA OIS database for cut stone was 71 percent respirable silica (Document ID 3958, Row 1084). OSHA expects that any underestimate of exposures in engineered stone facilities due to a higher percentage of silica will be offset by the fact that the engineered stone manufacturing process is better controlled.

To estimate silica exposures from slab finishing operations in the engineered stone industry, OSHA reviewed approximately 85 recent silica samples from the OIS database on fabricators involved in grinding and polishing activities in the cut stone industry

(Document ID 3958). From this sample group, samples where fabricators performed grinding and polishing operations using wet methods were selected, as this closely resembles the wet method controls used in machine grinding and polishing in the engineered stone industry.[38] OSHA eliminated samples involving cutting, samples with no mention of wet methods being used, and samples where handheld tools were used, because these samples did not represent similar exposure conditions to those in the engineered stone industry. The resulting nine samples ranged from 16.4 μg/m³ to 91.8 μg/m³ with a mean silica exposure level of 33.6 μg/m³ and a median exposure level of 27.9 μg/m³ (Document ID 3958, Rows 1015, 1088, 1018, 1004, 1001, 1017, 1003, 1002, 933). The highest silica exposure (91.8 μg/m³) occurred during a granite polishing operation using a wet method (Document ID 3958, Row 933). The sample information also noted the use of fans to move dust from the shop, which may have contributed to this exposure level. Four other samples from polishing operations had silica exposure levels below the new action level of 25 μg/m³ and one polishing sample was between the action level and the new PEL (Document ID 3958, Row 1015, 1088, 1004, 1018, 1003). The remaining three samples were from grinding operations. These results ranged from 27.9 μg/m³ to 39.3 μg/m³, all between the new action level of 25 μg/m³ and the new PEL of 50 μg/m³ (Document ID 3958, Rows 1001, 1017, 1002). Based on these data, OSHA expects that most exposures to silica during wet grinding and polishing operations in the engineered stone industry will be under the new OSHA PEL of 50 μg/m³.

4.7.3 Additional Controls

OSHA finds that, because existing controls in this relatively new and modernized industry likely maintain exposure levels below the final PEL of 50 μg/m³ most of the time, no additional engineering controls are likely to be necessary for most of these operations. The engineered quartz slab manufacturing plant evaluated by OSHA was a new, proprietary-built plant (constructed around 2000) with engineering controls and automated material handling and slab processing machinery designed to minimize dust generation (Document ID 1365, p. 23-7; 0816, p. 1). A comment from a representative of

[38] The use of wet methods by cut stone fabricators is sporadic, as demonstrated in a Washington state study in which only one-third of the fabricating facilities evaluated were primarily using wet methods at the time of the initial visit (Document ID 1146, pp. 578-579).

a distributer of stone-working equipment noted that most large scale or high volume new equipment is being manufactured with dust control in mind and reiterated that most large grinding machines are water-fed and equipped with dust collectors (i.e., LEV) (Document ID 1156). New equipment has the added advantage of increased automation, allowing the production workers to operate at a distance from the dust source.

Production workers in engineered stone products facilities are reportedly exposed to silica from intermittent work activities such as bulk bag opening (material handling), for mixing operations, mixing machine cleaning, compressed air use, and baghouse maintenance (Document ID 0650, p. 1). If additional administrative controls are necessary, they could include an improved method of opening and handling the large sacks of quartz prior to mixing to avoid creating dust. Engineering control technology is being used for most sources of exposure, but poor maintenance and rapid deterioration of the material delivery and exhaust ventilation ducting could result in exposure to airborne silica above the 50 µg/m³ PEL (Document ID 0650, p. 2). A new production line at the engineered quartz slab manufacturing plant discussed above that incorporates (undisclosed) improvements in the design of the line, as well as the use of more durable material in the pneumatic material delivery and local exhaust ventilation systems (ceramic ductwork), will reportedly improve performance of these systems (Document ID 0650, pp. 2-3). The new mixing area, in particular, can further control silica exposures during production operations such as through implementation of improved housekeeping procedures (e.g., eliminating the use of compressed air) and duct work maintenance; however, supporting exposure data are not available to OSHA (Document ID 1365, p. 23-5; 0650, p. 2)

To maintain worker exposures at or below 50 µg/m³, facilities will need to increase inspection and maintenance of pneumatic conveying systems (including the exhaust ventilation system). The extremely hard quartz particles abrade ductwork and eventually damage duct integrity, causing the system to leak. Specific concepts evaluated as improvements to the existing production line include installing new baghouses, replacing ductwork with ceramic piping for pneumatically conveyed raw materials, enhancing housekeeping, and using HEPA vacuums instead of compressed air (Document ID 0650, pp. 1-2). Additionally, as discussed in Section IV-4.4 – Cut Stone, rigorous control of water from wet processes prevents dust from being disturbed and becoming airborne after water evaporates (Document ID 1365, p. 11-21).

A potentially significant source of silica exposure in this industry is the use of compressed air for cleaning and housekeeping purposes. The information obtained during the interviews with a manufacturer described compressed air used for cleaning and listed the raw material storage and baghouse areas as locations where HEPA-filtered vacuums might be an option for cleaning (Document ID 0650, pp. 1-2). OSHA expects that in the engineered stone industry, using HEPA-filtered vacuums to clean surfaces contaminated with quartz dust and eliminating the use of compressed air for this purpose will substantially reduce airborne dust levels in the material handling area of the plant.

4.7.4 Feasibility Finding

OSHA received no comments related to the technological feasibility of the proposed rule for engineered stone manufacturing. Based on the above analysis, OSHA has determined that exposures for most production workers can be kept at or reduced to below 50 $\mu g/m^3$ with existing engineering controls that are operating within manufacturers' specifications and properly maintained. Comparable exposure data from material handling and mixing operations in the paint and coatings industry show 20 of 23 samples (87 percent) below the final PEL of 50 $\mu g/m^3$. Comparable exposure data on grinding and polishing operations in the cut stone industry using engineering controls similar to those in engineered stone manufacturing show 8 of 9 samples (89 percent) below the new PEL of 50 $\mu g/m^3$. OSHA concludes from these data that, with proper engineering controls such as wet methods and LEV, proper housekeeping, and regular maintenance of material delivery and ventilation systems, most exposures in production operations in the Engineered Stone industry where silica exposure is likely to occur can be kept at or reduced to below 50 $\mu g/m^3$ most of the time. Facilities should have a routine schedule for inspecting, maintaining, and replacing worn materials-handling and dust control systems with more durable materials to ensure that raw material conveyance ducts and dust collection systems work efficiently. Even then, because of the high silica content of the raw materials (93 percent quartz), OSHA expects that some workers will continue to experience elevated intermittent exposures during maintenance tasks, particularly in baghouses and raw material storage areas, and while cleaning the mixing machines. OSHA acknowledges that respirator use may be necessary during these short-term tasks to protect workers from exposures above the PEL.

Thus, OSHA concludes that, by controlling exposures to airborne dust generated during engineered stone production work like material handling, mixing, and slab finishing operations, engineered stone operations, most manufacturers can achieve exposure levels of 50 $\mu g/m^3$ or less for most workers, most of the time. Therefore, OSHA finds that the final PEL of 50 $\mu g/m^3$ is technologically feasible for the Engineered Stone Products industry when baseline and additional controls previously discussed are used. Supplemental respirator use may be necessary, however, for some maintenance activities.

4.8 FOUNDRIES (METAL CASTING)

Foundries melt and cast metal in molds to produce precisely formed metal castings, which workers then trim and clean to create finished products. Major end-use markets for these metal castings are manufacturers of automotive parts, pipe, industrial machinery, transportation equipment, and aerospace equipment. Depending on the casting processes used, workers in as many as a dozen foundry job categories work directly with materials that contain silica, including sand used to create molds, refractory mold release agents, furnace linings, and residual sand mold material that adheres to castings and scrap metal (Document ID 1365, p. 2-1).

Workers can be exposed to silica at many points throughout the coremaking or casting process. Table IV.4.8-B provides a list of the job categories and major sources of silica that contribute to workers' exposures. For the purpose of this analysis, OSHA has divided the foundry industry into four subsectors, based primarily on the types of metal and processes employed:

- Ferrous sand casting foundries.
- Nonferrous sand casting foundries.
- Non-sand casting foundries (ferrous and nonferrous).
- Captive foundries.

This division of the foundry industry into ferrous and non-ferrous casting is consistent with how foundries were divided in the Preliminary Economic Analysis (PEA) and is also consistent with the approach to describing the foundry industry presented by the American Foundry Society (AFS) (Document 2379, Attachment 2, p. 42). Non-sand casting foundries were analyzed separately since this type of foundry does not use large quantities of sand containing crystalline silica, and thus has a lower exposure to respirable crystalline silica (RCS). Captive foundries can be either ferrous or non-ferrous casting, but are analyzed separately for economic reasons since these are associated with various manufacturing industries other than foundries.

Ferrous sand casting foundries are foundries that produce molded products from molten iron or steel. They employ a major share of foundry workers potentially exposed to silica and are covered extensively in the first part of this section. Separate discussions are then presented for the other foundry sectors. Table IV.4.8-A shows the four foundry sectors and the associated North American Industry Classification System (NAICS) industries.

Sand casting is used to produce an estimated 60 percent of all cast metal products, both ferrous and nonferrous (Document ID 1460, pp. 27-28). The silica exposure hazards of casting using sand molds are far greater than those of casting methods not involving sand, such as permanent casting and die casting (Document ID 1365, p. 2-1; 1382). Therefore, the discussion in this section focuses on job categories with potential for silica exposure applicable primarily to sand casting foundries.

Among sand casting foundry workers, the workers at ferrous foundries typically have higher silica exposures than workers in other types of metal casting facilities, primarily because the higher temperatures required for melting ferrous metals, such as iron and steel, result in sand molds that are hotter, drier, and hence dustier than in other metal casting facilities (Document ID 1365, pp. 2-1 – 2-2; 0926). Although data from all types of ferrous sand casting foundries (NAICS 331511 and 331513) are included in OSHA's analysis of ferrous sand casting foundries, silica exposures of workers in gray and ductile iron foundries, (NAICS 331511) serve as the primary basis for discussion, since these foundries are the most numerous and the best studied with respect to worker exposure to silica.[39] While the potential for exposure is higher, the recommended controls to reduce workers' exposures in gray and ductile foundries are applicable to other foundries. Therefore, workers in these foundries serve as a basis of comparison for the three other major foundry groups addressed later in this foundry industry analysis.

[39] Gray iron is a type of cast iron known for its high compression strength but low ductility. Ductile Iron is a kind of malleable iron known for its high ductility (ability to deform and high tensile strength).

4.8) Foundries (Metal Casting)

Table IV.4.8-A
Foundry Sector NAICS

Foundry Sector	**NAICS Industries**	**Comment**
Ferrous Sand Casting Foundries	331511, Iron Foundries 331513, Steel Foundries (except Investment)	Foundries in these NAICS industries perform sand casting.
Nonferrous Sand Casting Foundries	331524, Aluminum Foundries, (except Die-Casting)—Part* 331525, Copper Foundries (except Die-Casting)—Part* 331528, Other Nonferrous Foundries (except Die-Casting)—Part*	Foundries in these NAICS industries perform sand casting.
Non-Sand Casting Foundries	331524, Aluminum Foundries, (except Die-Casting)—Part* 331525, Copper Foundries (except Die-Casting)—Part* 331528, Other Nonferrous Foundries (except Die-Casting)—Part* 331512 Steel Investment Foundries	Foundries in these industries do not perform sand casting.
Captive Foundries	Various manufacturing industries	Foundries in this sector perform metal casting as part of a parent company's operations. Captive foundries can be either sand casting or non-sand casting foundries

* "Part" included in the notation means that only part of this NAICS group is included in the indicated foundry sector, while the remainder of the group is included in another foundry sector. For example, some of the aluminum foundries in NAICS 331525 perform sand casting (placed in the non-ferrous sand casting foundry sector) and the remainder performs non-sand casting (in the non-sand casting foundry sector).

4.8.1 Ferrous Sand Casting Foundries

Description – Ferrous Sand Casting Foundries

The metal casting industry is diverse, employing many different casting processes for a wide variety of applications. The production of castings using sand molds includes the following basic processes: 1) preparing a mold, and often a central core; 2) melting and pouring the molten metal into the mold; and 3) cleaning the cooled metal casting to remove molding and core material and extraneous metal (Document ID 1368, p. 3). The sand molds are formed using moist sand created by mixing sand and clay. This malleable mixture is termed "green" sand.

The volume, size, and type of castings produced vary widely from one foundry to another, ranging from a few large specialized castings to thousands of small castings per shift. Depending on the size of the foundry, operators might be responsible for a single task or several tasks. In high-production foundries, workers are likely to be responsible for a single task (e.g., molder, core maker, shakeout operator), whereas in small shops a single worker might be assigned to several operations, such as combined responsibilities for furnace operation, hot metal transfer, and pouring (Document ID 1365, pp. 2-11 – 2-12; 1382).

Table IV.4.8-B presents a summary of the job categories, major activities, and primary sources of silica exposure of workers in sand casting foundries. For detailed descriptions of jobs, see Document ID 1365, pp. 2-11 – 2-95. The list of job categories presented in Table IV.4.8-B was developed based on review of more than 50 case files, numerous site visits conducted by the OSHA consultant, Eastern Research Group (ERG), and a variety of reports issued by NIOSH (Document ID 1365, p. 2-15). The categories are consistent with the exposure data presented by the American Foundry Society (AFS). In fact, of the over 8,000 exposure measurements described by AFS, 90 percent fall into the job categories listed by OSHA (Document ID 2379, Appendix 1, p. 9).

In addition to the categories listed in Table IV.4.8-B, foundries typically conduct the following operations in which the metal parts are further shaped or treated after they have been formed, unmolded and cooled: pattern-making, welding, arc-air gouging, heat treating, annealing (heat hardening), X-ray inspection of castings, machining, and buffing. However, these operations are not associated with substantial silica exposure and often take place in areas of the foundry that are not associated with sand and the metal molding process. For this reason, they are not discussed in detail in this analysis. Additionally, as described by Frank Mirer, currently at CUNY School of Public Health, who was the Director of Safety and Health at the United Auto Workers (UAW) for 25 years, for many job categories that do not involve working with silica containing materials, the primary source of silica exposure is the cross contamination from silica-emitting processes (Document ID 4204, Attachment 1, p. 31). Therefore, OSHA concludes that, to the extent there is exposure for workers performing these operations, reducing silica exposures from other sources will reduce exposures for these job categories as well.

Table IV.4.8-B
Job Categories, Major Activities, and Sources of Exposure of Workers in Ferrous Sand Casting Foundries

Job Category*	Major Activities and Sources of Exposure
Sand Systems Operator	Controlling processing and mixing of new sand, recycled sand, and mold or core additives in mixer (muller) or sand reclamation equipment. Sand is typically fed via hoppers. Might be batch or continuous. • Dust released during loading of hoppers. • Dust released during sand transport. • Dust raised by using compressed air for cleaning.
Molder	Monitoring molding machine operation. Might apply mold parting/coating compound. • Dust generated by handling dry cores and refractory mold coatings (washes). • Dust raised by using compressed air for cleaning mold surfaces. • Dust released by adjacent operations.
Coremaker	Overseeing transfer of mixed sand and additives to automated coremaking equipment. Cleaning and finishing cores. Applying core coatings. • Dust created by grinding, filing, and sanding cores. • Dust raised by using compressed air for cleaning. • Dust released by adjacent operations.
Furnace Operator	Controlling and monitoring furnaces used to produce molten metal. In small operations, might hand-load metal into furnaces. • Dust generated as furnace emissions. • Dust from molding sand adhered to scrap metal for remelt. • Dust from adding sand to molten metal (e.g., stainless steel). • Dust released by adjacent operations.
Pouring Operator	Transferring molten metal into ladle or holding furnace, then into molds, typically via a crane or monorail configuration. • Dust released by adjacent operations.
Shakeout Operator	Overseeing shakeout operation. Contact with equipment and castings depend on the degree of automation. • Dust generated by agitating, breaking, and separating molds from castings.
Knockout Operator	Removing sprues, gates, and risers (waste metal that is formed as molten metal passes through the cone-shaped conduit needed to fill the mold) from castings. • Dust generated by the use of hammers and saws to remove excess metal from the castings. • Dust released from adjacent operations.

Table IV.4.8-B Job Categories, Major Activities, and Sources of Exposure of Workers in Ferrous Sand Casting Foundries	
Job Category*	**Major Activities and Sources of Exposure**
Abrasive Blasting Operator	Cleaning residual mold or core material from castings typically operating an abrasive blasting cabinet. • Dust generated by performing shotblasting on open floor (if the casting is large) or in blasting booth. • Dust raised by using compressed air for cleaning surfaces. • Dust released from poorly maintained abrasive blasting cabinet. • Dust released form adjacent operations.
Cleaning/Finishing Operator	Removing remaining molding sand from castings. • Dust generated by using portable or bench tools such as chippers, grinders, and polishers. • Dust raised by using compressed air for cleaning surfaces.
Material Handler	Transporting sand, castings, or other materials using a front-end loader, forklift, or other material moving equipment. • Dust generated when adding or removing materials from the sand system. • Dust raised by manually sweeping or shoveling dry sand. • Dust raised by using compressed air for cleaning surfaces. • Dust released from adjacent operations.
Maintenance Operator	Repairing and maintaining foundry and sand-handling equipment. Might perform repair and maintenance of refractory furnace linings. • Dust released during repair and maintenance of equipment. • Dust generated during removal of old refractory linings using hammers, pneumatic chisels, and jackhammers. • Dust released from adjacent operations.
Housekeeping Worker	Removing spilled sand and debris from floors, conveyor discharges, abrasive machines, and dust collectors. • Dust raised during dry sweeping, vacuuming, shoveling, or front-end loader operations.
*Job categories are intended to represent job functions; actual job titles may differ and responsibilities may be allocated differently, depending on the facility. Source: Document ID 1365, p. 2-13.	

Ferrous Sand Casting Foundries—Exposure Profile and Baseline Conditions

To develop the exposure profiles for these job categories, OSHA compiled the best available data from all identified industrial hygiene literature that included sample information, and exposure monitoring conducted at selected site visits, using only information from 1990 to the present. OSHA relied on OSHA Special Emphasis Program (SEP) inspection reports, NIOSH reports, reports from state programs that performed workplace evaluations, and from OSHA Information System (OIS) data ranging from 2010 through 2014 (Document ID 1365, pp. 2-15 – 2-17; 3958).

The exposure profile for ferrous sand casting foundries appears in Table IV.4.8-E. The profile includes a total of 838 full-shift (8-hour) personal breathing zone (PBZ) samples, covering the twelve distinct job categories in Table IV.4.8-B. The overall median exposure is 58 μg/m^3, the mean is 131 μg/m^3, and the range is 6 μg/m^3 (LOD) to 5,851 μg/m^3. Of the 838 samples, 457 (54.5 percent) are above 50 μg/m^3, and 244 (29.1 percent) exceed 100 μg/m^3.

In their comments, AFS identified 11 of the foundries contained in the case studies used in this analysis. Five of these foundries are now out of business. AFS argues that OSHA should disregard data from defunct establishments when establishing feasibility. Furthermore, AFS believes that these defunct foundries can be used as examples to provide evidence of infeasibility (Document ID 4229, p. 17).

OSHA disagrees with AFS's assertions that the sampling data from these foundries should be disregarded. The AFS provided no explanation to support its assertion that these foundries went out of business as a result of being required to comply with the previous PEL. In addition, the exposure profiles are intended to be representative of the range of exposures in the foundry industry, and these foundries likely represent working conditions in foundries that that have not ceased operations, and should be included in OSHA's exposure profile. OSHA concludes that the case studies – even those representing establishments that are no longer operating – provide useful information on the job processes and resulting exposures, because the same activities continue to occur in other foundries. Furthermore, the 63 samples from these five foundries represent less than 5% of the 1267 samples from over 98 foundries included in the exposure profiles for the foundry industry, and therefore, removing or retaining these samples does not significantly alter the exposure profile.

The UAW submitted summary data that show geometric mean exposures at two foundries. Data from the first foundry, the General Motors Defiance foundry, show that geometric mean exposures remained below the previous PEL from 1998 through 2013, except for one year (Document ID 4031, Attachment B2). The second data set, from the General Motors Saginaw foundry, shows that geometric mean exposures remained below the previous PEL from 1998 through 2013 (Document ID 4031, Attachment E2). OSHA has not incorporated this data set in the exposure profile because individual personal breathing zone (PBZ) samples and job descriptions were not provided. However, while the data from this set tend to show slightly lower exposures than in OSHA's profile, the range of exposures is consistent with OSHA's data.

AFS also submitted to the record a survey it conducted to which 92 establishments, involving more than 8,000 workers, responded (Document ID 2379, Attachment 2, p. 27). These data show that 50 percent or more of the samples in 12 of the 13 job categories identified by AFS are below the 50 μg/m^3 PEL, which indicates that a PEL of 50 μg/m^3 is feasible for most of these job categories. AFS argues that "OSHA's data are 10 to 35 years old and significantly overstate current exposures," and that "the number of current workers exposed to levels of silica above 100 μg/m^3 is less than half of the number OSHA uses in the PEA" (Document ID 2379, Attachment 2, p. 27). As discussed further below, OSHA has updated the data used in the final exposure profile although, as in the case of the UAW data, OSHA has not included AFS data in the final exposure profile because individual PBZ results were not provided.

OSHA reviewed the AFS survey data that was submitted to the record and compared that data to exposure data from the PEA exposure profile and the more recent data from OSHA's OIS database (see this comparison in Table IV.4.8-C below). The more recent OIS data, which is from 2010 through 2014, and the AFS survey data indicate that exposures generally continue to be reduced in the foundry industry.

Table IV.4.8-C
AFS Survey Data Compared to PEA and OIS Data (2010-2014)

Job Category	**Percent exposed ≤ 50 µg/m³**			**Percent exposed ≤ 100 µg/m³**		
	AFS (%)**	**PEA* (%)**	**OIS (%)**	**AFS** (%)**	**PEA* (%)**	**OIS* (%)**
Sand Systems Operator	47	23	71	70	59	---
Molder	63	51	93	91	80	---
Coremaker	73	58	86	96	87	---
Furnace Operator	70	62	---	93	62	---
Pouring Operator	67	50	50	93	67	50
Shakeout Operator	58	40	54	77	70	91
Knockout Operator	52	46	43	90	65	86
Abrasive Blasting Operator	63	31	30	83	59	50
Cleaning/Finishing Operator	62	37	34	81	56	48
Material Handler	79	47	75	94	78	---
Maintenance Operator	74	42	---	93	67	---
Housekeeping Worker	72	28	---	80	71	---
Other	71	NA	70	21	NA	95
Total Exposed	**67**	**43**	**63**	**87**	**69**	**82**

* PEA and OIS data correspond to ferrous sand casting foundries.
** AFS did not specify the distribution of which types of foundries responded to the survey
Sources: Document ID 3958; 1720, p. IV-136; 2379, Attachment 2, p. 27.

Additionally, the AFS provided an analysis for the difference between the exposure profile presented in the PEA and the summary data from the AFS survey. AFS states (Document ID 2379, Attachment 2, p. 27):

> The difference between the older OSHA enforcement data and the current foundry data not only reflects continued efforts to reduce exposures, but also reflects a significant bias in the OSHA data. One reason for this is that OSHA uses high bias data from enforcement. There is a tendency for compliance officers to sample employees whose exposure is perceived to be the highest. Follow up sampling tends to be focused where problems have been found, so the sample database is further skewed toward higher exposures rather than a non-biased statistical sample. These sample data are not random and are not statistically representative.

OSHA agrees with AFS that the exposure profile from the PEA may overestimate exposures, as the OIS data also shows. For consistency, OSHA used only individual measurements in the exposure profiles. Given the absence of individual sample results in the AFS data, OSHA has relied upon the data from the PEA and augmented it with data from OIS and from the rulemaking record when the data included individual data points and sample descriptions. Nonetheless, the AFS data is useful to the agency in supporting its overall finding that a PEL of 50 μg/m^3 is technologically feasible for the foundry industry.

As the AFL-CIO noted regarding the AFS survey, "[t]he AFS data state that 67 percent of foundry operations, weighted for job distribution, are now below the 50 μg/m^3 PEL. This would appear to be 'most of the operations,' a criterion for feasibility" (Document ID 4204, p. 29). OSHA agrees with the assessment from the AFL-CIO that the AFS data indicate that, overall, exposures are already predominantly below the final PEL.

In addition to its own enforcement data, for this final exposure profile OSHA is also relying on data collected by NIOSH, individual States' evaluations, and the stakeholder public which constitute the entirety of publicly available and submitted data. To make the final exposure profile as representative as possible, and based on the stakeholder comments, OSHA has, in accordance with its general methodological approach to final exposure profiles, (see Section IV-2 – Methodology) modified the exposure profile for foundries to remove older exposure data and update the profile with more recent data available in the record. Thus, all samples collected prior to 1990 – a total of 154 samples – have been excluded from the final profile. The more recent OIS data, constituting 266 samples collected between 2010 and 2014, were added to the final profile.

In Table IV.4.8-D, OSHA has provided a new comparison of the data submitted by AFS and the final exposure profile. While the OSHA profile still tends to overestimate exposures compared to the AFS data partly due to the enforcement bias of the OIS data as discussed above, OSHA is convinced, based on the entirety of the rulemaking record, that its profile is a reasonable representation of the current exposures.

Baseline working conditions vary among facilities, and industries use a variety of controls, ranging from no controls to comprehensive facility-wide control strategies. As a result, foundries experience a wide range of exposures. Baseline conditions can be described by the distribution of exposures for each job category.

Table IV.4.8-D below shows that despite uncertainties in the biases inherent in the AFS survey data, the final exposure profile in the Final Economic Analysis (FEA) likely overestimates exposures in comparison to the AFS survey data. Comparison of the exposure data in the FEA to that in the Preliminary Economic Analysis (PEA) suggests that the final exposure profile reflects reductions in the percentage of measurements above 50 μg/m^3 in 9 out of 12 job categories. This reduction is likely due to the removal of older (pre-1990) data and replacement with newer OIS data (2010-2014).

Table IV.4.8-D.
AFS Survey Data Compared with FEA Exposure Profile

Job Category	**Percent ≤ 50 μg/m³**		**Percent ≤ 100 μg/m³**	
	AFS (%)**	**FEA* (%)**	**AFS** (%)**	**FEA* (%)**
Sand Systems Operator	47	38	70	63
Molder	63	57	91	84
Coremaker	73	57	96	87
Furnace Operator	70	73	93	73
Pouring Operator	67	50	93	70
Shakeout Operator	58	43	77	63
Knockout Operator	52	51	90	74
Abrasive Blasting Operator	63	33	83	59
Cleaning/Finishing Operator	62	35	81	54
Material Handler	79	50	94	81
Maintenance Operator	74	46	93	71
Housekeeping Worker	72	36	80	91
Other	71	NA	21	NA
Total Exposed	67	46	87	71

* FEA data correspond to ferrous sand casting foundries.
**AFS did not specify the distribution of which types of foundries responded to the survey
Sources: Document ID 3958; 1720, p. IV-136; 2379, Attachment 2, p. 27.

Relatively Well-Controlled and Poorly Controlled Foundries

Among the foundries with exposure results included in the Table IV.4.8-E are two subsets of facilities selected to represent foundries in which silica is relatively well controlled and foundries in which it is poorly controlled. OSHA reviewed reports from several foundries that have been relatively successful in reducing exposures and several that experienced widespread elevated exposures. The Agency focused on foundries where OSHA, NIOSH, or a State agency had collected air samples for multiple job categories and provided some documentation of working conditions at the time. OSHA then compared the exposure controls and work practices reported in the documentation for each (Document ID 1365, pp. 2-18 – 2-19).

Specifically, the group of relatively well-controlled foundries includes facilities at which the majority of the full-shift results were less than or equal to 50 $\mu g/m^3$, although a few results occurred above that level. These results indicate the level of silica exposure that workers can experience in foundries where their own activities generate little airborne silica and, at the same time, where other sources are also limited. The group of relatively well-controlled foundries includes four gray and ductile iron foundries evaluated in 1989, 1994, 1997, and 1999 (Document ID 1365, pp. 2-18 – 2-19; 1409, pp. 2, (pdf) p. 10; 0268, pp. 3, 6 and Table 2; 0147, pp. 49, 51, 70-93; 0082, pp. 3, 37, 59-64, 186). The four poorly controlled foundries are three gray and ductile iron foundries and one stainless steel foundry that range in size from 55 to 340 production workers. Two of these facilities were evaluated in 1992, while the others were visited in 1996 and 1999 (Document ID 1365, pp. 2-18 – 2-19; 1463, p. 3 and Table 2 (pdf) pp. 26-29; 1379, p. 2 and Table 2 (pdf) pp. 24-25; 0080, pp. 52, 54, 56-220; 0131, pp. 8, 15, 17, 25-26, 29-72).

The well-controlled foundries and the poorly controlled foundries were well matched with respect to size. The range of the number of production workers for the four well-controlled foundries was 39 to 400 workers (Document ID 0082, p. 3; 0147, p. 49; 0268, p. 3; 1409). For the poorly controlled foundries, the production employment range was 55 to 420 workers (Document ID 0080, p. 54; 0131, p. 15; 1379, p. 2; 1463, p. 3). OSHA does not have the information to compare the two groups with respect to other characteristics such as size of castings, and process details. However, the agency has no reason to believe that these foundries differ significantly except in the implementation of worker exposure controls.

The relatively large number of measurements available to OSHA for ferrous sand casting foundries (838 silica sample results) permits a more detailed treatment for foundries than other industry sectors for which OSHA has more limited data sets. The evaluation of well-controlled and poorly controlled facilities allows OSHA to understand the impact of facility-wide control on overall exposures.

The review of relatively well-controlled and poorly controlled foundries shows some clear distinctions between the two groups. The relatively well-controlled facilities were more likely to have installed enclosures and local exhaust ventilation (LEV) for dusty activities, such as for sand-handling equipment, shakeout, knockout, and cleaning/finishing tasks. These foundries were also more likely to have automated processes, such as for mold making or core making, routine grinding, shot-blasting, and conveying parts into enclosures for dusty processes (shakeout, shot blast equipment). Workers normally controlled these processes remotely, sometimes from behind partitions. Additionally, records describing these foundries are more likely to note other special controls in place to reduce airborne silica dust. Examples include adding pneumatic sand transport equipment, using washed lake sand (with low respirable-sized particle content), and purchasing sand additives premixed (because the mixing process released additional dust) (Document ID 1365, pp. 2-18 – 2-19; 1409, p. 2; 0268, pp. 7-8; 0147, pp. 53, 72-75; 0082, pp. 88-89, 91, 120, 135).

The poorly controlled facilities tend to rely more heavily on general exhaust ventilation (ceiling or wall fans not associated with any specific process). Notes on the facilities often commented on the lack of LEV (or on having LEV installed for a process such as welding, but not for adjacent processes associated with elevated silica levels, such as grinding in the cleaning/finishing area). Sand systems equipment (e.g., sand mill or reclaimer) were more likely to be unventilated, require maintenance and/or leak. Leaking equipment often contributes to the exposure of workers in more than one job category. For example, OSHA reported that the reclaimed sand mill at one foundry contributed to the silica exposure levels of a material handler and several cleaning/finishing operators who worked nearby. Furthermore, these foundries used compressed air extensively to remove silica contamination from surfaces, a practice that was associated with multiple job categories (Document ID 1365, pp. 2-18 – 2-19; 1463, pp. 18-19; 1379, pp. 7, 15; 0080, p. 16; 0131, pp. 12, 73).

Additionally, Dr. Mirer similarly observed in written testimony that many workers' silica exposures are due to dust released from adjacent operations. He stated that if these dust releases are controlled, the exposures of workers in adjacent areas will be substantially reduced, as follows:

> For molder, coremaker, furnace operator, knockout operator, abrasive blasting operator, material handling, and maintenance operator, "dust released from adjacent operations" is listed as a source of exposure, and is listed as the only source for pouring operator. Thus, for furnace operators (median 34 μg/m^3, mean 109 μg/m^3) and pouring operators (median 48 μg/m^3, mean 79 μg/m^3), their own activities at their work stations do not emit silica. Yet, these workers suffer substantial silica exposures. This demonstrates that a cloud of silica permeates these factories, and some fraction, perhaps 40 μg/m^3, of the median exposure would be reduced by control of other, silica-generating operations (Document ID 4204, p. 104).

The importance and feasibility of controlling all sources of silica and its effect on exposure to workers in other job categories is thus reflected in the final exposure profile and its representation of baseline conditions in both well-controlled and poorly controlled facilities, as well as those falling in between those two extremes.

Exposure Profile and Baseline Conditions for Sand Systems Operators

The exposure profile in Table IV.4.8-E for sand system operators includes 56 samples of respirable crystalline silica.[40] The median exposure is 74 μg/m^3, the mean is 197 μg/m^3, and the range is 11 (<LOD) to 2,430 μg/m^3. Of the 56 samples, 35 (62.5 percent) are above 50 μg/m^3, and 24 (37.5 percent) exceed 100 μg/m^3.

Most sand systems operators use automated mixers to blend sand with clay, water, and additives. While most facilities have some form of local exhaust ventilation (LEV), the mixing equipment (mixers, screens, hoppers) typically is not fully enclosed or equipped with effective LEV (Document ID 1365, p. 2-21).

The two highest exposures were obtained at two separate facilities and are associated with poor ventilation and work practices, both over 2300 μg/m^3 (Document ID 1365, p. 2-20; 1375, pp. 1, 13, 16; 0094, pp. 60-61, 119-120, 143, 162-181).

[40] All samples in Table IV.4.8-E are full-shift, personal breathing zone (PBZ) samples.

The lowest results (both limits of detection (LOD) values) for this job category are associated with sand systems operators working in areas where sand transport systems were isolated (enclosed or pneumatic) and mullers were fitted with exhaust ventilation (Document ID 1365, p. 2-21; 0018, p. 93; 0268, pp. 8-9).

Baseline conditions include inconsistent use of LEV, with only 38 percent of workers currently exposed at or below the 50 μg/m^3 PEL. Additionally, AFS reports that 47 percent of its members' sand system operators have exposures that are at or below the PEL. This indicates that OSHA's analysis of baseline exposures is similar to AFS's assessment of sand system operators and both sets of data suggest that there are inadequate controls in many facilities.

Exposure Profile and Baseline Conditions for Molders

The exposure profile in Table IV.4.8-E for molders includes 158 samples. The median exposure is 43 μg/m^3, the mean is 65 μg/m^3, and the range is 6 (LOD) to 1,417 μg/m^3. Of the 158 samples, 68 (43 percent) are above 50 μg/m^3, and 26 (16.4 percent) exceed 100 μg/m^3.

OSHA finds that baseline conditions for molders include the use of various semi-automated molding machines designed to shape and compact silica sand (Document ID 1365, p. 2-29). The processes used often require manual handling of the mold. Although general exhaust ventilation is often present (e.g., wall or ceiling exhaust fans), it is also common for molders to work without LEV (Document ID 1365, p. 2-29). Molders typically use green sand (a moldable mixture of sand and clay) (Document ID 1139, p. 18) and use compressed air to clean molds.

Exposure levels for molders tend to be higher in facilities where silica dust is poorly controlled throughout the facility. Some of the highest results for molders are associated with facilities where the results for other job categories also exceed 100 μg/m^3 (Document ID 1365, p. 2-28; 1379; 0104).

Some of the lowest results (two 13 μg/m^3 [LODs], one 20 μg/m^3, and one 23 μg/m^3) were obtained by NIOSH and OSHA for four molders working in two foundries where pneumatic or enclosed conveyors were used to transport sand (Document ID 1365, p. 2-28; 0268, p. 13; 0501, p. 6).

Baseline conditions include the use of semi-automated compacting machines and inconsistent use of LEV, with 57 percent of all samples below the final PEL. Additionally, AFS has reported that 63 percent of its members' molding operations already experience levels at or below the final PEL of 50 μg/m^3. OSHA's description of baseline exposures for molding operations is similar to that of AFS.

Exposure Profile and Baseline Conditions for Core Makers

The exposure profile in Table IV.4.8-E for core makers includes 108 samples. The median exposure is 39 μg/m^3, the mean is 75 μg/m^3, and the range is 8 (LOD) to 1,780 μg/m^3. Of the 108 samples, 46 (43 percent) are above 50 μg/m^3, and 14 (13 percent) exceed 100 μg/m^3.

Core makers use sand to make inserts for molds that allow for hollow metal parts to be molded. Core makers operate or work near automated equipment associated with sand processing for core making. Additionally, some coremakers manually handle cores to coat, clean, assemble, or position the cores. Work is typically conducted without LEV, but general ventilation might be present (Document ID 1365, p. 2-34).

Core makers are routinely exposed to silica dust generated by adjacent sand processing and transport equipment, use of compressed air, and dust migrating into the core making area from sources elsewhere in the foundry. The two highest results (380 μg/m^3 and 1,780 μg/m^3) were obtained in 1999 in a California foundry (Document ID 1365, p. 2-33; 1175, p. 9). At the same time, a result of 90 μg/m^3 was obtained for a third core maker at the same facility. Although no information is available on the specific activities of the core makers, the report suggests that ventilation was "stagnant" in the core area and that air from the melting and charge preparation area entered the space where the core makers worked (Document ID 1175, p. 2). In contrast, eight exposure levels, all lower than the final PEL, were obtained for core makers working in two foundries that employed pneumatic sand transport systems (Document ID 1365, p. 2-34; 0268, pp. 8, 12-13; 0132, pp. 238, 242).

Baseline conditions include the use of automated equipment and manual handling to process the casting cores, with 57 percent of core makers already experiencing levels at or below the 50 μg/m^3 PEL. AFS has reported that 73 percent of its members' core-making activities are already at levels of less than 50 μg/m^3. As such, OSHA may be underestimating the core maker population that already achieves the final PEL.

Exposure Profile and Baseline Conditions for Furnace Operators

The exposure profile in Table IV.4.8-E for furnace operators includes 11 samples. The median exposure is 20 μg/m^3, the mean is 83 μg/m^3, and the range 12 μg/m^3 (LOD) to 281 μg/m^3. Of the 11 samples, 3 (27.3 percent) are above 50 μg/m^3 (all 3 exceed 100 μg/m^3).

The primary sources of exposure for most furnace operators include the silica dust generated from poorly controlled adjacent operations, such as emissions from hot, dry sand released from molds at shakeout (Document ID 1365, p. 2-38; 1382; 1368, p. 78), and dust released when operators add sand to the furnace to correct slag acidity (Document ID 1365, p. 2-38; 0518). However, no information was available to indicate exposure levels specifically associated with these practices.

The highest reading (281 μg/m^3) was obtained in 1995 for a furnace operator who repaired the furnace lining (with refractory materials) every day (Document ID 1365, p. 2-38; 0025, p. 177).[41] Similarly, readings of 198 μg/m^3 and 280 μg/m^3 were obtained for furnace operators in a foundry where the respirable quartz levels were largely uncontrolled, according to NIOSH, and the sources of exposure included not only furnace emissions but also adjacent operations (Document ID 1376, pp. 10, 13-14). The report does not indicate whether these furnace operators participated in maintenance of refractory furnace linings.

Three of the lowest readings for furnace operators (29 μg/m^3 and two less than or equal to 12 μg/m^3) were measured at a single facility where operators worked in a control booth

[41] See the foundry "maintenance operator" job category for information on other foundry workers whose primary silica exposure is from work with refractory materials.

or on a ventilated melt deck (Document ID 1365, p. 2-38; 0028, pp. 27-36). At another facility, a result of 20 μg/m^3 was obtained for a furnace operator tending a furnace with slotted hoods above and a retractable enclosing hood for charging the furnace with iron (Document ID 1175, p. 9).

Baseline conditions for furnace operators include exposures from adjacent operations and exposures from furnace emissions. Engineering controls are effective in reducing exposures but are not used consistently (Document ID 0025, pp. 113, 149; 1376, p. 13; 0028; 1175, p. 2). The exposure profile shows that 73 percent of furnace operators already achieve the 50 μg/m^3 PEL. AFS survey data agree with OSHA's profile, as the survey data indicate that 70 percent of furnace operators have baseline exposures of 50 μg/m^3 or less.

Exposure Profile and Baseline Conditions for Pouring Operators

The exposure profile in Table IV.4.8-E for pouring operators includes 20 samples. The median exposure is 48 μg/m^3, the mean is 69 μg/m^3, and the range is 10 μg/m^3 (LOD) to 176 μg/m^3. Of the 20 samples, 10 (50 percent) are above 50 μg/m^3, and 6 (30 percent) are above 100 μg/m^3.

Two high readings (both 150 μg/m^3) for pouring operators were obtained from a single foundry visited by the Industrial Commission of Ohio in 1987 (Document ID 1365, p. 2-41; 0265, p. 12). Respirable quartz levels throughout this foundry were poorly controlled. Even though these samples were removed from the profile because the data were obtained prior to 1990, they demonstrate that elevated exposures occur in uncontrolled environments.

Another elevated level, 157 μg/m^3 was obtained for a worker operating a pouring crane at a foundry visited by NIOSH in 1992 (Document ID 1365, p. 2-41; 1379, p. 25). At this foundry, half of the results from four job categories exceeded 100 μg/m^3, indicating airborne respirable quartz was released in or spread to most areas in the facility. According to the NIOSH report, the pouring crane operators at this facility were exposed to respirable quartz primarily from shakeout operations (Document ID 1365, p. 2-42; 1379, p. 12).

Based on available reports, OSHA has determined that pouring operators commonly perform manual manipulation of ladles or operating cranes and might use automated equipment in an open pouring area with no engineering controls or dust suppressing work practices. Furthermore, pouring operations are generally located in the same area as furnace and shakeout operations, which can release considerable silica dust. LEV is not a standard feature of pouring areas in ferrous foundries. Where LEV was reportedly associated with a pouring task, the ventilation system was noted to be in poor condition (Document ID 1365, pp. 2-41 – 2-42; 0008, pp. 3, 16-40, 32-34; 1376, p. 13; 1379, p. 3; 1354, p. 4).

The exposure profile in Table IV.4.8-E shows that 50 percent of pouring operators currently achieve the 50 μg/m^3 PEL. AFS reports that 67 percent of these workers already achieve the PEL (Table IV.4.8-C and Table IV.4.8-D), suggesting that OSHA is overestimating the population of pouring operators exposed over the final PEL.

Exposure Profile and Baseline Conditions for Shakeout Operators

The exposure profile in Table IV.4.8-E for shakeout operators includes 90 samples. The median exposure is 59 μg/m^3, the mean is 83 μg/m^3, and the range is 10 μg/m^3 to 361 μg/m^3. Of the 90 samples, 51 (56.6 percent) are above 50 μg/m^3, and 20 (22.2 percent) exceed 100 μg/m^3. The 90 shakeout operator results were collected during de-molding operations under a variety of working conditions.

At a gray iron foundry producing 100,000 tons of castings like engine blocks and cylinder heads, NIOSH measured exposures of 12 μg/m^3 (LOD), 21 μg/m^3, 22 μg/m^3, and 53 μg/m^3 for shakeout area crane operators working in cabs supplied with fresh air (Document ID 1365, p. 2-46; 0268, pp. 3, 5, 6). At that facility, which also had an active silica management program, nine results obtained for manual shakeout operations were mixed, ranging from 22 μg/m^3 to 104 μg/m^3 (Document ID 1365, p. 2-46; 0268, pp. 6, 12).

Four full-shift PBZ respirable quartz exposure results for shakeout operators at another foundry evaluated by NIOSH ranged from 37 to 214 μg/m^3, again indicating the potential for variability in respirable quartz exposures for a single job category at a single facility.

Based on notes included in the report, these higher results are assumed to be associated with the use of an open shaker table and the use of a front-end loader to break large molds on the open floor (Document ID 1365, p. 2-46; 1463, (pdf) p. 14, Table 2).

Shakeout conditions vary dramatically depending on the age and condition of the equipment or facility. A review of OSHA SEP, NIOSH, and State reports indicate that foundries frequently have installed LEV in the shakeout area. However, enclosures and ventilation are not uniformly effective as used, particularly on older equipment. New and modern shakeout equipment is generally associated with LEV designed to help manage dust from this process (Document ID 1365, p. 2-46; 0764; 1148).

Baseline conditions include the frequent use of LEV, showing that more modern shakeout equipment is more effective in reducing exposures. Additionally, the exposure profile shows that 43 percent of shakeout operations already achieve the 50 μg/m^3 PEL. AFS reports that 58 percent of its members' shakeout operations achieve exposure levels equal to or below 50 μg/m^3, which indicates that OSHA may be overestimating the extent of workers exposed above the final PEL.

Exposure Profile and Baseline Conditions for Knockout Operators

The exposure profile in Table IV.4.8-E for knockout operators includes 35 samples. The median exposure is 50 μg/m^3, the mean is 81 μg/m^3, and the range is 13 μg/m^3 (LOD) to 497 μg/m^3. Of the 35 samples, 17 (48.7 percent) are above 50 μg/m^3, and 9 (25.8 μg/m^3) exceed 100 μg/m^3.

Knockout operators use hand and power tools or vibrating equipment on castings delivered from the shakeout process to remove sand from castings and unwanted scrap metal left from the pouring process. Knockout procedures involve use of manual or semi-automated stationary workstations, typically with some form of LEV. However, these ventilation systems are not necessarily well maintained or operating efficiently (Document ID 1365, p. 2-56).

Five elevated readings for knockout operators (540 μg/m^3, 380 μg/m^3, 310 μg/m^3, 140 μg/m^3, and 90 μg/m^3) were collected at a single foundry where the workers used vibrating equipment to remove sand from casting interiors (Document ID 1365, p. 2-54; 1374, p. 4, (pdf) p. 24 Table 6, (pdf) p. 25 diagram). While knockout operators (along with sandblasters) had the highest exposure levels at this facility, NIOSH found elevated silica exposures in all foundry departments and recommended that the facility investigate the use of engineering controls such as local exhaust ventilation, downdraft molding platforms, and isolation of work areas to reduce worker exposure to silica, indicating that exposures at this facility were largely uncontrolled (Document ID 1374, p. 18). These samples were removed from the final profile, as the data predate 1990. However, this example shows that elevated exposures can occur as a result of poor overall control of airborne dust.

Three of the lowest results (13 $\mu g/m^3$, 24 $\mu g/m^3$, and 30 $\mu g/m^3$) and one moderately elevated reading (87 $\mu g/m^3$) were obtained on two sampling dates for two workers who used pneumatic chisels to open holes in castings (Document ID 1365, p. 2-55; 0268, pp. 5-7). On each of the two sampling dates, these knockout operators spent half the shift at ventilated workstations chiseling castings that had already passed from an enclosed two-stage shakeout area to an automated, enclosed abrasive grinder, and were carried to the knockout operator on a partially enclosed conveyor.

Baseline conditions for knockout operators include the use of LEV, with varying efficiencies in dust control. Additionally, the exposure profile shows that 51 percent of knockout operators already achieve the PEL. AFS data also support OSHA's baseline exposure assessment as AFS reports that 52 percent of its members' knockout operations achieve levels below 50 $\mu g/m^3$.

Exposure Profile and Baseline Conditions for Abrasive Blasting Operators

The exposure profile in Table IV.4.8-E for abrasive blasting operators includes 61 samples. The median exposure is 80 $\mu g/m^3$, the mean is 148 $\mu g/m^3$, and the range is 13 $\mu g/m^3$ (LOD) to 1,002 $\mu g/m^3$. Of the 61 samples, 41 (67.2 percent) are above 50 $\mu g/m^3$, and 25 (41 percent) exceed 100 $\mu g/m^3$.

Abrasive blasting operators use abrasive media to remove tightly adhered mold and core materials and prepare the surfaces of castings for further processing. Based on a review of OSHA, NIOSH, and State reports, OSHA concludes that the vast majority of abrasive blasting operators (95 percent) in the foundry industry use automated or semi-automated blasting equipment (e.g., steel shot blast machines) (Document ID 1365, p. 2-62).[42] This equipment is typically designed to be fully (or nearly fully) enclosed and connected to an exhaust ventilation system with a dust collector; however, enclosures often leak and the associated ventilation is not necessarily effective (Document ID 1365, p. 2-62).

Elevated exposures appear to be associated with poor work practices. Two of the highest results, 238 μg/m^3 and 1002 μg/m^3 (as well as a third result of 91 μg/m^3) were obtained in 1992 at a gray and ductile iron foundry. NIOSH noted that the workers used compressed air (presumably for cleaning) while they operated steel shot blasting machines equipped with LEV (Document ID 1365, p. 2-61; 1463, pp. 15, (pdf) pp. 26-27 Table 2). At a different foundry visited by OSHA, a result of 909 μg/m^3 was reported for an abrasive blasting operator who monitored a continuous process steel shot blast machine as well as the dust collection tote (bag). This worker replaced the tote when it was full (Document ID 1365, p. 2-61; 0056, p. 104). This result suggests that the dust collection system performed poorly, that the act of monitoring and replacing the dust tote contributed to the silica exposure, or that both might have been factors.

Some of the lowest results for this job category are associated with control measures that isolate the operator from the process and control sources of dust surrounding the shot blasting machine. A result of 46 μg/m^3, approximately half the median for this job category, is associated with an abrasive blasting operator who operated an enclosed shot blasting machine from behind a transparent barrier. Automated manipulators positioned the parts. This gray iron foundry had implemented numerous exposure controls throughout the facility and results rarely exceeded 50 μg/m^3 in most job categories (Document ID 1365, p. 2-62; 0268, pp. 5-7). OSHA obtained two results of 34 μg/m^3 and 47 μg/m^3 at a gray and ductile iron foundry that had enclosed and ventilated sand- and casting-handling equipment leading to and from the automated shot blasting machine.

[42] Most of the foundry industry abrasive blasting machines use steel shot as media. Therefore, the silica exposure to these abrasive blasting operators is predominantly from residual mold and core materials adhered to the casting, rather than originating in the abrasive blasting media. However, recycled abrasive blasting media that are poorly cleaned can carry residual mold and core materials.

These abrasive blasting operators spent a couple of hours sorting castings and the remainder of the shift operating the shot blasting equipment. Results obtained during earlier evaluations of this facility were substantially higher, as discussed in the review of additional controls for this job category (Document ID 1365, p. 2-62; 0128, pp. 16, 19, 24, 72).

Baseline conditions include the use of ventilated enclosures. The exposure profile shows that 33 percent of abrasive blasting operations currently achieve the 50 μg/m^3 PEL. AFS reports that 63 percent of its members' abrasive blasting operations currently achieve exposures below 50 μg/m^3, suggesting that OSHA is overestimating baseline exposures for abrasive blasting.

Exposure Profile and Baseline Conditions for Cleaning/Finishing Operators

The exposure profile in Table IV.4.8-E for cleaning/finishing operators includes 228 samples. The median exposure is 81 μg/m^3, the mean is 202 μg/m^3, and the range is 12 μg/m^3 (LOD) to 1,868 μg/m^3. Of the 228 samples, 148 (65 percent) are above 50 μg/m^3, and 105 (56 percent) exceed 100 μg/m^3. Considering that 24 percent of exposures (54 samples) exceed 250 μg/m^3, cleaning/finishing operators have many of the highest silica exposures in the foundry industry.

Based on NIOSH, OSHA SEP, and State reports, OSHA concludes that most cleaning/finishing operators use handheld grinding equipment, without LEV, for a substantial portion of the shift. While the same workers also might use stationary grinding equipment, OSHA finds that it is the handheld equipment that is both most typical and the greater source of exposure (Document ID 1365, p. 2-70).

A 2009 study by Lee obtained results of 161 μg/m^3, 181 μg/m^3, 216 μg/m^3, and 245 μg/m^3 for cleaning/finishing operators grinding on casings during an inspection of a facility (Document ID 0779, p. D16; 1359, p. 1). Although grinding stations were equipped with LEV, the LEV did not appear to be effective based on the amount of dust observed in the air and on the work surfaces (Document ID 0779, p. D15).

Some of the highest results (all greater than 500 μg/m^3) were associated with three facilities where most exposures for multiple job categories also were elevated (Document ID 1407, pp. 8-10; 1379, pp. 24-25; 1175, p. 9). One of the highest respirable quartz readings, 1,120 μg/m^3, was obtained for a cleaning/finishing operator who performed hand grinding on large castings on the open floor (Document ID 1365, p. 2-68; 1463, p. 26).

Some of the highest exposures for grinders were at a facility visited by NIOSH that performed only casting cleaning operations. Castings at this facility were delivered on flatbed trucks. The castings were cleaned by workers operating 25 individual grinding stations separated by plywood partitions. Compressed air was used to remove excess sand from internal cavities. The 20 results for cleaning/finishing operators ranged from 300 μg/m^3 to 1,868 μg/m^3. Based on NIOSH recommendations for controlling exposures of the use of downdraft tables for small castings, high velocity low volume tool hoods and the use of flexible exhaust duct for large castings, OSHA infers that these readings are associated with minimal or no such controls (Document ID 1365, p. 2-69; 1378, pp. 4-5, 14-15, (pdf) 29-30 Table 2).

OSHA concludes that baseline conditions include the widespread use of handheld grinders to perform cleaning and finishing operations. LEV is not commonly used for control. Additionally, the exposure profile shows that 35 percent of workers engaged in these operations currently achieve the final PEL. AFS reports that 62 percent of cleaning/finishing operations already achieve exposures at or below 50 μg/m^3, suggesting that OSHA may be overestimating baseline exposures for cleaning/ finishing operators.

Exposure Profile and Baseline Conditions for Material Handlers

The exposure profile in Table IV.4.8-E for material handlers includes 36 samples. The median exposure is 49 μg/m^3, the mean is 75 μg/m^3, and the range is 11 μg/m^3 (LOD) to 231 μg/m^3. Of the 36 samples, 18 (50 percent) are above 50 μg/m^3, and 7 (19.4 percent) exceed 100 μg/m^3.

Material handlers use mobile equipment to transport materials and castings throughout foundries and are subject to background silica dust associated with the conditions and controls found in those work areas. Information contained in OSHA SEP, NIOSH, and State reports suggests that enclosed cabs are not typically available or used to limit exposures (Document ID 1365, p. 2-79). Material handlers routinely assist with cleaning tasks, typically involving dry sweeping or using compressed air.

Some of the lowest exposure levels are associated with a facility that had made substantial and successful efforts to control silica dust across the entire facility. NIOSH obtained four results, all at or below the LOD (11 µg/m^3 to 13 µg/m^3), for two material handlers who operated powered equipment in a well-controlled facility (Document ID 1365, p. 2-79; 0268, pp. 8, 9, 12-13).

Baseline conditions include the use of open-cab equipment to transport materials and castings throughout the facilities. OSHA estimates that 50 percent of material handlers already achieve the final 50 µg/m^3 PEL. AFS reports that 79 percent of its members' material handling operations already achieves levels below 50 µg/m^3, suggesting that OSHA may be overestimating baseline exposures.

Exposure Profile and Baseline Conditions for Maintenance Operators

The exposure profile in Table IV.4.8-E for maintenance operators includes 24 samples. The median exposure is 63 µg/m^3, the mean is 369 µg/m^3, and the range is 12 µg/m^3 (LOD) to 5,851 µg/m^3. Of the 24 samples, 13 (54.1 percent) are above 50 µg/m^3, and 7 (29.1 percent) exceed 100 µg/m^3. Based on a review of OSHA SEP, NIOSH, and State reports, OSHA finds that most reported silica exposure for maintenance operators is due to work repairing (patching) or replacing refractory furnace and ladle lining materials (Document ID 1365, p. 2-84).

Section IV-4.19 – Refractory Repair addresses the similar (but more frequent and often large scale) activities of contractors who travel from facility to facility providing refractory maintenance services. Those contractors are more likely to perform the periodic complete tear-out and replacement of refractory linings,[43] while foundry

[43] According to a supplier, 75 percent of establishments that use refractory furnaces also use a contract service to reline the furnaces (Document ID 1365, p. 2-81; 1159).

maintenance operators are more likely to perform small-scale patch and repair jobs to maintain refractory linings between replacement cycles. The patch and repair tasks are typically performed weekly (Document ID 1365, p. 2-81; 0121, pp. 15-19, 25-26), but that might be necessary more or less frequently depending on several factors such as the type of refractory material and how the furnace is used.

Maintenance operators most commonly perform these manual refractory repair processes in areas with general ventilation only. Furnace ventilation systems cannot be considered an effective control for those maintenance operators who maintain refractory furnaces. The ventilation systems associated with furnaces are designed to exhaust heat and rising fumes but they are inadequate to control silica dust and often are not functional during refractory maintenance activities (Document ID 1365, p. 2-84; 0080, p. 30).

Maintenance operators also are subject to background levels of silica dust associated with the conditions and controls found in the work areas where they maintain equipment or make repairs during upset conditions. However, the results available to OSHA for maintenance operators are primarily associated with refractory repair activities (Document ID 1365, p. 2-84).

Baseline conditions include small-scale repair operations on furnace linings, usually without dedicated ventilation. The exposure profile shows that 46 percent of maintenance operators already achieve the PEL under these uncontrolled conditions. The AFS reports that 74 percent of its members' maintenance operations already achieve 50 μg/m^3 or less, suggesting that the profile may be overestimating the amount of workers exposed above the final PEL.

Exposure Profile and Baseline Conditions for Housekeeping Workers

The exposure profile in Table IV.4.8-E for housekeeping workers includes 11 samples. The median is 71 μg/m^3, the mean is 66 μg/m^3, and the range is 16 μg/m^3 (LOD) to 172 μg/m^3. Of the 11 samples, 7 (63.6 percent) exceed 50 μg/m^3, and 1 (9.1 percent) exceeds 100 μg/m^3.

Based on a review of OSHA SEP, NIOSH, and State reports, OSHA concludes that housekeeping workers most frequently use manual methods to perform cleaning tasks. Exposures of housekeeping workers are closely related to the general exposure levels within the facility and to the specific area where they spend most of their time. Although reports contain few details regarding the specific activities that expose housekeeping workers to silica dust, data suggest that adjacent operations are the primary source of exposure for housekeeping workers, although their own work will likely contribute to their exposure when dry sand is involved (e.g., cleaning up spills from upset conditions) (Document ID 1365, p. 2-92).

Some of the lowest results for housekeepers include a value for a housekeeping worker shoveling and sweeping spilled mold sand. In this case, the result was less than or equal to 16 μg/m^3, the LOD. At the same gray and ductile iron foundry, results for a maintenance operator and two knockout operators were also below 50 μg/m^3 (Document ID 1365, p. 2-91; 0038, pp. 37-46, 51-57). Two other results, both 30 μg/m^3 (one was the LOD), were obtained at two ferrous metal sand casting foundries evaluated by the Michigan Department of Public Health in the early 1990s. One worker reportedly was responsible for cleaning an area where LEV was present. The other was classified as a “floor sweeper” (no further information available) (Document ID 1365, p. 2-91; 0249, p. 10; 1408, p. 9).

The highest exposure was reported for a foundry visited by OSHA, where a result of 172 μg/m^3 was obtained for a “cleanup” worker whose duties included vacuuming sand. Other exposure values obtained on the same date at this facility included results of 87 μg/m^3 and 96 μg/m^3 for pouring operators (nearly twice the median level for that job category). The following month, two results of 276 μg/m^3 and 291 μg/m^3 were obtained for shakeout operators (nearly five times greater than the median for this group), suggesting that the shakeout line might have been a contributing source of silica exposure for the other workers (Document ID 1365, p. 2-91; 0118, pp. 4, 13, 15, 22, 25-26).

Baseline conditions include manual cleaning such as shoveling and sweeping, with indications that airborne silica from adjacent operations contribute to elevated exposures for housekeeping workers. The exposure profile shows that 36 percent of these workers are currently exposed to levels at or below the final PEL. AFS reports that that 72 percent of its members' housekeeping operations already achieve levels below 50 μg/m^3, suggesting that OSHA may be overestimating baseline exposures for housekeeping workers.

Table IV.4.8-E
Personal Respirable Crystalline Silica Exposure Range and Distribution of Results for Ferrous Sand Casting Foundries (NAICS 331511, 331513)

	Exposure Summary			Exposure Range		Exposure Profile				
Job Categories	**N**	**Mean (μg/m³)**	**Median (μg/m³)**	**Min (μg/m³)**	**Max (μg/m³)**	**<25 (μg/m³)**	**≥25 and ≤50 (μg/m³)**	**>50 and ≤100 (μg/m³)**	**>100 and ≤250 (μg/m³)**	**>250 (μg/m³)**
Sand Systems Operator	56	197	74	11	2,430	10 (17.9%)	11 (19.6%)	14 (25%)	14 (25%)	7 (12.5%)
Molder	158	65	43	6	1,417	54 (34.2%)	36 (22.8%)	42 (26.6%)	25 (15.8%)	1 (0.6%)
Core Maker	108	75	39	8	1,780	31 (28.7%)	31 (28.7%)	32 (29.6%)	10 (9.3%)	4 (3.7%)
Furnace Operator	11	83	20	12	281	6 (54.5%)	2 (18.2%)	0 (0%)	1 (9.1%)	2 (18.2%)
Pouring Operator	20	69	48	10	176	6 (30%)	4 (20%)	4 (20%)	6 (30%)	0 (0%)
Shakeout Operator	90	83	59	10	361	12 (13.3%)	27 (30%)	31 (34.4%)	13 (14.4%)	7 (7.8%)
Knockout Operator	35	81	50	13	497	5 (14.3%)	13 (37.1%)	8 (22.9%)	8 (22.9%)	1 (2.9%)
Abrasive Blasting Operator	61	148	80	13	1,002	3 (4.9%)	17 (27.9%)	16 (26.2%)	18 (29.5%)	7 (11.5%)
Cleaning/Finishing Operator	228	202	81	12	1,868	37 (16.2%)	43 (18.9%)	43 (18.9%)	51 (22.4%)	54 (23.7%)
Material Handler	36	75	49	11	231	10 (27.8%)	8 (22.2%)	11 (30.6%)	7 (19.4%)	0 (0%)
Maintenance Operator	24	369	63	12	5,851	5 (20.8%)	6 (25%)	6 (25%)	2 (8.3%)	5 (20.8%)
Housekeeping Worker	11	66	71	16	172	2 (18.2%)	2 (18.2%)	6 (54.5%)	1 (9.1%)	0 (0%)
Ferrous Sand Casting Foundries Total	**838**	**131**	**58**	**6**	**5,851**	**181 (21.6%)**	**200 (23.9%)**	**213 (25.4%)**	**156 (18.6%)**	**88 (10.5%)**

Table IV.4.8-E

Personal Respirable Crystalline Silica Exposure Range and Distribution of Results for Ferrous Sand Casting Foundries (NAICS 331511, 331513)

	Exposure Summary			**Exposure Range**			**Exposure Profile**				
Job Categories	**N**	**Mean ($\mu g/m^3$)**	**Median ($\mu g/m^3$)**	**Min ($\mu g/m^3$)**	**Max ($\mu g/m^3$)**		**<25 ($\mu g/m^3$)**	**≥25 and ≤50 ($\mu g/m^3$)**	**>50 and ≤100 ($\mu g/m^3$)**	**>100 and ≤250 ($\mu g/m^3$)**	**>250 ($\mu g/m^3$)**

Notes: All samples summarized are personal breathing zone (PBZ) results representing 8-hour time-weighted average exposures.
Job categories are intended to represent job functions; actual job titles might differ, and responsibilities might be allocated differently, depending on the facility.
Percentages may not add to 100 percent due to rounding.

Sources: Document ID 1720, p. IV-136; 3958; 0006; 0008; 0009; 0018; 0025; 0026; 0028; 0038; 0041; 0051; 0054; 0057; 0059; 0060; 0080; 0081; 0082; 0093; 0094; 0100; 0104; 0107; 0116; 0117; 0118; 0120; 0121; 0124; 0125; 0127; 0128; 0130; 0131; 0132; 0139; 0141; 0147; 0162; 0163; 0182; 0188; 0089; 0190; 0191; 0196; 0233; 0249; 0257; 0258; 0259; 0260; 0263; 0264; 0268; 0501; 0511; 0576; 0779; 1175; 1375; 1376; 1378; 1379; 1381; 1407; 1408; 1409; 1463; 3952; 3953.

Ferrous Sand Casting Foundries—Additional Controls

In evaluating additional controls needed to improve upon the baseline and reach the PEL for most foundry workers most of the time, OSHA has considered the differences in foundry sizes and processes, and concludes that the control technologies discussed in this section can be applied to foundries of different sizes and processes. Where the processes differ and those differences could substantially impact OSHA's conclusions (such as working with large castings), the Agency has evaluated appropriate alternative controls. The Agency has reviewed the control technologies that address each of the sources of exposure for each job category. As discussed further below, the comments and data provided, if anything, tend to support the Agency's conclusions that engineering controls and work practices are technologically feasible to reduce exposure to or below the PEL for most operations in most foundry environments.

OSHA thus disagrees with the general argument made by the AFS in its post-hearing comments that, because there are significant differences among foundries such as the melting process, molding and core chemistry, and cleaning and finishing methods (Document ID 4229, p. 13), the Agency is mistaken to generalize or extrapolate about exposure controls for foundries. AFS has additionally provided more specific critiques of the PEA analysis (Document ID 2379, Appendix 2; 4229, p. 15) to which OSHA responds below in the sections on additional controls for each job category. More general comments, which OSHA addresses here, include criticisms of:

- The use of data from foundries that have ceased operation;
- The way OSHA uses some specific data;
- The recommended use of substitutes such as olivine sand for regular sand;
- The recommended use of low-silica refractories;
- OSHA's understanding of the use and maintenance of refractories; and
- The recommended use of housekeeping methods other than compressed air to clean molds.

Each of these points made by AFS is addressed below.

AFS's criticism of OSHA's use of data from foundries that are no longer in operation implies that the implementation of the engineering controls caused the business failure. If this was AFS's implication, it failed to provide evidence proving it. It is well known that foundries in various sectors like automotive and steel have been experiencing consolidations for many years; these circumstances, rather than the implementation of engineering controls, may have led to the foundries in question going out of business. The processes used in these foundries are similar to those processes used in foundries that continue in business. The exposures and the processes associated with these exposures are therefore instructive in assessing worker exposure levels and the efficacy of controls.

With respect to OSHA's use of specific data, AFS argues that OSHA has been selective in presenting data. For example, AFS criticizes OSHA's reliance on Irwin (2003) to show exposure reductions relevant to molding, shakeout, and housekeeping activities. AFS argues that the samples in this study show that there was substantial variability in the exposure levels and that several of the samples exceed the final PEL, implying that it would not be feasible to assure that exposures are below the PEL (Document ID 2379, Appendix 2, pp. 6-7).

OSHA believes that AFS misunderstood how OSHA used various studies. OSHA uses all relevant exposure data for the exposure profile to represent how workers are being exposed prior to the promulgation of this standard. The exposure profile includes data from both well and poorly controlled facilities. Accordingly, in the exposure profile a specific job category may show a wide variability in exposures, in some cases ranging from below the LOD to 100 times greater than the PEL. However, OSHA's methodology is to use data from both before and after engineering controls are applied, if such data is available in the studies. For example, if sampling data show a significant decrease in exposure after the implementation of control measures, these data are used as evidence of the effectiveness of that control.

AFS also commented that that olivine sand is not currently available in the United States and that it is not suitable for all applications (Document ID 2379, Appendix 2, p. 5). In proposing this substitution, OSHA understands that substitution is not a viable option for all foundries, but concludes that it is viable for some foundries and applications. Substitution is an important component of the hierarchy of controls and OSHA has investigated all of the available types of controls that help reduce exposures. In fact, AFS's publication, “Control of Silica Exposure in Foundries,” acknowledges that “[s]ubstituting with a low or no silica-containing material is a prime example” of a silica exposure control (Document ID 3733, pp. 3-5). OSHA also notes that, although none of the feasibility findings are based on substitution, the record shows that some facilities have successfully substituted less silica-containing granular media (Document ID 1365, pp. 2-24, 2-52 – 2-53; 0268, pp. 5-13). The use of substitutes is also discussed below in the individual job categories where substitution is a relevant topic.

AFS also commented that using low-silica refractories may be limited for the following reasons:

> Being one of the three building blocks of nearly all refractories, Silica (along with Alumina and Magnesia) is present in nearly all refractory products. Even “low silica” formulations may contain 5 –30 percent Silica.
>
> For most foundry applications “low silica” may not be feasible. Silica provides refractory property benefits such as low thermal conductivity and thermal dimensional stability which are required for successful refractories.
>
> (Document ID 2379, Appendix 2, p. 21).

OSHA understands that low-silica refractories are not feasible for every operation. However, in the PEA, OSHA presented evidence for commercially available low-silica refractories associated with exposures below the LOD (Document ID 1720, p. IV-153). OSHA is presenting this as an alternative control option for some operations.

AFS also states that OSHA has mischaracterized the nature of foundry refractory work as follows:

> OSHA may also be confused on the nature of foundry refractory work. There are large relining jobs that happen only periodically, but just as much (if not more) refractory work occurs on an ongoing basis to maintain

> runners, ladles, melting units, etc. which are degraded from daily contact with molten iron.
>
> (Document ID 2379, Appendix 2, p. 20).

OSHA has included a description for the job activities of maintenance workers, and it is not inconsistent with what AFS argues. Table IV.4.8-B of this analysis states that Maintenance Operator duties include repairing and maintaining refractory furnace linings. Controls for these workers are discussed below in the additional controls section for this job category. In addition, Section IV-4.19 – Refractory Repair separately analyses refractory repair operations performed by contractors specializing in this type of work. OSHA understands that large scale refractory repair is typically performed by a separate industry but that foundry workers on occasion may also perform this type of work.

Another AFS comment is on the use of compressed air. AFS stated that "[i]n some cases the only feasible method for cleaning is the use of compressed air guided through long, narrow wands that can be inserted into the part." AFS states (Document ID 2379, Appendix 2, p. 14):

> In castings of complex or intricate shape excess sand may accumulate in voids and crevices. It is not possible to reach many of these locations with a vacuum attachment. Beyond access issues, even intense vacuuming will often not provide the needed power to dislodge excess sand from casting voids and crevices. It also is not feasible to use wet methods as this would damage the equipment and create a safety hazard due to water accumulation on the surrounding floors. (<u>Id.</u>)

OSHA understands that in some situations compressed air may be the only feasible alternative to clean the casting. This is why the final rule contains a provision that allows employers to use compressed air for cleaning under limited circumstances. Specifically, paragraph (h)(2) of the standard for general industry and maritime states, in pertinent part, as follows:

> (2) The employer shall not allow compressed air to be used to clean clothing or surfaces where such activity could contribute to employee exposure to respirable crystalline silica unless:
>
> > (i) The compressed air is used in conjunction with a ventilation system that effectively captures the dust cloud created by the compressed air; or
> >
> > (ii) No alternative method is feasible.

One of the effects of using compressed air is the generation of dust that can expose other workers. As Dr. Mirer testified, control of dust emitting sources, so-called "cross-contamination, has a profound effect on silica-dust levels. Dr. Frank Mirer, stated he wanted to:

> …emphasize that the sources emitting silica exposures of >100 μg/m^3 are a major source of the worker silica exposures between 50 μg/m^3 and 100 μg/m^3. Were the >100 μg/m^3 exposures controlled, most worker exposures currently in the 50-100 μg/m^3 range would be below 50 μg/m^3, and substantial numbers would be less than 25 μg/m^3. . . . Thus, for furnace operators (median 34 μg/m^3, mean 109 μg/m^3) and pouring operators (median 48 μg/m^3, mean 79 μg/m^3), their own activities at their work stations do not emit silica. Yet, these workers suffer substantial silica exposures. This demonstrates that a cloud of silica permeates these factories, and some fraction, perhaps 40 μg/m^3, of the median exposure would be reduced by control of other, silica-generating operations. Similar subtractions could be applied to all operations, which would reduce the grand median to close to 25 μg/m^3 (Document ID 4204, p. 104).

OSHA agrees with Dr. Mirer's analysis and presents data below that indicate that Dr. Mirer's reductions may be conservative estimates. See discussion under Additional Controls for Molders (Ferrous Sand Casting Foundries).

Additional Controls for Sand Systems Operators

The exposure profile in Table IV.4.8-E shows that 38 percent (21 of 56 samples) of sand systems operators in ferrous sand casting foundries have exposures at or below the final PEL of 50 μg/m^3. AFS reported that 47 percent of its members' sand system operations currently achieve the PEL, suggesting that OSHA may be overestimating baseline exposures for this job category (see Table IV.4.8-D).

Based on the Table IV.4.8-E exposure profile and other information in the rulemaking record, OSHA concludes that exposures at or below the PEL are generally attributable to the use of enclosed and ventilated sand processing and transport equipment. For the remaining sand system operators who are exposed above 50 μg/m^3, OSHA concludes that additional controls will be needed to achieve the PEL, and that foundries can achieve significant exposure reductions through effective LEV and enclosures for sand mixing, processing, and transport equipment. Published industry and voluntary guidelines for sand mixer and mullers, bins, hoppers, and screens specify that equipment must be well enclosed and exhausted at a minimum rate of 150 cubic feet per minute (cfm) (200 cfm in the case of screens) per square foot of opening (Document ID 1365, p. 2-22; 1607, pp. 10-23).

Some of the lowest results are associated with sand systems operators working in areas where sand transport systems were isolated (enclosed or pneumatic) and mullers were fitted with exhaust ventilation. For example, an exposure level of less than or equal to 11 μg/m^3 was attained for a sand systems operator controlling a muller that had both the muller belts and elevator fully enclosed (Document ID 0018, pp. 93, 98-100). Exposure levels of less than or equal to 13 and 30 μg/m^3; (two sampling days) were associated with pneumatic sand transport equipment (Document ID 1365, p. 2-21; 0268, pp. 5-13).

AFS argues that the automated process used at the facility visited by NIOSH is atypical, and that the facility could “take advantage of automation because it has reduced production to relatively few part numbers compared to most other foundries” (Document ID 2379 Appendix 2, p. 4). AFS argues that the automation control used for this foundry cannot be extrapolated to other smaller foundries that have different configurations. AFS also mentions that 11 of the 63 samples in this foundry exceeded the PEL (Document ID 2379, Appendix 2, p. 4; 4229, p. 14).

AFS is implying that other foundries that produce more parts would not be able to rely on automated processes. However, AFS has not provided evidence to support this claim. At this foundry, NIOSH makes no mention of the impact of automation on production rates, and NIOSH describes this as a "modern, highly automated facility with the management and workers committed to continuous improvement" (Document ID 0268, p. 11). Regarding automation, NIOSH further states:

> Automation of activities has reduced the number of employees potentially exposed and facilitated the isolation of dusty processes where employee presence is no longer required. Activities where this has had discernable impact include automatic shaker conveyors replacing the beef line [overhead power chain conveyor], automated high pressure molding units, automatic grinding and shot blast equipment, and a muller that only requires the operator to monitor sand quality (Document ID 0268, p. 8).

Additionally, automation has been observed in multiple studies in different environments in foundries (Document ID 1365, pp. 2-22 – 2-23). AFS also asserts, with no evidentiary basis, that automation and some controls such as pneumatic sand moving systems often increase exposures to respirable silica rather than reducing them (Document ID 2379, Appendix 1, p. 14). OSHA finds these assertions unpersuasive given NIOSH's observations and the data collected and presented in this section on the effectiveness of a wide variety of controls, including pneumatic sand moving systems (Document ID 1365, pp. 2-22 – 2-23; see, *e.g.*, 0268, pp. 8, 12-13; 0132, pp. 238, 242).

An OSHA SEP report shows that a steel foundry used a combination of controls to reduce exposures by 82 percent, from 159 $\mu g/m^3$ to 28 $\mu g/m^3$. This facility achieved this exposure reduction by: fully enclosed mullers and hoppers, improving existing LEV, renovating the sand handling system across the entire facility, wetting hot sand reclaimed from the shakeout area, changing work practices, improving housekeeping, using pre-mixed additives, and controlling silica exposure sources throughout the facility (Document ID 1365, p. 2-23; 0511, pp. 1-6).

Enclosed, ventilated, continuous-process sand recycling and reclamation equipment is commercially available for foundries (Document ID 1365, p. 2-23; 1148). According to the manufacturer, this type of multifunctional equipment can be configured to accomplish most sand handling, from shakeout and cast cleaning to screening and mixing in fresh molding sand. These systems can be used with a multitude of sand products for various castings (Document ID 1365, pp. 2-23 – 2-24; 1714; 1465).

Substitution may be an option for some foundries. Substituting non-silica granular media (which is less toxic than silica) for silica sand used for molds and cores can virtually eliminate the silica exposures of all sand systems operators. Although the extent of exposure reduction from the use of substitution materials has not been quantified for sand systems operators in ferrous sand casting foundries, it has been documented in nonferrous sand casting foundries (Document ID 1365, pp. 2-24, 2-52 – 2-53).

Additional Controls for Molders

The exposure profile in Table IV.4.8-E shows that 57 percent (90 out of 158 samples) of molders have exposures at or below the final PEL of 50 μg/m^3. AFS reports that 63 percent of its members' molding operations already achieve these levels as well (see Table IV.4.8-D). These data show that exposures of most molders are already at or below the final PEL.

For molders that are still above the PEL after controlling for major sources emitting silica dust, OSHA finds that additional controls will be necessary to achieve the PEL, and that minimizing molders' contact with dust released from dry sand and silica mold washes will further reduce their exposures. Additional controls include installing or upgrading LEV near molding equipment, improving housekeeping procedures to minimize the spread of sand, reducing use of compressed air and dry sweeping, and controlling dust from nearby processes (e.g., sand mixing, transport, recovery, shakeout). Alternatively, non-silica substitutes that are less toxic than silica can be used for washes and cores.

NIOSH and OSHA evaluated pneumatic and enclosed systems to isolate the storage and transport of dry sand in two facilities. The four molder results from these foundries include two results of 13 μg/m^3 (LOD), 20 μg/m^3, and 23 μg/m^3 (Document ID 1365, p. 2-28; 0268, p. 13; 0501, p. 6). At another facility, OSHA reported a 65- to 70-percent reduction in exposures (from 140 μg/m^3 to 50 μg/m^3 and 42 μg/m^3) after the facility made improvements to sand delivery systems and exhaust ventilation systems throughout the facility (Document ID 1365, p. 2-30; 0132, pp. 238, 242, 244).

AFS argues that OSHA fails to mention the other sampling results associated with SEP report 100494079 (Document ID 0132), such as the overexposures of core makers and a grinder operator. Additionally, AFS argues that the use of this reference contradicts OSHA's argument that enclosed/automated sand delivery systems are effective as follows: "The reference in the PEA also indicates that the pneumatic sand system operation, listed as a solution in the first example above, was part of the exposure problem for the core room" (Document ID 2379, Appendix 2, p. 6).

OSHA notes that the inspection data demonstrate that improvements made to sand delivery systems and exhaust ventilation systems throughout the facility resulted in a 65 to 70 percent reduction in exposures. The inspection report finds:

> Efforts to reduce employee exposure to respirable silica dust to levels within the OSHA Standard appeared to be successful. The continued effectiveness of these engineering controls is dependent on ongoing machinery, exhaust ventilation and sand delivery system maintenance program (Document ID 0132, pp. 238, 242, 244).

OSHA understands that overexposures and variability in exposures occur due to operational situations. The fact that the employer made improvements to the sand delivery system, and that this improvement is associated with exposure reduction, shows that enclosed and ventilated transport systems are effective in reducing exposures.

Because work activities can vary throughout the day, a combination of engineering controls and housekeeping may be needed to reduce exposures below 50 $\mu g/m^3$. A foundry evaluated by OSHA showed a 60-percent reduction in exposure (from 123 $\mu g/m^3$ to 49 $\mu g/m^3$) when the facility implemented a wide variety of controls. The controls included installing an efficient dust collector, enclosing a sand chute, adding a water spray to a sand feed belt, adding LEV to the return sand belt and bucket elevator, and improving housekeeping (Document ID 0182, pp. 41, 201-203).

While the contribution to exposure reduction from housekeeping alone has not been quantified in ferrous sand casting foundries, poor housekeeping practices that disturb dust (dry sweeping and using compressed air) can diminish the effects of other controls

(Document ID 1365, p. 2-30). However, data suggest that good housekeeping in combination with other controls will provide substantial exposure reduction. Irwin (2003) reported on a foundry that used a combination of LEV (enclosing and ventilating the mold dumping and sand return areas) and adding a rotary media tumbler to substantially reduce worker exposure levels (Document ID 0752, p. 20). In addition, the foundry changed work practices and performed aggressive housekeeping. Altogether, implementing these controls reduced the exposure levels by at least 80 percent. The precise reduction could not be determined because no silica was detected in the sample; however, ERG estimated an 8-hour TWA exposure level of less than or equal to 40 µg/m^3.[44] Similar results were obtained on multiple sampling dates (Document ID 0752, p. 20).

AFS objected strongly to OSHA’s prohibition on dry sweeping and the use of compressed air for removing residual sand during molding operations. AFS noted that many molding operations require molders to sweep excess dry sand into the sand recycling system. AFS also mentioned that fixed brushes on automated equipment are used to direct waste sand into the recycling system. AFS contends that OSHA’s rule would replace these activities with vacuum systems which they claim are ineffective and not feasible (Document ID 2379, pp. 34-35; 4229, pp. 24-25).

First, OSHA’s prohibition on dry sweeping is contained in Paragraph (h) – Housekeeping of the standard for general industry and maritime. As discussed in the Summary and Explanation for this paragraph, dry sweeping or dry brushing is prohibited where such activity could contribute to employee exposure to respirable crystalline silica. Thus, the final rule would not prohibit dry brushing unless it could contribute to employee exposure. Moreover, paragraph (h) only prohibits dry sweeping and dry brushing where wet sweeping, HEPA-filtered vacuuming or other methods that minimize the likelihood

[44] Irwin (2003) did not report sample durations. This estimate is based on the respirable dust result (0.55 µg/m^3 after controls were in place) and the OSHA-calculated PEL (1.0 µg/mm^3) provided for the initial uncontrolled sample and derived using the general industry equation for the PEL for respirable dust containing silica. ERG reversed the calculation to find the percentage silica in the initial respirable dust sample. Assuming the percent silica would be similar in the two samples, ERG estimated that the 8-hour TWA was less than or equal to 40 µg/m^3 (Document ID 1365, p. 2-31).

of exposure are feasible. Therefore, the use of dry brushing would be permitted if other methods are not feasible.

Second, the prohibition on the use of compressed air contained in paragraph (h)(2) is also qualified. As OSHA explains in the Summary and Explanation for paragraph (h), the Agency has found convincing evidence that wet methods and HEPA-filtered vacuums are not safe and effective in all situations. Therefore, paragraph (h)(2) allows employers to use compressed air for cleaning where the compressed air is used in conjunction with a ventilation system that effectively captures the dust cloud created by the compressed air, or where no alternative method is feasible. These limited exceptions should encompass the situations described above by AFS, and give employers the necessary flexibility in permitting the use of compressed air where wet methods or HEPA-filtered vacuums are infeasible, or where the dust cloud created by use of compressed air is captured and therefore does not present a hazard to employees.

OSHA, nonetheless, concludes that vacuuming of molds offers an alternative to using compressed air for removing silica contamination. This conclusion is supported by a NIOSH report on a foundry that occasionally used vacuums, in addition to compressed air, for removing loose sand from molds and flasks. NIOSH recommended enclosing the cleaning operation with a receiving hood or replacing the use of compressed air cleaning with vacuuming. NIOSH also recommended the use of a sweeping compound during sweeping or replacement with portable vacuums to minimize dust generation and accumulation (Document ID 1365, p. 2-31; 0233, p. 22).

Additional Controls for Core Makers

The exposure profile in Table IV.4.8-E shows that 57 percent (62 out of 108 samples) of core makers have exposures at or below the final PEL of 50 μg/m^3. AFS reported that 73 percent of core making activities already achieve the PEL (see Table IV.4.8-D) (Document ID 2379, Attachment 2, p. 27), indicating that OSHA may be overestimating the percentage of workers currently exposed above this level. OSHA concludes that this evidence shows that exposures can be reduced to levels at or below 50 μg/m^3.

The primary cause of exposures over 50 μg/m^3 for core makers is often dust from adjacent sand processing and transport equipment or other foundry processes. Therefore, OSHA finds that controlling dust from adjacent sources will substantially reduce the exposures of most core makers. For example, installing a pneumatic transport system reduced exposures to below 21 μg/m^3 from levels ranging from 80 μg/m^3 to 360 μg/m^3 (Document ID 1365, p. 2-35; 0132, pp. 238, 242-244). NIOSH saw similar results of low exposures (less than 36 μg/m^3) for core makers working in an area with a pneumatic sand transport system (Document ID 1365, p. 2-35; 0268, pp. 8, 12-13).

Area sample results from a foundry evaluated by OSHA further demonstrate the extent to which other foundry operations can affect background silica levels in the core making area. This foundry identified sand systems operations, molding, and shakeout areas as the primary sources of silica in the facility. Migrating dusts settled into other areas causing elevated exposures to adjacent workers. An initial area sample collected in the core making area showed worker exposures of 200 μg/m^3. The foundry took steps to control the release of silica and improve the general ventilation and sand-handling systems, and clean accumulated dust in all production areas within the building. Additional samples showed exposures to core makers dropped at least 75 percent to 12 μg/m^3 and 24 μg/m^3 (Document ID 1365, pp. 2-35 – 2-36; 0511, pp. 1-6).

Additional Controls for Furnace Operators

The exposure profile in Table IV.4.8-E shows that 73 percent (62 out of 108 samples) of furnace operators have exposures at or below the final PEL of 50 μg/m^3. Similarly, AFS reports that 70 percent of its members' furnace operations currently achieve the final PEL (see Table IV.4.8-D). Therefore, OSHA finds that additional controls will be required to achieve the PEL for the remaining furnace operators who are overexposed.

Where adjacent operations release silica dust, OSHA finds that control of these operations will reduce exposure levels of furnace operators. Since furnace and pouring operations are often located in the same general area, control strategies described below for pouring operators also would benefit furnace operators to a notable extent. For example, in a highly automated foundry that made substantial efforts to control silica in all operations, NIOSH reported exposure readings of 27 μg/m^3 and 29 μg/m^3 for a worker called a chill tester who was performing tasks between the furnace and the pouring machine (Document ID 1365, p. 2-39; 0268, pp. 4, 9, 13).

Furnace operators handle sand or sand-contaminated scrap metal when they add these items to furnaces. In foundries where silica-contaminated foundry returns contribute to the exposure of furnace operators, the use of cleaner scrap and removal of sand from such returns prior to furnace charging will further reduce exposures. Metal scrap can be cleaned using rotary media mills (Document ID 1715). Regarding this citation, AFS argues:

> OSHA presents no data from any site using this control equipment, but instead relies on a supplier's claim of applicability. This evidence is hardly convincing. Moreover, for this job category the exposure assumption that OSHA (sic) about furnace operators is not consistent with foundry experience. Furnace operator exposure to silica is more likely to come from refractory repair operations than from contaminated scrap. OSHA deals with controls for refractory work under maintenance, but maintenance workers are more often engaged in machine repair activities and seldom in refractory repair which requires highly specialized knowledge and skill (Document ID 2379, Appendix 2, p. 11).

AFS appears to be arguing that silica-contaminated scrap does not generate silica-dust exposures for furnace operators but stops short of stating that contaminated scrap is never a source of silica exposure for furnace operators. OSHA's finding, however, is simply that in those facilities where contaminated scrap does contribute to furnace operators' exposures, equipment exists to clean the scrap, lessening the amount of silica that furnace operators handle. Moreover, with respect to AFS's assertion that furnace operators are more likely exposed to silica dust during refractory repair, the evidence shows that this source can be feasibly mitigated by using remotely controlled equipment, portable exhaust ventilation systems, and other controls; or employing a contractor using these controls. See Section IV-4.19 Refractory Repair.

AFS asserts based on a settled enforcement case that controlling exposures from furnace refractory repair is not feasible (Document 2379, Appendix 3, p. 14). AFS argues that

OSHA's failure to re-inspect this facility after the firm notified OSHA that they had instituted limited worker exposures through rotation and the use of powered air purifying respirators was evidence that the agency agreed that controls for furnace refractory repair were not feasible.

AFS's perspective on this case is incomplete and must be understood in the context of the settlement agreement. According to the records presented by AFS (Document ID 2379, Appendix 3, p. 28) the firm had installed a refractory push-out system that addressed the major part of the overexposures cited in this case and the administrative controls and respirators were used only to remove the refractory from the top cap of the furnace. Settlement agreements are an effort by OSHA to achieve the safest working conditions for the employees in the facility as a whole and take into account many other factors, not the least of which is achieving exposure reductions expeditiously by avoiding protracted legal proceedings. This is applicable in this case.

Facilities might need to alter work practices where furnace operators introduce silica sand as an additive to molten metal. For example, the operator might add sand at a point where existing ventilation will capture dust generated by the process. Other options include installing retractable enclosing hoods to add sand under controlled circumstances (Document ID 1365, p. 2-39; 1175, p. 4).

AFS stated that "sand would be an unusual additive to metal in a furnace and adding sand would be a minor contributor to furnace operator exposure" (Document ID 2379, Appendix 2, p. 11). However, the AFS's "Casting Answers and Advice" describes adding silica sand to maintain an "acid" slag (Document ID 0518). NIOSH also describes the addition of bags of silica-containing silicon carbide graphite (Document ID 1365, p. 2-37; 1382).

Ensuring that ventilation systems are installed and functioning properly as well as installing well-ventilated climate controlled monitoring booths (where feasible) will further reduce exposures. Use of a furnace operator control booth was associated with an exposure reading of 13 $\mu g/m^3$ (LOD), a 50-percent decrease compared to the exposure result for one of two furnace operators working outside the control booth at the same facility (Document ID 1365, p. 2-40; 0028, pp. 27-36). The other furnace operator that worked outside the booth had an exposure level of 13 μg/m^3 as well, making it difficult to confirm the benefit of this particular booth. The option of a booth for exposure control has proven effective in other industries; however, in foundries they are only effective for the more automated furnaces that require little hands-on tending.

Additional Controls for Pouring Operators

The exposure profile in Table IV.4.8-E shows that 50 percent (10 out of 20 samples) of pouring operators have exposures at or below the final PEL of 50 μg/m^3. AFS reports that 67 percent of its members' pouring operations already are below 50 μg/m^3 (see Table IV.4.8-D). Therefore, OSHA finds that additional controls will be necessary to achieve the PEL for the remaining pouring operators who are overexposed.

During mold pouring, molten metal is poured into molds of compacted sand that are often contained in pouring boxes or other containers (Document ID 1365, pp. 2-40 – 2-41). The sand is not actively disturbed while pouring, and thus little silica emission is expected to directly result from pouring activities. As a result, pouring operator exposures above 50 μg/m^3 are generally due to uncontrolled dust in adjacent operations. As previously stated, furnace operations and pouring operations often are located near each other. It is also typical for the shake-out operations, a source of significant silica emissions, to be located adjacent to the mold pouring area (Document ID 1365, pp. 2-41 – 2-42). Therefore, controlling adjacent operations will reduce the exposure levels of pouring operators. Balancing (adjusting) the overall facility ventilation to prevent airflow patterns that draw dusty air from other processes into the pouring area will achieve an additional level of control and further reduce exposures for workers in adjacent areas.

In cases where exposures cannot be reduced below the PEL through controlling silica emissions in adjacent operations, pouring operators can be isolated with operator booths or cabs supplied with fresh air maintained under positive pressure. NIOSH recommended enclosing crane cabs and ventilating them with fresh outside air, as well as controlling silica dust in adjacent operations to control exposures for pouring crane operators (Document ID 1379, p. 13). A mobile duct system that provides the cab with fresh outdoor air is commercially available for bridge crane operators (Document ID 1406, p. 664). While the benefit of this control has not been quantified for pouring operators, OSHA reported a result of less than or equal to 13 μg/m^3 (below the LOD) for a furnace operator working in a control room provided with fresh air; this result was less than half the exposure level of a furnace operator working outside the control room at the same foundry (Document ID 1365, p. 2-40; 0028, pp. 27-36).

Pouring operators conducting manual processes might be isolated by creating a pouring room physically separate from other activities. During an inspection, OSHA measured an exposure level of 22 μg/m^3 for a pouring operator isolated from other operations while exposures for molders exceeded 80 μg/m^3 for the same facility (Document ID 1365, p. 2-42; 0008, pp. 3, 16-40, 43-44). An alternative approach to isolating pouring operations might be through controlled airflow. AFS and the American Council of Government Industrial Hygienists (ACGIH) both describe LEV controls for several different pouring configurations (Document ID 0517; 0515).

Additional Controls for Shakeout Operators

The exposure profile in Table IV.4.8-E shows that 43 percent (39 out of 90 samples) of shakeout operators have exposures at or below the final PEL of 50 μg/m^3. AFS reports that 58 percent of its members' shakeout operations currently are exposed to levels below the PEL (see Table IV.4.8-D). Therefore, OSHA finds that additional controls will be necessary to achieve the PEL for the remaining shakeout operators who are overexposed.

The selection and relative effectiveness of controls is dependent on the size of the castings. Those facilities whose shakeout operators mainly work with small or medium-sized castings can effectively control silica levels in the shakeout area by enclosing the process and improving ventilation in a coordinated control effort to reduce exposures.

Several cases demonstrate the value of enclosed and ventilated shakeout equipment, particularly when combined with other dust control measures. An enclosed dust collection system was associated with full-shift PBZ readings for shakeout operators of less than or equal to 13 μg/m^3 (2 readings), 30 μg/m^3, and 41 μg/m^3. These readings were obtained at a foundry that had made a systematic effort to identify and abate all sources of dust emission with the establishment of an abatement team consisting of an engineer, maintenance and production supervisors, and workers (Document ID 1365, p. 2-51; 1408, p. 9).

Regarding the use of this study in this analysis, AFS commented:

> It is clear from the discussion in the report that the exposure result of 41 μg/m^3 cannot be extrapolated to other foundries and that OSHA does not believe that it represents a reliable example of either accurate exposure measurement or exposure control for even this foundry. It cannot be appropriately cited as evidence of feasible control for shakeout operations. Few foundries have open air shakeout operations (Document ID 2379, Appendix 2, p. 12).

In the original site visit report, OSHA provides a description of the shakeout process:

> All doors in the shake-out area were open to the outside thus providing ample natural ventilation. We would recommend that monitoring be conducted during the winter when this area is enclosed. Respirable dust can remain suspended for several hours which would allow for greater exposures to silica. The potential for an excessive exposure to silica is significant if allowed to accumulate in an unventilated room (Document ID 1408, p. 2).

OSHA has included the PBZ exposure of 41 μg/m^3 taken from the shakeout operator at this facility as evidence of the level of exposure achieved during working conditions at that time. The report shows that three samples below the 50 μg/m^3 PEL were reported for shakeout operators. The report stated that the shakeout room had natural (general) ventilation, and that in the absence of this ventilation higher exposures could occur. General ventilation can be achieved by an HVAC system in facilities with doors and windows closed. Additionally, this foundry made facility-wide efforts to control silica exposures. OSHA concludes that this general ventilation was one of the factors that contributed to the low silica exposures. OSHA also recognizes that shakeout operations can produce elevated exposures in uncontrolled conditions (Document ID 1365, p. 2-46).

In another example, a foundry enclosed the shakeout conveyor and exhausted the enclosure at a rate of 8,000 cfm (for a 10-foot segment, or a rate of 800 cfm/linear foot) as part of a comprehensive effort to reduce exposure throughout the facility. With the enclosure in place, results of 13 μg/m^3 and 37 μg/m^3 were obtained for workers in the shakeout area (Document ID 1365, pp. 2-51 – 2-52).

For small and medium-sized casting applications, alternatives to vibrating shakeout equipment that enclose the shakeout operation are available. Such systems include rotary sand/casting separators, rotary media drums, or shotblast machines (Document ID 1434; 0927; 1148). When connected to an appropriate exhaust ventilation system, this equipment (which entirely encloses the process of separating sand from castings) can separate the shakeout operator from the source of exposure. For example, at one of the same foundries mentioned earlier in the discussion of molders, a combination of enclosed and ventilated sand handling and mold dumping areas and a rotary media tumbler substantially reduced shakeout operator exposure levels at a foundry evaluated by OSHA (Document ID 0752, pp. 19-20). At this facility, shakeout operators dump molds onto a shaker conveyor, operated a rotary media drum that removes additional sand from the casting, and then hung the castings on an overhead conveyor. Initially, this process was associated with an operator exposure level that was 380 percent of the calculated PEL, measured as respirable silica-containing dust (or 326 μg/m^3 RCS). The employer then "designed and built an enclosure that ran the length of the shakeout conveyor from the mold dump position to the [media tumbler]" and also increased exhaust ventilation to the area. Once these changes were in place and the facility had been vacuumed and power washed, shakeout operator silica exposure levels decreased to levels in the estimated range of 20 μg/m^3 to 40 μg/m^3 (Document ID 0752, p. 20).[45]

For larger castings, enclosing the process is preferred to isolating the operator from the process because emissions from shakeout operations have been shown to contribute to excessive exposures not only for the shakeout operator but also in adjacent operations. However, isolating the operator from the process can be effective when the entire process

[45] Silica was not sampled, so this estimate is based on the initial 2,930 μg/m^3 (2.93 mg/m^3) and post-abatement 550 μg/m^3 (0.55 mg/m^3) respirable dust results (Document ID 0752, p. 20).

is isolated within the facility. NIOSH evaluated a facility that enclosed an entire shakeout and finishing line in an isolation room. The crane operators worked in a positive pressure cab supplied with fresh air (Document ID 0268, pp. 4-5). Exposures for operators on two different days ranged from the LOD (less than or equal to 12 μg/m^3) to 53 μg/m^3 (Document ID 0268, p. 6). Furthermore, a Mine Safety and Health Administration (MSHA) evaluation of heavy equipment cabs reported an 86 percent reduction in respirable dust (inside compared with outside the cab) for well-sealed, filtered cabs with air conditioning. This reduction was associated with an exposure to respirable dust inside the cab of 0.13 mg/m^3, with 24 percent silica content, resulting in an exposure to a silica-dust level of 31 μg/m^3 (Document ID 1365, p. 2-80; 0823, p. 5). OSHA concludes that when large-casting shakeout operations can be conducted remotely, an operator's booth using similar technology would offer the operator a comparable level of protection.

For very large castings that must be de-molded manually, ventilation can still provide some exposure reduction. The use of portable enclosures and portable ventilation systems, as well as ventilated tools, can help reduce exposures (Document ID 1365, p. 2-49). OSHA estimates that such controls can reduce exposures below 100 μg/m^3 and additionally will reduce exposures of adjacent operations where shakeout operations are the major source of exposures (Document ID 1365, p. 2-53). Based on available information, OSHA concludes that no more than 5 percent of shakeout operators are involved in producing castings of this size (Document ID 1365, p. 2-47).

Alternatively, silica exposures can be eliminated by substituting non-silica granular molding media for silica sand and using alternative refractory mold coatings (Document ID 1365, p. 2-52; 1287; 1691; and see discussion above). These alternatives are readily available from commercial sources and are associated with silica exposures below the LOD (Document ID 1365, p. 2-52; 1412, p. 10). OSHA understands that substitution is not a practical alternative in many situations, but employers should be aware of the potential benefits in reducing silica exposures when possible.

Additional Controls for Knockout Operators

The exposure profile in Table IV.4.8-E shows that 51 percent (18 out of 35 samples) of knockout operators have exposures at or below the final PEL of 50 µg/m^3. Similarly, AFS reports that 52 percent of its members' knockout operations are at or below the final PEL (see Table IV.4.8-D). Therefore, OSHA finds that additional controls will be necessary to achieve the PEL for the remaining knockout operators who are overexposed. Additional control for reducing exposures include reducing the amount of sand on the castings that enter the knockout area and installing or improving LEV on the tools and workstation where operators remove sand and excess metal from castings.

For example, a combination of controls reduced knockout operator exposures to levels of 50 µg/m^3 or less at a foundry visited by the Michigan Department of Public Health's Bureau of Environmental and Occupational Health. Between 1989 and 1994, the foundry installed new controls in the knockout area and added some new shakeout equipment. Two samples collected for "knock off" operators in 1994 resulted in full-shift PBZ concentrations of 30 µg/m^3 and 50 µg/m^3. The improvements to the knockout line included the installation of a 50,000-cfm canopy hood exhaust system, a 10,000-cfm make-up air system, baffle plates and side shields, and a new vibrator to the monorail conveyor carrying castings. The vibrating monorail conveyor shook off most excess sand in a ventilated tunnel while transporting the castings to the knockout area, where workers eventually removed residual scrap metal from the castings (Document ID 1409).

AFS argues that OSHA has selectively taken two sample results from a single day in 1994 out of context to support its feasibility argument. AFS points out that this report states "results indicate that employees remain slightly overexposed to silica on occasions" and that the report concludes by recommending continual improvement of ventilation controls. AFS argues that the standard requires compliance with the PEL at all times, not merely on certain days. The two-page report plus one data page makes it quite clear with two separate cautionary statements that the sample results cited in the PEA are not evidence of consistent control (Document ID 2379, Appendix 2, pp. 12-13).

OSHA did not selectively look at only two samples but used a traditional comparison of exposures before and after controls were installed to determine how effective the controls were in reducing exposures. The Michigan Department of Public Health inspectors noted "that the company was installing new ventilation controls in the knock-off area which are designed to reduce employee exposure to silica dust within permissible limits" (Document ID 1409, p. 2). In 1989, two samples prior to the installation of these controls in the knockout area were reported to be above 1000 μg/m^3. In 1994, after the installation of controls, which were reported as "new LEV" and "good ventilation" in the knockout area, inspectors obtained results of 30 and 50 μg/m^3 (Document ID 1365, p. 2-56; 1409, p. 2; (pdf) pp. 10-11 Air Contaminate Data). This before and after comparison is evidence that the engineering controls installed in the knockout area were successful in reducing exposures from exposures at least 20 times the final PEL to levels at or below 50 μg/m^3.

Foundries have several options for reducing the amount of residual sand adhering to castings to prevent them from reaching the knockout operator workstations. Rotary media drums that offer more vigorous or longer shakeout cycles can loosen additional sand. Modern high-frequency vibrating units offer another option. These machines can be used with exhaust ventilation and/or sand reclamation equipment to control dust (Document ID 1365, p. 2-56; 0622, 1434; 1715). NIOSH visited a foundry where, on two different product lines, castings were placed through a high-frequency shaking process after the primary shakeout was completed. On one product line, the high-frequency shaker was used after several other cleaning steps; on the second line, castings entered the high-frequency shaker prior to most other cleaning and knockout operations (Document ID 1365, p. 2-57; 0268, pp. 4-5). These two lines demonstrate that foundries have considerable leeway in assigning the order in which various cleaning and processing steps occur. The sooner that all but the most tightly adhered sand can be removed, the less likely the loose sand will affect the silica exposures of downstream workers.

AFS stated that the shakeout and knockout areas present challenges in applying ventilation because the ventilation system can interfere with the operator's access to the work. AFS offered no indication of how often such access is needed, nor did it offer any specific concerns about designs. OSHA acknowledges that large parts pose a greater control challenge but as described below, OSHA has determined that effective ventilated enclosures can be designed that allow appropriate access at work stations. AFS described one foundry that produces a 70,000 pound part. AFS stated that the shaker table for this part is ventilated but that the ventilation "does not guarantee 100 percent capture of the dust" (Document ID 2379, Appendix 1, p. 20). AFS further stated that the part must be moved with an overhead crane. The Agency notes that the ventilation system is not required to be 100 percent effective in capturing dust. It is only required to provide sufficient ventilation such that the PEL is not exceeded. It further notes, as discussed below, that only 5 percent of parts are considered too large for ordinary engineering controls (Document ID 1365, p. 2-47) AFS offered no exposure data that can be used to assess the effectiveness of the above-described ventilation system to achieve the PEL. The rulemaking record similarly did not contain such data. From the brief description provided by AFS, OSHA concludes that the worker that might be exposed in this situation is the crane operator. As noted above, there are feasible controls for crane operators, such as ventilated cabs, that are capable of reducing exposures by 90-95 percent. See Additional Controls for Shakeout Operators (Ferrous Sand Casting Foundries).

When removing adhered scrap metal from castings, saws and grinders can be fitted with LEV or located in partially enclosed, ventilated booths. Handheld tools used on larger castings also can be fitted with tool-mounted LEV or used in a ventilated booth. These tools are often associated with finishing operations and are discussed under that job category. See Additional Controls for Cleaning/Finishing Operators (Ferrous Sand Casting Foundries). AFS stated that one foundry had investigated the use of dust collection systems on handheld grinders and found that "at that time" there were no handheld grinders that could handle the size of the castings without grossly interru[pting] the finishing process (Document ID 2379, Appendix 3, p. 21). The AFS comment did not note when this assessment was done. OSHA points out that there are currently many effective and commercially-available controls for handheld grinders (see the Summary and Explanation for Paragraph (c) of the construction standard) and that studies have shown that hand held-grinders can be used successfully through a shift (Document ID

0521, p. 342). As has been discussed for other job categories in ferrous sand casting foundries, substitution of silica-containing mold and core materials with non-silica alternatives that are less toxic than silica would virtually eliminate the silica exposure of knockout operators. Alternative material, including ceramic media, and zircon sand, are readily available from commercial sources (Document ID 1365, p. 2-59; 1287; 1691).

Additional Controls for Abrasive Blasting Operators

The exposure profile in Table IV.4.8-E shows that 33 percent (20 out of 61 samples) of abrasive blasting operators have exposures at or below the final PEL of 50 μg/m^3. AFS reports show that 63 percent of its members' abrasive blasting operations currently are below the PEL, suggesting that OSHA may be overestimating baseline exposures (see Table IV.4.8-D). Based on this and other evidence in the rulemaking record, OSHA finds that additional controls will be necessary to achieve the PEL for 37 to 67 percent of abrasive blasting operators.

Abrasive blasting operators experience exposures from airborne dust originating from adjacent operations and from the blasting process. As discussed above, most of the workers whose exposures are between 50 and 100 μg/m^3 should see a reduction in exposure to 50 μg/m^3 or less when the foundry controls the silica emissions from adjacent operations. The blasting equipment typically used in foundries are enclosed systems that, when properly maintained, ensure that the silica remains in the system and is not available for worker exposure (Document 1365, p. 2-62).

To the extent that abrasive blasting operators experience secondary exposure from adjacent operations, the exposure levels of these workers will be reduced when the exposures of adjacent workers in other job categories, like shakeout and knockout processes, are reduced.

For abrasive blasting operator silica exposures that continue to be elevated once adjacent sources of respirable dust are controlled, the primary control methods involve repairing or enclosing the machines to seal leaks, and augmenting ventilation systems to achieve 500 feet per minute (fpm) air flow through all openings as recommended for blasting cabinets by the ACGIH or to achieve the air flow recommended by the machines' manufacturer (Document ID 1365, p. 2-63; 0515). Blasting machine manufacturers offer programs to rebuild and retrofit these machines and also provide long-term service contracts. New abrasive blasting machines are readily available from a variety of commercial sources (Document ID 1692). OSHA has determined that abrasive blasters used by the foundry industry are designed to be sealed systems from which silica contamination does not escape unless they are damaged or poorly maintained.

A series of air sampling results demonstrate the value of identifying, enclosing, and ventilating *all* substantial sources of exposure associated with abrasive blasting operations. OSHA visited a gray and ductile iron foundry where the abrasive blasting operator exposures were due to a combination of dust sources. The foundry made incremental modifications and eventually reduced operator silica results by 75 to 85 percent, to levels of less than 50 μg/m^3. Initially, in 1994, two workers sorted castings from a conveyor arriving from the shakeout area and loaded and unloaded an automated shot blasting machine. The ventilation was poor (“0 CFM”) in the sorting area, and results of 178 μg/m^3 and 184 μg/m^3 were obtained for these two operators. The facility replaced the shot blasting machine and associated ventilation, as well as covered and ventilated a section of the conveyor coming from the shakeout. During a second evaluation it was evident that these changes had not reduced the silica exposure levels (195 μg/m^3 and 246 μg/m^3) (Document ID 1365, pp. 2-63 – 2-64; 0128, pp. 72, 255-257, 258 [“0 CFM]-260).

Several months later, the workers continued to perform similar work, but were now placing castings sorted from the conveyor into skip buckets used to load the blasting machine. During this third evaluation, results of 47 μg/m^3 and 107 μg/m^3 were obtained for the two abrasive blasting operators, whose primary source of exposure was now reportedly dust from the shakeout conveyor and skip buckets. The foundry next added an enclosure over the skip buckets and further covered a sand conveyor next to the shot blasting machine. The shakeout conveyor, however, was noted to be a continuing source of exposure during a fourth evaluation, at which time results of 72 μg/m^3 and 80 μg/m^3 were reported for the abrasive blasting operators. Finally, 21 months after the initial evaluation, the facility added an enclosure and LEV to the exit from the shakeout, and also added LEV to the skip bucket enclosure. These controls, combined with previous modifications (new blasting machine with LEV, enclosed and exhausted sand and shakeout conveyors) produced results of 34 μg/m^3 and 47 μg/m^3 for the abrasive blasting operators who continued to sort castings (25 percent of the shift) and operate the shot blasting machine (Document ID 1365, p. 2-64; 0128, pp. 65, 72).

AFS has objected to OSHA's use of this evidence to demonstrate effectiveness of controls. AFS states that OSHA "incorrectly concludes that the isolated samples cited demonstrate reliable compliance" (Document ID 2379, Appendix 2, p. 16). Additionally, AFS cites the following passage from a 1996 letter from an OSHA area director (AD) to the foundry under review:

> Employee working as a Blast Operator on 2/7/96 was exposed to silica at a level greater than one half of the permissible exposure limit of 1.08 mg/m^3. The employee was exposed to a Time Weighted Average of .581 mg/m^3 which is 54 percent of the permissible exposure limit for a period of 431 minutes. It is reasonable to expect that on any particular day an overexposure to respirable silica could occur (Document 0128, p. 9).

AFS concludes incorrectly that this letter contradicts OSHA's use of these samples to show effective control. The issue that AFS raises is not a feasibility of controls issue, as the samples clearly show that controls were effective in reducing exposures. Instead, AFS raised an issue of general OSHA policy to encourage employers to engage in voluntary monitoring as part of a comprehensive approach to industrial hygiene. In this particular case, the OSHA representatives were concerned about airborne dust from the shakeout area and the effect on the shot blasters sampled. This is why the Area Director recommended further sampling after noting that dust could be seen coming from an "unshrouded section of the shaking conveyor" (Document ID 0128, p. 19), and why OSHA recommends controlling all sources of silica dust at the worksite, not only at the particular's employee's workstation. Nevertheless, the controls in the cited case were clearly feasible and effective to control excessive dust for the blasting operators (Document ID 0128, p. 19).

Another option for reducing sand on castings is to perform a two-stage blasting operation in which the casting is initially "pre-cleaned" using fully enclosed equipment before the blasting is finished by hand. OSHA visited a facility that manually blasted castings with aluminum oxide in a ventilated booth and obtained an initial exposure of 436 μg/m^3 (Document ID 0054, pp. 241, 243-244). After changing the process to include pre-cleaning the castings in an automated shot blasting machine before finishing the blasting by hand, the exposure declined to 51 μg/m^3, an 88 percent reduction (Document ID 0054, p. 8). At this facility, OSHA also obtained a result of 33 μg/m^3 for an operator who loaded and unloaded an automated shot blasting machine, which was fully enclosed and equipped with properly functioning LEV (Document ID 1365, pp. 2-64 – 2-65; 0054, pp. 246, 248-249, 251).

Work practices also affect the silica exposure levels of abrasive blasting operators. Sealed and ventilated abrasive blasting cabinets must remain closed for a period of time after blasting ceases (long enough for the ventilation system to cycle several complete air changes inside the cabinet). This period allows the ventilation system to remove residual airborne dust before the operator opens the door, releasing any contaminant remaining inside. In addition, the use of compressed air for cleaning dusty surfaces should be avoided. Two of the highest results in the exposure profile (1,002 μg/m^3 and 238 μg/m^3) are associated with workers who used compressed air to blow dust from surfaces around steel shot blasting machines (Document ID 1365, p. 2-65; 1463, pp. 4, 14, 19, and (pdf) pp. 26-28 Table 2).

Where very large castings (too large to fit into an abrasive blasting machine) must be blasted with abrasives, use of a ventilated blasting booth designed for this purpose can be an effective control. Although operator exposures might remain above the PEL, use of an enclosed booth will minimize the migration of silica dust to other areas of the facility. Abrasive blasting under these conditions must comply with 29 CFR 1910.94 – Ventilation, and the workers performing this abrasive blasting must be equipped with suitable respirators in accordance with 29 CFR 1910.94 and 29 CFR 1910.134 – Respiratory Protection.

Wet abrasive blasting is an additional control option for abrasive blasting operators working on very large castings (whether in the open or in a booth). Wet abrasive blasting is used on other silica-containing materials, such as concrete, and has the potential to limit silica exposures from this source if adequate water is used during the blasting (Document ID 1365, p. 2-65; 0230). The use of water on ferrous castings is rare, but not unprecedented. In 1997, NIOSH visited a gray and ductile iron foundry where finishing operators used water to wet castings while performing grinding (Document ID 1365, p. 2-66; 1381, p. 2).

As noted for other job categories, and in the discussion above for Additional Controls (Ferrous Sand Casting Foundries), by replacing silica sand with alternative granular media that is less toxic than silica for mold and core materials, foundries can eliminate these primary sources of silica exposure (Document ID 1365, p. 2-59; 1287; 1691).

Additional Controls for Cleaning/Finishing Operators

The exposure profile in Table IV.4.8-E shows that 35 percent (80 out of 228 samples) of cleaning/finishing operators have exposures at or below the final PEL of 50 μg/m^3. AFS reports that 62 percent of its members' cleaning and finishing operations already achieve 50 μg/m^3 or less, suggesting that OSHA may be overestimating the worker population exposed above the PEL. Therefore, OSHA finds that additional controls will be necessary to achieve the PEL for the remaining cleaning/finishing operators who are overexposed, some by a wide margin (54 out of 228 samples, or 24 percent have exposures above 250 μg/m^3). Additional controls include pre-cleaning castings, local exhaust ventilation, the elimination of cleaning with compressed air, and wet methods.

Exposure levels of cleaning/finishing operators are dependent on a number of factors, including size and shape of casting, degree of burnt-in sand, extent of defects requiring removal, and whether compressed air is used for cleaning. Therefore, options to reduce exposure focus on controlling these factors.

NIOSH has recommended the following general approaches to reducing dust levels in casting cleaning operations: reduce casting defects, pre-clean castings as thoroughly as possible prior to chipping/grinding, apply LEV to these operations, and eliminate the use of compressed air for cleaning (Document ID 1373, p. 35; 1381, pp. 9-10). Other control options include the use of wet grinding/finishing methods and process automation (Document ID 1365, p. 2-76; 0268, p. 8; 1381, p. 1).

Pre-Cleaning Castings

Casting defects can trap mold and materials that produce airborne silica dust during chipping and grinding. When residual mold and core material are present, most castings (small and medium sized) can be pre-cleaned using enclosed, automated, and ventilated processes, such as vibrating abrasive media, rotary media drums, or enclosed shot blasting (Document ID 1695; 1692; 1148). Pre-cleaning reduces the amount of time and effort required to clean and finish castings (Document ID 1714). Exposure levels of 27 $\mu g/m^3$, 36 $\mu g/m^3$, and 40 $\mu g/m^3$ were measured for cleaning/finishing operators working with handheld and stationary grinding equipment on castings that were pre-cleaned using a shot blast machine. Compared with the exposure levels measured before the introduction of pre-cleaning (93 $\mu g/m^3$ and 116 $\mu g/m^3$), these results represent an exposure reduction of 57 to 77 percent (Document ID 1365, p. 2-72; 0081, pp. 147-148, 431-433, 435-437).

AFS has commented that several issues should be considered for the pre-cleaning stage. AFS states (Document ID 2379, Appendix 2, pp. 18-19):

> This method of control is dependent on part configuration and results may not be consistent if operations or products change within the foundry. In addition, the performance of this control cannot be extrapolated to other operations with different processes and products.
>
> In some cases extraneous metal must be removed (manual cleaning) to facilitate use of automated processes because the extra metal prevents proper fixturing, blocks access to part interiors, or may cause damage to automated equipment.

OSHA understands these issues, but, lacking further information to characterize how limited the use of pre-cleaning parts is in relation to changes in product or operations, cannot agree with AFS. Nor has AFS described specific configurations for which pre-cleaning is not a workable solution. One configuration that OSHA has discussed at length in this analysis is the size of parts. OSHA has discussed the fact that the largest castings are difficult to enclose; however, these castings are estimated to make up only about 5 percent of operations (Document ID 1365, p. 2-53). Additionally, AFS has not provided information to characterize how much manual cleaning affects exposures in the context of ventilated and enclosed shot blasting. The evidence of exposure reduction offered in these studies is therefore still valid.

AFS commented on the data OSHA used in the PEA for assessing the effectiveness of controls in cleaning and finishing operations. AFS asserted that “there is no documentation of the reduction to levels … described in the PEA” (Document ID 2379, Appendix 2, p. 3). The exposure data that AFS objected to are derived from case files which display the exposure data in terms that compare to the formula-based PEL that existed prior to this standard. OSHA has recalculated the exposure results for the FEA to allow comparison to the new 50 $\mu g/m^3$ PEL. See Section IV-2 – Methodology for an explanation of this calculation. These data show that exposures below the 50 $\mu g/m^3$ can be achieved.

For several cases cited by OSHA, AFS observed that the agency agreed to extensions of abatement dates to allow the foundries to continue their efforts to reduce exposures. Such extensions are common in OSHA enforcement cases and are based on the Agency’s assessment of the circumstances in individual establishments, such as their good faith efforts to control exposures and other factors. Thus, extended abatement periods do not necessarily correlate with the time needed to install controls or to the ultimate feasibility of the controls.

Finally, in its post hearing brief, AFS contended that “[m]ost foundries already pre-clean castings before cleaning and finishing operations so the reduction would not apply” (Document ID 4229, p. 15). As described above, OSHA is relying on data from a case that PBZ sampling reflected exposures before and after pre-cleaning was instituted. These data reflected an exposure reduction of 57 to 77 percent, the direct effect of pre-cleaning in that facility (Document ID 1365, p. 2-72; 0081, pp. 147-148, 431-433, 435-437).

AFS's statement that most foundries already use pre-cleaning confirms for OSHA that pre-cleaning is a feasible method of reducing exposures.

Local Exhaust Ventilation (LEV)

To reduce exposures while using manually operated power tools in cleaning/finishing operations, NIOSH recommends the following options: 1) vacuum suction system on the tool itself (e.g., a high-velocity low-volume [HVLV] LEV system); 2) a mobile extraction hood; 3) stationary side-draft or downdraft LEV benches; and/or 4) retractable ventilation booth for castings that do not fit on benches (Document ID 1365, p. 2-72; 1368). However, there are limitations with these systems. Option 1 might interfere with tool operation, and clogging of inlet ports has been identified as a problem; and option 3 does not provide direct capture during cleaning of cavities. Still, LEV can provide substantial exposure reduction. NIOSH also notes for cleaning operations that downdraft and/or side draft LEV hoods are preferable to overhead exhaust systems, because overhead exhaust systems can draw silica dust from the point of generation through the worker's breathing zone (Document ID 0246, pp. 8-9).

Gressel, a researcher at NIOSH, reported on a study showing a 59 percent (cone grinder) to 77 percent (cup grinder) reduction of respirable dust exposures after workers switched to using a downdraft booth fitted with a turntable to allow manipulation of castings during cleaning (Document ID 0718, p. 357). The system was designed to ACGIH recommendations (reproduced in Document ID 0515) and included a new ventilation system that had an exhaust volume of 2,900 cfm. NIOSH recommended the use of such workstations as a means of reducing exposure.

Although HVLV hoods for controlling dust emission from portable tools have been available for many years, the foundry industry has not widely accepted them. Historically, HVLV systems involved the use of shrouds fitted to tools, which sometimes obscured the work from the worker's view and proved cumbersome to move about complex casting shapes (Document ID 1365, p. 2-73; 1383). AFS discussed the limitations of LEV on power tools (Document ID 2379 Appendix 1, pp. 25-26). AFS's objections were based on a 1979 NIOSH report. Ventilated tools, particularly grinders, continue to evolve and are becoming more widely available and better accepted in other industries. OSHA points out that there are currently many effective and commercially available controls for handheld grinders (see the Summary and Explanation for Paragraph (c) of the construction standard). In addition, testifying on the use of ventilation in the steel industry at the public hearings Mr. Michael Wright, the Director of Health, Safety and Environment at the United Steelworkers, stated in this context:

> Ventilation is a very good one [engineering control], and that can be applied, both on a very, very large scale, with very large ventilation equipment like we use in the steel industry, which basically removes contaminants from whole furnaces, down to, for example, in grinding and in some places where you're essentially grinding the sand off of a cast piece, the grinders can be equipped with ventilation systems on the handheld grinder. So it's an effective control, really, at all levels (Document ID 3584, Tr. 2577-2578).

LEV systems for stationary tools, such as bench grinders, are readily available and have been shown to reduce exposures in foundries. The ACGIH recommends specific LEV designs for seven different styles of grinding equipment (Document ID 0515). LEV booths present another option for controlling dust from both stationary equipment and hand tools. As noted under baseline conditions for this job category, exposure results of 30 $\mu g/m^3$ were obtained for two operators using separate booths, each with a grinding bench serviced by LEV (Document ID 1365, p. 2-74; 0257, pp. 1, 9, 14).

A case study completed at a foundry in New York showed that a ventilation system, which had been demonstrated to be effective in controlling emissions from another foundry process called air carbon-arc gouging (removing metal from a part using an electric arc), could be used to control silica exposures related to grinding with portable tools. Grinding benches were equipped with a “tabletop booth” consisting of a wrap-around design, which provided supply-air on both sides of the worker’s body as well as exhaust ports at the rear of the bench. The foundry reported that tabletop booths operated at exhaust rates with optimum exhaust rate of 15,000 cfm have “consistently controlled silica exposures during grinding to below OSHA’s Permissible Exposure Level” (Document ID 1720, p. IV-157; 0744, pp. 375-376). OSHA concludes that this type of

LEV could provide some exposure reduction, but the effectiveness of this approach depends on a number of variables, including the size and shape of the castings and the amount of grinding necessary.

Eliminate Cleaning With Compressed Air

NIOSH consistently recommends the elimination of compressed air for cleaning to reduce silica exposures (Document ID 1378, p. 15; 1381, p. 10). ERG, OSHA's contractor, describes an informal review of 26 results for cleaning/finishing operators working at five foundries where NIOSH or OSHA had observed use of compressed air (Document ID 1365, p. 2-75). The review showed that compressed air used by cleaning/finishing operators to blow sand off castings and equipment was associated with elevated exposure results, including a median of 487 μg/m^3 for those 26 results. Furthermore, all 26 results were 230 μg/m^3 and higher. These results are elevated compared with a median of 196 μg/m^3 for all cleaning/finishing operators shown in the exposure profile including exposures below the LOD. The majority of these results are associated with cleaning/finishing operators using pneumatic handheld grinding, sanding, and chipping tools. As an alternative to cleaning with compressed air, preferable practices include wet cleaning methods or vacuuming using appropriately filtered vacuums (see Summary and Explanation of paragraph (h) of the standard for general industry and maritime).

As workers use compressed air to clean, accumulated dust in the surrounding work area becomes airborne and can contribute to worker exposure. OSHA visited a foundry with background silica levels of 63 μg/m^3 associated with the use of compressed air. This background silica concentration would add to the exposures of those workers performing operations that generate silica dust.[46] The foundry made no physical changes in the casting cleaning department, but walls and dust accumulation points in the area were vacuumed and washed. As a result, no background silica dust was detected, and respirable dust levels were reduced 60 to 80 percent in the cleaning/finishing area. Thus, when the compressed air was no longer used and the areas where the dust that was

[46] This area sample result (as opposed to a breathing zone result) is not included in the industry profile.

disturbed by the practice of using compressed air had settled were cleaned, the background level was not detected; this demonstrates the extent to which accumulated dust from poor housekeeping practices and dust spread from other foundry departments can influence cleaning/finishing operator results (Document ID 1365, pp. 2-75 – 2-76; 0511, pp. 3-4).

AFS has commented that this foundry (cited Document ID 0511) visit by OSHA is not representative of other exposures in other foundries. AFS states (Document ID 2379, Appendix 2, pp. 7-8):

> The cleaning department data consist of thirteen samples over an approximately 75 day period. Only one sample contained silica, an extremely unusual finding for foundries and certainly not representative of other foundries' experience, which often find the level of silica in the cleaning room to be higher than in other areas of the foundry.

OSHA does not consider this facility to be unusual or unrepresentative, except perhaps to the extent that it is unusual for a foundry to control silica emissions throughout the facility - from controlling the dust at the source to implementing housekeeping measures to controlling background levels. The results documented during this inspection show that the implementation of the combination of control measures identified throughout the facility can successfully control exposures for cleaning/finishing operators (Document ID 0511, p. 4).

Wet Methods

Wet methods might be the best option for cleaning/finishing operators working on some of the largest castings, which cannot be pre-cleaned using automated methods and which are too large for conventional booths and downdraft tables. Although wet methods are not widely used in ferrous sand casting foundries, this control has been used in this type of facility. A foundry evaluated by NIOSH in 1996 used wet methods to help reduce dust during chipping and grinding of large grey iron castings ranging in mass from 1 to 28 tons (Document ID 1381, p. i). Although NIOSH noted that a worker frequently used water to wet castings, compressed air was also used to remove sand from internal cavities. As a result, an exposure of 380 μg/m^3 was recorded for the cleaning/finishing operator (Document ID 1365, p. 2-69; 1381, pp. 2, 12). OSHA has reason to believe that this exposure would have been substantially lower if a high-efficiency particulate air (HEPA)-filtered vacuum system had been used instead of compressed air.

Wet methods are successfully used in other industries such as the stone cutting industry. Kitchen countertop fabricators experienced up to an 88-percent decrease in silica exposures when finishing operators switched to water-fed angle and edge grinders (Document ID 1146, pp. 578-579).

NIOSH investigated a water-spray dust control used by construction workers breaking concrete with jackhammers. Compared with uncontrolled conditions, the use of water spray reduced exposures between 72 and 90 percent (Document ID 1365, p. 2-51; 0865, p. iv). Williams and Sam (1999) also reported that a water spray nozzle mounted on a handheld pneumatic chipper decreased respirable dust exposures approximately 70 percent, even in the enclosed environment of concrete mixing trucks (Document ID 1365, p. 2-76; 1226, p. 26).

Beamer et al. (2005) conducted a study of dust suppression using misting nozzles to reduce silica while brick cutting using a stationary saw. Misting at different flow rates resulted in respirable mass fractions of dust that were 63 to 79 percent lower using low misting and high misting nozzles, respectively, and 93 percent lower using free-flowing water (Document ID 0549, p. 503). NIOSH completed a similar study evaluating water spray devices to suppress dust created while jack hammering. The study reported between a reduction of between 72 and 90 percent (Document ID 1365, p. 2-88; 0865, p. iv). Foundries can apply these methods to achieve similar exposure reductions. Testifying at the public hearing on behalf of the Wisconsin Committee on Occupational Safety and Health, Mr. James Schultz opined that for a variety of foundry operations "[i]t's possible and with proper engineering, I think it could be very feasible to include misting to control dust" (Document ID 3586, Tr. 3238).

In summary, a number of silica control options are available to cleaning/finishing operators using handheld and bench tools to remove embedded mold and core materials.

Additionally, as discussed for other job categories, foundries that are able to switch to alternate granular media that is less toxic than silica sand can eliminate this source of exposure for cleaning/finishing operators.

Additional Controls for Material Handlers

The exposure profile in Table IV.4.8-E shows that 50 percent (18 of 36 samples) of material handlers have exposures at or below the final PEL of 50 μg/m^3. AFS reported that 79 percent of its members' material-handling operations already achieve levels of 50 μg/m^3 or less, suggesting that OSHA may have overestimated the percentage of material handlers exposed to silica above the PEL and that, instead (see Table IV.4.8-D), the PEL has already been achieved for most material handlers under baseline conditions.

OSHA finds that additional controls will be necessary to achieve the PEL for the remaining material handlers who are overexposed, and that the majority of the remaining overexposed workers, as discussed above, can be reduced below the PEL or lower when effective controls are implemented to reduce silica dust generated from other operations (i.e., sand systems, molding, shakeout, knockout, cleaning/finishing). Where material handlers generate dust through their own activities, additional controls or alternate work practices may be needed. For example, material handlers can minimize the distance that sand falls and the speed with which they add sand to hoppers, both of which will limit the amount of dust released into the air during these activities (Document ID 1365, p. 2-79).

Enclosed operator cabs operating under positive pressure equipped with air filtration and air conditioning offer another option for reducing the exposure of material handlers in facilities that have not implemented controls in high dust generating operations. NIOSH studied exposure reductions using enclosed cabs in the railroad industry and reported a 97 percent reduction in the concentration of respirable quartz inside a sealed cab - from 440 μg/m^3 outside the cab to below the limit of detection (14 μg/m^3) inside the sealed cab (Document ID 0884, pp. 14, 20). Similarly, Hall et al., demonstrated reductions of greater than 90 percent with simultaneous testing inside and outside cabs (Document ID 0719, p. 47). Exhaust ventilation on the material transfer points served by material handlers offers another control option. Improving or adding enclosures and exhaust ventilation on the bins and hoppers into which material handlers place sand would likely offer the same benefit (up to a 83-percent exposure reduction) achieved by foundries that have made such changes to sand transfer equipment (Document ID 1365, p. 2-80; 0139, pp. 59, 61, 134-136).

Finally, as noted for other job categories, essentially all silica exposures of material handlers can be eliminated by foundries that are able to substitute non-silica materials that are less toxic than silica as the granular media used in molds and cores.

Additional Controls for Maintenance Operators

The exposure profile in Table IV.4.8-E shows that 46 percent (11 out of 24 samples) of maintenance operators have exposures at or below the final PEL of 50 µg/m^3. AFS reported that 74 percent of its members' maintenance operations already achieve levels of 50 µg/m^3 or less, suggesting that OSHA may be overestimating the percentage of maintenance operators for whom additional controls are necessary to achieve the final PEL (see Table IV.4.8-D). Therefore, OSHA finds that additional controls will be necessary to achieve the PEL for the remaining maintenance workers who are overexposed.

The primary silica exposure for maintenance operators occurs during routine patching or repair and periodic replacement of refractory materials. Additional sources of exposure, from adjacent processes and equipment maintained by the maintenance operator, will be controlled when the exposure levels of workers associated with those processes and equipment are controlled (Document ID 1365, pp. 2-81 – 2-84).

Additional controls, as discussed below, include the use of reduced-silica refractory materials, automated and remotely controlled processes, precast refractory materials, improved work practices, LEV, and wet methods. In describing these controls, OSHA has drawn from the experiences of contract refractory service providers and other industries, whose workers perform work similar to that of the foundry maintenance operators who patch, maintain, and occasionally replace refractory materials. OSHA expects that these controls will be equally effective for controlling silica exposure during refractory furnace maintenance.[47]

Reduced-Silica Refractory Materials

Refractory materials with low silica content (0 to 5-percent silica compared with 90-percent silica) are readily available from commercial sources, although low silica refractory material is often not compatible with the high temperature furnaces in which refractory materials are used (Document ID 0691).

OSHA visited a gray iron foundry that reduced the silica exposure of workers who relined furnaces by 90 percent after implementing a comprehensive exposure control program that included switching to a low-silica gunning refractory applied to furnace walls (for exposure levels reported at this facility, see below in the discussion of combined control methods). Since the replacement refractory material was stronger and lasted longer, refractory workers also were able to use less material during cupola repair operations (Document ID 1365, p. 16-12; 0121, pp. 10-21, 24).

When switching from high silica to low silica-content refractories, employers will need to consider the possible hazards of substitutes. For example, under high temperatures and oxidative conditions (as in a furnace), the chromite compounds contained in some refractories can be converted to hazardous chromium VI (Document ID 0527, p. 5; 0568, p. 9). Because both installation and removal activities can generate airborne dust,

[47] Increased reliance on professional maintenance contracts has decreased the amount of time foundry employees spend replacing refractory materials (Document ID 0969). An industry source confirmed that refractory relining services are used by an estimated 90 percent of all companies, across all industries that use furnaces requiring relining (including foundries) and this number has been constant for the past decade (Document ID 0969). These companies offer service contracts to reline and maintain refractories on a schedule, using trained personnel. Professional refractory contractors are better equipped for safe handling of refractory materials (e.g., with remotely controlled equipment and portable exhaust ventilation systems) than foundry workers who might perform this work only occasionally. More consistent installation quality also reduces the frequency of relining. Additionally, some refractory management companies also offer a service to reline furnaces off site (Document ID 0969). The exposures and additional controls for professional refractory maintenance contractors are addressed under Section IV-4.19–Refractory Repair.

employers must evaluate the need to protect employees from other contaminants found in refractories before *and* after service life.

Automated and Remotely Controlled Processes

Automated refractory demolition and installation methods can reduce the number of workers exposed, the duration of exposure, and possibly the exposure levels of workers who perform large-scale refractory removal jobs. Examples include “pusher” systems installed in coreless induction furnaces to push out refractory linings (Document ID 0684), remote chipping equipment attached to a hydraulically controlled articulated arm commonly available on some types of construction equipment (Document ID 1162), and automated systems for installing dry rammable refractory material in coreless induction furnaces (Document ID 1367, pp. 11-12). For additional discussion of these control options, see Section IV-4.19 – Refractory Repair, which covers the maintenance service contractors who repair and replace refractory materials. OSHA recognizes that, in general, these methods are more useful and more available to workers involved in large-scale refractory replacement than to maintenance operators who perform periodic patching and repair. However, this control method is included here because some foundry workers occasionally participate in large-scale removal activities.[48]

Precast Refractory Materials

Relining of induction and other furnace types also might be accomplished using precast refractory materials that are set in place as units, with minimal risk of exposure. Precast refractory materials can look like typical construction bricks, or they can have more sophisticated geometries that facilitate installation. For example, curved shapes can be cast that sit flush against the furnace wall. The custom-made precast materials are sealed with refractory grout, mixed from a powder (Document ID 1365, p. 2-86; 0713; 0969). When appropriate for a particular application, preformed refractory shapes can reduce

[48] Some furnace linings are replaced monthly, but most are replaced yearly or even every several years. Information in the record about the frequency of furnace relining is inconsistent. A foundry equipment supplier estimated that many foundry furnaces are relined every 3-4 weeks and some last as long as 8 weeks (Document ID 0691, p. 1). Other sources discussed annual relines (Document ID 1367, p. 9; 1161). A third source, an installer of refractories, stated that refractories usually last a lot longer than a few weeks (Document ID 0969). Another source, a refractory installer, stated that furnaces can last many years depending on maintenance (Document ID 1161).

installation labor, improve performance, and provide a longer service life compared with some brick and poured materials. When repairs are required, standard shapes mean that replacement parts can be kept on hand and that repairs can be isolated to the worn section of the lining, eliminating the need for complete tear-out (Document ID 1179). Because of these and other advantages, companies currently use precast shapes instead of powdered products (monolithics) for certain applications more frequently (Document ID 0713). In 2011, the growth of precast refractory shapes in the United States was expected to exceed monolithics (Document ID 0578, p. 1).

Work Practices

Work practices, such as limiting the number and location of operators working in a furnace at one time, can reduce refractory worker exposures during removal activities. Sweeney and Gilgrist (1998) reported a higher silica exposure level (170 $\mu g/m^3$) for a refractory worker operating in a lower position than a second refractory worker (78 $\mu g/m^3$) within a 1,100-pound holding furnace for molten aluminum. The authors reported 8-hour TWAs for both exposures, assuming zero exposure for approximately 1 hour of the 8-hour shift. The worker who experienced higher exposure levels reportedly bent over to grab and discard the pieces of refractory material debris while the other worker operated the jackhammer. This put the lower worker's breathing zone closer to the jackhammer's point of operation and dust generation than the breathing zone of the jackhammer operator. However, both workers were overexposed to silica-containing respirable dust (Document ID 1178, p. 1).

Where faulty equipment contributes to awkward work practices, a preventive maintenance program can help reduce worker silica exposures. Workers experienced an exposure reduction of 89 percent when a foundry initiated several control measures, including a preventive maintenance program to ensure proper function of air guns and related equipment used to spray refractory furnace lining materials (Document ID 1365, p. 16-15; 0121, p. 15) (for exposure levels reported at this facility, see the section below discussing combined control methods). In a second foundry, a worker's silica exposure level decreased after a foundry replaced the missing tool restraint on a pneumatic chipper used to remove the refractory lining from a large ladle. The tool restraint eliminated the need for this worker to lean into the ladle (where dust was generated) to hold the chipping blade in place. This improvement to the tool, in conjunction with other controls, reduced exposure levels of the worker by 70 percent (Document ID 1365, p. 16-15; 0576, pp. 719-720).

Ventilation (Local Exhaust Ventilation)

Several options are available to control dust generated when refractory workers must chip or apply refractory linings from a position inside the furnace. In addition to using low silica materials, appropriate controls include temporary general dilution ventilation installed in the furnace, LEV on the chipping tool, and wet methods.

A company that provides refractory overhaul services developed a method for installing temporary LEV in a gas-fired furnace. This method is used for complete lining removals, but also is applicable to smaller patching jobs. The method, associated with silica exposures between 50 $\mu g/m^3$ and 100 $\mu g/m^3$, involves company-built exhaust fans fitted with air filters (three filters of increasing efficiency in series). Plastic sheeting is used as necessary to ensure that fresh air enters the furnace only from the most advantageous point, causing clean air to flow past the worker's breathing zone (Document ID 1365, p. 2-87; 1161). Fan/filter boxes are set into the opposite and lower end of the furnace to exhaust dusty air from near the chipping point (Document ID 1365, p. 2-87). The position of sheeting and boxes might need to be moved in order to continue providing optimal air flow as the work progresses to other sections of the furnace. Although the fan/filter boxes are specially built for this purpose, they are made of materials readily available at hardware stores (Document ID 1365, p. 2-87; 1162).

LEV also is a dust control option for refractory workers who empty bags or mix refractory powders. For smaller jobs, workers who dump bags of silica-containing materials can empty the bags into a movable hopper (or other receptacle), then use a flexible sleeve to guide material from the hopper to the distribution point (e.g., a furnace bottom). A portable exhaust trunk (preferably with a semicircular slot or flanged hood) positioned near the bag dumping hopper can capture a portion of the dust released during that activity. Because additional silica exposure can occur when workers compress empty bags, this task also should be located near a portable exhaust trunk/hood. Bag dumping for large jobs can sometimes be eliminated by obtaining powdered materials in bulk bags (e.g., 1-ton sack) filled by the supplier with the predetermined amount of product required for the job. As a standard feature, bulk bags come fitted with a sleeve through which material is dispensed. Bulk bags and sleeves are used for installing high silica rammable refractory powder in induction furnaces. Maintaining the bottom of the sleeve, which releases material, at a level just below the surface of deposited material can keep dust emissions to a minimum (Document ID 1365, pp. 16-16 – 16-17; 0691; 1367).

The benefits of tool-mounted systems for controlling silica have been demonstrated in other industries, including the construction and ready-mix concrete industries. The chipping of refractory materials is similar to chipping concrete, another silica-containing material. NIOSH tested two tool-mounted LEV shrouds for handheld pneumatic chipping equipment (60 pound jackhammers), one custom built and the other a commercially available model. Comparing multiple short-term samples, NIOSH found that the shrouds were capable of reducing respirable dust by 50 to 60 percent from a geometric mean of 2,060 $\mu g/m^3$ when no controls were used to 0.87 mg/m^3 when the commercially available shroud was used. The custom made shroud was less effective. Although the commercially available and the custom-build shroud reduced respirable dust levels, the reductions were not large statistically (Document ID 1365, p. 2-74; 0865, p. 6).

In a separate evaluation, NIOSH showed that this type of LEV system controls dust equally well for smaller chipping equipment. NIOSH collected short-term samples while workers used 25- or 30-pound jackhammers to chip concrete from inside concrete mixer truck drums (comparable to a foundry furnace due to the quantity of hardened concrete accumulated over many months and the enclosed working conditions in the drum). During 90- to 120-minute periods of active chipping, mean silica levels decreased 69 percent (from 970 $\mu g/m^3$ to 300 $\mu g/m^3$) when the workers used a tool-mounted LEV shroud in these enclosed spaces (Document ID 1365, p. 2-74; 0862, pp. 10-11).

AFS challenges the application of the tool-mounted LEV studied in the NIOSH site visit (Document ID 0862) in applying this control to foundries. AFS states the reasons as follows:

> First, this example appears to be directed at refractory operations, which as noted above are a minor component of maintenance activities and do not apply at all to activities of most maintenance workers.
>
> Second, with respect to refractory operations the concrete mixers had consistent configurations whereas foundries typically have different sizes and shapes of melting, holding, pouring and transfer equipment which precludes using a single approach to control. In addition, foundry vessels utilizing refractory linings contain significantly more material than the surface buildup seen in a concrete mixer. The material removed from a concrete mixer is only the excess material accumulated on the surface of the drum. A foundry furnace contains excess material in the form of solidified metal on the surface, but also has a lining that is several inches thick covering the entire inside of the furnace (Document ID 2379, Appendix 2, p. 21).

OSHA agrees that tool-mounted LEV may not be applicable for all situations. However, NIOSH also evaluated a combination of ventilation controls as part of the same study. The tool-mounted LEV shroud plus general exhaust ventilation provided an additional exposure reduction compared with uncontrolled conditions, resulting in a 78 percent decrease in mean silica readings (from 970 μg/m^3 to 220 μg/m^3) (Document ID 1365, p. 2-74; 0862, pp. 10-13). While tool-mounted LEV shrouds on chipping equipment reduce worker exposures, their use is more complicated in very tight spaces (such as some furnaces), where maneuvering the additional air hose can be awkward. Although ventilated chipping tools by themselves may not achieve exposure levels below the PEL, their use will reduce exposure levels and may be combined with other methods like additional general ventilation. One refractory service provider noted that they worked outdoors when possible and that they utilized fans and filter boxes when working indoors (Document ID 1365, p. 16-17; 1161, p. 1).

Wet Methods

Wet methods can be successfully used to control silica exposures in a number of operations, including chipping, sawing, spraying, and handling of dusty refractory materials. The use of water in handling dusty refractory materials acts the same as it does in other silica-containing substrates such as concrete, brick, block and stone. For instance, wet methods are currently effectively used in refractory repair services (see Section IV-4.19 – Refractory Repair). Therefore, OSHA expects that wet methods will be equally effective in the handling of refractory materials during maintenance operations.

Studies have quantified the benefit of using wet methods to control respirable dust generated during chipping with handheld equipment. NIOSH investigated a water spray dust control used by construction workers breaking concrete with 60- and 90-pound jackhammers. A spray nozzle was fitted to the body of the chipping tool, and a fine mist was directed at the breaking point. Using both a direct reading instrument and a high-flow cyclone and filter media, NIOSH collected 10-minute readings with and without the spray activated, and found respirable dust concentrations were between 72 percent and 90 percent lower when the water spray was used (Document ID 1365, p. 2-76; 0865, p. 6). Williams and Sam (1999) reported that a water spray nozzle mounted on a handheld pneumatic chipper decreased respirable dust approximately 70 percent in the worker’s breathing zone (Document ID 1365, p. 2-76). Tool-mounted water spray devices can be assembled using materials obtained from a hardware store and include a garden spray nozzle, tubing, clamps, and a control valve (Document ID 1365, p. 2-88; 0741; 0838; 0914). NIOSH completed another study evaluating water spray devices to suppress dust created while jackhammering. The study reported a 72-percent reduction in PBZ respirable dust exposures (Document ID 1365, p. 2-88; 0865, p. iv).

Water spray also is useful for suppressing dust during cleanup. After chipping, one refractory services provider (2003b) used a garden mister to wet refractory debris in the bottom of the furnace (Document ID 1365, p. 2-89; 1162). This step helped control dust as the waste was removed from the furnace. Another supplier, however, noted that using water caused some problems because it makes the bottom of the furnace slippery (Document ID 1365, p. 16-18; 1161).

Workers must use caution when introducing water into a furnace. Some refractory materials crumble and become muddy or slippery when wet with excessive amounts of water (Document ID 1365, p. 16-18; 1414; 1161). Additionally, wetting portions of the furnace lining that will not be removed (when making smaller repairs) requires an extra step to dry the refractory material before the furnace is brought to working temperature. However, despite these complications, wet methods remain an effective option for controlling silica dust from high energy activities such as pneumatic chipping and should be considered when high silica materials are involved. A spray of fine mist directed at the point of dust generation has been shown to be effective. Several refractory services companies that work with furnace refractories in foundries noted that they routinely use water, applied with a garden hose or mister, but did not provide exposure assessment data to indicate the method's effectiveness (Document ID 1161, p. 1; 1162, p. 1). At an open air location, a flow rate of 350 milliliters (12 ounces) per minute reportedly dried quickly, without adding a substantial amount of water to the work site (Document ID 1365, pp. 16-18 – 16-19; 0865, p. iv). In indoor environments, workers can use a shop vacuum to collect the water (Document ID 0675, p. 1098), but need to ensure general dilution ventilation is sufficient and ensure that vacuum exhaust air does not contain silica or is collected so that it does not become an additional source of exposure in the work area.

Combined Control Methods

Depending on the sources of respirable dust, a combination of control methods can reduce silica exposure levels more effectively than a single method. A routine cupola relining (removal and replacement) in the ferrous foundry industry demonstrates the benefit of using a combination of controls by achieving up to a 92 percent reduction in exposures (Document ID 1365, p. 16-19). Before implementing controls, OSHA collected samples for three workers with results of 270 $\mu g/m^3$, 368 $\mu g/m^3$, and 630 $\mu g/m^3$. This facility then substituted refractory material with reduced silica and greater moisture content (8 percent, rather than 4 percent, moisture), improved equipment and materials to reduce malfunction and task duration, wet refractory material before removal, and assigned a consistent team of trained workers to the task. After the foundry made these changes, silica exposure samples were collected on three dates. The values included six results between 30 μg/m^3 and 50 μg/m^3, one of 61 μg/m^3, and a short-term result below the LOD (<70 μg/m^3).[49] Reduced silica in the respirable dust sample and shorter task times (relining required less time with the improved methods) account for most of the exposure reduction (Document ID 1365, pp. 16-19 – 16-20; 0121, pp. 5-9).

A second report on a facility performing refractory relining also demonstrates the benefits of using a combination of control measures. A full-shift silica result of 215 μg/m^3 was obtained while a worker chipped away the old refractory lining using faulty equipment, and then mixed the replacement refractory material. According to the manufacturer's material safety data sheet (MSDS), the ladle lining contained 56-percent silica. Burmeister noted that the "pneumatic chipper lacked a tool retainer, requiring the worker to hold the chipping bit, putting the worker much closer to the source of the exposure than would have been necessary had the pneumatic chipper been equipped with a retainer." The foundry responded to the high exposure result by holding a training meeting and seeking worker input on abatement actions; implementing a "water control system to reduce dust generated during the pneumatic chipping process"; purchasing chisel retainers to eliminate the need for the worker to reach into the ladle during chipping; and purchasing a vacuum to remove dust and debris from the ladle. With these changes in place, a consultant found that exposure was reduced to 74 μg/m^3, representing a 66-percent reduction. OSHA notes the absence of ventilation controls and concludes that this facility might have achieved still lower silica exposure levels by using LEV or tool-mounted vacuum suction to capture dust, or by managing fresh air flow past the worker's breathing zone (Document ID 1365, p. 16-22; 0576, pp. 719-720).

Additional Controls for Housekeeping Workers

The exposure profile in Table IV.4.8-E shows that 36 percent (4 of 11 samples) of housekeeping workers have exposures at or below the final PEL of 50 μg/m^3. AFS reported that 72 percent of its members' housekeeping activities already achieve the PEL, suggesting that OSHA may be significantly overestimating the percentage of housekeeping workers exposed above the PEL (see Table IV.4.8-D).

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[49] One of the results of 30 μg/m^3 was also below the LOD (Document ID 1365, p. 16-20; 0121).

Exposure values at or below the PEL are often associated with facilities that make an effort to limit silica exposures of workers in other job categories across the facility. OSHA finds that additional controls will be necessary to achieve the PEL for the remaining housekeeping workers who are overexposed, and expects many of these workers to have reduced exposure levels of 50 μg/m^3 or below once modifications are made to control silica in the dustiest processes (i.e., sand systems operations, shakeout, knockout, abrasive blasting, clean/finishing).

For those housekeeping workers who must clean spills during upset conditions and clean areas where dust gradually accumulates over time, additional controls will be necessary to reduce worker exposures. Additional controls include wet methods, HEPA-filtered vacuums, portable exhaust ventilation, and reduced reliance on compressed air for cleaning.

Silica particles do not become airborne as readily when damp as when they are dry. Housekeeping workers can limit their exposures to silica by cleaning up spilled mold and core sand and washes while they are still damp. The material should be contained or removed so that it does not become a source of exposure when it dries. As evidence of the feasibility of this control method, NIOSH obtained six results for housekeeping workers who cleaned up damp, spilled molding sand every 2 to 4 minutes (with each mold cycle). Although their silica results (65 to 90 μg/m^3) were somewhat elevated because of other dust sources in the area, OSHA finds that the exposures were probably lower than if the sand had been allowed to dry before the workers removed it (Document ID 1365, p. 2-93; 0233, pp. 13-14, 20, 23-25).

Cleaning up spilled sand and core washes, by containing the waste before it dries, will reduce airborne dust generation. When housekeeping workers encounter dry sand, simply adding moisture will reduce dust generation during cleanup. Vacuuming, shoveling, and scraping generate less dust than dry sweeping (Document ID 1365, p. 2-93). A study of construction industry workers found that when compared with dry sweeping, exposures were approximately three times lower when construction workers used squeegees to scrape surfaces and approximately five times lower when workers used vacuums (Document ID 1163, pp. 216-217). OSHA expects similar results in foundries.

When exposures are controlled across the facility, the use of vacuums for cleaning can provide additional exposure control. However, if vacuums are not sealed properly, they can become a source of dust generation and exposure. Portable vacuums must be emptied frequently according to manufacturers' instructions to ensure adequate suction and prevent the vacuum contents from becoming an additional source of exposure (Document ID 1365, p. 2-93; 0632). Special precautions and work practices will need to be developed to make certain that the cleaning of filters does not introduce dust. As an alternative, large stationary or skid-mounted vacuum systems can provide adequate suction with vacuum ports at multiple locations. The suction ports can be positioned near locations where they are most likely to be needed, and the exhaust air and dust will pass through a traditional foundry air-cleaning device, such as a bag house.

Use of compressed air for cleaning also can contribute to workers' silica exposure levels. While low pressure compressed air is usually considered less of a safety hazard than high pressure air, any blowing can cause respirable sized silica particles to become airborne. In a study of construction workers in the United States, Flanagan et al. (2003) made 1-minute measurements using a direct reading dust monitor while 10 workers performed various cleaning tasks (Document ID 1365, p. 2-94; 0676). The investigators found that the cleaning equipment associated with the highest respirable dust exposure level was the backpack blower (Document ID 0676, p. 323).

Where dust accumulations are prevalent, control efforts should start with a thorough cleaning to remove silica dust from rafters, walls, and equipment. Irwin (2003) reported on a foundry (described previously) that reduced silica exposure levels in several job categories from levels in the range of 200 $\mu g/m^3$ and higher, to 50 $\mu g/m^3$ or lower (Document ID 1365, p. 2-94; 0752). Among other modifications, "the foundry temporarily shut down while the entire facility was thoroughly vacuumed and power washed down to remove many years of accumulated silica- containing dust." The down time was used to make other modifications as well, such as completely renovating the sand-handling system (Document ID 0752, p. 20).

Finally, with the substitution of non-silica containing materials for mold and coremaking, silica exposures can be virtually eliminated.

Ferrous Sand Casting Foundries—Feasibility Findings

Feasibility Findings for Sand Systems Operators

The exposure profile in Table IV.4.8-E shows that the silica exposures of 38 percent of sand systems operators in ferrous sand casting foundries are already 50 μg/m^3 or less. AFS survey data report that OSHA may be overestimating baseline exposures, as AFS reports that 47 percent of its members' sand system operations currently achieve the final PEL. Based on this and other information in the rulemaking record, OSHA finds that the standard is technologically feasible for sand systems operators when baseline and additional controls previously discussed are used.

Two evaluations in the record demonstrate that employers can achieve the PEL for their sand system operators through the use of engineering controls. An OSHA SEP report shows that exposure reduction levels of up to 82 percent were achieved using a combination of controls. These controls include installing LEV and fixing leaks in the mixer combined with other controls, such as replacing existing equipment with completely enclosed or pneumatic sand processing and transportation equipment, as well as improved work practices and improved housekeeping (Document ID 1365, p. 2-23; 0511). A steel foundry that implemented this combination of controls reduced respirable dust levels to 0.99 mg/m^3, with a silica of 28 percent, resulting silica exposures of 28 μg/m^3 (Document ID 1365, p. 2-23; 0511). Similarly, a NIOSH evaluation found exposure results below 30 μg/m^3 for workers in areas where sand transport systems were isolated and mullers were fitted with ventilation (Document ID 1365, pp. 2-29 – 2-30; 0018, p. 93; 0268, pp. 8-9, 13).

Foundries can mostly eliminate the silica exposures of all workers by substituting for sand with one of the alternate non-silica granular media commercially available for foundries. For example, silica exposures dropped below the LOD for all workers when a foundry in Ohio used olivine sand, a non-silica containing sand (Document ID 1365, p. 2-26; 1412, p. 10). OSHA recognizes, however, that substitution may not be an option for many applications, and employers must evaluate alternate granular media to ensure that workers are adequately protected from any associated hazards.

Applying the 82 percent reduction to the 28 exposures between 50 μg/m^3 and 250 μg/m^3 as shown in Table IV.4.8-E results in 88 percent of the exposures for sand systems operators being below the 50 μg/m^3 PEL. Therefore, OSHA concludes that the 50 μg/m^3 PEL can be achieved for most sand system operators.

Feasibility Findings for Molders

The exposure profile in Table IV.4.8-E shows that the silica exposures of 57 percent of molders in ferrous sand casting foundries are already 50 μg/m^3 or less. AFS survey data report that 63 percent of its members' molding operations already achieve the final PEL. These two independent data sets agree that the final PEL is already being achieved for most molding operations most of the time.

Based on this and other information in the rulemaking record, OSHA finds that the standard is technologically feasible for molders when baseline and additional controls previously discussed are used in combination. Additional controls that can be used include improving the enclosures and ventilation associated with equipment that delivers and processes sand in molding areas, and eliminating poor housekeeping and work practices that disturb dust (e.g., dry sweeping and use of compressed air). Evidence shows that exposure levels of 42 μg/m^3 to 40 μg/m^3 are associated with improvements in engineering controls (Document ID 1365, p. 2-30; 0132, pp. 238, 242, 244) and a silica exposure level of 40 μg/m^3 or less was achieved when a foundry also implemented aggressive housekeeping practices in addition to LEV and work practice controls (Document ID 1365, pp. 2-30 – 2-31; 0752, p. 20).

As was discussed under the heading Additional Controls for Molders (Ferrous Sand Casting Foundries), the controls that have been shown to be effective for molders are those controls that reduce contamination from other adjacent operations, particularly the sand handling system and general housekeeping. Thus, the exposure levels of workers in this job category will be reduced when facilities control the exposures of adjacent workers in other job categories. OSHA concludes that by implementing the controls described above and controlling adjacent sources of exposure, with few exceptions foundries will be able to reduce the exposure levels of molders to levels of 50 μg/m^3 or less.

Based on the available exposure data and evidence of effective controls, OSHA concludes that the 50 μg/m^3 PEL can be achieved for most molders.

Feasibility Findings for Core Makers

The exposure profile in Table IV.4.8-E shows that the silica exposures of 57 percent of core makers in ferrous sand casting foundries are already 50 μg/m^3 or below. AFS survey data report that OSHA may be significantly overestimating baseline exposures, as AFS reports that 73 percent of its members' core making activities already achieves the PEL. Based on this and other information in the rulemaking record, OSHA finds that the standard is technologically feasible for core makers when baseline and additional controls previously discussed are used.

OSHA thus finds that the exposure level of most of the remaining core makers can be reduced to levels of 50 μg/m^3 or less by effective control of silica release from adjacent operations (e.g., shakeout, finishing, sand systems operations). In addition, a thorough cleaning followed with improved housekeeping (i.e., switching to HEPA-filtered vacuums instead of compressed air) will reduce exposure levels further. A foundry that took steps to control the release of silica and also improved the general ventilation and sand-handling systems within the building reduced core maker exposure levels to 12 μg/m^3 and 24 μg/m^3, which shows that even higher reduced (Document ID 1365, p. 2-36; 0511).

Based on exposure data and evidence of effective controls, OSHA concludes that the 50 μg/m^3 PEL can be achieved for most core makers.

Feasibility Findings for Furnace Operators

The exposure profile in Table IV.4.8-E shows that the silica exposures levels of 73 percent of furnace operators in ferrous sand casting foundries are already 50 μg/m^3 or below. Similarly, AFS reports that 70 percent of its members' furnace operations are at or below the PEL. These two independent data sets agree that the PEL is already being achieved by most furnace operators. Based on this and other information in the rulemaking record, OSHA finds that the standard is technologically feasible for furnace operators when baseline and additional controls previously discussed are used, including when the spread of silica dust from other areas of the foundry to the furnace area is reduced and when better ventilation systems are used.

To reduce all furnace operator exposures to the PEL of 50 μg/m^3, OSHA finds that facilities will need to ensure that all existing emission control systems are functioning properly throughout the foundry, or install such systems where feasible to reduce dust generation from tasks specifically performed by furnace operators (Document ID 1365, p. 2-40; 0028; 0268; 0752; 1376).

In foundries where silica-contaminated foundry returns contribute to the exposure of furnace operators, metal scrap can be cleaned using rotary media mills (Document ID 1365, p. 2-39; 1434; 1715). If sand must be added to the furnace (as part of the formulation or to protect the furnace lining from aggressive metals), a retractable enclosing hood will permit the worker to add sand under controlled circumstances (Document ID 1365, p. 2-39; 1175, p. 9).

In the infrequent event that furnace operators repair refractory furnace linings, exposures can be reduced using the same controls available to workers in the foundry maintenance operator job category covered elsewhere in this section.

Based on exposure data and evidence of effective controls, OSHA concludes that the 50 μg/m^3 PEL can be achieved for most furnace operators except for those conducting certain refractory lining repairs, which is an infrequent occurrence.

Feasibility Findings for Pouring Operators

The exposure profile in Table IV.4.8-E shows that the silica exposures of 50 percent of pouring operators in ferrous sand casting foundries are already 50 μg/m^3 or below. AFS reported that 67 percent of pouring operators already achieve the PEL, suggesting that OSHA may have underestimated the percentage of pouring operators whose exposures are currently below the PEL. Based on this and other information in the rulemaking record, OSHA finds that the standard is technologically feasible for pouring operators when baseline and additional controls previously discussed are used.

OSHA finds that pouring operator exposure levels above 50 μg/m^3 are generally due to uncontrolled exposures in adjacent operations. For those pouring operators whose exposures might still be above 50 μg/m^3 after dust control for adjacent operations has been addressed, additional controls might be implemented. As discussed under the heading Additional Controls for Pouring Operators (Ferrous Sand Casting Foundries), such controls include isolation of the pouring operation, adjustment of air flow in the facility to prevent dusty air from being drawn into the pouring area, or use of booths and cabs to isolate operators from silica exposures.

Based on exposure data and evidence of effective controls, OSHA concludes that the 50 μg/m^3 PEL can be achieved for most pouring operators when exposures in the rest of the foundry are adequately controlled.

Feasibility Findings for Shakeout Operators

The exposure profile in Table IV.4.8-E shows that the silica exposures for 43 percent of shakeout operators in ferrous sand casting foundries are already 50 μg/m^3 or below. AFS reported that 58 percent of its members' shakeout processes already achieve the final PEL, suggesting that OSHA may be overestimating baseline exposures. Based on this and other information in the rulemaking record, OSHA finds that the standard is technologically feasible for shakeout operators when baseline and additional controls previously discussed are used.

By using additional controls, including enclosing operations, improving existing ventilation, or installing new systems, exposure levels can be reduced for most shakeout operators to levels of 50 μg/m^3 or less. For example, four shakeout operator exposure results were 41 μg/m^3 or less at three foundries that implemented various dust control measures in the shakeout area (e.g., shakeout enclosure added, ventilation system improved, rotary media mills installed, conveyors enclosed and ventilated) and made other systematic efforts to abate dust emissions (MI 1483 as cited in Document ID 1365, pp. 2-51 – 2-52). In its post hearing brief, the United Steelworkers commented:

> At a USW foundry, exposure monitoring of a shakeout operator was collected and trended from 1986 to 2013. This trend depicts a significant decline in exposure when the company began to utilize the hierarchy of controls and substitute the high silica content products with less concentrated products (Document ID 4214, p. 16).

While most shakeout operators' exposures will be controlled to the PEL of 50 μg/m^3 or below by using the controls described above, some operators (an estimated 5 percent of the total) will not be able to use the same methods to reach this level because the casting size or the need to manipulate castings will make it more difficult to enclose or ventilate the process (Document ID 1365, p. 2-47). For these operators, achieving exposures below 100 μg/m^3 using engineering controls is more realistic. Until engineering controls can be developed to manage silica concentrations in their work areas, employers will need to sample and to provide appropriate respiratory protection to protect these shakeout operators.

Finally, depending on the production process characteristics, substituting non-silica granular media that is less toxic than silica for silica sand in the molding and core making processes may be feasible in some operations. As discussed for the sand systems operator job category, these media are commercially available and are associated with silica exposure levels below the LOD for all job categories evaluated (Document ID 1365, p. 2-26; 1412, p. 10; 3733, pp. 2-3). However, because the ability to use substitutes depends on the processes involved, OSHA is not relying on substitution to support its technological feasibility finding.

Based on exposure data and the evidence of effective controls, OSHA concludes that the 50 μg/m^3 PEL can be achieved for most shakeout operators. The supplemental use of respirators may be necessary for the small percentage of shakeout operators who work on large castings in circumstances where substitution to non-silica granular media is not feasible.

Feasibility Findings for Knockout Operators

The exposure profile in Table IV.4.8-E shows that the silica exposures of 51 percent of knockout operators in ferrous sand casting foundries are already 50 μg/m^3 or below. Similarly, AFS reported that 52 percent of its members' knockout operations have exposures at or below 50 μg/m^3. These two independent data sets show that at least half of all knockout operations currently achieve the PEL under baseline conditions. Based on this and other information in the rulemaking record, OSHA finds that the standard is technologically feasible for knockout operators when baseline and additional controls previously discussed are used.

OSHA thus finds that the remaining knockout operators with exposures above 50 μg/m^3 will require a combination of additional controls. As previously discussed, these include limiting the amount of sand loosely adhered to castings entering the knockout process, and LEV or ventilated tools in areas where excess sand and scrap metal are removed. Because loose sand is the greatest source of exposure to knockout operators who experience the highest silica concentrations, OSHA concludes that the silica exposure levels for even the most highly exposed operators can be reduced effectively when most of this sand is removed before the casting reaches the knockout area and without releasing silica dust into the work area air.

At a foundry in Michigan a combination of controls that included improved ventilation, better workstation enclosures (e.g., side shields and baffles), and new equipment to shake excess sand off castings (in a ventilated tunnel en route to the knockout area) reduced knockout operator exposures to levels of 30 and 50 μg/m^3 (Document 1409, pp. 9-11).

In addition, those operators who work on large castings will require LEV attached to hand tools to reduce exposures (discussed in cleaning/finishing operations). Using LEV-equipped hand tools on large castings where no other controls are feasible will reduce exposures below 100 μg/m^3, but might not reduce exposures below 50 μg/m^3 (Document ID 1365, pp. 2-59 – 2-60). Therefore, as with shakeout operators, OSHA concludes that results of under 100 μg/m^3 can be achieved for the approximately 5 percent of knockout operators working on very large castings, but information is insufficient to confirm that exposure levels for these workers can be reduced to levels of 50 μg/m^3 or less. The supplemental use of respirators may be necessary for the small percentage of knockout operators working on large castings after feasible engineering like LEV and work practice controls have been implemented.

Alternatively, as discussed for sand systems operators, foundries able to switch to non-silica granular media that is less toxic than silica sand can virtually eliminate the silica exposure of all knockout operators. However, because the ability to use substitutes depends on the processes involved, OSHA is not relying on substitution to support its technological feasibility finding.

Based on the exposure data and the evidence of effective controls, OSHA concludes that the 50 μg/m^3 PEL can be achieved for most knockout operators. The supplemental use of respirators may be necessary for the small percentage of knockout operators who work on large castings in circumstances where substitution to non-silica granular media is not feasible.

Feasibility Findings for Abrasive Blasting Operators

The exposure profile in Table IV.4.8-E shows that the silica exposures of 33 percent of abrasive blasting operations in ferrous sand casting foundries are already 50 μg/m^3 or below. AFS reported that 63 percent of its members' operations already achieve the PEL. OSHA attributes the difference to poor dust controls that included leaking ventilated booths and inefficient LEV in foundries visited by OSHA and NIOSH (Document ID 1365, pp. 2-61 – 2-65). The AFS survey data, however, suggests that OSHA may be underestimating baseline exposures. Based on this and other information in the rulemaking record, OSHA finds that the standard is technologically feasible for abrasive blasting operators when baseline and additional controls previously discussed are used.

Because abrasive blasting operations are closed systems and minimize silica entering the general work area (see Additional Controls for Abrasive Blasting Operators (Ferrous Sand Casting Foundries)), OSHA has concluded that, unless the abrasive blasting enclosure is compromised, a portion of abrasive blaster's exposure levels above 50 μg/m^3 is due to uncontrolled exposures in adjacent operations (Document ID 1365, pp. 2-62 – 2-64). Where exposures remain above 50 μg/m^3, additional controls are available to address overexposures that occur if the equipment leaks, is damaged or needs maintenance. As seen earlier in this analysis, a gray ductile foundry made modifications that included a new blasting machine with LEV, enclosed and exhausted sand conveyors, adding an enclosure and LEV to the shakeout exit, and added LEV to the skip bucket enclosure. Over a period of almost two years, the foundry reduced operator silica results by 75 to 85 percent, to levels less than 50 μg/m^3 (Document ID 1365, pp. 2-63 – 2-64; 0128, pp. 16, 19, 24, 65, 72, 149-154). Another facility found an 88-percent exposure reduction to 51 μg/m^3 after workers started using automated, fully enclosed shot blasting for pre-cleaning castings (Document ID 1365, pp. 2-63 – 2-64; 0054, p. 8).

As noted in Additional Controls for Abrasive Blasting Operators (Ferrous Sand Casting Foundries), pre-cleaning small and medium-sized castings in automated shot blasting machines to reduce the amount of residual sand on the castings also provide a substantial reduction in exposures for these operators when the entire process cannot be accomplished using automated equipment.

For the largest castings, it may not be possible to perform blasting in ventilated blasting booths to limit exposure to other workers. An estimated five percent of abrasive blasting operators manually clean very large castings (the same percentage of shakeout operators are estimated to handle large castings) (Document ID 1365, pp. 2-53, 2-66). To the extent possible, these workers should perform this activity in ventilated blasting booths to limit exposure to other workers. Employers may consider a two-stage blasting process that includes pre-cleaning in a ventilated and enclosed booth. Many of these largest castings must be blasted manually because larger-sized pieces cannot be isolated within a blasting cabinet, thus necessitating other means of worker protection. As in the construction industry, wet abrasive blasting can offer exposure reductions during manual operations

(Document ID 1365, pp. 2-65 – 2-66). OSHA concludes that these controls will reduce exposures during blasting of these largest castings, but not necessarily to levels at or below the PEL.

Based on the exposure data and the evidence of effective controls, OSHA concludes that the 50 μg/m^3 PEL can be achieved for a majority of abrasive blasting operators by automating and enclosing abrasive blasting operations using properly ventilated equipment and following manufacturer's recommendations for abrasive blasting machine use and maintenance. This conclusion is based on the expectation that silica exposures from adjacent sources will be reduced when the exposure of adjacent workers in other job categories is controlled. Therefore, OSHA finds that compliance with the PEL for abrasive blasting operators is feasible. OSHA also finds, however, that for foundries that produce large castings, respirator use may be necessary.

Feasibility Findings for Cleaning/Finishing Operators

The exposure profile in Table IV.4.8-E shows that the silica exposures of 35 percent of cleaning/finishing operators in ferrous sand casting foundries are already 50 μg/m^3 or below. AFS reported that 62 percent of its members' cleaning and finishing operations already achieve levels of 50 μg/m^3 or less, suggesting that OSHA may be overestimating baseline exposures. Based on this and other information in the rulemaking record, OSHA finds that the standard is technologically feasible for cleaning/finishing operators when baseline and additional controls previously discussed are used.

At one foundry, installation of a downdraft dust collection bench (LEV) for workers using handheld equipment to clean and finish castings reduced exposure levels to 20 μg/m^3 and 24 μg/m^3 (a reduction of 69 percent on average) (Document ID 1365, p. 2-73). At another foundry, pre-cleaning castings using a shot blast machine (prior to performing finishing operations using handheld and stationary grinding equipment) reduced exposures to 27 μg/m^3, 36 μg/m^3, and 40 μg/m^3) (Document ID 1365, p. 2-72; 0081, pp. 147-148).

OSHA expects that pre-cleaning castings will be as effective and possibly more effective when cleaning castings with larger quantities of adhered mold material. This expectation is based on the ability of pre-cleaning equipment to prepare castings equally well regardless of the initial quantity of mold material adhering to the castings' surface. For a typical casting, the shot blast machines, tumbling media mills, and related equipment (singly or in series) leave only the most ingrained mold material, so cleaning/finishing operators must grind only the trace volume of residual mold material, and the resulting silica exposures are minimized (Document ID 1695; 1692; 1148).

Since pre-cleaning and use of dust collection equipment are independent controls, OSHA estimates that foundries that pre-clean castings *and* install LEV can reduce the silica exposure of finishing operators using handheld equipment by a combined 90 percent (assuming the average exposure reduction for each control is achieved). For example, an exposure of 500 $\mu g/m^3$ conservatively can be reduced by 67 percent (the midpoint of the 57 to 77 percent range cited in Additional Controls for Cleaning/Finishing Operators (Ferrous Sand Casting Foundries)) to 165 $\mu g/m^3$ by thoroughly pre-cleaning castings, and can be further reduced on average by 69 percent, to 51 $\mu g/m^3$, by providing workers with LEV workstations (such as downdraft tables) (Document ID 0718, p. 357), for a total reduction approaching 90 percent.

OSHA finds that further dust management efforts can reduce exposures to lower levels. As noted in the section on additional controls for this job category, effective plant cleaning to remove sources of accumulated dust has been shown to reduce background respirable dust exposure levels by 60 to 80 percent (Document ID 1365, p. 2-75; 0511, p. 3).

OSHA further finds that eliminating the use of compressed air for cleaning will significantly reduce the exposure levels of many of the most highly exposed cleaning/finishing operators (those 11 percent with exposures currently exceeding 500 $\mu g/m^3$). ERG-G (2008) found that 26 cleaning/finishing results associated with compressed air for cleaning had a median of nearly 500 $\mu g/m^3$ (487 $\mu g/m^3$), compared with the median of 73 $\mu g/m^3$ for cleaning finishing operators as a whole (Document ID 1365, pp. 2-67, 2-70). OSHA estimates that by eliminating cleaning with compressed air, many of these workers will experience exposure levels closer to the median for the entire job category (i.e., substantially below 500 µg/m^3). At these reduced levels, these workers will benefit from the exposure control methods described in the previous paragraphs to the same extent as the other 89 percent of workers in this job category.

OSHA finds that the exposures for most of the remaining overexposed workers can be reduced to 50 µg/m^3 or less by using a combination of controls, including effectively pre-cleaning castings, using ventilated workstations, improving housekeeping, and eliminating the use of compressed air for cleaning and the use of wet methods. OSHA concludes that the 50 µg/m^3 PEL can be achieved for most cleaning/finishing operators most of the time.

Feasibility Findings for Material Handlers

The exposure profile in Table IV.4.8-E shows that the silica exposures of 50 percent of material handlers in ferrous sand casting foundries are already 50 µg/m^3 or below. AFS reported that 79 percent of its members' material handling operations already achieves exposure levels at or below 50 µg/m^3, suggesting that OSHA may be overestimating baseline exposures. Based on this and other information in the rulemaking record, OSHA finds that the standard is technologically feasible for material handlers when baseline and additional controls previously discussed are used. OSHA thus finds that once foundries have controlled the exposures of workers in other job categories (which contribute the majority of the airborne silica to which material handlers are exposed), the exposures of the vast majority of the remaining overexposed material handlers also will be controlled to the same level.

Where material handlers' activities generate silica dust, exposures will be reduced through use of work practices that minimize dust release (minimizing the distance that sand falls during material handling and adding sand slowly to hoppers so that the hopper capacity is not exceeded). If exposures continue to exceed the PEL of 50 µg/m^3, foundries can install enclosed cabs on heavy material-handling equipment. While OSHA believes that material handlers who have exposures of 100 µg/m^3 or less can alter work practices to reduce their exposures, reductions might be insufficient to achieve exposures below 50 µg/m^3. Enclosed, ventilated cabs are associated with exposure reductions of 90 to 97 percent and can reduce even the highest material handler result to a level less than 50 μg/m^3 (Document ID 0719, p. 47; 0884, pp. 14, 20). AFS commented that OSHA's assumption that material handlers in U.S. foundries use forklifts is incorrect and asserts that using wheelbarrows to transport sand is common. However, AFS also indicates that the typical foundry may have 10 forklifts (Document ID 2379 Appendix 3, p. 21). Had AFS chosen to present some data about exposures associated with using wheelbarrows, OSHA could have factored this into the analysis.

As noted for other job categories, OSHA further finds that switching to alternate granular media that is less toxic than silica for molds and cores will essentially eliminate the silica exposures of material handlers. However, because the ability to use substitutes depends on the processes involved, OSHA is not relying on substitution to support its technological feasibility finding.

Based on the exposure data and evidence of effective controls, OSHA concludes that the 50 μg/m^3 PEL can be achieved for most material handlers.

Feasibility Findings for Maintenance Operators

The exposure profile in Table IV.4.8-E shows that silica exposures of 46 percent of maintenance operators in ferrous sand casting foundries are already 50 μg/m^3 or below. AFS survey data indicate that OSHA may be significantly overestimating baseline exposures, as AFS reported that 74 percent of its members' maintenance activities already achieve the PEL. Based on this and other information in the rulemaking record, OSHA finds that the standard is technologically feasible for maintenance operators when baseline and additional controls previously discussed are used.

OSHA thus finds that exposures below the 50 μg/m^3 PEL for maintenance operators are primarily achieved by using low-silica refractory materials where practical and implementing work practices that limit their exposures and activities to small-scale patching or repair tasks (Document ID 1365, pp. 2-89 – 2-90; 0121, pp. 7, 12, 10-21, 24).

Refractory repair is the primary source of silica exposure for these workers. While they might also encounter indirect exposure from the activities of workers in other job categories, maintenance operators' exposures from those sources will be eliminated when the other job categories are controlled. Maintenance operators can also encounter silica during upset conditions (Document ID 1365, p. 2-84).

OSHA has concluded that the exposure levels of many of the remaining operators (those with current exposure values of 250 $\mu g/m^3$ or less) can be reduced to levels of 50 $\mu g/m^3$ or less by using these same methods. This means that up to 80 percent of maintenance workers will achieve compliance with the PEL using these methods. A foundry that implemented a comprehensive exposure control program that included switching to low-silica refractory reduced exposure levels by 92 percent (Document ID 1365, p. 2-89; 0121, pp. 10-21, 24). The extent and the consistency of worker exposure reduction will depend on the silica content of the replacement materials and the proportions in which they are used compared with other refractory materials.

In foundries that cannot use reduced silica refractory patching products (because of incompatibility with production processes), additional control methods will be needed. OSHA finds that these facilities will be able to reduce maintenance operator exposure levels if they use a combination of chipping equipment fitted with LEV shrouds (or water spray when possible), work practices that limit exposure, and general exhaust ventilation that improves air circulation within the furnace during small-scale tasks (Document ID 1365, p. 2-89; 0862). However, the level of 50 $\mu g/m^3$ might not be achieved for all of these workers. NIOSH found that tool-mounted LEV when used with increased general ventilation reduced worker silica exposure levels by 78 percent in enclosed concrete mixer drums, but could not reliably maintain exposures to the level of the PEL (50 $\mu g/m^3$) (Document ID 1365, p. 2-74; 0862, pp. 10-13). OSHA acknowledges the need for maintenance workers to wear respiratory protection when patching refractories.

The exposure level of in-plant maintenance operators engaged in completely replacing refractory linings during overhaul activities also can be reduced using these controls, but to a somewhat lesser extent (to levels of 100 $\mu g/m^3$) because of the extent and duration of the project.[50] OSHA estimates that exposures during complete furnace replacements can be controlled by relying on a combination of controls that include LEV, automated or remotely operated equipment, the use of low silica-containing refractory materials, pre-wetting materials being removed, misting the air during removal, and high-moisture installation. These controls have been shown to reduce exposures during refractory repairs to levels of 50 µg/m^3 or less (see Section IV-4.19 – Refractory Repair). Based on the effectiveness of these controls described under the heading Additional Controls for Maintenance Operators (Ferrous Sand Casting Foundries), OSHA anticipates that using these controls during foundry-furnace repairs will reduce the exposure of most maintenance operators who maintain or replace refractory materials to levels below 50 µg/m^3.

Based on the exposure data and evidence of effective controls, OSHA concludes that the 50 µg/m^3 PEL can be achieved for most maintenance operators most of the time. However, supplemental respiratory protection may be necessary for maintenance operators where reduced silica refractory patching products cannot be used.

Feasibility Findings for Housekeeping Workers

The exposure profile in Table IV.4.8-E shows that the silica exposures of 36 percent of housekeeping workers in ferrous sand casting foundries are already 50 µg/m^3 or below. AFS survey data indicate that OSHA may be significantly overestimating baseline exposures, as AFS reported that 72 percent of its members' housekeeping operations already achieve the PEL. Based on this and other information in the rulemaking record, OSHA finds that the standard is technologically feasible for housekeeping workers when baseline and additional controls previously discussed are used.

OSHA thus finds that the exposure levels of most overexposed housekeeping workers will be reduced to 50 µg/m^3 or less when the exposures of workers in other job categories

[50] Based on information reported by Refractory Products Supplier A (2010) (Document ID 1159) that 75 percent of facilities use a professional service for this work (suggesting that the remaining 25 percent perform it using their own workers), OSHA has determined that this group of maintenance operators is represented by the 21 percent shown in Table IV.C-16 who currently have exposures exceeding 250 µg/m^3. As noted previously, complete relining occurs only occasionally: monthly for some furnaces and annually (or every 3 years) for other furnaces.

also are controlled. If housekeepers in a foundry continue to experience elevated exposures after the silica levels associated with other job categories have been controlled, an initial thorough cleaning to remove residual accumulated silica can reduce exposure levels. A foundry reduced silica exposure in several job categories from levels of 200 μg/m^3 and higher to 50 μg/m^3 or lower by making a number of modifications, including a thorough cleaning with vacuuming and power washing to remove many years of silica dust accumulation (Document ID 1365, p. 2-94; 0752, p. 20).

Additional controls, such as using HEPA-filtered vacuums, using wet methods to clean up spilled sand (i.e., clean while the sand is still damp, using sweeping compounds) and eliminating use of compressed air, can further reduce exposures during those tasks performed by housekeeping workers that generate additional dust. OSHA concludes that with implementation of these control strategies, described in detail under the heading Additional Controls for Housekeeping Workers (Ferrous Sand Casting Foundries), all exposures for housekeeping workers can be reduced below 50 μg/m^3.

Based on the exposure data and evidence of effective controls, OSHA concludes that overall silica exposures in ferrous sand casting foundries will be significantly reduced as a result of the engineering controls provisions of the final rule. These overall exposure reductions will also reduce exposures to housekeeping workers. OSHA concludes that the 50 μg/m^3 PEL can be achieved for most housekeeping workers.

Ferrous Sand Casting Foundries—Overall Feasibility Finding

Based on the best available evidence, as presented above, OSHA finds that compliance with the PEL is technologically feasible in ferrous sand casting foundries in most operations most of the time. OSHA also concludes that engineering and administrative controls may sometimes not be sufficient to reduce exposures to 50 μg/m^3 or less, particularly for foundries that make large castings. In those instances, supplemental respiratory protection may be needed. OSHA thus finds that the final PEL of 50 μg/m^3 is technologically feasible for ferrous sand casting foundries.

4.8.2 Nonferrous Sand Casting Foundries

Description

The job categories, manufacturing processes, and equipment are essentially the same for ferrous and nonferrous sand casting foundries, as are the sources of silica exposure within these foundry types. Only the metal type of the material being cast differs. However, among all sand casting foundries, ferrous foundry workers typically have higher silica exposures than workers in other metal casting facilities. This is primarily due to the higher temperatures required for ferrous casting, causing molds that are hotter, drier, and hence dustier during shakeout operations (Document ID 1365, p. 2-95; 0926). For the same reasons, in nonferrous sand casting foundries, sand-handling and molding sand removal tasks, that is, knockout, abrasive blasting, and cleaning/finishing, contribute less dust exposure not only to these job categories but throughout the foundry. Some nonferrous metals are compatible with different casting materials than are typically used for ferrous casting. For example, historically, olivine sand (with very low silica content) was thought to produce better casting quality for aluminum than for iron, and thus is used more frequently in the aluminum casting sector (Document ID 1365, p. 2-95; 0683). AFS indicated that olivine sand was no longer available (Document ID 2379, Appendix 2, p. 5). Although there are other types of low silica content media available, the record does not reflect the extent to which these media can be used in the different processes (Document ID 3733, pp. 2-3). Regardless, based upon the studies reviewed above showing that there are feasible engineering and administrative controls that abate dust exposures in the ferrous sand casting foundries, the similarities among the tasks performed in ferrous and nonferrous sand casting, and the lower exposures discussed in more detail below, OSHA finds that exposures in nonferrous sand casting can be reduced to below the 50 μg/m^3 PEL without reliance on low silica media substitutes.

Because the same fundamental processes are used in nonferrous foundries as are used in ferrous foundries, the job categories are the same. The exposure sampling data available for this subsector aligns well with the job categories included in Table IV.4.8-F. The median, mean, and range of exposures of nonferrous sand casting workers are presented by job category in Table IV.4.8-F. Exposure results in these facilities are generally lower, though within the range of results reported for ferrous sand casting foundries. With one exception (the maximum result for cleaning/finishing workers), the medians and maximum exposure levels in every job category are lower for nonferrous foundries than for ferrous foundries.[51] However, the profile shows that there is the potential for elevated silica exposure among nonferrous sand casting foundry workers in all job categories.

Exposure Profile, Baseline Conditions, and Additional Controls for Nonferrous Sand Casting Foundries

For each job category, the following sections discuss the similarities and any relevant differences between nonferrous sand casting foundries and ferrous sand casting foundries as they apply to worker activities and exposure levels. The focus is primarily on the exposure levels because the processes and tasks performed are so similar between ferrous and nonferrous sand casting foundry workers. The discussion indicates whether the exposure control options and conclusions presented for ferrous sand casting foundries apply in nonferrous sand casting foundries.

The exposure profile in Table IV.4.8-F for nonferrous sand casting foundries includes 252 full-shift, PBZ samples of respirable crystalline silica. The median exposure is 16 μg/m^3, the mean is 38 μg/m^3, and the range is 10 μg/m^3 (LOD) to 1,915 μg/m^3. Of the 252 samples, 40 (15.9 percent) are above 50 μg/m^3; of which 7 (2.8 percent) exceed 100 μg/m^3, while 212 (84.1 percent) are at or below 50 μg/m^3. All job categories for which there are data show most workers with exposures at or below 50 μg/m^3. The samples were collected primarily by NIOSH and OSHA and include OIS data from more recent OSHA inspections. OSHA thus based the exposure profile on the best available evidence of worker exposure in this industry and considers it to reflect baseline conditions. The AFS did not submit exposure data on nonferrous foundries.

[51] The maximum value among the data available to OSHA for cleaning/finishing operators in nonferrous sand casting foundries (1,915 μg/mm^3) is 3 percent higher than the maximum for ferrous sand casting foundries (1,868 μg/m^3). However, this figure might not indicate increased potential for elevated exposures. Just 1 percent of the cleaning/finishing operators in nonferrous sand casting foundries experienced a result above 250 μg/m^3, while 22 percent of the exposure levels reported for workers in the same job category exceeded 250 μg/m^3 in the ferrous sand casting foundries (see Tables IV.4.8-F and IV.4.8-E).

4.8) Foundries (Metal Casting)

The affected job categories, worker duties, sources of exposure, and equipment in nonferrous sand casting foundries are the same as in the ferrous sand casting industry. Exposure levels in this industry tend to be lower than in ferrous sand casting foundries because the nonferrous metals are typically cast at lower temperatures than ferrous metals, resulting in less drying and fracturing of silica mold and core materials. Where additional controls are needed for nonferrous foundries, the same types of controls discussed above for ferrous foundries will be effective in controlling exposures. Therefore, as in the ferrous sand casting industry, OSHA finds that the silica exposures of most workers can be controlled to 50 $\mu g/m^3$ or less most of the time.

Table IV.4.8-F
Personal Respirable Crystalline Silica Exposure Range and Distribution of Results for Nonferrous Sand Casting Foundries
(Parts of NAICS 331524, 331525, 331528, 331529)

	Exposure Summary			Exposure Range			Exposure Profile				
Nonferrous Sand Casting Foundries	**N**	**Mean (μg/m³)**	**Median (μg/m³)**	**Min (μg/m³)**	**Max (μg/m³)**		**<25 (μg/m³)**	**≥25 and ≤50 (μg/m³)**	**>50 and ≤100 (μg/m³)**	**>100 and ≤250 (μg/m³)**	**>250 (μg/m³)**
Sand Systems Operator	10	30	20	13	78		6 (60%)	2 (20%)	2 (20%)	0 (0%)	0 (0%)
Molder	61	35	20	12	441		39 (63.9%)	13 (21.3%)	7 (11.5%)	1 (1.6%)	1 (1.6%)
Core Maker	53	17	12	12	98		48 (90.6%)	3 (5.7%)	2 (3.8%)	0 (0%)	0 (0%)
Furnace Operator	5	14	14	13	16		5 (100%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)
Pouring Operator	8	14	14	12	17		8 (100%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)
Shakeout Operator	31	52	35	12	212		12 (38.7%)	8 (25.8%)	7 (22.6%)	4 (12.9%)	0 (0%)
Knockout Operator	26	29	24	10	84		14 (53.8%)	8 (30.8%)	4 (15.4%)	0 (0%)	0 (0%)
Abrasive Blasting Operator	11	26	14	13	58		6 (54.5%)	4 (36.4%)	1 (9.1%)	0 (0%)	0 (0%)
Cleaning/Finishing Operator	44	74	25	12	1,915		22 (50%)	11 (25%)	10 (22.7%)	0 (0%)	1 (2.3%)
Material Handler	2	26	6	16	35		1 (50%)	1 (50%)	0 (0%)	0 (0%)	0 (0%)
Maintenance Operator	1	12	12	12	12		1 (100%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)
Housekeeping Worker	0	NA	NA	NA	NA		NA	NA	NA	NA	NA
Nonferrous Sand Casting Foundries Total	**252**	**38**	**16**	**10**	**1,915**		**162 (64.3%)**	**50 (19.8%)**	**33 (13.1%)**	**5 (2%)**	**2 (0.8%)**

Notes: All samples summarized are personal breathing zone (PBZ) results representing 8-hour time-weighted average exposures.
Job categories are intended to represent job functions; actual job titles might differ, and responsibilities might be allocated differently, depending on the facility.
Percentages may not add to 100 percent due to rounding.

Sources: Document ID 1720; 3958; 0033; 0049; 0074; 0086; 0096; 0097; 0119; 0123; 0140; 0167; 0216; 0237; 0251.

<u>*Feasibility Finding for Nonferrous Foundries*</u>

Feasibility Finding for Nonferrous Sand Systems Operators

Processes and activities in nonferrous sand casting foundries are essentially the same as those found in ferrous sand casting foundries (Document ID 1365, p. 2-97). Both types of sand casting foundries use “green sand” (a moldable mixture of sand and clay) for their operations. Additionally, both types of foundries recycle molding sand using automated equipment to crush lumps and incorporate more clay (Document ID 1365, pp. 2-19 – 2-20). Ferrous and nonferrous foundries use the same types and configurations of molds. Ten results summarized in Table IV.4.8-F show exposures ranging from 13 to 78 μg/m^3, with a median of 20 μg/m^3.

The exposure profile in Table IV.4.8-F for sand system operators in nonferrous sand casting foundries includes 10 samples. The median exposure is 20 μg/m^3, the mean is 30 μg/m^3, and the range is 13 μg/m^3 (LOD) to 78 μg/m^3. Of the 10 samples, 8 (80 percent) are at 50 μg/m^3 or less. OSHA finds that additional controls will be necessary to achieve the PEL for the remaining 20 percent of workers who are overexposed. OSHA concludes that the controls and conclusions for sand systems operators in ferrous sand casting foundries also apply in nonferrous sand casting foundries because both types of foundries use the same equipment and sand in a similar manner and in similar processes (Document ID 1365, p. 2-95). Therefore, by implementing those controls as needed, nonferrous sand casting foundries will likely be able to reduce the exposure levels of most sand systems operators to levels of 50 μg/m^3 or less.

Based on the exposure data and evidence of effective controls, OSHA concludes that the 50 μg/m^3 PEL can be achieved for sand system operators in nonferrous sand casting foundries. The standard is therefore technologically feasible for this job category.

Feasibility Finding for Nonferrous Molders

Molder activities in nonferrous sand casting foundries are the same as those in ferrous sand casting foundries. The molding equipment, sand type and quantities, and worker activities are nearly identical in both types of foundries (Document ID 1365, pp. 2-95 - 2-96).

The exposure profile in Table IV.4.8-F for molders in nonferrous sand casting foundries includes 61 samples. The median exposure is 20 μg/m^3, the mean is 35 μg/m^3, and the range is 12 μg/m^3 (LOD) to 441 μg/m^3. Of the 61 samples, 52 (85.2 percent) are at 50 μg/m^3 or less. OSHA finds that additional controls will be necessary to achieve the PEL for the remaining 15 percent of molders who are overexposed.

Because of the similarities in processes and materials, OSHA concludes that the controls for molders in ferrous sand casting foundries apply in nonferrous sand casting foundries as well. By implementing those controls as needed, nonferrous sand casting foundries will be able to reduce the exposure levels of all molders to levels of 50 μg/m^3 or less. Based on the exposure data and evidence of effective controls, OSHA concludes that the 50 μg/m^3 PEL can be achieved for molders in nonferrous sand casting foundries. The standard is therefore technologically feasible for this job category.

Feasibility Finding for Nonferrous Core Makers

Core making is identical in nonferrous and ferrous sand casting foundries. In both types of foundries, core makers oversee transfer of the same type of sand and additives into automated core making equipment to make similar types of cores (Document ID 1365, pp. 2-95 - 2-96).

The exposure profile in Table IV.4.8-F for core makers includes 53 samples. The median exposure is 12 μg/m^3, the mean is 17 μg/m^3, and the range is 12 μg/m^3 (LOD) to 98 μg/m^3. Of the 53 samples, 51 (96.2 percent) are at 50 μg/m^3 or less. OSHA finds that additional controls to achieve the PEL will be necessary for the remaining 4 percent of core makers who are overexposed.

Because of the similarities in tasks and exposure sources, OSHA concludes that the controls for core makers in ferrous sand casting foundries apply in nonferrous sand casting foundries as well. By implementing those controls as needed, nonferrous sand casting foundries will be able to reduce the exposure levels of all core makers to levels of 50 μg/m^3 or less. Based on the exposure data and evidence of effective controls, OSHA concludes that the 50 μg/m^3 PEL can be achieved for core makers in nonferrous sand casting foundries. The standard is therefore technologically feasible for this job category.

Feasibility Finding for Nonferrous Furnace Operators

Furnace operator functions are similar in nonferrous sand casting foundries and ferrous sand casting foundries. Although there are some variations in furnace types that are used for the various nonferrous metals, the furnace design is unlikely to affect operator silica exposure levels (Document ID 1365, p. 2-99).

The exposure profile in Table IV.4.8-F for furnace operators in nonferrous sand casting foundries includes 5 samples, all with exposure levels below the LODs (median exposure and mean are both 14 μg/m^3). These results are within the lowest end of the range reported for furnace operators in ferrous sand casting foundries.

OSHA concludes that furnace operator activities, such as controlling and monitoring the furnaces used to pour molten metal, are similar in both types of foundries. Based on the exposure profile, OSHA finds that the exposure levels of all furnace operators in nonferrous sand casting foundries are already at levels of 50 μg/m^3 or less, and additional controls are not necessary for this job category. OSHA recognizes that data are limited for furnace operators in the nonferrous sand casting industry. However, median exposures in both nonferrous and ferrous foundries are well below the final PEL of 50 μg/m^3, and indeed well below the action level of 25 μg/m^3. This supports the finding that the controls described for furnace operators in ferrous sand casting foundries apply to furnace operators in nonferrous sand casting foundries.

Based on the exposure data and evidence of effective controls, OSHA concludes that the 50 μg/m^3 PEL can be achieved for furnace operators in nonferrous sand casting foundries. The standard is therefore technologically feasible for this job category.

Feasibility Finding for Nonferrous Pouring Operators

Pouring operator activities are similar to those in ferrous sand casting foundries. Workers in both types of foundries transfer molten metal into a ladle or holding furnace, and then into molds (Document ID 1365, p. 2-99).

The exposure profile in Table IV.4.8-F for pouring operators in nonferrous sand casting foundries includes 8 samples, all with exposures below 17 μg/m^3 (median exposure and mean are both 14 μg/m^3). These results are within the lowest end of the range reported for furnace operators in ferrous sand casting foundries.

Based on the exposure profile, OSHA finds that the exposure levels of all pouring operators in nonferrous sand casting foundries are already at levels of 50 μg/m^3 or less, and additional controls are not necessary for this job category. As with the furnace operators, data are limited for pouring operators. Since median exposures in both types of foundries discussed are well below the final PEL of 50 μg/m^3 and indeed below the action level of 25 μg/m^3, OSHA concludes that the controls described for pouring operators in ferrous sand casting foundries apply to pouring operators in nonferrous sand casting foundries.

Based on the exposure data and evidence of effective controls, OSHA concludes that the 50 μg/m^3 PEL can be achieved for pouring operators in nonferrous sand casting foundries. The standard is therefore technologically feasible for this job category.

Feasibility Finding for Nonferrous Shakeout Operators

Shakeout operators perform the same functions and use the same equipment in nonferrous foundries as in ferrous sand casting foundries. In both types of foundries, these workers monitor equipment that separates castings from the same types of sand mold materials (Document ID 1365, p. 2-99).

The exposure profile in Table IV.4.8-F for shakeout operators in nonferrous sand casting foundries includes 31 samples. The median exposure is 35 μg/m^3, the mean is 52 μg/m^3, and the range is 12 μg/m^3 to 212 μg/m^3. Of the 31 samples, 20 (64.5 percent) are at 50 μg/m^3 or less.

OSHA finds that additional controls will be necessary for the remaining 35 percent of shakeout operators who are overexposed. OSHA finds that the controls described for this job category in ferrous sand casting foundries are the same for shakeout operators in nonferrous sand casting foundries; therefore, the remaining shakeout operators' exposures can be controlled to a similar extent by implementing those controls discussed for the equivalent group in the ferrous sand casting foundries. Although not suggested by the exposure profile in Table IV.4.8-F, it is possible that a few shakeout operators in these foundries might require respiratory protection under the same circumstances (i.e., very large castings) as for shakeout operators in ferrous sand casting foundries.

Based on the exposure data and evidence of effective controls, OSHA concludes that the 50 μg/m^3 PEL can be achieved for shakeout operators in nonferrous sand casting foundries, with the possible exception of those with very large castings (which is not reflected in the exposure profile of baseline conditions). The standard is therefore technologically feasible for this job category.

Feasibility Finding for Nonferrous Knockout Operators

Knockout operator functions are identical in ferrous and nonferrous sand casting foundries (Document ID 1365, p. 2-100). Operators in both types of foundries use hammers and saws to remove sprues, gates, and risers (i.e., the waste pieces of the metal casting that result from the molten metal passing through the fill tube for each mold) from castings. Although workers in both types of foundries also remove the same type of sand from castings, the lower casting temperatures in nonferrous sand foundries result in processes that are less dry and dusty (Document ID 1365, p. 2-95).

The exposure profile in Table IV.4.8-F for knockout operators in nonferrous sand casting foundries includes 26 samples. The median exposure is 24 μg/m^3, the mean is 29 μg/m^3, and the range is 10 μg/m^3 (LOD) to 84 μg/m^3. Table IV.4.8-F shows that, of the 26 samples, 22 (84.6 percent) are at 50 μg/m^3 or less.

OSHA finds that additional controls to achieve the final PEL of 50 μg/m^{3}will be necessary for the remaining 15 percent of knockout operators who are overexposed. OSHA concludes that the controls described for this job category in ferrous sand casting foundries are the same as those for knockout operators in nonferrous sand casting foundries. Therefore, OSHA finds that the remaining knockout operator exposures can be controlled to a similar extent by implementing those controls discussed for this job category in the ferrous sand casting foundries. Although not suggested by the exposure profile in Table IV.4.8-F, if extremely elevated exposures are encountered, it is possible that a few knockout operators in these foundries might require respiratory protection under the same circumstances (i.e., very large castings) as for the comparable group in ferrous sand casting foundries.

Based on the exposure data and evidence of effective controls, OSHA concludes that the 50 μg/m^3 PEL can be achieved for knockout operators in nonferrous sand casting foundries, with the possible exception of those with very large castings (which is not reflected in the exposure profile of baseline conditions). The standard is therefore technologically feasible for this job category.

Feasibility Finding for Nonferrous Abrasive Blasting Operators

The activities of abrasive blasting operators in nonferrous sand casting foundries are the same as in ferrous sand casting foundries. Blasters remove the same type of sand using enclosed systems, but lower casting temperatures in nonferrous foundries create conditions that are less dry and dusty than in ferrous sand foundries (Document ID 1365, pp. 2-95, 2-100).

The exposure profile in Table IV.4.8-F for abrasive blasters in nonferrous sand casting foundries includes 11 samples. The median exposure is 14 μg/m^3, the mean is 26 μg/m^3, and the range is 13 μg/m^3 to 58 μg/m^3. Of the 11 samples, 10 (90.9 percent) are at 50 μg/m^3 or less. Although 9 percent of the results exceed 50 μg/m^3, none exceeds 100 μg/m^3.

OSHA finds that additional control to achieve the final PEL of 50 μg/m^3 will be necessary for the remaining 9 percent of abrasive blasting operators who are overexposed. OSHA concludes that the controls described for this job category in ferrous sand casting foundries (including controlling exposures in the other job categories contributing to overall exposures) are the same as those for abrasive blasting operators in nonferrous sand casting foundries; therefore, the remaining abrasive blasting operators exposures can be controlled to a similar extent. Although not reflected in the exposure profile in Table IV.4.8-F, if extremely elevated exposures are encountered, it is possible that a few abrasive blasting operators in these foundries might require respiratory protection under the same circumstances (i.e., very large castings) as for this job category in ferrous sand casting foundries.

Based on the exposure data and evidence of effective controls, OSHA concludes that the 50 µg/m^3 PEL can be achieved for abrasive blasting operators in nonferrous sand casting foundries, with the possible exception of those with very large castings (which is not reflected in the exposure profile of baseline conditions). The standard is therefore technologically feasible for this job category.

Feasibility Finding for Nonferrous Cleaning/Finishing Operators

Cleaning/finishing operators perform the same activities in nonferrous sand casting foundries as in ferrous sand casting foundries. In both types of foundries, these workers use the same tools to grind out similarly constituted residual mold material and to finish the casting.

The exposure profile in Table IV.4.8-F for cleaning/finishing operators in nonferrous sand casting foundries includes 44 samples. The median exposure is 25 µg/m^3, the mean is 74 µg/m^3, and the range is 12 µg/m^3 to 1,915 µg/m^3. Of the 44 samples, 33 (75 percent) are at 50 µg/m^3 or less. OSHA finds that additional control to achieve the final PEL of 50 µg/m^3 will be necessary for the remaining 25 percent of cleaning/finishing operators who are overexposed. OSHA concludes that these workers require the same additional controls described for cleaning/finishing operators in ferrous sand casting foundries.

Based on the exposure data and evidence of effective controls, OSHA concludes that the 50 µg/m^3 PEL can be achieved for cleaning/finishing operators in nonferrous sand casting foundries. The standard is therefore technologically feasible for this job category.

Feasibility Finding for Nonferrous Material Handlers

The activities of material handlers in nonferrous sand casting foundries are the same as in ferrous sand casting foundries. They typically use powered material handling equipment to transport sand, castings, or other materials.

The exposure profile in Table IV.4.8-F for material handlers in nonferrous sanding casting foundries includes 2 samples. Both samples are below 50 µg/m^3 (16 µg/m^3 and 35 µg/m^3, with a median of 26 µg/m^3). Based on the exposure profile, OSHA finds that the exposure levels of all material handlers in nonferrous sand casting foundries are already at 50 μg/m^3 or less and additional controls are not necessary for this job category. Although the data available for material handlers are limited, the median exposure for material handlers in ferrous sand casting foundries is only 49 μg/m^3, and AFS reported that 79 percent of its members' material-handling operations in ferrous sand casting foundries already achieve the PEL. OSHA concludes that the controls described for material handlers in ferrous sand casting foundries apply to material handlers in nonferrous sand casting foundries in cases where exposures exceed the PEL.

Based on the exposure data and evidence of effective controls, OSHA concludes that the 50 μg/m^3 PEL can be achieved for material handlers in nonferrous sand casting foundries. The standard is therefore technologically feasible for this job category.

Feasibility Finding for Nonferrous Maintenance Operators

In both nonferrous sand casting and ferrous sand casting foundries, maintenance operators repair and maintain foundry and sand-handling equipment, including refractory furnace linings. However, maintenance operators who repair nonferrous furnace linings might not need to perform this task as frequently since the lower melting temperatures of nonferrous metals potentially cause less damage to the linings (Document ID 1365, p. 2-101).

The exposure profile in Table IV.4.8-F for maintenance operators in ferrous sand casting foundries includes only 1 sample, which was an LOD value of 12 μg/m^3. While OSHA has only obtained one sample, this exposure is at the low end of the range of exposures for maintenance operators in ferrous sand casting foundries. Table IV.4.8-E shows that 46 percent of maintenance operators in ferrous sand casting foundries currently achieve the PEL, while AFS reported that 74 percent of its member's maintenance operations already achieve the PEL.

Since exposures for nonferrous sand casting foundries are generally expected to be lower, OSHA concludes that the final PEL of 50 μg/m^3 or less has already been achieved for maintenance operators in nonferrous sand casting foundries. Furthermore, refractory maintenance activities in nonferrous foundries are not likely to result in any greater exposure for maintenance operators than in ferrous foundries. The lower melting temperatures of some nonferrous metals, such as aluminum, are less destructive of furnace linings, which therefore require less frequent repair. In the event that elevated exposures do occur, OSHA finds that the controls for maintenance operators in ferrous sand casting foundries also apply in nonferrous sand casting foundries and that by implementing those controls as needed, nonferrous sand casting foundries will be able to reduce the exposure levels of all maintenance operators to levels of 50 µg/m^3 or less.

Based on the exposure data and evidence of effective controls, OSHA concludes that the 50 µg/m^3 PEL can be achieved for maintenance operators in nonferrous sand casting foundries. The standard is therefore technologically feasible for this job category.

Feasibility Finding for Nonferrous Housekeeping Workers

The activities of housekeeping workers in nonferrous sand casting foundries are the same as in ferrous sand casting foundries. In the PEA, OSHA presented a single result of 66 µg/m^3 that was obtained from a report on a nonferrous sand casting foundry in 1988.

OSHA has decided to exclude samples collected prior to 1990, and as a result OSHA has removed this sample from the exposure profile since the Agency has concluded that evidence from ferrous sand casting foundries for this job category is sufficient to characterize exposures for these workers in nonferrous sand casting foundries. Therefore, the exposure profile in Table IV.4.8-F contains no samples for housekeeping workers. However, the exposure profile in Table IV.4.8-E for housekeeping workers in ferrous sand casting foundries shows that 36 percent (4 out of 11 samples) of those workers currently achieve the PEL under baseline conditions, while AFS reported that 72 percent of its members' housekeeping activities already achieve the PEL.

Based on information presented above for other job categories (the major sources of silica exposure for housekeeping workers), OSHA concludes that silica exposure levels for this job category arise from the same sources in nonferrous sand casting foundries and are unlikely to exceed and are likely lower than the profile presented for housekeeping workers in the ferrous sand casting industry (Table IV.4.8-E). The controls for housekeeping workers in ferrous sand casting foundries also apply in nonferrous sand casting foundries. OSHA concludes that by implementing those controls as needed, nonferrous sand casting foundries will be able to reduce the exposure levels of all housekeeping workers to levels of 50 μg/m^3 or less.

Based on the exposure data for housekeeping workers in ferrous sand casting foundries and evidence of effective controls, OSHA concludes that the 50 μg/m^3 PEL can be achieved for housekeeping workers in nonferrous sand casting foundries. The standard is therefore technologically feasible for this job category.

Nonferrous Sand Casting Foundries—Overall Feasibility Findings

OSHA concludes that controls identified to reduce worker exposures in ferrous sand casting facilities also will reduce exposures to an equivalent extent in nonferrous sand casting facilities. This conclusion is based on evidence that the same casting methods involving sand are commonly used to cast most metals and that exposures in nonferrous sand casting foundries are generally comparatively lower. Therefore, based on the exposure data and availability of effective controls, OSHA finds that the 50 μg/m^3 PEL can be achieved for all job categories in nonferrous sand casting foundries, at least most of the time. The final PEL of 50 μg/m^3 is therefore technologically feasible for the nonferrous sand casting industry.

4.8.3 Non-Sand Casting Foundries (Ferrous and Nonferrous)

Description

Non-sand casting foundries include facilities that cast any metal primarily using methods other than bonded sand molds (sand bonded with clay or other additives). Casting methods include, but are not limited to, unbonded sand molding (e.g., lost foam), investment casting, casting with ceramic and plaster molds, and permanent mold casting (including centrifugal mold processes). Poured metal is shaped by a substance other than sand, typically a sturdy shell-like layer of refractory material, which can contain substantial amounts of quartz or cristobalite (Document ID 1365, p. 2-102). The refractory shell materials contain silica, and permanent molds are often washed with silica mold-release agents. Sand casting foundries sometimes use similar materials to line sand molds and cores, but non-sand casting foundries depend more heavily on these refractory substances in the molding process (Document ID 1365, p. 2-102).

Although sand is not the primary molding material, a reduced amount of sand might be involved in these casting methods. Some processes use loose, unbonded sand to fortify or provide structural support around the refractory mold. Additionally, sand cores might be inserted into any type of mold (Document ID 1365, p. 2-102; 1139).

In general, job categories are similar to those in ferrous sand casting foundries. With the exception of molders, which use non-silica molds, workers in non-sand casting foundries perform the same activities, have similar sources of exposure, and are exposed to similar levels of silica in both types of foundries (Document ID 1365, p. 2-102).

Non-sand Casting Foundries - Exposure Profile, Baseline Conditions, and Additional Controls

Table IV.4.8-G summarizes, by job category, the best available evidence of the full-shift PBZ silica exposure results for non-sand casting foundry workers. The exposure profile in Table IV.4.8-G shows that exposures of 50 μg/m^3 or less have already been achieved for the vast majority of workers in nine of the 11 job categories (molders, core makers, furnace operators, pouring operators, abrasive blasting operators, cleaning/finishing operators, material handlers, maintenance operators, and housekeeping workers). The exposure profile shows that only shakeout and knockout operations do not achieve exposures below the PEL most of the time under baseline conditions.

Considered overall, almost three-quarters of workers sampled in the non-sand casting foundries currently have exposures below the PEL. As discussed below, the job categories with higher exposures - the shakeout operators, knockout operators, abrasive blasting operators and cleaning/finishing operators - who can experience higher exposures due to the nature of their tasks, will benefit equally from the controls identified for these workers in ferrous sand casting foundries due to the similarity of the tasks performed.

For each job category, the following section discusses relevant differences between non-sand casting foundries and ferrous sand casting foundries as they apply to worker activities and exposure levels. The discussion indicates whether the exposure control options and conclusions presented for ferrous sand casting foundries apply in non-sand casting foundries. Where necessary, the section also describes required modifications to the controls. OSHA also provides its assessment of the feasibility of the PEL by job category and availability of exposure controls.

The exposure profile in Table IV.4.8-G for non-sand casting foundries includes 124 full-shift, PBZ samples. The median exposure is 16 μg/m^3, the mean is 71 μg/m^3, and the range is 8 μg/m^3 to 980 μg/m^3. Of the 124 samples, 92 (74.2 percent) are at or below the final PEL of 50 μg/m^3. OSHA finds that the additional controls identified for the different job categories in ferrous sand casting foundries will be necessary to achieve the PEL for the remaining 25.8 percent of workers in non-sand casting foundries. Based on the exposure profile and evidence of the effectiveness of these controls, the overall conclusion is that OSHA finds the standard to be technologically feasible for each of the job categories in non-sand casting foundries and for the non-sand casting foundry industry generally.

Table IV.4.8-G
Personal Respirable Crystalline Silica Exposure Range and Distribution of Results for Non-Sand Casting Foundries
(Parts of NAICS 331512, 331521, 331524, 331525, 331528)

	Exposure Summary			Exposure Range		Exposure Profile				
Non-Sand Casting Foundries	**N**	**Mean (μg/m³)**	**Median (μg/m³)**	**Min (μg/m³)**	**Max (μg/m³)**	**<25 (μg/m³)**	**≥25 and ≤50 (μg/m³)**	**>50 and ≤100 (μg/m³)**	**>100 and ≤250 (μg/m³)**	**>250 (μg/m³)**
Sand Systems Operator	0	NA	NA	NA	NA	0	0	0	0	0
Molder	29	44	21	9	291	16 (55.2%)	6 (20.7%)	4 (13.8%)	2 (6.9%)	1 (3.4%)
Core Maker	3	12	12	10	13	3 (100%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)
Furnace Operator	4	19	15	12	35	3 (75%)	1 (25%)	0 (0%)	0 (0%)	0 (0%)
Pouring Operator	7	33	12	10	150	6 (85.7%)	0 (0%)	0 (0%)	1 (14.3%)	0 (0%)
Shakeout Operator	7	183	220	10	420	1 (14.3%)	1 (14.3%)	1 (14.3%)	2 (28.6%)	2 (28.6%)
Knockout Operator	15	140	56	9	614	4 (26.7%)	3 (20%)	5 (33.3%)	0 (0%)	3 (20%)
Abrasive Blasting Operator	13	138	14	10	980	7 (53.8%)	1 (7.7%)	2 (15.4%)	1 (7.7%)	2 (15.4%)
Cleaning/Finishing Operator	34	54	16	8	820	18 (52.9%)	11 (32.4%)	2 (5.9%)	2 (5.9%)	1 (2.9%)
Material Handler	3	41	8	8	107	2 (66.7%)	0 (0%)	0 (0%)	1 (33.3%)	0 (0%)
Maintenance Operator	4	14	12	12	20	4 (100%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)
Housekeeping Worker	2	13	13	12	14	2 (100%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)
Non-Sand Casting Foundries Total	**124**	**71**	**16**	**8**	**980**	**69 (55.6%)**	**23 (18.5%)**	**14 (11.3%)**	**9 (7.3%)**	**9 (7.3%)**

Notes: All samples summarized are personal breathing zone (PBZ) results representing 8-hour time-weighted average exposures.
Job categories are intended to represent job functions; actual job titles might differ, and responsibilities might be allocated differently, depending on the facility.
Percentages may not add to 100 percent due to rounding.

Sources: Document ID 1720; 3958; 0014; 0017; 0062; 0074; 0078; 0122; 0134; 0135; 0142; 0151; 0172; 0215; 0267; 1175.

<u>*Non-sand Casting Foundries – Feasibility Finding*</u>

Feasibility Findings for Sand Systems Operators in Non-sand Casting Foundries

In non-sand casting foundries, the activities of sand systems operators are limited to mixing sand for cores in those facilities that use sand cores and to handling any un-bonded core sand returned from the shakeout process. Core sand and refractory materials are not typically reclaimed and reused in non-sand casting foundries. Thus, sand reclamation is less complicated and presumably less dusty than in ferrous sand casting foundries.

OSHA was not able to identify any exposure measurements for sand systems operators in non-sand casting foundries; however, the reduced use of sand and the modest exposure levels encountered for most job categories in these foundries suggest that exposure levels for this group would likely be in the lower end of the range reported for ferrous sand casting foundries. It is notable that in non-sand casting foundries, 74 percent of exposures in all job categories are already below the 50 μg/m^3 PEL. In 6 of 12 job categories in ferrous foundries, by contrast, more than 50 percent of the exposures exceed the 50 μg/m^3 PEL. For non-sand casting foundries only 2 of 12 job categories (shakeout and knockout operators) have more than half of the exposures in excess of the 50 μg/m^3 PEL. Because of the decreased amount of sand handling, fewer sand systems operators with lower exposures are likely to be employed in non-sand casting foundries than in sand casting foundries. In some cases, these duties are likely performed by a worker in another job category, such as core maker or molder. Their exposures are discussed below.

OSHA is unable to estimate what percentage of sand systems operators in non-sand casting foundries are currently below the PEL under baseline conditions. Based on the above information, however, the Agency concludes that for those workers in this industry who do have sand-handling duties, the available controls described for sand systems operators in ferrous sand casting foundries will be sufficient to control any exposures that occur in non-sand casting foundries as well. OSHA further concludes that by implementing those controls as needed, non-sand casting foundries will be able to reduce the exposure levels of all sand systems operators to levels of 50 μg/m^3 or less. Therefore, OSHA finds that the 50 µg/m^3 PEL can be achieved for sand system operators in non-sand casting foundries. The standard is thus technologically feasible for this job category.

Feasibility Findings for Molders

The silica exposures of molders in non-sand casting foundries originate from different mold materials than in sand casting foundries. Green and chemically bonded sand molding processes are non-existent in non-sand casting foundries. Instead, molders weigh and mix a slurry of refractory material (typically containing substantial quantities of silica as quartz or cristobalite, or both), then repeatedly dip expendable patterns (e.g., foam, wax) in the mold material to form a shell (Document ID 1365, p. 2-104; 0215). Some molders also pour the refractory investment material around a pattern set in a flask. Molders might also sift dry silica-containing sand over dipped patterns to fortify the mold shell as it forms. In foundries using permanent molds, molders spray or pour refractory material into the metal molds (Document ID 1365, p. 2-104; 0498; 1139). Molders oversee these typically semi-automated molding processes; however, molders might perform these processes manually for small runs or in a facility that performs one of these methods only occasionally.

The exposure profile in Table IV.4.8-G for molders in non-sand casting foundries includes 29 samples. The median exposure is 21 µg/m^3, the mean is 44 µg/m^3, and the range is 9 µg/m^3 (LOD) to 291 µg/m^3. Of the 29 samples, 22 (75.9 percent) are at the final PEL of 50 µg/m^3 or less. All samples are from SEP inspection reports and OSHA's OIS System.

One of the highest results (150 µg/m^3) was associated with a molder who cleaned permanent centrifugal molds (Document ID 1365, p. 2-105; 1175, pp. 2, 9). In a similar facility that also used permanent centrifugal molds, NIOSH noted that similar exposure levels were attributed to refractory mold release agents, which were applied to the interior of the permanent mold that forms products like iron pipes as the molten metal is poured into the mold while it spins. The agent is then brushed out of the mold after completion of the casting process. NIOSH noted significantly reduced exposures in a facility that switched from a silica flour mold release agent to a product containing less than 1.5 percent silica (Document ID 1365, p. 2-105; 0900, pp. 3-4, 14-15, (pdf) p. 24 Table 1).

Sequential sampling sessions show the effect of switching from silica sand to an alternate granular media even when the foundry uses molding methods other than green sand casting. OSHA obtained results of 50 $\mu g/m^3$ and 90 $\mu g/m^3$ for molders (compaction, compaction helper) at a steel investment[52] foundry that compacted un-bonded silica sand around lost-foam molds (Document ID 1365, p. 2-105; 0142, pp. 18-19, 133, 157). This facility replaced the silica sand with olivine, a low silica content alternative, and reduced exposures to below the LOD (less than or equal to 12 $\mu g/m^3$) (Document ID 0142, pp. 9, 10-14). These are among the lowest results reported for this job category.

Non-sand casting methods can involve refractory investment materials that contain cristobalite instead of, or in addition to, quartz. OSHA obtained a result for a molder that contained respirable cristobalite (129 $\mu g/m^3$) in addition to respirable quartz (162 $\mu g/m^3$), producing a combined respirable silica result of 291 $\mu g/m^3$. The molder manually emptied bags of silica-containing investment material into a bucket that included reaching in to stir the dry ingredients and break up clumps by hand (Document ID 1365, p. 2-104; 0498, pp, 46, 58-59). These results demonstrate the additive effect of quartz and cristobalite on the worker's overall silica result, as well as the risk of exposures above the PEL if appropriate controls are not used.

OSHA finds that the remaining 24 percent of workers exposed above the PEL will require additional controls. The controls described for ferrous sand casting foundries apply to non-sand casting foundries. As described in more detail in the earlier discussion of molders in ferrous sand casting foundries, specific controls include improved enclosures and ventilation on sand delivery systems, ventilated workstations, work practices that limit the spread of silica-dust, and substitution of non-silica containing materials where feasible.

[52] Investment refers to a liquid refractory or ceramic mixture that may contain silica that is poured into wax coated mold. Investment casting is used to produce small precision parts.

Non-sand casting foundries that mix refractory products require ventilated bag-dumping stations and mixing equipment. Workers who handle powdered silica materials, e.g., empty bags, weigh, and mix, can be exposed to dust when it is released from these processes, and when emptied bags are compressed for disposal. One control option involves bag-dumping stations with properly ventilated enclosures, which capture dust released during both bag emptying and bag disposal. One SEP report demonstrated the effectiveness of addressing bag dumping by enclosing and ventilating the container being filled with investment powder. In this case, exposures that were more than 400 μg/m^3 were reduced to less than 50 μg/m^3 (Document ID 0498, pp. 20-24). In addition, ERG obtained respirable quartz exposure monitoring data for workers using bag dumping stations to empty 50-pound bags of silica-containing materials into mixers at a paint manufacturing facility. The stations consisted of hoppers topped with grates that were enclosed by LEV hoods. This ventilation system automatically removed empty bags (by suction) and transferred them to an enclosed storage area. This technology reduced exposures from a level greater than 250 μg/m^3 to below the LOD. ERG obtained five full-shift PBZ silica exposure readings of less than or equal to 12 μg/m^3 (the LOD) for five workers who emptied bags of silica-containing material using the bag-dumping stations (Document ID 1365, p. 2-105; 0199).

ERG also obtained a full-shift PBZ exposure reading of 263 μg/m^3 for a worker at the same site who used a bag-dumping station equipped with an LEV system that failed to operate for approximately two hours (Document ID 1365, p. 2-106; 0199). Without the LEV system operating, the worker was required to manually stack and compress empty bags adjacent to the station, which generated visible dust. The difference between the elevated exposure readings obtained for the worker as compared with the low exposure readings when the LEV was working indicates the effectiveness of LEV-equipped bag-dumping stations.

NIOSH evaluated a second type of bag-dumping station equipped with an enclosure, empty bag compactor, bag disposal chute, and LEV system (Document ID 1365, p. 2-106; 1369). The LEV system ventilated both the enclosure and compactor. NIOSH evaluated the unit by measuring respirable dust levels with real-time aerosol monitors before and while workers emptied bags of crushed limestone into these hoppers. NIOSH determined that the unit effectively controlled respirable dust (Document ID 1369). Ventilated bag-dumping stations that include a ventilated compactor are readily available from commercial sources (Document ID 1224). OSHA concludes that ventilated bag-dumping stations would be equally effective in reducing silica exposures for molders in non-sand casting foundries.

Automated transfer equipment also can reduce dust released as hoppers are filled. Some of the lowest results (two 13 $\mu g/m^3$ [LODs], one 20 $\mu g/m^3$, and one 23 $\mu g/m^3$) were obtained by NIOSH and OSHA for four molders working in two ferrous sand casting foundries where pneumatic or enclosed conveyors were used to transport sand (Document ID 1365, p. 2-28; 0268, p. 4, 12; 0501, pp. 5, 63, 65, 67, 71-73). Non-sand casting foundries have systems that move much smaller amounts of silica-containing materials. OSHA expects that pneumatic and enclosed conveying of materials will be equally effective in non-sand casting foundries. Pneumatic and enclosed conveyors are also used in other industries. For example, OSHA inspected a structural clay facility and found an 86-percent reduction in silica exposures after the facility installed an enclosed, automated sand transfer system (Document ID 1365, p. 2-106; 0161). OSHA concludes that installing such a system could similarly reduce exposures to molders in non-sand casting foundries.

OSHA also concludes that for those facilities that clean refractory materials from permanent molds, vacuuming in lieu of using compressed air will reduce exposures. As discussed above, paragraph (h) of the standard for general industry and maritime prohibits the use of compressed air in cleaning clothing or surfaces where such activity could contribute to employee exposure to respirable crystalline silica except where the compressed air is used in conjunction with a ventilation system that effectively captures the dust cloud created by the compressed air, or where no alternative method is feasible. The use of compressed air and brushes is discussed at length in the Ferrous Sand Casting Foundries section above (Section IV-4.8.1) and is also applicable to non-sand casting foundries.

For these reasons, OSHA concludes that controls are available for reducing exposures such as improving or adding ventilation to bag-dumping stations, adding or improving ventilated bag compactors, as well as enclosing and ventilating mixing equipment. Based on the exposure profile and evidence of effective controls, OSHA finds that the 50 μg/m^3 PEL can be achieved for molders in non-sand casting foundries most of the time. The standard is therefore technologically feasible for this job category.

Feasibility Findings for Core Makers

Core makers work only in those facilities in non-sand casting foundries that produce or handle sand cores. These workers produce and handle sand cores that are essentially the same as cores produced and handled in other types of foundries (Document ID 1365, p. 2-102).

The exposure profile in Table IV.4.8-G for core makers in non-sand casting foundries includes 3 samples, which constitute the best available evidence of these workers' exposures. The three results were all LOD values, well below the final PEL of 50 μg/m^3 and the action level of 25 μg/m^3. Therefore, OSHA concludes that core makers will rarely need additional controls. Due to the similarity of the tasks and dust sources, however, the controls and conclusions described for core makers in ferrous and nonferrous sand casting foundries can be used to achieve the PEL for core makers in non-sand casting foundries.

Based on the exposure data and evidence of effective controls, OSHA finds that the 50 μg/m^3 PEL can be achieved for core makers in non-sand casting foundries. The standard is therefore technologically feasible for this job category.

Feasibility Findings for Furnace Operators

Furnace operator functions are the same in non-sand casting foundries as in other foundries. The exposure profile in Table IV.4.8-G for furnace operators in non-sand casting foundries includes 4 samples, which constitute the best available evidence of these workers' exposures. The four results are all below the final PEL of 50 μg/m^3 and three are below the action level of 25 μg/m^3. Therefore, OSHA concludes that furnace operators will rarely need additional controls. However, if overexposures do occur, the controls and conclusions described for furnace operators in ferrous and nonferrous sand casting foundries apply equally in non-sand casting foundries due to the similarity of operator functions.

Based on the exposure data and evidence of effective controls, OSHA finds that the 50 μg/m^3 PEL can be achieved for furnace operators in non-sand casting foundries. The standard is therefore technologically feasible for this job category.

Feasibility Findings for Pouring Operators

Pouring operator functions in non-sand foundries are the same as those in ferrous sand casting foundries; however, the equipment and materials differ. Pouring operators in non-sand casting foundries use a variety of mold types, including permanent molds for metals such as aluminum (made of a metal with a higher melting temperature) and investment molds described above. Pouring operators using permanent molds can be exposed to silica when molders who work in close proximity apply or remove refractory coating from the molds (Document ID 1365, p. 108).

The exposure profile in Table IV.4.8-G for pouring operators in non-sand casting foundries includes 7 samples, which constitute the best available evidence of these workers' exposures. The median exposure is 12 μg/m^3, the mean is 33 μg/m^3, and the range is 10 μg/m^3 (LOD) to 150 μg/m^3. Of the 7 samples, 6 (85.7 percent) are at the final PEL of 50 μg/m^3 or less. OSHA attributes the one exposure that exceeded the PEL to stagnant air and lack of ventilation (Document ID 1175, p. 9).

The silica content of mold release agents can influence the exposure levels of workers in the pouring area. Two of the available results for this job category, 36 μg/m^3 and 150 μg/m^3, were obtained for pouring operators at two foundries where workers (molders or pouring operators) applied and removed refractory mold release agents on permanent centrifugal molds (Document ID 1365, p. 2-108; 0900, (pdf) p. 24, Table 1; 1175, (pdf) p. 9, Table E-2). The lower of these results (36 μg/m^3) was associated with a "low silica parting compound" used as the mold release agent (Document ID 0900, p. 4). OSHA expects that similar exposure reduction for the higher exposure (150 μg/m^3) can be achieved by using a low silica mold release agent. Additionally, the study associated with the higher sampling result noted that the area was poorly ventilated (Document ID 1175, (pdf) p. 1). Additional general ventilation and LEV for mold cleaning activities could effectively reduce the exposures from this source.

Based on the exposure data and evidence of effective controls, OSHA finds that the 50 μg/m^3 PEL can be achieved for pouring operators in non-sand casting foundries when exposures in the rest of the foundry are adequately controlled. The standard is therefore technologically feasible for this job category.

Feasibility Findings for Shakeout Operators

Shakeout operator functions are generally similar to those in ferrous sand casting foundries. However, in sand casting foundries, manual processes for removing mold and core materials are consolidated into this operation (despite worker job titles associated with knockout operations), while sprue and riser removal are consolidated under the knockout operations.

The exposure profile in Table IV.4.8-G for shakeout operators in non-sand casting foundries includes 7 samples, which constitute the best available evidence of these workers' exposures. The median exposure is 220 μg/m^3, the mean is 183 μg/m^3, and the range is 10 μg/m^3 (LOD) to 420 μg/m^3. Of the 7 samples, 2 (28.6 percent) are at the final PEL of 50 μg/m^3 or less.

Three of the seven samples (all from one steel investment foundry) contained cristobalite only (no quartz detected) at exposure levels of 222 μg/m^3, 283 μg/m^3, and 420 μg/m^3, while one sample result of 100 μg/m^3 from the same foundry included equal parts quartz and cristobalite (Document ID 1365, pp. 2-108 – 2-109; 0078, pp. 89, 91, 101, 103, 106, 108). The shakeout operations in this foundry were quite primitive and included removing sand and refractory materials in enclosed areas with no controls in place. The inspection report notes poor ventilation as well as the use of compressed air for blowing contamination from workers' clothing and dry sweeping (Document ID 0078, p. 54). The 220 μg/m^3 exposure measurement was collected in a lost foam casting operation in which the employee was removing sand from the casting using a jackhammer and chipping hammer with inadequate ventilation (Document ID 0134, pp. 14, 34).

The exposure profile in Table IV.4.8-G shows that exposure levels of 50 μg/m^3 or less have already been achieved for 29 percent of shakeout operators. The remaining overexposed workers will require additional controls. Because of the lack of controls present and the use of poor work practices (the use of compressed air and dry sweeping) under baseline conditions, OSHA concludes that significant reductions in exposures are possible using the control methods described above for Shakeout Operators in Section IV-4.8.1 – Ferrous Sand Casting Foundries and that those methods will be effective in reducing exposures to the 50 μg/m^3 PEL. Because the tasks and dust sources are similar, OSHA expects that controls like enclosed and ventilated shakeout equipment, combined with other dust control measures such as local exhaust ventilation, and the use of vacuums rather than compressed air and dry sweeping (Document ID 0078, p. 54; 0134, p. 14) will control shakeout operator exposures in non-sand casting foundries.

Based on the ability of controls in ferrous sand casting foundries to reduce exposures to levels of the PEL or below and the similarity in the nature of the shakeout processes, OSHA finds that those controls will be similarly effective for shakeout operations in non-sand casting foundries. Therefore, based on the exposure data and evidence of effective controls, OSHA finds that the 50 μg/m^3 PEL can be achieved for most shakeout operators in non-sand casting foundries. As in ferrous casting foundries for shakeout operators, OSHA expects that the supplemental use of respirators may be necessary for the small percentage of shakeout operators who work on large castings in circumstances where substitution to non-silica granular media is not feasible. The standard is therefore technologically feasible for this job category.

Feasibility Findings for Knockout Operators

Knockout operator functions are generally the same as in ferrous sand casting foundries. However, as stated earlier, manual processes for removing mold and core materials are consolidated into the shakeout process. Sprue and riser removal activities are consolidated under the knockout operations.

The exposure profile in Table IV.4.8-G for knockout operators in non-sand casting foundries includes 15 samples. The median exposure is 56 μg/m^3, the mean is 140 μg/m^3, and the range is 9 μg/m^3 (LOD) to 614 μg/m^3. Of the 15 samples, 7 (46.7 percent) are at the final PEL of 50 μg/m^3 or less. As with the other results in the exposure profile, these samples are the best available evidence of these workers' exposures. One of the highest results (598 μg/m^3) was from an investment casting foundry and contained cristobalite but no detectable quartz (Document ID 1365, p. 2-109). (OSHA has little information about the conditions that lead to the highest exposure level, 614 μg/m^3.)

OSHA finds that additional controls will be necessary to achieve the PEL for the remaining 53 percent of knockout operators who are overexposed. Based on the similarities between knockout operator tasks in this and other types of foundries, OSHA concludes that additional controls for knockout operators in ferrous sand casting foundries apply equally effectively in non-sand casting foundries. Similar to ferrous foundries, a small percentage of knockout operators in these foundries might require respiratory protection under the same circumstances (i.e., very large castings) as mentioned for shakeout operators in ferrous sand casting foundries.

Based on the exposure data and evidence of effective controls, OSHA concludes that compliance with the 50 μg/m^3 PEL can be achieved for knockout operators in non-sand casting foundries most of the time. As in ferrous casting foundries, the supplemental use of respirators may be necessary for the small percentage of knockout operators who work on large castings in circumstances where substitution to non-silica granular media is not feasible. The standard is therefore technologically feasible for this job category.

Feasibility Findings for Abrasive Blasting Operators

Abrasive blasting is used in non-sand casting foundries to remove silica-containing investment materials or mold washes from the castings. Activities of abrasive blasting operators in non-sand casting foundries are the same as in ferrous sand casting foundries. The exposure profile in Table IV.4.8-G for abrasive blasters in non-sand casting foundries includes 13 samples from a variety of inspection reports and industry studies, representing the best available evidence of these workers' exposures. The median exposure is 14 μg/m^3, the mean is 138 μg/m^3, and the range is 10 μg/m^3 (LOD) to 980 μg/m^3. Of the 13 samples, 8 (61.5 percent) are at the final PEL of 50 μg/m^3 or less.

OSHA finds that additional controls will be necessary to achieve the PEL for the remaining 39 percent of abrasive blasting operators who are overexposed. Due to the similarity in the tasks and dust sources, OSHA concludes that the controls for abrasive blasting operators in ferrous sand casting foundries to control respirable silica dust released while removing green sand molding materials using enclosed blasting systems will work as effectively in non-sand casting foundries.

Based on the exposure data and evidence of effective controls, OSHA finds that the 50 μg/m^3 PEL can be achieved for abrasive blasting operators in non-sand casting foundries most of the time. As for abrasive blasting in ferrous casting foundries, respirator use may be necessary for foundries that produce large castings. The standard is therefore technologically feasible for this job category.

Feasibility Findings for Cleaning/Finishing Operators

Cleaning/finishing operators perform the same activities in non-sand casting foundries as in ferrous sand casting foundries. As noted above, silica mold materials and washes can remain adhered to castings using non-sand casting methods just as they do in sand casting foundries, although the quantity might be lower, because the washes are thinly applied coatings (Document ID 1287, p. 25). For example, mold washes are typically used in small quantities as release agents, to capture more details from the pattern, or to increase mold life (protect it), on permanent molds, lost foam, and investment casting patterns. Where they are used, these agents remain present as trace contaminants on the finished casting rather than as large chunks or deeply embedded veins in the metal. Regardless of the casting or mold release material used, however, cleaning/finishing operators use the same tools and processes to clean the castings (Document ID 1365, 2-110; 0900, pp. 4, 14; 1287, pp. 23-27).

The exposure profile in Table IV.4.8-G for cleaning/finishing operators in non-sand casting foundries includes 34 samples (combined quartz and cristobalite). The median exposure is 16 µg/m^3, the mean is 54 µg/m^3, and the range is 8 µg/m^3 (LOD) to 820 µg/m^3. Of the 34 samples, 29 (85.3 percent) are at or below the final PEL of 50 µg/m^3.

OSHA finds that additional controls will be necessary to achieve the PEL for the remaining 15 percent of abrasive blasting operators who are overexposed. Because of the similarities between cleaning/finishing operator activities in this and other types of foundries, OSHA concludes that the controls provided for cleaning/finishing operators in ferrous sand casting foundries are equally effective in non-sand casting foundries.

Based on the exposure data and evidence of effective controls, OSHA finds that the 50 µg/m^3 PEL can be achieved for cleaning/finishing operators in non-sand casting foundries. In the event that exposure levels of a few operators still remain above 50 µg/m^3, respiratory protection will be necessary for those workers. The standard is therefore technologically feasible for this job category.

Feasibility Findings for Material Handlers

Material handlers in non-sand casting foundries perform the same types of tasks as material handlers working in ferrous sand casting foundries. The exposure profile in Table IV.4.8-G for material handlers in non-sand casting foundries includes 3 samples, which are the best available evidence of these workers' exposures. The median exposure is 8 µg/m^3, the mean is 41 µg/m^3, and the range is 8 µg/m^3 (LOD) to 107 µg/m^3. Two of the three samples are below the 25 µg/m^3 action level. The sample with the high exposure level was obtained in a foundry that had few controls for an employee whose job duties included shoveling sand in the basement. OSHA recommended improvements in ventilation and the use of vacuums for clean-up rather than dry sweeping and using compressed air (Document ID 0134, pp. 14, 58-59). These recommendations are similar to the controls that OSHA describes above for Material Handlers (in Section IV-4.8.1 – Ferrous Sand Casting Foundries), where OSHA concluded that enclosed, ventilated cabs are associated with exposure reductions of 90 to 97 percent and can reduce even the highest material handler result to a level less than 50 µg/m^3 (Document ID 0719, p. 47; 0884, pp. 14, 20).

OSHA finds that additional controls will be necessary to achieve the final PEL of 50 µg/m^3 for any material handlers in non-sand casting foundries who are overexposed. Because the work activities of material handlers are the same within both types of foundries, OSHA concludes that the controls for those workers in ferrous sand casting foundries are equally effective in non-sand casting foundries.

Based on the exposure data and evidence of effective controls, OSHA finds that the 50 µg/m^3 PEL can be achieved for material handlers in non-sand casting foundries. The standard is therefore technologically feasible for this job category.

Feasibility Findings for Maintenance Operators

Maintenance operators in non-sand casting foundries perform the same types of tasks as they perform in other types of foundries that cast the same metals. These tasks include refractory repairs. For example, a report on a non-sand casting foundry included four sampling results of maintenance operators performing refractory repair work in a cast iron foundry.

The exposure profile in Table IV.4.8-G for maintenance operators in non-sand casting foundries includes 4 samples, which are the best available evidence of these workers' exposures. The median exposure is 12 µg/m^3, the mean is 14 µg/m^3, and the range is 12 µg/m^3 (LOD) to 20 µg/m^3.

OSHA concludes that because the exposure levels of all (100 percent) maintenance operators in non-sand casting foundries are already below the final PEL of 50 µg/m^3 (all 4 results were below the action level of 25 µg/m^3), additional controls are not likely to be necessary for this job category. However, OSHA acknowledges that the available data might underestimate exposure for maintenance operators in non-sand casting foundries, who have the potential for exposure at the same levels encountered by workers performing the same refractory repair tasks at ferrous sand casting foundries. OSHA finds that, if elevated exposures do occur, additional controls will be necessary to achieve the PEL for any maintenance worker who is overexposed, and expects that the controls described for maintenance operators in ferrous sand casting foundries will be equally effective to control the dust exposures of maintenance operators in non-sand casting foundries.

Based on the exposure data and evidence of effective controls, OSHA finds that the 50 μg/m^3 PEL can be achieved for material handlers in non-sand casting foundries. The standard is therefore technologically feasible for this job category.

Feasibility Findings for Housekeeping Workers

The work activities of housekeeping workers in non-sand casting foundries are the same as those of the equivalent job category in ferrous sand casting foundries. The exposure profile in Table IV.4.8-G for housekeeping workers in non-sand casting foundries includes 2 samples, which were obtained from a report on a non-sand casting foundry. Both samples were less than or equal to the LOD (12 μg/m^3 and 14 μg/m^3) (median of 13 μg/m^3). These best available results are within the range reported for ferrous sand casting foundries (Document ID 1365, p. 2-111; 0017). OSHA concludes that the exposure levels of all (100 percent) housekeeping workers in non-sand casting foundries are already below the final PEL of 50 μg/m^3. Therefore, additional controls are not likely to be necessary for this job category. OSHA further concludes that, if elevated exposures do occur, the controls for housekeeping workers in ferrous sand casting foundries should be equally effective to achieve exposures of 50 μg/m^3 or less for housekeeping workers in non-sand casting foundries.

Based on the exposure data and evidence of effective controls, OSHA finds that the 50 μg/m^3 PEL can be achieved for housekeeping in non-sand casting foundries. The standard is therefore technologically feasible for this job category.

Non-Sand Casting Foundries—Overall Feasibility Finding

OSHA finds that controls identified to reduce worker exposures in ferrous sand casting foundries also will reduce exposures to an equivalent extent in non-sand casting foundries. This finding is based on evidence that although non-sand casting foundries use sand and other materials that contain silica in casting processes, for example, in cores or to pack investment molds, that result in dust from sources similar to those in the ferrous sand casting foundries, the amount of silica-containing materials used is much less. Therefore, OSHA finds that the controls discussed for ferrous sand casting foundries will be at least as effective to reduce dust emissions in non-sand foundries. Where production methods diverge (e.g., the use of mold release agents on permanent molds), additional controls are available as described above.

Based on the exposure levels reported for this industry in Table IV.4.8-G and the availability of effective controls for most working conditions, OSHA finds that exposure levels of 50 μg/m^3 or less can be achieved for most operations, most of the time, in non-sand casting foundries. Therefore, the final PEL of 50 μg/m^3 is technologically feasible for non-sand casting foundries.

4.8.4 Captive Foundries

Captive Foundries Description

Captive foundries are foundries based within the facilities of another non-foundry industry. They cast metal using the same range of processes that are found in the foundry industry. A captive foundry might cast any metal in any quantity, use any molding process, clean castings, and process and reclaim sand using the same range of methods and equipment used by ferrous sand casting, nonferrous sand casting, or non-sand casting foundries (Document ID 1365, p. 2-111). Furthermore, the job categories found in captive foundries mirror those found in other foundries. For example, a state industrial commission reviewed data collected from a captive gray iron foundry that produces large truck brake drums. Job categories sampled included those found in ferrous sand casting foundries. As another example, OSHA inspected sand casting foundries (both ferrous and nonferrous) belonging to an enameled iron and metal products manufacturer and sampled shakeout operators (Document ID 1365, p. 2-112; 0168). In addition, the UAW submitted descriptions of some of the job categories in a captive foundry owned by Caterpillar, a manufacturer of farm machinery, that are the same as those addressed in the ferrous and non-ferrous sand casting foundries and the non-sand casting foundries. The specific activities noted by UAW for the job categories they list are similar to the activities noted by OSHA for the foundry sector (Document ID 2282, Attachment 3, pp. 9-10).

The difference between a captive foundry and other foundries involves the business relationship between the foundry and the organization it supplies, rather than a fundamental difference in the metal casting process. Captive foundries fill specific requirements of their parent companies, whether the need is for large numbers of identical pieces, a small number of customized items, or specialty handling of a wide range of castings. As such, a captive foundry operation is incorporated into the larger manufacturing process of the parent operation.[53]

[53] OSHA notes that information contained in some documents does not permit the facilities to be classified as captive or independent foundries. As a result, some information on facilities that are actually captive foundries might appear in the analysis for other foundry types. Table IV.4.8-H summarizes data from facilities known to be captive foundries at the time the samples were collected.

Table IV.4.8-H
Personal Respirable Crystalline Silica Exposure Range and Distribution of Results for Captive Foundries

	Exposure Summary			Exposure Range		Exposure Profile				
Captive Foundries	**N**	**Mean (µg/m³)**	**Median (µg/m³)**	**Min (µg/m³)**	**Max (µg/m³)**	**<25 (µg/m³)**	**≥25 and ≤50 (µg/m³)**	**>50 and ≤100 (µg/m³)**	**>100 and ≤250 (µg/m³)**	**>250 (µg/m³)**
Molder	4	18	13	12	34	3 (75%)	1 (25%)	0 (0%)	0 (0%)	0 (0%)
Core maker	1	14	14	14	14	1 (100%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)
Furnace Operator	3	31	12	12	69	2 (66.7%)	0 (0%)	1 (33.3%)	0 (0%)	0 (0%)
Shakeout Operator	13	78	56	20	197	1 (7.7%)	4 (30.8%)	3 (23.1%)	5 (38.5%)	0 (0%)
Knockout Operator	3	21	12	12	38	2 (66.7%)	1 (33.3%)	0 (0%)	0 (0%)	0 (0%)
Abrasive Blasting Operator	7	249	30	12	1,330	3 (42.9%)	1 (14.3%)	1 (14.3%)	0 (0%)	2 (28.6%)
Cleaning/Finishing Operator	10	27	18	12	69	6 (60%)	2 (20%)	2 (20%)	0 (0%)	0 (0%)
Maintenance Operator	10	381	19	12	1,456	5 (50%)	1 (10%)	0 (0%)	0 (0%)	4 (40%)
Housekeeping	2	21	21	12	30	1 (50%)	1 (50%)	0 (0%)	0 (0%)	0 (0%)
Sand System Operator	0	NA	NA	NA	NA	NA	NA	NA	NA	NA
Pouring Operator	0	NA	NA	NA	NA	NA	NA	NA	NA	NA
Material Handler	0	NA	NA	NA	NA	NA	NA	NA	NA	NA
Captive Foundries Total	**53**	**134**	**28**	**12**	**1,456**	**24 (45.3%)**	**11 (20.8%)**	**7 (13.2%)**	**5 (9.4%)**	**6 (11.3%)**

Notes: All samples summarized are personal breathing zone (PBZ) results representing 8-hour time-weighted average exposures.
Job categories are intended to represent job functions; actual job titles might differ, and responsibilities might be allocated differently, depending on the facility.
Percentages may not add to 100 percent due to rounding.

Sources: Document ID 1720; 3958; 0152; 0168; 0171.

Captive Foundries—Exposure Profile, Additional Controls, and Overall Feasibility Findings

The exposure profile in Table IV.4.8-H includes 53 full-shift, PBZ samples for captive foundries. These samples are the best available evidence of worker exposures in captive foundries. The median exposure is 28 μg/m^3, the mean is 134 μg/m^3, and the range 12 μg/m^3 to 1,456 μg/m^3. Eight of nine job categories (all but shakeout operator) already experience exposures below the PEL. No sample exposures were available for three operations (sand system operator, pouring operator, and material handler).

Of the nine job categories for which Table IV.4.8-H has data, five (furnace operator, shakeout operator, abrasive blasting operator, cleaning/finishing operator, and maintenance operator) show some exposures under baseline conditions over the final PEL of 50 μg/m^3, ranging from 20 percent (2 out of 10 samples for cleaning/finishing operator) to 61.6 percent (8 out of 13 samples for shakeout operator). The two highest samples (1,330 μg/m^3 and 1,456 μg/m^3) were in abrasive blasting and maintenance operations, respectively. Based on these data, OSHA finds that additional controls will be necessary to achieve the final PEL of 50 μg/m^3 for the remaining workers in the various job categories who are overexposed. OSHA concludes that the casting processes, tasks performed, and dust sources in captive foundries are comparable to those discussed with respect to non-captive foundries. Therefore, where overexposures exist, OSHA concludes that the controls discussed for ferrous sand casting foundries will be equally effective in reducing exposures in each of the job categories in captive foundries.

Based on these exposure data and evidence of effective controls, OSHA finds that the 50 μg/m^3 PEL can be achieved for most operations in captive foundries most of the time. Therefore, the standard is technologically feasible in captive foundries.

4.9 GLASS PRODUCTS

4.9.1 Description

Silica sand is the main raw material used in the manufacture of glass products, including flat glass, container glass, and fibrous glass (Document ID 1365, p. 7-1). Industries that manufacture glass products are classified primarily in the following six-digit North American Industry Classification System (NAICS) codes: 327211, Flat Glass Manufacturing; 327212, Other Pressed and Blown Glass and Glassware Manufacturing; and 327213, Glass Container Manufacturing. This section also includes facilities in NAICS 327993, Mineral Wool Manufacturing, that produce fibrous glass and glass wool insulation products directly from sand.

Depending on the facility and type of glass production, operations might be highly mechanized or involve manual operations. Mass production glasses (such as flat glass, container glass, and fiberglass) involve automated raw materials handling processes and continuous, enclosed melting processes. These production processes require large amounts of sand or cullet.[54] Small-run glass manufacture, such as manufacture of specialty glass and art glass, however, involves intermittent production that can utilize a combination of automated and manual operations (Document ID 1365, p. 7-2).

The potential for silica exposures is limited to the so-called “hot end” of the process, where sand, cullet, and other raw materials are unloaded, transferred, and mixed prior to melting. Once melted, the silica in the sand is converted to amorphous silica and no longer presents a significant exposure hazard to workers downstream of the melting stage.

The two job categories with the potential for silica exposure in the glass products industry are raw material handlers and batch operators (and associated workers), who are the only glass product manufacture workers who work at the "hot end" of the manufacturing

[54] Cullet is waste and scrap glass (Document ID 1365, p. 7-6). Since glass, including cullet, is in the amorphous state, cullet is not a significant source of crystalline silica dust (Document ID 1720, p. IV-205).

process. Table IV.4.9-A provides information on these job categories and their sources of exposure.

Table IV.4.9-A Job Categories, Major Activities, and Sources of Exposure of Workers in the Glass Products Industry (NAICS 327211, 327212, 327213, 327993)	
Job Category*	**Major Activities and Sources of Exposure**
Material Handler	Overseeing the delivery of sand and other raw materials. • Dust from automatic or manual transfer of sand.
Batch Operators and Associated Workers	Transferring raw materials to weigh stations, mixers, and furnaces; performing housekeeping/maintenance in the vicinity of such operations. • Dust from automatic or manual transfer of sand. • Re-suspension of settled dust during housekeeping/maintenance activities.
*Job categories are intended to represent job functions; actual job titles may differ and responsibilities may be allocated differently, depending on the facility. Source: Document ID 1720, p. IV-205.	

4.9.2 Exposure Profile and Baseline Conditions

The exposure profile in Table IV.4.9-B includes 14 full-shift personal breathing zone samples of respirable crystalline silica for the Glass Products Industry. It shows a median exposure of 71 μg/m^3, a mean of 110 μg/m^3, and a range from 12 μg/m^3 to 350 μg/m. Table IV.4.9-B shows that, of the 14 samples, 9 (64 percent) are above 50 μg/m^3 and 5 (36 percent) exceed 100 μg/m^3. To obtain the exposure profile, OSHA reviewed exposure monitoring data for the Glass Products Industry from two NIOSH reports of site visits to large flat glass manufacturing facilities and from an OSHA Special Emphasis Program (SEP) inspection report of a large glass products facility (Document ID 0085; 0221; 0886). OSHA inspection data submitted to the rulemaking record from OSHA's Information System (OIS) provide two additional sample results from two recent inspections that OSHA has added to this analysis (Document ID 3958). No additional exposure data for the glass industry is in the rulemaking record. Glass Association of North America (GANA) indicated that some employees are exposed over the PEL and that there was not enough data to support that all of the flat glass will be able to meet the final PEL (Document ID 2215, pp. 4-5). GANA did not provide any exposure data to support this statement. Therefore, OSHA did not add any additional data to the profile. However, OSHA's exposure profile is consistent with GANA's statement and indicates that the majority of the exposures are above the final PEL. These exposures represent current baseline conditions.

Exposure Profile and Baseline Conditions for Material Handlers

The exposure profile in Table IV.4.9-B includes 6 samples for material handlers in the Glass Industry. It shows a median exposure of 130 μg/m^3, a mean of 156 μg/m^3, and a range from 46 μg/m^3 to 350 μg/m^3. Five of the six samples (83 percent) are above 50 μg/m^3. “Hot-end” material handlers primarily work outdoors to oversee the delivery of sand and other raw materials to the facility. These materials are transported primarily via rail car or truck, with the exception of certain small-run specialty glass producers, which receive sand in smaller containers such as bags or fiber drums. Sand is typically unloaded and transported to storage units by automated equipment, such as pneumatic or gravity conveyors, which material handlers set up and operate. Material handlers may not be required to remain at the unloading site for their entire shift (Document ID 1365, p. 7-3).

No additional data were identified for material handlers beyond that presented in the PEA, in which OSHA reviewed the exposure results for six workers from one OSHA SEP inspection report and two NIOSH reports (Document ID 1720, pp. IV-205 – IV-206). Details on conditions that led to the highest exposure were not provided.

Exposure Profile and Baseline Conditions for Batch Operators and Associated Workers

The exposure profile Table IV.4.9-B includes 8 samples for batch operators and associated workers in the Glass Industry. It shows a median exposure of 40 μg/m^3, a mean of 75 μg/m^3, and a range of 12 μg/m^3 to 262 μg/m^3. Four of the eight samples are above 50 μg/m^3. Batch operators and associated workers are responsible for transferring raw materials to weigh stations, mixers, and furnaces. Depending on the size and type of glass production facility, the batching systems can be fully automated or can involve manual operations. OSHA estimates that up to 10 percent of batch operations involve manual charging of mixers and furnaces (Document ID 1365, p. 7-9).

Other workers in the batch area may inspect equipment and perform maintenance operations or housekeeping activities. Based on the available literature and personal communications with representatives of glass products manufacturers, OSHA estimates that, while few facilities have implemented engineering controls to minimize exposures associated with maintenance operations, 75 percent of facilities use dust suppressants, high-efficiency particulate air (HEPA)-filtered vacuums, or industrial-scale portable vacuum systems to control exposures during housekeeping activities (Document ID 0085, p. 14; 0221, p. 6; 1365, p. 7-10; 0698, p. 1).

The six samples previously reported in the PEA for batch operators, which were derived from one OSHA SEP inspection report and one NIOSH report. Two additional sample results were obtained from OIS inspection data, having values of 12 $\mu g/m^3$and 140 $\mu g/m^3$, and added to the exposure profile for this industry (Document ID 1720; 3958, Rows 264, 382).

Table IV.4.9-B
Personal Respirable Crystalline Silica Exposure Range and Distribution of Results for Workers in the Glass Products Industry
(NAICS 327211, 327212, 327213, 327993)

	Exposure Summary			Exposure Range			Exposure Profile				
Glass Industry	**N**	**Mean (μg/m³)**	**Median (μg/m³)**	**Min (μg/m³)**	**Max (μg/m³)**		**<25 (μg/m³)**	**≥25 and ≤50 (μg/m³)**	**>50 and ≤100 (μg/m³)**	**>100 and ≤250 (μg/m³)**	**>250 (μg/m³)**
Material Handler	6	156	130	46	350		0 (0%)	1 (16.7%)	2 (33.3%)	2 (33.3%)	1 (16.7%)
Batch Operators and Associated Workers	8	75	40	12	262		4 (50%)	0 (0%)	2 (25%)	1 (12.5%)	1 (12.5%)
Glass Industry Total	**14**	**110**	**71**	**12**	**350**		**4 (28.6%)**	**1 (7.1%)**	**4 (28.6%)**	**3 (21.4%)**	**2 (14.3%)**

Notes: All samples summarized are personal breathing zone (PBZ) results representing 8-hour time-weighted average exposures.
Job categories are intended to represent job functions; actual job titles might differ, and responsibilities might be allocated differently, depending on the facility.
Percentages may not add to 100 percent due to rounding.
Sources: Document ID 1720; 3958; 0085; 0221; 0886.

Supplemental Data and Supporting Information Submitted to the Record

The North American Insulation Manufacturers Association (NAIMA) submitted as post-hearing evidence a summary of exposure data from glass industry plants producing insulation products (Document ID 3999). The summary data provided no individual sample results so these data could not be added to the exposure profile for this industry. For rock and slag wool manufacturing, all reported exposures were below the final rule's action level of 25 μg/m^3. For glass wool manufacturing, mean exposures for "routine manufacturing" were all below the action level (arithmetic mean 15 μg/m^3, geometric mean (which is a mathematical representation of the median) 12 μg/m^3, maximum value of 93 μg/m^3). For "non-routine" glass wool manufacturing, arithmetic mean exposures were 34 μg/m^3 (geometric mean 17 μg/m^3), well below the revised PEL, although a maximum value of 340 μg/m^3 was reported (Document ID 3999, Attachment 1, pp. 3-4). Information on the working conditions associated with these exposure results was not provided, so it is not possible to determine what work activities or exposure conditions were associated with those exposures that exceeded the final rule's PEL of 50 μg/m^3.[55]

These NAIMA data portray exposures in the rock and slag wool manufacturing industry as being lower than those summarized in the exposure profile for the glass manufacturing industry as a whole (Table IV.4.9-B). OSHA's exposure profile relies heavily on data drawn from OSHA inspections (SEP and OIS data), which tend to measure the most highly exposed workers, and might overestimate median exposures (Document ID 0085; 3958; 0677, p. 146). Thus, OSHA concludes that current worker exposures in this industry are no higher than those presented in the exposure profile (Table IV.4.9-B) and likely to be lower. Overall, the NAIMA data support OSHA's finding that the final rule's PEL is feasible for routine day-to-day operations in glass manufacture because the majority of sample results provided were well below 50 μg/m^3 TWA.

[55] NAIMA described non-routine tasks as "involving infrequent routine maintenance tasks, such as cleaning the batch house, where raw material is fed into a furnace, which is done several times per year, and changing baghouse bags, which is done approximately annually" (Document ID 3999, p. 2). However, OSHA was unable to determine which of these tasks were associated with the exposure samples.

Commenters from the glass manufacturing industry did not question the feasibility of complying with the final rule's PEL for routine operations; to the contrary, testimony from industry representatives included statements and data supporting the revised PEL. In hearing testimony, Mr. Steve Smith of Verallia, a glass container manufacturer, stated that "[w]orkers performing daily activities already meet the proposed standard" (Document ID 3584, Tr. 2846). Mr. Robert Stone, Director of OSHA's Office of Regulatory Analysis, asked Mr. Smith: "other than for maintenance and upset conditions or malfunctions, do you have any other types of overexposures with silica in your operations?" Mr. Smith replied that "the answer to that question is no. [In] our day-to-day operations, we can meet this standard" (Document ID 3584, Tr. 2864).

In written comments, NAIMA acknowledged that, in the rock and slag wool manufacturing industry, "according to OSHA's count and NAIMA's data, relatively few workers face exposure levels that equal or exceed the proposed PEL — and then only for a small fraction of their total work period each year" (Document ID 2348, Attachment 1, p. 27). NAIMA explained that the following controls have been implemented by the mineral wool industry:

- Baghouses or bin vents on silos, mixing operations, and receiving tanks.
- Baghouse monitoring (*e.g.*, differential pressure monitoring, bag break detection) for emissions control.
- Clean, climate-controlled control rooms both in the batch house and in the furnace deck area. In some facilities the batch house control room is remote and not located in the batch house.
- Fully enclosed conveyors and transfer points used in sand handling.
- Capturing fugitive emissions from furnaces and melters.
- Use of wetting screws at the point of batch delivery into the furnace or melter.
- Use of central vacuuming systems, and/or use of outside industrial vacuum trucks for cleaning (Document ID 2348, Attachment 1, p. 21).

NAIMA noted that, on average, mineral wool industry workers' exposure to silica does not exceed 50 μg/m^3, and often does not exceed 25 μg/m^3. However, NAIMA argued that those average exposure levels "do not prove that current engineering controls alone are feasible in all plants for all workers at all times" (Document ID 2348, Attachment 1, p. 27). Technological feasibility has been interpreted to mean that a typical firm will reasonably be able to implement engineering and work practice controls sufficient to reduce exposures to or below the PEL in most operations most of the time. See discussion of technological feasibility in Section II, Pertinent Legal Authority section of the preamble.

NAIMA also noted that no mineral wool products manufacturing data was used in preparing OSHA's Preliminary Economic Analysis of the glass products manufacturing sector (Document ID 2348, pp. 18-19). OSHA appreciates NAIMA's contribution to the rulemaking record and the steps plants have already taken to reduce workers' exposures. While no sample data were available for inclusion in the exposure profile from mineral wool products facilities, OSHA has considered information in the record regarding processes and exposure controls in the manufacture of fiberglass, a type of mineral wool. Based on an interview (conducted by OSHA contractor ERG) with a fiberglass manufacturer, OSHA concludes that the nature of the operations in mineral wool manufacturing is sufficiently similar to the glass industry as a whole to rely on the baseline conditions and exposure profile laid out in the PEA (Document ID 0699). In addition, NAIMA's data clearly indicate that workers in glass mineral wool manufacturing are already exposed below 50 μg/m^3; therefore, it is likely that OSHA has overestimated the costs and controls needed for glass mineral wool manufacturing (Document ID 3999, Attachment 1, pp. 3-4).

4.9.3 Additional Controls

Additional Controls for Material Handlers

The exposure profile in Table IV.4.9-B shows that 17 percent (1 out of 6) of material handlers have exposures below 50 μg/m^3 under baseline working conditions. Therefore, OSHA finds that the remaining 83 percent will need additional controls to reduce exposures to below the final PEL of 50 μg/m^3. Control options include using sized and washed sand containing fewer fine particles (when permitted by final product properties), which is widely available from sand suppliers; fully enclosing and ventilating all conveyors and transfer points used in sand handling; implementing general dust control measures to minimize dusty conditions that exacerbate exposure levels; and educating workers on protective work practices (Document ID 1365, p. 7-10; 0703, p. 1).

A glass product manufacturing facility with an actively enforced silica control program reported that only one in a thousand PBZ air samples exceeded the ACGIH TLV of 50 μg/m^3 when the following practices were followed: purchase pre-washed, size-selected sand which exceeds respirable size; fully ventilate with negative pressure all dry sand conveying equipment; perform preventive maintenance; automate sand handling where possible; and train workers and enforce work practices that control silica release. This facility also noted that many larger manufacturers add moisture to the batch mixer for process reasons, which has an additional hygiene benefit of reducing dust in air and therefore reducing silica exposures (Document ID 0703).[56]

When a fine sand particle size must be used for production purposes (e.g., glass fiber production), another facility has achieved low silica exposures by using a pneumatic sand conveyance system instead of conveyor belts (Document ID 0699, p. 1). This fiberglass manufacturer attributes low exposure levels (typically below the limit of detection (LOD)) to good facility design, using sealed pneumatic pipes for all transport, and good work practices. In addition, this facility trains workers to watch for and respond appropriately to leaks and uses careful clean-up methods (Document ID 0699, p. 2).

Additional Controls for Batch Operators and Associated Workers

The exposure profile in Table IV.4.9-B shows that 50 percent (4 of 8) of batch operators and associated workers have exposures above the final PEL of 50 μg/m^3, and the other 50 percent have exposures below 25 μg/m^3, the final rule's action level. For the workers with exposures above the PEL, additional controls will be required to achieve the PEL. The same control methods described previously for material handlers also will benefit workers in the batch area. At the two facilities described above, these practices resulted in

[56] No individual sampling results relating to this facility's estimate were actually provided to the rulemaking record, and thus could not be included in the exposure profile for this sector.

silica exposure levels generally well below 50 μg/m^3 for workers, including workers in batch areas.

Two of the sample results included in the exposure profile (Table IV.4.9-B) represent batch operators at a large glass products facility who operated automated equipment to weigh materials and transfer them to mixers; these individuals had exposure results of 14 μg/m^3 and 60 μg/m^3 (Document ID 1720, p. IV-209; 0085, pp. 33-36).[57] Further exposure reductions could be achieved by fully enclosing and ventilating all conveyors and transfer points, and isolating batch operators in enclosed, ventilated control booths. Facilities with manual batch operations could reduce exposures by installing automated batch handling equipment.

Exposures to workers engaged in batch area-related maintenance and housekeeping tasks also can be controlled below 50 μg/m^3. Reduction of dust leakage, spillage, and other sources of silica material in the batch area (as described above) should serve to generally reduce dust levels. Diligent, routine housekeeping in batch areas is required to reduce dust accumulation and limit the potential for exposure to re-suspended dust. Using HEPA-filtered vacuums and dust suppressant during housekeeping activities, rather than dry sweeping and using compressed air, also will reduce exposures.[58] OSHA has determined that housekeeping activities can be performed efficiently when engineering controls are fully implemented and maintained on sand handling equipment since there will be fewer fugitive emissions of dust to clean up (Document ID 1540, pp. 209-210).

Glass industry comments submitted to the record described several other types of control options that have been found to be feasible and effective in reducing exposures. William Mann, VP of Health and Safety for Verallia, testified about Verallia's use of central

[57] These workers had total respirable dust exposures of 0.204 mg/m^3 and 0.83 mg/m^3, with percent silica values in these samples of 6.8 percent and 7.2 percent, respectively (Document ID 0085, pp. 33-36). The silica exposure is determined as follows: 0.204 mg/m^3 x 1000 μg/mg x .068 = 13.9 μg/m^3. Likewise, 0.83 mg/m^3 x 1000 μg/mg x .072 = 59.8 μg/m^3.

[58] In hearing testimony, Dr. Paul Schulte recommended "...vacuum systems, portable or centralized" as an alternative to dry sweeping. (Document ID 3579, Tr. 142). Portable vacuum systems are recommended, described, and illustrated in the NIOSH Dust Control Handbook for Industrial Minerals (Document ID 1540, pp. 207 – 209).

vacuum systems for housekeeping (Document ID 3584, Tr. 2860). GANA, the Glass Packaging Institute (GPI), and NAIMA also described using central vacuum systems to reduce silica exposures for workers performing housekeeping activities in glass manufacturing plants (Document ID 2215, Attachment 1, p. 4; 2290, p. 5; 2348, Attachment 1, p. 21). William Yanek, Executive Vice President of GANA, described wet sweeping as a means of reducing exposures during housekeeping as well (Document ID 2215, Attachment 1, p. 9). In hearing testimony, Mr. Steve Smith and Mr. William Mann of Verallia discussed the use of vibrating pipes as an effective means of reducing the frequency of pipe clogs in materials transfer equipment which would otherwise require workers to open a pipe to clear a jam, and can lead to high silica exposures (Document ID 3584, Tr. 2856-2857).

Oral testimony and written comments from the glass manufacturing industry focused on a few specific concerns regarding feasibility. Industry representatives expressed concern about the feasibility of controlling exposures during upset conditions, such as malfunctions or response to batch leaks, without reliance on respiratory protection, "because the type and level of maintenance malfunction events are essentially endless." (Document ID 3584, Tr. 2834-2836; 2290, Attachment 1, p. 2; 2215, Attachment 1, p. 4). OSHA recognizes that upset conditions, such as unforeseeable failure of engineering controls or failure of process equipment that can only be accessed by removing or disabling containment controls, are a potential exposure concern that poses special challenges. These types of situations are discussed more fully in Section IV-1 – Introduction, earlier in this technological feasibility chapter.

Industry representatives challenged the feasibility of controlling exposures during maintenance activities (Document ID 3584, Tr. 2844 - 2851; 3581, Tr. 1725; 2290, Attachment 1, p. 2). In hearing testimony, Mr. Smith of Verallia, described air filter changes as a maintenance activity where exposure control without respiratory protection would not be feasible (Document ID 3584, Tr. 2849 – 2851). OSHA notes, however, that as an alternative to respiratory protection in controlling exposures during air filter changes, some industries use bag-out style filters to encapsulate contaminated filters (Document ID 3883, p. 8-38). Such bag-out techniques could be adopted to reduce reliance on respirators in the glass industry. Respirators may be needed where these other controls do not reduce exposures below the PEL.

In written comments, NAIMA stated that its sampling data showed the following categories of job tasks "which have at least one sample that exceeds the proposed [silica] PEL… where respiratory protection is needed":

- Hot end repair/mechanic (involves maintenance and repair projects; sample results range from 4 $\mu g/m^3$ to 84 $\mu g/m^3$).
- Batch house cleaning (involves cleaning spilled materials in batch house and unloading area, an infrequent maintenance task performed several times per year, which may use vacuuming, wet or other dust suppressant methods, dry sweeping and compressed air; sample results range from 22 $\mu g/m^3$ to 170 $\mu g/m^3$).
- Baghouse maintenance (involves replacing baghouse bags, performed annually, sample results range from 3.6 $\mu g/m^3$ to 76 $\mu g/m^3$) (Document ID 2348, Attachment 1, pp. 16 - 17).

Based on this testimony and experience in analogous situations in other industries, OSHA expects that engineering controls can be implemented for many maintenance activities.

For example, portable exhaust ventilation systems are often used as an engineering control where fixed, permanent local exhaust is not practical or feasible, such as in welding or spray painting. These systems are mounted on a wheeled cart and include particulate filters and flexible exhaust hoses that can be positioned at the point of contaminant generation (Document ID 3658, pp. 2-168 – 2-169; 3659, p. 3-36). In the case of batch house cleaning, additional reductions in silica exposures can likely be achieved by reducing reliance on dry sweeping and use of compressed air, and replacing these dust generating practices with more appropriate controls, such as HEPA-vacuuming and wet or other dust suppressant methods. The Agency has also acknowledged that for very short-term, infrequent activities such as maintenance of engineering controls or servicing of sand handling machinery that is normally enclosed, use of respiratory protection may be appropriate.

Some industry representatives commented that it is not feasible to eliminate the use of compressed air for cleaning in all cases, such as when cleaning tight spaces or hard-to-reach crevices (Document ID 3584, Tr. 2837; 2215, Attachment 1, p. 9; 2348, Attachment 1, p. 37). For example, in hearing testimony, Mr. Steve Smith, VP of Environmental and Regulatory Affairs for Verallia, explained that it would be very difficult to clean a batch scale without relying on compressed air cleaning (Document ID 3584, Tr. 2852). OSHA concludes, however, that the need for such cleaning can be reduced through improved ventilation at the scale and/or enclosure of sand handling equipment, which should minimize the need for cleaning the scales. Additionally, crevice tools are commercially available accessories that can be fitted to standard 35 mm or 1-1/2” diameter vacuum hoses in order to clean hard-to-reach crevices (Document ID 3998, Attachment 10, pp. 32 and 43). It may also be possible in some cases to more fully enclose or seal off hard-to-reach areas so that dust cannot accumulate in them, thus eliminating the need for cleaning.

In some limited circumstances, compressed air cleaning may be the only feasible method of cleaning. In this situation, care must be taken to ensure the use of compressed air does not contribute to airborne silica exposures in the workers’ breathing zone. One way to reduce employee exposure in this situation would be to use a longer compressed air wand to create a separation between the worker’s breathing zone and any airborne respirable silica disturbed by compressed air cleaning activities.[59] Use of longer handled-tools to reduce breathing zone exposures to airborne contaminants is a standard approach under the hierarchy of controls. For example, in an assessment of dowel drilling (NIOSH EPHB report 347-15a), NIOSH recommended use of a long-handled tool to reduce exposures to airborne silica when marking pavement (Document ID 4153, pp. 18-19, 31). It may also be possible to use portable local exhaust in combination with compressed air cleaning, which would capture any dust disturbed by compressed air cleaning before it can enter a worker’s breathing zone. OSHA has previously determined that the set-up of compressed air combined with LEV is permissible when other options such as wet methods or

[59] Wands are already used with compressed air, as observed by NIOSH in a foundry assessment, although the length of the wands used were not actually described (Document ID 0233, pp. 6, 9).

vacuuming are not feasible (e.g., Cadmium and Lead in Construction standards, 29 CFR 1910.1027(k)(6); 1926.62(h)(5)) and as such, has allowed compressed air to be used in conjunction with a ventilation system.

Regarding specific exposure controls, industry commented that use of specific controls should not be mandated, because, while they have been implemented effectively in many circumstances, they are not feasible in all cases. These include use of cullet (Document ID 2215, Attachment 1, p. 5; 2348, Attachment 1, p. 9), prewashed sand or sand of specified grain sizes (Document ID 2215, Attachment 1, p. 5; 2348, Attachment 1, pp. 22-23), and pneumatic conveyance systems (Document ID 2348, Attachment 1, pp. 23-24; 2215, Attachment 1, p. 7). The respirable crystalline silica standard for general industry is performance-oriented, and does not mandate the use of any specific controls. Alternative controls exist, such as implementation of enclosed, ventilated conveyance systems and transfer points; enclosed, ventilated operator control booths; automated batch handling equipment; HEPA-filtered vacuums; dust suppressants during housekeeping activities; general dust control measures; and educating workers on adequate work practices. Employers are free to use any combination of these and other control strategies to meet the PEL in the final rule.

4.9.4 Feasibility Finding

Feasibility Finding for Material Handlers

Based on the exposure profile in Table IV.4.9-B, which shows that, 83.3 percent of material handlers currently have exposures above the final PEL, OSHA expects that additional controls to achieve silica levels of 50 μg/m^3 or less will be required for these overexposed workers. Other information in the record, including communication with a fiberglass manufacturing facility, however, indicates that by using a combination of control methods, all glass manufacturing facilities can achieve levels below 50 μg/m^3 on a regular basis for all workers, including material handlers (Document ID 0699, pp. 1-2; 1365, p. 7-13). Appropriate engineering controls include automated and ventilated equipment for unloading raw materials from shipping containers and transferring them to storage units. Other modifications include fully enclosing and ventilating all sand conveyance devices (including the transfer points) and implementing administrative controls such as improved housekeeping and active dust management procedures.

OSHA concludes that implementation of the control methods described in this section will reduce exposure levels for most material handlers to 50 μg/m^3 or below. Therefore, OSHA finds that the standard is feasible for material handlers in the glass industry.

Feasibility Finding for Batch Operators and Associated Workers

Based on the exposure profile in Table IV.4.9-B, which shows that half of batch operators and associated workers currently have exposures over the final PEL, OSHA concludes that additional controls will be required for these overexposed workers. Employers can reduce exposures to 50 μg/m^3 for those batch area and associated workers using the same combination of engineering and administrative controls described for material handlers. Such controls include automated and ventilated equipment for transferring raw materials to mixers and furnaces, and administrative procedures for managing released sand. OSHA acknowledges that respirator use by batch area workers may be necessary in limited situations when engineering controls cannot be feasibly implemented, such as during certain maintenance activities or upset conditions.

OSHA concludes that implementation of the control methods described in this section, including the occasional use of respirators where engineering and work practice controls alone are insufficient, will reduce exposure levels to 50 μg/m^3 or lower for most batch operators and associated workers in the batch areas of glass product manufacturing. Therefore, OSHA finds that the standard is feasible for batch operators and associated workers in the glass industry.

Overall Feasibility Finding for the Glass Industry

OSHA concludes that, based on the exposure profile and evidence in the record, effective control measures can be implemented to achieve compliance with the final PEL of 50 μg/m^3 for most operations, most of the time, in the Glass Industry. Therefore, OSHA finds that the final PEL of 50 μg/m^3 is technologically feasible for the Glass Products Industry.

4.10 JEWELRY

4.10.1 Description

The jewelry manufacturing industry uses silica-containing materials in casting and finishing operations. Worker exposure to silica can occur during investment casting[60] involving the use of investment casting compounds, which are powdered refractory materials that often contain quartz or cristobalite (Document ID 1370). Workers in this industry also perform abrasive blasting using silica sand as abrasive media for cleaning the investment material from castings, which can result in worker exposure (Document ID 1365, p. 8-1). Workers performing lapidary operations (cutting, polishing, and engraving precious stones) are potentially exposed to silica generated by gemstones (such as agate, amethyst, aventurine, jasper, and quartz crystal) and by abrasives used for grinding and polishing jewelry products (Document ID 1402). Jewelers typically perform small-scale, bench-top operations, using relatively small amounts of silica-containing materials (Document ID 1365, p. 8-1). Facilities manufacturing jewelry are classified in the 2007 six-digit North American Industry Classification System (NAICS) codes: 339911, Jewelry (except costume) Manufacturing; 339913, Jewelers' Material and Lapidary Work Manufacturing; and 339914, Costume Jewelry and Novelty Manufacturing[61] (Document ID 1365, p. 8-1).

Table IV.4.10-A summarizes the major activities and sources of exposure for jewelers, the single job category with potential exposure to silica in this industry.

[60] "Investment casting" is a form of metal casting that involves enclosing a three-dimensional pattern in a heat-resistant ceramic mold called "investment material." Lost-wax casting is an example of a type of investment casting commonly used in jewelry production facilities and dental laboratories (Document ID 0201, p. 3-5).

[61] The applicable 2012 NAICS code is 33910, Jewelry and Silverware Manufacturing.

Table IV.4.10-A Job Category, Major Activities, and Sources of Exposure of Workers in the Jewelry Industry (2007 NAICS 339911, 339913, 339914)	
Job Category*	**Major Activities and Sources of Exposure**
Jeweler	Mix investment material and cast jewelry products. • Dust released during manual transfer and mixing of silica-containing investment material. • Dust generated while separating castings from investment material. Cleaning and abrasive blasting of jewelry. • Dust from abrasive blasting operations involving silica-containing media and/or castings coated with silica-containing investment material. Cutting, grinding, and/or polishing of jewelry. • Dust from grinding or polishing of jewelry with silica-containing abrasives. • Dust from cutting, grinding, or polishing of gemstones containing silica.
*Job categories are intended to represent job functions; actual job titles might differ, and responsibilities might be allocated differently, depending on the facility. Source: Document ID 1365, pp. 8-2 – 8-3.	

4.10.2 Exposure Profile and Baseline Conditions

The exposure profile in Table IV.4.10-B includes 11 personal breathing zone (PBZ) samples of respirable crystalline silica, for the jewelry industry. The median exposure is 12 μg/m^3, mean of 120 μg/m^3, and the range is 4 μg/m^3 to 565 μg/m^3. Table IV.4.10-B shows that, of the 11 samples, 4 (36.4 percent) are above 50 μg/m^3, while 7 (63.6 percent), are below 25 μg/m^3.

As described in the Preliminary Economic Analysis (PEA), OSHA identified two PBZ respirable quartz exposure samples for jewelers from two OSHA Special Emphasis Program (SEP) inspection reports (Document ID 0150, p. 40; 0145, p. 21). The exposure monitoring data presented in these reports were not collected over full work shifts; however, the reports indicate that activities associated with potential exposure were infrequent and not performed during the unsampled portions of the workers' shifts (see, e.g., Document ID 0145, p. 71 (sandblasting occurs "maybe once every two weeks")). As a result, OSHA contractor ERG calculated 8-hour time-weighted average (TWA) exposures based on the reported data and assuming no exposure during the unsampled period. In this manner, ERG calculated an 8-hour TWA of 15 micrograms per cubic meter (μg/m^3) for a jeweler who, under these realistic assumptions, performed abrasive blasting of gold and silver using an unventilated glovebox blasting cabinet and silica sand media (originally 21 μg/m^3 for a 349 minute sample) (Document ID 1365, pp. 8-4 - 8-5;

0150, p. 40). According to the inspection report, visible airborne dust leaked from the cabinet while it was in operation (Document ID 0150, p. 57). The worker performed abrasive blasting operations for approximately 5 to 20 percent of each 8-hour shift (i.e., roughly 30 to 100 minutes per shift) (Document ID 1365, p. 8-5).

For a jeweler at the second site who performed abrasive blasting of metallic medals for approximately 15 percent of the shift, the exposure was less than the limit of detection (12 µg/m^3 as an 8-hour TWA, less than or equal to 77 µg/m^3 for the 76 minute sampling period[62]). The jeweler used garnet media (a substitute abrasive blasting media that contains less than 0.5 percent silica) in an unventilated glovebox cabinet (Document ID 1365, p. 8-5; 0145). The cabinet leaked blast media through holes during the abrasive blasting operation and released visible airborne dust when opened by the worker to remove or reposition the medals. The room had open windows, and the jeweler used a floor fan for comfort.[63]

In addition to the two SEP inspection results detailed above, and because so few suitably documented data were available for the jewelry application group, OSHA considered supplemental PBZ data reported in OSHA's Integrated Management Information System (IMIS) (Document ID 1698; 4185) as well as adding the OSHA Information System (OIS) sample results (Document ID 3958).[64]

The only additional IMIS sample result, collected in 2009, was below the limit of detection. Because information on sample volume is not available for IMIS results, it is

[62] The elevated LOD (less than or equal to 77 µg/m^3) is a function of the extremely short sample duration (76 minutes).

[63] Two additional results from a New Jersey Department of Health (NJDOH) report and a NIOSH report, are excluded from the exposure profile (Document ID 1365, p. 8-5). Both results are reported as below the LOD, but supporting information is insufficient to determine the LOD. In addition, the NIOSH sample covered only some of the worker's potential sources of silica exposure and likely does not represent total exposure for that day. One jeweler conducted polishing inside a booth equipped with LEV, while the other jeweler worked without ventilation (Document ID 1365, pp. 8-4 – 8-5).

[64] Table IV.4.10-B contains IMIS sampling results associated with Standard Industrial Classification (SIC) codes 3911 (Jewelry, Precious Metal), 3915 (Jewelers' Findings and Materials, and Lapidary Work), and 3961 (Costume Jewelry and Costume Novelties, Except Precious Metal).

not possible to determine the sample limit of detection, and thus OSHA could not include such results in the exposure profile presented in Table IV.4.10-B.

The OIS data provided three additional sample results that OSHA has added to this analysis (Document ID 3958). All three OIS data points are from a single inspection, and involved tasks such as casting operations and model making. All three sampled employees were described as using local exhaust ventilation, and all three sample results were below 25 μg/m^3.

In addition, OSHA has updated the exposure profiles contained in the PEA to include only those IMIS samples collected after 1990 (see Section IV-2 – Methodology), resulting in the removal of 10 sample results (Document ID 1698). A total of five IMIS samples collected after 1990 were below the limit of detection and have been excluded from Table IV.4.10-B as well.[65] While it is likely that exclusion of so many non-detect values (31 percent of all sample results) would lead to an overestimate of the distribution of exposures in this application group, the data presented in Table IV.4.10-B do indicate that elevated exposures can occur in this industry when controls are not in place while workers perform abrasive blasting. Results as high as 565 μg/m^3 were reported in IMIS in this application group as recently as 1997. Since 2000, exposure levels reported in this application group have been less than 25 μg/m^3.

No other data or comments were submitted to the rulemaking record relating to technological feasibility in the jewelry manufacturing sector. Based on the available information in the record, baseline controls for this sector include either LEV for finishing operations or use of substitute media for abrasive blasting operations (generally only a single control is in place). Facilities commonly use unventilated glovebox abrasive

[65] In the PEA, which included IMIS samples for the period 1979 through 2002, a total of 34 results were available for the jewelry sector, with sixteen results having detectable silica, and 18 results (52 percent) as non-detects or below the LOD, and thus excluded from the exposure profile. Among the sixteen samples with detectable silica, 56 percent were below 50 μg/m^3. Results ranged from 4 μg/m^3 to 565 μg/m^3, with a median of 39 μg/m^3 and a mean of 108 μg/m^3. Seven results (43 percent) exceeded 50 μg/m^3, and 5 results (31 percent) exceeded 100 μg/m^3.

blasting cabinets. Activities associated with silica exposure are often performed for less than 20 percent of each shift.

OSHA did not receive any evidence contradicting or supplementing OSHA's preliminary analysis of current conditions in the jewelry industry. Therefore, the Agency considers the Table IV.4.10-B to be representative of baseline exposures and conditions.

Table IV.4.10-B
Personal Respirable Crystalline Silica Exposure Range and Distribution of Results for Workers in the Jewelry Industry (NAICS 339911, 339913, 339914)

	Exposure Summary			Exposure Range			Exposure Profile				
Jewelry Industry	**N**	**Mean (μg/m³)**	**Median (μg/m³)**	**Min (μg/m³)**	**Max (μg/m³)**		**< 25 (μg/m³)**	**≥ 25 and ≤ 50 (μg/m³)**	**> 50 and ≤ 100 (μg/m³)**	**> 100 and ≤ 250 (μg/m³)**	**> 250 (μg/m³)**
Jewelry Industry Total	**11**	**120**	**12**	**4**	**565**		**7 (63.6%)**	**0 (0%)**	**0 (0%)**	**2 (18.2%)**	**2 (18.2%)**

Notes: All samples summarized are personal breathing zone (PBZ) results and represent 8-hour time-weighted average exposures.
Job categories are intended to represent job functions; actual job titles might differ, and responsibilities might be allocated differently, depending on the facility.
Percentages may not add to 100 percent due to rounding.

Sources: Document ID 1720, p. IV-214; 3958; 4185; 1698; 0145; 0150.

4.10.3 Additional Controls

The exposure profile in Table IV.4.10-B shows that a little over 36 percent (4 of 11 samples) of jewelry workers have exposures over the final PEL of 50 μg/m^3. Therefore, OSHA finds that additional controls will be necessary to achieve the PEL for these overexposed workers. Although OSHA concludes that adequate controls are widely used, where necessary, as evidenced by the nearly 64 percent (7 out of 11) of sampled jewelers in the exposure profile who have exposures below 25 μg/m^3. These additional controls include:

- Covered containers and LEV during investment mixing.
- Wet methods and/or LEV when separating investment material from castings (e.g., breaking molds under a water stream or mist).
- Properly designed and ventilated abrasive blasting cabinets.
- Alternative low-silica or silica-free blast media.
- Clean blast media for each session (to avoid recycling media contaminated with refractory material unless it can be cleaned).
- Improved work practices (such as allowing the blasting cabinet ventilation to clear the equipment of dust before opening the cabinet).
- Wet methods and/or LEV during finishing operations.
- Improved housekeeping (such as use of a high-efficiency particulate air (HEPA)-filtered vacuum, daily where necessary).

Although no information is available quantifying the effectiveness of each individual method in reducing silica exposures specifically within the jewelry industry, these are standard, time-tested approaches that have been effectively used in many industries to control occupational exposures to a variety of hazardous particulates, including silica. Jewelers employing at least one control typically achieved levels of silica below 25 μg/m^3 (the earlier discussion of baseline conditions for this industry describes use of either LEV for finishing operations or use of substitute media for abrasive blasting operations; also, facilities commonly use unventilated glovebox abrasive blasting cabinets (Document ID 1365, p. 8-7; 0145; 0150; 3958)). In addition, dental laboratory technicians who perform work similar to that of jewelers (mixing investment material, casting precious and semi-precious metals, cleaning and finishing small castings, and abrasive blasting in cabinets) have reduced silica exposures by using several similar exposure controls that should be equally effective in the jewelry industry (see Section IV-4.6 – Dental Laboratories). The effectiveness of these controls is demonstrated by silica exposure levels below the LOD (10 μg/m^3 in this case) obtained for all workers in a dental laboratory that used sealed mixers, wet methods for grinding and divesting castings, benchtop local exhaust ventilation, and an abrasive blasting cabinet when performing small-scale metal casting, finishing, and abrasive blasting processes that were nearly identical to those used in jewelry manufacturing (Document ID 0201). Based on the similarity of the tasks and the scale of these operations in these two industries, and having received no comments concluding otherwise, OSHA concludes that control options available in dental laboratories will be just as effective in jewelry manufacturing facilities. Comments received regarding dental laboratories indicated that ventilation controls and substitute blasting media are feasible and effective in reducing exposures, and that leaks from unvented gloveboxes can contribute to exposure (Document ID 3585, Tr. 3128-3129; 1763, pp. 2-3). To the extent commenters expressed concerns about OSHA's assessments of the control options available to dental laboratories, OSHA's responses in that section also apply to the use of those controls with respect to manufacturing jewelry.

At one dental laboratory, technicians used a covered and sealed mixer to blend water with powdered silica investment materials (containing 70 percent silica). After casting, the investment mold was cracked and castings removed (called "divesting") under a stream of water to suppress dust. Workers also used water-fed and ventilated grinding equipment, performed abrasive blasting with new (clean) media in a ventilated cabinet, and worked at benches fitted with LEV (Document ID 0201, pp. 11 - 15). Three dental technicians working with these controls had exposures below the limit of detection (10 μg/m^3 in this case).

The two samples described in the OSHA SEP inspection reports noted visible dust escaping from unvented abrasive blasting cabinets, indicating the potential for silica-containing dust to escape from the cabinets (Document ID 1365, p. 8-5; 0150; 0145).[66] While unvented blasting cabinets are often sufficient in jewelry or dental laboratories where they are used in small facilities for only a portion of the work shift, unvented cabinets, with open ports for the arms, may not be sufficient when used for a full shift, or when a number of blasting cabinets are in simultaneous use. Mr. John Adams, Vice President of the American Federation of Government Employees (AFGE) Local 2778, representing dental laboratory workers at the Atlanta Veterans Administration hospital, noted that:

> Leaks in a blasting box can cause exposure. Exposure is also caused by opening the door to the blasting box before the dust had settled. Dust in a blasting box must be removed by a dust collection system to prevent dental lab workers from being exposed to silica (Document ID 1763, p. 2).

Where silica exposures above 50 μg/m^3 are associated with use of unvented blasting cabinets, OSHA notes that, in accordance with the hierarchy of controls, equipping such units with HEPA-filtered local exhaust ventilation, and ensuring proper use and maintenance of blasting cabinets, would be effective control measures.

Due to the similarity in work processes and controls between the dental laboratory and jewelry sectors, and the evidence of those types of exposures in the two OSHA SEP inspection reports for the jewelry sector, OSHA has determined that this comment from Mr. Adams is equally applicable to jewelry manufacture. Overall, dental laboratory industry data suggest that jewelers who perform similar tasks using similar controls are unlikely to experience exposure levels above 50 μg/m^3 or even the action level. Baseline controls in use in dental labs, namely local exhaust ventilation, including ventilated blasting gloveboxes and other enclosures, are such that exposures for 97 percent of sampled dental lab workers are already below 50 μg/m^3, with 55 percent below the LOD (as summarized in exposure profile Table IV.4.6-B in Section IV-4.6 – Dental Laboratories in this technological feasibility analysis). Based on these data from a closely

[66] While the measured exposures did not exceed 50 μg/m^3 in these relatively short term samples, the detectable silica in the exposure sample for the worker performing silica sandblasting underscores the importance of ensuring proper functioning of containment devices such as a blasting cabinet.

analogous process and industry, OSHA expects that use of these same controls in the jewelry sector will eliminate exposures exceeding 50 μg/m^3.

4.10.4 Feasibility Finding

Based on the exposure profile in Table IV.4.10-B and other record evidence discussed above, OSHA finds that the standard is technologically feasible for most jewelry workers most of the time when baseline and additional controls previously discussed are used. Many jewelry manufacturing facilities already achieve respirable crystalline silica levels of 50 μg/m^3 or less for most of their workers. Based on information summarized in Table IV.4.10-B, OSHA finds that *at least* 63.6 percent of jewelers' exposures are already below 50 μg/m^3. This percentage likely underestimates the number of jewelers with exposures less than 50 μg/m^3 because nondetectable results were excluded from the IMIS data summarized in Table IV.4.10-B.

For the nearly 36 percent of jewelers with exposures above 50 μg/m^3, OSHA expects that exposures below 50 μg/m^3 will be achieved if properly ventilated abrasive blasting cabinets are used. Employers may also be able to achieve the same result by implementing one or more of the other controls identified above. This finding is based on the similarities between the processes used by dental laboratory technicians and those performed by jewelers, the evidence of similar types of exposures between the dental labs and jewelry manufacturers, and the absence of comments disputing OSHA's estimates in the PEA or the comparison between dental labs and jewelry manufacture. Controls that can reduce silica exposure during jewelry manufacturing include LEV for mixing and finishing operations, sealed equipment or wet methods for handling silica-containing investment casting materials, ventilated abrasive blasting cabinets, and alternative (low- or non-silica) abrasive blasting media.

Therefore, OSHA finds that the final PEL of 50 μg/m^3 is technologically feasible for the Jewelry industry.

4.11 LANDSCAPING SERVICES

4.11.1 Description

Landscape companies are primarily engaged in providing landscape care and maintenance services, including the installation of trees, shrubs, plants, lawns, and gardens. As part of their services, some landscape companies also construct walkways, retaining walls, patios, fences, ponds, or similar structures (hardscape). Establishments providing landscaping services are classified in the six-digit North American Industry Classification System (NAICS) code 561730, Landscaping Services (Document ID 1365, p. 18-1).

In Chapter IV of the Preliminary Economic Analysis (PEA), OSHA preliminarily concluded that only landscape and horticultural service workers performing masonry-related activities have the potential for silica exposure (Document ID 1720, p. IV–218). Several commenters disagreed, stating that other tasks associated with landscaping services had a potential for exposure to respirable crystalline silica. For example, the Construction Industry Safety Coalition (CISC) and the Interlocking Concrete Paving Institute (ICPI) stated that OSHA omitted the following activities from its preliminary analysis:

- Placing and compacting aggregate base;
- Placing bedding sand;
- Compacting pavers;
- Sweeping joint sand into paver joints; and
- Compacting joint sand.

Additionally, CISC listed the “demolition of concrete and masonry structures” and “installing erosion control” (Document ID 2319, Attachment 1, p. 20), and the ICPI added “excavating” and “removing dust off surfaces” (Document ID 2246, p. 8).

These views were supported by the National Association of Home Builders (NAHB) and the Associated Builders and Contractors, Inc. (ABC) who also listed “moving soil” (Document ID 2296, p. 35) and the “handling of paving stones and compaction of interlocking pavers" (Document ID 2289, p. 3) as landscaping activities that could contribute to exposure.

These industry comments convinced OSHA to expand upon its preliminary analysis of the landscaping services industry and to include in its final analysis activities related to the following activities: movement of sand, gravel, and soil; excavation of soil; placing of the sand or aggregate base; compaction of the sand or aggregate base; and sweeping sand into joints. OSHA has concluded based on this further analysis that these activities have the potential to expose workers to respirable silica and that they should therefore be included in the Final Economic Analysis (FEA).

While CISC listed "handling and installing pavers, and cleaning and preparing surfaces for sealing" as potential silica-generating activities, the ICPI excluded them from their list of silica-generating tasks (although it included these activities as part of the process) (Document ID 2246, p. 8; 2319, Attachment 1, p. 20). OSHA agrees with the ICPI that these activities are not likely to contribute to exposures above the PEL and therefore has decided not to include these tasks in its analysis of technological feasibility for the industry.

Based on the comments and supporting material in the docket, the Agency has determined that landscaping services consist of three major activities: 1) lawn maintenance services; 2) cutting silica-containing materials when installing "hardscapes" like retaining walls, patios, and walkways; and 3) moving and compacting sand, gravel, and soil.

Lawn Maintenance Services: In the PEA, OSHA determined that workers engaged primarily in lawn maintenance services, e.g., mowing, trimming, planting, mulching, fertilizing, leaf removal, are not routinely exposed to silica. The Agency did not, therefore, address these workers in the preliminary analysis (Document ID 1720, IV-218). This assumption was not disputed in any of the submitted comments; accordingly, OSHA has not included these workers in its final analysis of landscaping services.

Cutting Silica-Containing Landscaping Materials: OSHA also preliminarily determined that activities related to cutting brick, concrete, stone, and pavers with masonry saws did have exposure to silica. Although the quantity of this work varies with the operation and nature of the firm's services, OSHA has determined that, overall, these activities represent a relatively minor portion of the industry's labor time and only a small share of the industry is engaged routinely in installation of hardscapes where block and brick cutting operations occur (Document ID 1365, p. 18-2). OSHA assumed that if a firm generates a majority of its revenues from this type of activity, the firm is classified as a construction firm and not as a landscaper (Document ID 1720, IV-218). This assumption was not disputed in any of the submitted comments.

Because OSHA has determined that respirable crystalline silica exposures of landscape workers using masonry saws can be well controlled by the controls described in Sections IV-5.6 – Masonry and Concrete Cutters Using Portable Saws and IV-5.7 – Masonry Cutters Using Stationary Saws, and in particular Table 1, the Agency has not included a detailed exposure profile for these workers in this section. This approach differs from the PEA, which addressed only exposures from masonry saws for landscape workers. The controls for masonry saws, however, which are not discussed further in this section, would have the indirect effect of lowering background and secondary exposures of other workers in the work area. In addition to the controls described in Sections IV.5.6 and IV.5.7 relating to portable and stationary masonry saws of this Final Economic Analysis (FEA), this section on Landscaping Services describes silica dust reduction controls that are applicable to the installation of pavers, patios and walkways.

Movement and Compaction of Sand, Gravel, and Soil: Although the quantity of work involving the movement and compaction of sand, gravel and soil varies with the operation and nature of the firm's services, OSHA has determined that, overall, these activities represent a relatively minor portion of the industry's labor time as the vast majority of workers are engaged primarily in lawn and tree maintenance services. Only a small share of the landscaping services industry is engaged routinely in the movement and compaction of sand, gravel, and soil and experiences exposures to silica (Document ID 1365, p. 18-2; 2246, pp. 8-11; 2289, p. 3; 2296, pp. 6-7; 2319).

Final Industry Description

For the final technological feasibility analysis, OSHA has determined that landscaping service workers with potential silica exposure are those workers performing activities related to the movement and compaction of sand, gravel, and soil such as installing erosion control, placing aggregate base and bedding sand, compacting sand and soil, and sweeping joint sand into paver joints. In addition, OSHA has excluded masonry cutting that sometimes occurs in but is not typically characteristic of this industry. For exposures and controls relating to masonry cutting, refer to Sections IV-5.6 – Masonry and Concrete Cutters Using Portable Saws and IV-5.7 – Masonry Cutters Using Stationary Saws.

Sources of exposure for these workers come directly from the dust generated by the movement of the soil, sand, and aggregate. Table IV.4.11-A describes the major activities and sources of exposure of these workers.

Table IV.4.11-A
Job Category, Major Activities, and Sources of Exposure of Workers in the Landscaping Services Industry (NAICS 561730)

Job Category*	Major Activities and Sources of Exposure
Landscape Worker	Moving aggregate and sand; installing erosion control; placing aggregate base and bedding sand; compacting sand and soil; and sweeping joint sand into paver joints. • Dust generated by the movement of the material

*Job categories are intended to represent job functions; actual job titles might differ, and responsibilities might be allocated differently, depending on the landscaping employer.
Sources: Document ID 2246, pp. 8-11; 2289, p. 3; 2296, pp. 6-7; 2319, p. 20.

4.11.2 Exposure Profile and Baseline Conditions

The exposure profile in Table IV.4.11-B includes 7 full-shift personal breathing zone (PBZ) respirable crystalline silica samples for landscape workers who are involved in manual labor including hardscape installation and sand moving. The median exposure is 33 μg/m^3, the mean is 34 μg/m^3, and the range is 6 μg/m^3 to 66 μg/m^3. Of the 7 samples, 2 (28.6 percent) exceed 50 μg/m^3.

The sampling data OSHA has consist of two samples for landscape workers from the OSHA Information System (OIS) with 8-hour time weighted averages (TWA) of 12[67] and 17 μg/m^3, and one 303-minute sample from the 2000 Shield's database for a worker on a sidewalk project, with an 8-hour TWA of 66 μg/m^3 (Document ID 1143; 3958, Rows 731-732).[68] This worker spent the shift laying pavers and sweeping sand into the joints of pavers while another worker on site performed concrete sidewalk cutting using a masonry saw (Document ID 1143). OSHA also identified four additional samples from OSHA's Integrated Management Information System (IMIS) database that OSHA has included in Table IV.4.11-B because of the limited data available through other sources (Document ID 4185). These four samples came from four workers performing landscape activities.[69] The highest exposure of 66 μg/m^3 came from a worker classified as a paver. A second paver on the same site had an exposure of 33 μg/m^3. A hardscape installer had an exposure of 6 μg/m^3 and a worker listed as a landscaper had the second highest exposure of 59 μg/m^3. No further detail about the tasks these workers were doing while sampling occurred is known.

In the PEA, OSHA was not able to identify any data on the silica exposures of landscape workers who did not use saws. OSHA therefore relied on data from similar activities in other industries, that is, masonry workers using saws outdoors, a subcategory of the exposure profile for Section IV-5.6 – Masonry and Concrete Cutters Using Portable Saws, a construction application group, in developing the preliminary exposure profile (Document ID 1720, p. IV-219). Because OSHA was subsequently able during the

[67] Results reported as "zero" or "non-detect" are assigned a value equal to the limit of detection (LOD)(12 in the sample referred to above). The LOD is determined individually for each sample based on the volume of air sampled and the method used to analyze the sample, therefore, the limit of detection varies between samples. See Section IV-2–Methodology for additional information on LODs.

[68] Because the sample from the Shields database was collected for less than 360 minutes and assumed a zero exposure for the unsampled portion of the shift, OSHA recalculated the TWA consistent with Section IV-2–Methodology regarding the handling of General Industry data and assumed there was a continuous exposure during the unsampled portion of the shift in order to obtain an 8-hrhour TWA of 67 μg/m^3. The sample value for this worker was reported by the OSHA compliance officer as 42 μg/m^3.

[69] These data are difficult to interpret because information regarding specific worker activities, workplace conditions, engineering controls, personal protective equipment, and sample duration is not available. However, the IMIS data represent the only other source of current information to date for this analysis.

rulemaking to identify sampling data for the landscape industry which are more representative, it has removed the construction data points used in the PEA for the Final Exposure Profile for this industry.

No studies directly relating to worker exposures while installing hardscapes or conducting landscape activities were submitted to the docket. Several analyses discuss exposures during soil moving activities and demolition clean-up, activities arguably similar to those that may be performed during hardscape installations. As discussed further below, although the analyses provide some useful comparisons, the working conditions described, which include the use of power tools by other workers not classified as moving materials or cleaning-up and the materials being moved like concrete, are dissimilar to those conditions most often experienced by landscape workers. These analyses, therefore, in some ways instructive, do not undermine the Final Exposure Profile.

A literature review by Beaudry et al. (2013) analyzed construction workers exposure to silica dust during the "manual moving of small rocks, soil, etc." done by unskilled laborers with shovels, brooms and occasionally motorized tools, utilizing data collected in Canada, France, and the United States (Document ID 3797, p. 19).[70] While the exposure results in this study are somewhat higher than the exposure profile in Table IV.4.11-B (range of zero to 350 μg/m^3), the study does not provide information on which power tools or dust controls, if any, were in use during sampling and how much of the material contained concrete debris and therefore, OSHA is unable to gauge their effect on the results (Document ID 3797 p. 83). [71] More pertinent to landscape workers, is the comparison in Beaudry, Appendix 6, which compared silica exposure levels for workers

[70] The focus of the literature review was to identify exposure information applicable to the work environment in Quebec, Canada; therefore, Beaudry, et al., eliminated data points that were not relevant to the work environment in Quebec.

[71] Significant differences exist between OSHA's data and the dataset used by Beaudry, et al. OSHA's exposure profile relies on exposure results obtained for workers in the United States and does not incorporate international data because working conditions may differ from those typically found in the United States. Additionally, when data was available only in summary form (e.g., eight exposure results described only by their mean in the source document), OSHA discussed this information separately, rather than including it in the exposure profile calculations.

based on the substrate. This comparison reflects significantly lower exposures for employees working with soil (Document ID 3797, p. 87). Sampling of workers working with soil ranged from 0 to 170 μg/m^3, had a median of 20 μg/m^3 and geometric mean of 30 μg/m^3. With sand, the range was 10 to 530 μg/m^3 with a median of 60 μg/m^3 and a geometric mean of 80 μg/m^3. With brick and concrete blocks, the range was 0 to 960 μg/m^3 with a median of 210 μg/m^3 and a geometric mean of 160 μg/m^3 (Document ID 3797, p. 87). Based on this comparison of silica exposure and substrate, OSHA has determined that landscape workers who move soil have significantly lower exposures than those workers involved in the cleanup of worksite and demolition materials containing concrete.

The sample data reviewed in Beaudry et al. demonstrate that exposures to silica when working with soil are lower than when working with brick and block (mean of 30 μg/m^3 compared to 160 μg/m^3). In addition, the mean exposure for soil is consistent with OSHA's exposure profile. Beaudry et al. (2013) included, however, some exposures significantly higher than those identified in the exposure profile. Because the report evaluated clean-up of materials including concrete in the construction industry, OSHA is unable to determine if these elevated exposures were the result of construction tools not typically used by landscape workers and, therefore, not likely to occur regularly in the landscape industry.

In a 2006 study, Flanagan et al., compiled construction site silica-monitoring data for U.S.-based workers from various sources.[72] This study reported 49 samples for workers using a broom and /or shovel with a geometric mean of 30 μg/m^3 and 61 samples for clean-up workers with a geometric mean of 50 μg/m^3 (Document ID 0677, p. 147). The findings for workers using brooms and shovels are consistent with the exposures identified in the profile for landscape workers while the exposure reported for clean-up workers are slightly higher.

[72] Beaudry, et al., note a significant (20 percent) contribution from the Flanagan dataset (Document ID 3797, p. i; Document ID 0677). Because neither dataset were made available to OSHA, the Agency cannot determine the amount over overlap in samples between the two reports.

The workplace conditions and control methods in place for most of these workers is unknown. Flanagan et al. did not capture information on the materials worked with in this study; however, a large portion of the samples were taken on new construction projects, during building renovations and demolition projects where materials commonly worked with would contain silica concentration higher than soil (Document ID 0677, Attachment 2). Again, because landscape workers do not work with concrete and silica-containing materials on a regular basis, OSHA judges that their exposures will be more typical of the results in the final exposure profile.

The ICPI provided descriptive information on the tasks where exposure is likely to occur during the installation of hardscapes. Charles McGrath of ICPI stated that “Seventy-eight percent of our industry is residential” and that work is not typically done using mechanical equipment, which is usually reserved for large jobs like ports and parking lots (Document ID 3589, Tr. 4407). However in his written comments, he stated that “compacting pavers into the bedding sand is probably the second largest generator of silica dust on any paver project” and this is done using a mechanized plate compactor (Document ID 2246, p. 10). He further explained that while a rubber mallet and hammer can be used instead of a compactor, it increases the installation time significantly (Document ID 2246, p. 10).

Vibrating machines are used during the filling of paver joints with sand as well. According to the ICPI, the traditional method is to repeatedly sweep dry sand containing polymers over the surface into the joints and then vibrate the pavers to ensure they are filled (Document ID 2246, p. 10). However, Warren Quinn with the American Nursery and Landscape Association stated that most landscapers do not use sand when laying paving brick; instead they use stone dust (Document ID 0961).

During the public hearing, the ICPI agreed with others that excavating is not a significant source of silica exposure and generally does not present a risk when installing pavers, stating, “For the purpose of installing paver system, workers do not have to excavate deep into the earth. If the soil is very dry, there may be dust; but in most cases the soil is damp beneath the surface of the earth producing little dust” (Document ID 3589, Tr. 4397). The

ICPI did state that in the case where a surface, such as a concrete patio or walkway, has to be demolished before the installation of the hardscape, the dust from the concrete could contribute to exposures (Document ID 3589, Tr. 4397-4398). The Agency does not disagree with ICIP about the potential for elevated exposures during demolition activities. Based on the studies OSHA reviewed in this section and a review of the databases described, however, demolition does not appear to be a typical source of exposure for landscape workers (no landscaping work/activities are associated with demolition in these large industry studies of construction tasks). Moreover, the demolition of concrete structures, which typically involves tools such as jackhammers, concrete saws and drills, is work performed primarily by employers in the construction industry. And, these activities, the equipment, and available controls are addressed in the pertinent construction sections.

With respect to the installation of pavers and paving brick, and cleanup activities associated with that work, Warren Quinn, with the American Nursery and Landscape Association, clarified that sand cleanup activities are typically done with mechanized blowers and vacuums rather than push brooms (Document ID 0961).

As previously noted, the Agency has not included a detailed exposure profile for landscape workers cutting masonry products during the installation of hardscapes in the final exposure analysis. OSHA, however, did obtain one sample of the silica exposure of landscaper who cut masonry products. This worker had an exposure of 181 $\mu g/m^3$ and was cutting pavers outdoors without any dust controls in place. It is unknown what type of saw the worker was using (portable or stationary) and whether any other workers were using mechanized tools in the area. Due to the limited data received, OSHA does not have enough information to draw a conclusive analysis for landscape workers who cut silica-containing products; however, OSHA expects that the profile for these workers would be similar to the exposures experienced by workers using masonry saws outdoors. Section IV-5.6 – Masonry and Concrete Cutters Using Portable Saws reported a mean exposure of 200 $\mu g/m^3$ and median of 150 $\mu g/m^3$ for workers outdoors with no controls in place, consistent with the exposure for the landscape worker reported above. OSHA also concludes that implementation of the controls described in Sections IV-5.6 – Masonry and Concrete Cutters Using Portable Saws and IV.5-7 – Masonry Cutters Using Stationary Saws will control these workers' exposures.

Based on the information discussed above, OSHA has determined that landscape workers are exposed to silica dust during the movement and compaction of sand, gravel, and soil, such as moving soil, installing erosion control; placing aggregate base and bedding sand; compacting sand and soil; and sweeping joint sand into paver joints, using brooms, shovels, and occasionally using mechanized machinery. OSHA has determined that these activities are not used by the landscape industry on a frequent basis but when performed, the majority of workers are not using controls to reduce exposures.

Because a wide variety of conditions exist in the landscape industry, OSHA has determined that the baseline conditions are best represented by the median for all exposure levels for this job category, as summarized in Table IV.4.11-B. OSHA finds that the results represented in Table IV.4.11-B offer the best available evidence of existing exposure levels. Thus, the exposure level associated with baseline conditions for landscape workers is represented by a median of 33 $\mu g/m^3$.

Table IV.4.11-B
Personal Respirable Crystalline Silica Exposure Range and Distribution of Results for Workers in the Landscaping Services Industry (NAICS 561730)

	Exposure Summary			Exposure Range			Exposure Profile				
Landscaping Services Industry	**N**	**Mean (μg/m³)**	**Median (μg/m³)**	**Min (μg/m³)**	**Max (μg/m³)**		**< 25 (μg/m³)**	**≥ 25 and ≤ 50 (μg/m³)**	**> 50 and ≤ 100 (μg/m³)**	**> 100 and ≤ 250 (μg/m³)**	**> 250 (μg/m³)**
Landscape Worker	7	34	33	6	66		3 (42.9%)	2 (28.6%)	2 (28.6%)	0 (0%)	0 (0%)
Landscaping Services Industry Total	**7**	**34**	**33**	**6**	**66**		**3 (42.9%)**	**2 (28.6%)**	**2 (28.6%)**	**0 (0%)**	**0 (0%)**

Notes: All samples summarized are personal breathing zone (PBZ) results representing 8-hour time-weighted average exposures.
Job categories are intended to represent job functions; actual job titles might differ, and responsibilities might be allocated differently, depending on the facility.
Percentages may not add to 100 percent due to rounding.

Sources: Document ID 1143; 3958; 4185.

4.11.3 Additional Controls for Landscape Workers

The exposure profile in Table IV.4.11-B shows that 2 of 7 samples (28.6 percent) of landscape workers have exposures above the final PEL of 50 μg/m^3. OSHA finds that additional controls will be necessary for any overexposed landscape worker, and that the majority of these workers will likely achieve the PEL when effective controls are implemented to reduce silica dust generated by the movement of material. As shown in Table IV.4.11-B, the highest result sampled was 66 μg/m^3. Based on this information, OSHA concludes that even a modest improvement in dust management will result in exposure levels less than the PEL of 50 μg/m^3 for most landscape workers most of the time.

The primary control for workers performing activities that could generate silica dust in the landscape industry is the implementation of wet methods. In a few instances workers may be able to use vacuums to clean up excess material; however, OSHA was unable to find information in the docket explaining the practicality of implementing this control due to the mobile nature of the industry.

Additionally, exposures will be reduced by the implementation of outdoor work practices such as positioning the workers away from or downwind from dust sources.

Wet Methods

Wet methods for dust control during landscape work include spraying silica-containing materials with water before moving them with shovels, brooms, rakes or other hand tools; adding water sprays to mechanized equipment such as plate compactors; wetting material when equipment is used; and ensuring sand, soil and aggregate remain damp while working with it. Wetting the material reduces exposure to respirable crystalline silica by preventing the fine particles mixed with the aggregate from becoming airborne (Document ID 1365, pp. 3-10, 13-19, 19-22). As discussed below, OSHA expects that wet methods can control silica dust exposures for most landscaping activities like sweeping, excavating soil, and compacting aggregates and similar products with minimal water usage.

In a study on using water for dust control in the mineral processing and mining industry, NIOSH discusses the use of water spray systems, explaining that when using sprays, one of the primary considerations is the droplet size and for optimal dust capture, the particle and water droplet sizes should be roughly equivalent. NIOSH explains that when wetting bulk material to achieve airborne dust prevention, droplet sizes above 100 micrometers (μm) (preferably 200 to 500 μm) should be used. However, for airborne dust suppression, where the goal is to knock down existing dust in the air, the water droplets should be in similar size ranges to the dust particles. To achieve this, droplets in the range of 10 to 150 μm have been shown to be most effective. For dust particles in the respirable range this equates to a finely atomized water spray ranging from a thin fog to a mist (Document ID 1540, pp. 63-64). This is confirmed by industry representatives for dust suppression, Bartell and Jett, who state that wet methods where droplet size matches the diameter of the respirable dust is the most effective use of sprays and results in minimal water usage (Document ID 0548, pp. 1-2). Bartell and Jett further explain that droplet size is important because too large droplets can lead to over wetting, resulting in problems with material consistency and equipment without improving dust capture efficiency (Document ID 0548, pp. 1-2).

In its discussion of wet spray systems, NIOSH states that in most cases, a properly designed spray system using finely atomized water sprays will not exceed 0.1 percent moisture application. NIOSH does note that systems that address prevention over larger areas with larger droplet sprays may add up to 1.5 percent moisture to the process (Document ID 1540, p. 61). While this study addresses dust control on a larger scale than that typically seen during landscape work, due to the similar properties of the material, the same concept can be applied to these worksites. Hoses and sprays which optimize dust capture will result in minimal water consumption and added weight to the materials while being moved. In addition, OSHA has determined that using wet methods during the unloading of bulk materials (i.e., decorative gravel, crushed granite and sand) at the jobsite will help control the exposures of workers present by minimizing fugitive dust.

Nij et al. (2009) studied dust control measures in the construction industry in the Netherlands for activities similar to the movement of material often done by landscape workers. The study included six workers who were sweeping and clearing rubble on the work site (Document ID 2347, Attachment 5). A total of 12 PBZ respirable silica samples were collected for 6 workers with sample durations of 6.5 hours or more. The samples ranged in value from 1.6 μg/m^3 to 97 μg/m^3 and had an arithmetic mean of 32 μg/m^3 and a geometric mean of 17 μg/m^3 (Document ID 2347, Attachment 5, p. 214). Nij found that the effect of spraying water to control respirable dust varied widely when sweeping, resulting in total respirable dust reductions of 12 to 99 percent (Document ID 2347, Attachment 5, p. 215), and determined that wet dust suppression during sweeping required proper wetting in order to be the most effective.

The tools and methods used for site cleanup and clearing rubble on construction sites in the Nij study are similar to tasks in the landscape industry involving the movement of material. In both industries, workers sweep, shovel, and scoop material to relocate it; however, in landscaping, workers may additionally use these tools to place and spread materials over large areas. Although it is not certain how much of the work involved the movement of sand, rock, and soil in the Nij study, workers on site were using power tools to cut, chip, drill, and saw concrete, lime sandstone, breeze block, and mortar, all of which contain silica. OSHA assumes therefore that laborers onsite were working with those materials as well (Document ID 2347, Attachment 5, pp. 212, 214).[73] OSHA concludes that the exposures in the Nij study would be equivalent to or higher than those experienced by a typical landscape worker due to the higher silica content of the materials (concrete, lime sandstone, breeze block, and mortar) described in the study when compared to the material generally found in landscaping.

Beaudry et al. (2013) also noted the importance of using wet methods when sweeping, transporting and handling materials to reduce exposures (Document ID 3797, p. 25). In light of the lower levels of silica found in soil, OSHA also expects that the controls Nij et al., studied for reducing the silica exposure for these workers would have similar results

[73] Breeze block is a highly cellular material made form quartzite, lime, and water (Document ID 2347, Attachment 5, p. 212).

in controlling exposures in landscaping if properly implemented, reducing levels to below the PEL (Document ID 3797, p. 87).

Before hardscapes can be installed, the ground must be properly prepared to prevent settling and to minimize cracking and deterioration of the structure. Preparation typically involves excavation of soil to ensure the surface is level, the placing of sand or aggregate base, and the compaction of the sand or aggregate base to ensure a stable foundation for the hardscape. However, as explained above in the Exposure Profile and Baseline Conditions section, soil excavating will usually be done with damp soil which results in less airborne dust (Document ID 3589, Tr. 4397).

The next step in the process, placing and compacting aggregates, is typically done with plate compactors of varying sizes. The amount of silica dust created can be controlled by wetting the aggregate. Care must be taken, however, to assure that the water added does not exceed the optimum moisture content for compacting aggregate and make it impossible to achieve the necessary density level required for a stable base required by many construction specifications as well the ICPI recommendations (Document ID 2246, p. 9). Placing bedding sand would be similar to placing aggregate, and water could be used to help control dust so long as the bedding sand does not become too wet, making it unworkable (Document ID 2246, p. 9).

Based on the information in this analysis, OSHA concludes that when properly implemented, water is an effective control to reduce silica dust exposure when compacting aggregate; however, employers will need to adjust the flow of water and droplet size based on the specifications of the project. In addition, employers will need to train workers to observe dust release and adjust the flow rate or spray direction to maximize visible dust control and minimize dust. Workers must also be trained to observe the spray quality (its effect on visible dust) and stop work to clean or replace a nozzle that becomes clogged.

As explained above, to optimize the effectiveness of water sprays, water droplets the same size as the dust particles should be sprayed at the dust emission point. With this approach, the least amount of water possible can be used while remaining effective, and allow proper management of the water supplied and eliminated (Document ID 3797, p. 23).

Brouwer et al. (2004), conducted a field study to investigate the effectiveness of the atomization of water as a method for dust control during the use of plate compactors while compacting soil. The study was conducted using two types of compactor: a light weight, flat plate compactor and heavy weight, V-plate type (Document ID 4157, p. 70). Thirty-minute samples were taken with and without automated water sprays while soil was compacted in an enclosed hall (Document ID 4157, p. 70). Both compactors were equipped with flat spray nozzles on each side (4 total) and the water flow rate was set at 1 liter per minute (L/min), resulting in approximately 0.23 L/min going to each spray nozzle (Document ID 4157, p. 70). The study was performed on six separate days over four weeks with a total of 16 samples taken. Exposures for the light weight compactor range from an 8-hour TWA of 150 μg/m^3 to 790 μg/m^3 without the use of the automated water sprays, and below the limit of quantification (LOQ) of 20 μg/m^3 to 169 μg/m^3 with atomization (Document ID 4157, p. 70). For the heavyweight plate compactor, exposures range from 110 μg/m^3 to 400 μg/m^3 without automated water sprays and 80 μg/m^3 to 250 μg/m^3 with the addition of water sprays (Document ID 4157, p. 70).

The researchers attribute the elevated uncontrolled exposures on the light weight type compactor to the operator's location, which was closer to the device compared to the heavy weight compactor. In addition, the light weight compactor had a higher beat frequency (heavy beat frequency 1300-2100 b/min versus light beat frequency of 3000 b/min), which generated more dust (Document ID 4157, p. 72). Switching the atomization resulted in a significant reduction of silica concentrations for the light weight contractor but not for the heavy weight type. Visual observations during the study revealed a higher coverage of the spray generated by the nozzles located at the front of the light weight type compactor compared to that of the heavy weight type (Document ID 4157, p. 72). The authors note that the atomization devices used in this study were prototypes and the location of the spray nozzles needed to be optimized (Document ID 4157, p. 73). OSHA concludes that adjustments to the location of the nozzles, droplet sizes, and initial velocity of the droplets generated might increase effectiveness of the atomization, resulting in exposure levels below PEL.

Unlike the Brouwer study conditions, which were conducted inside, in landscaping, compacting is done outdoors (Document ID 4157, p. 70). Outdoors, the air movement allows natural dispersion of the silica dust and lower exposures. Based on the Brouwer study demonstrating exposure reductions of up to 88 percent when compacting soil indoors, likely improvements in water atomization as well as additional available control measures like equipment-mounted local exhaust ventilation (LEV), OSHA concludes that silica-dust exposures can be feasibly reduced during most compacting activities to below the PEL most of the time.

OSHA acknowledges, however, that there are landscaping activities like installing certain types of paver systems where wet methods are not available. The ICPI stated that many paver system projects use joint sand stabilizers to help secure the sand in the paver joints so neither adding water or a dust reducing sweeping compound are options (Document ID 2246, p. 10). David Smith on behalf of ICPI explained that these stabilizers are generally polymer substances in the acrylics family that are activated with water (Document ID 3598, Tr. 4400-4401). The pavers are laid and then sand, together with a polymer substance, is swept into the joints. A very light spray of water on the surface activates the polymer materials causing the sand to stiffen. This is done to prevent erosion of the sand from between the pavers. He further explained that it is not possible to dampen the sand-polymer mixture before sweeping it into the paver joints because the material becomes sticky and adheres to the surface (Document ID 3598, Tr. 4400-4401). In his written comment, Charles McGrath with the ICPI stated that preparing a paver surface for hydrating joint sand is typically done by blowing dust off the surface using a leaf blower (Document ID 2246, p. 10).

OSHA acknowledges the concern ICPI has with wetting sand and understands that there are instances when wet methods for reducing silica dust exposure may not be implemented. Based on the frequency and duration of those tasks, the Agency believes that there are alternate control exposures that can be implemented to reduce exposures to below the PEL through the use of ventilation and/or work practice controls as discussed under the headings Ventilation and Work Practice Controls and Alternate Processes, below in this subsection.

Ventilation

Beaudry suggests that in cases where water cannot be used due to operational considerations, or when cracked materials or rough surfaces are present, the use of an industrial vacuum with a high efficiency filter for clean-up can reduce exposures (Document ID 3797, p. 25). Nij showed that the use of vacuums in lieu of sweeping resulted in total respirable dust exposure reductions of 84 to 99 percent (Document ID 2347, Attachment 5, p. 215). OSHA anticipates that respirable silica dust would be comparably reduced as well. LEV in the Landscaping Services industry would primarily consist of vacuums to clean up dirt and debris from the worksite instead of sweeping. Vacuuming collects dust particles before they become airborne while using compressed air or blowers causes these particles to become airborne, increasing the potential for greater exposures.

In their written comments, the ICPI stated that "[s]ome tasks such as compacting pavers cannot use vacuum devices to reduce exposures." He explained that vacuuming the sand is not an option as it typically removes the sand from the joints with the dust from the surface (Document ID 2246, p. 10). As previously noted, Warren Quinn with the American Nursery and Landscape Association stated that sand cleanup activities are typically done with mechanized blowers and vacuums rather than push brooms (Document ID 0961). OSHA acknowledges that vacuums may not be feasible under the circumstances described, but where this option can be implemented; its use can effectively reduce exposures.

Work Practice Controls and Alternate Processes

Work practices such as limiting the number and location of workers around the movement of material or when compacting sand and aggregate can reduce exposures to workers during these activities. OSHA expects that work practice controls can be implemented in all but the most challenging circumstances. Good work practice controls include training workers to stay upwind of dust sources and avoid dust clouds, which may indicate the presence of airborne respirable silica dust. Workers should move around the work site and position themselves away from the dust source. Although no quantitative exposure reduction data exist regarding worker positioning in relation to dust created by landscape activities, OSHA concludes based on general industrial hygiene principles that exposures will be reduced when workers do not position themselves within or downstream of silica-containing dust clouds.

Another control for reducing exposure to silica during the installation of hardscapes is the use of layouts and designs that do not require or that minimize cutting, and the use of mechanical splitters to score and snap pavers. In addition to reducing exposures for those workers who operate the saws, this control reduces dust emissions on the worksite, lowering the secondary exposures of other workers in the area.[74] Curb blocks and pavers used in the landscape industry are available in a variety of shapes and dimensions, and patterns can be chosen that eliminate the need for cutting. Manufactured half blocks or closure units can be used in place of cut block and smaller blocks can be used to fill in spaces around obstacles or edges (Document ID 3756, Attachment 6, pp. 4 and 7). Mechanical block splitters are available for snapping pavers, and they do not create excessive dust (Document ID 3756, Attachment 6, p. 6). Mechanical block splitters do not require the use of water for dust suppression, which may make them easier to use on remote locations or in subfreezing temperatures. Some block splitters may not accommodate larger pavers or flag stones used in hardscape installation, and saws with water for dust suppression will still be necessary (Document ID 3756, Attachment 6, p. 8).

4.11.4 Feasibility Finding

Based on the exposure profile in Table IV.4.11-B and other record evidence discussed above, OSHA finds that the standard is technologically feasible for most landscape workers most of the time when baseline and additional controls previously discussed are

[74] Controlling exposures for those workers who use saws to cut brick, block and pavers through the use of wet methods and local exhaust ventilation (LEV) is discussed in Sections IV-5.6–Masonry Cutters Using Potable Saws and IV-5.7–Masonry Cutters Using Stationary Saws.

used. As previously noted, workers cutting silica-containing landscaping materials when installing hardscapes such as retaining walls, patios, and walkways make up a minor portion of the industry's labor time; only a small share of the industry is engaged routinely in the installation of hardscapes where block and brick cutting operations occur. OSHA determined that firms that generate a majority of their revenue from this type of work are classified as construction, and this determination was not disputed. Moreover, and importantly, the exposures from block and brick cutting are well controlled by the controls described in Section IV-5.6 – Masonry and Concrete Cutters Using Portable Saws. A further discussion of the processes, exposure levels, conditions, and silica dust control options available for workers performing these activities are discussed in that section.

Accordingly, OSHA concludes that most of the workers in the landscaping services industry already experience exposures lower than the PEL of 50 μg/m^3, most of the time. OSHA has determined that landscape service workers face less frequent exposures than workers engaged in construction activities involving the movement of concrete rubble, stones, sand, and other materials. This is due in part to the generally low silica content of soil, the smaller scale of the jobs using less mechanized machinery than similar tasks in the other industries, and the infrequent nature of landscaping work that produces respirable silica.

Where workers currently experience exposure levels above 50 μg/m^3, additional controls to reduce exposures below the PEL include increased attention to the rate and position of water used for wet dust suppression; using work practices that position the worker away from the dust; and controlling silica exposure from adjacent sources. While the use of vacuums might reduce silica exposures substantially, OSHA acknowledges that currently they have limited applicability in the landscape industry.

Davis Landscape commented that they believe it would be "exponentially more difficult to meet the proposed PEL of 50 μg/m^3" (Document ID 2383, Attachment 4). OSHA does not agree. The exposure information available to the Agency demonstrates that the majority of workers are already experiencing exposures below 50 μg/m^3. As demonstrated in this section for the few remaining workers with higher exposures, there are available controls that if implemented will result in material reductions in exposures.

The exposure profile in Table IV.4.11-B shows 72 percent (5 out of 7 samples) of samples already at or below the PEL of 50 $\mu g/m^3$. No evidence contradicting or supplementing these data were entered into the rulemaking record. Accordingly, OSHA concludes that most landscape workers are currently exposed to silica levels below 50 $\mu g/m^3$. For workers who are currently exposed above 50 $\mu g/m^3$, the engineering and work practice controls described in this section can be implemented to reduce silica exposure levels to 50 $\mu g/m^3$ or less in most operations, most of the time. Therefore, OSHA finds that the final PEL of 50 $\mu g/m^3$ is technologically feasible for the Landscaping Services industry.

4.12 MINERAL PROCESSING

4.12.1 Description

The nonmetallic mineral processing industry includes those establishments that are primarily engaged in the processing of minerals, including clays, ceramic and refractory minerals, barite, slag, roofing granules, sand, and other nonmetallic minerals. These processes include calcining (processed by burning or incinerating), dead burning (calcining (as a carbonate rock) at a higher temperature and for a longer time), or otherwise post-mining processing beyond beneficiation, as defined by the North American Industry Classification System (NAICS) 327992, Ground or Treated Mineral and Earth Manufacturing and 327999, All Other Miscellaneous Mineral Products.[75] This industry includes facilities that batch, blend, extrude, and package dry and de-aired moist clays. Many of the raw materials processed by this industry contain varying amounts of naturally occurring silica and include nonmetallic minerals such as clay, diatomaceous earth, graphite, and mica (Document ID 1365, p. 20-1).

Similar processes occur infrequently in other industries besides nonmetallic mineral processing such as 325314, Fertilizer (Mixing Only) Manufacturing and 339999, All Miscellaneous Manufacturing. However, OSHA has determined that these types of activities are limited in occurrence and the potential for exposure to respirable crystalline silica in these industries is uncommon. Nonetheless, samples from NAICS codes 325314, Fertilizer (Mixing Only) Manufacturing, and 339999, All Miscellaneous Manufacturing, were included in the exposure profile for the mineral processing industry because OSHA determined that, at the time of sampling, the workers were performing tasks that were very similar to the tasks performed in the this industry (Document ID 3958).

[75] Beneficiation is the process whereby the extracted material is reduced to particles that can be separated into mineral and waste; it is considered a mining activity and is, therefore, not regulated by this rule (Document ID 1720, p. IV-225).

The nonmetallic mineral processing industry produces intermediate or finished products from mined or quarried nonmetallic minerals.[76] Depending on the specific establishment, production workers might perform one or more jobs with the potential for exposure to respirable crystalline silica, including loader/material handler; operator of equipment like the crusher, screener, batch, mixer, and dryer; bagger; laborer; or housekeeper. The activities and equipment used by workers also can vary by facility depending on whether operations are performed manually or by fully automated systems. Consequently, job function and associated exposure to silica varies by establishment (Document ID 1365, pp. 20-2 – 20-4). Table IV.4.12-A presents a summary of the primary activities associated with silica exposure of workers in this industry.

Several stakeholders and trade associations, including the National Industrial Sand Association (NISA), International Diatomite Producers Association (IDPA), Industrial Minerals Association - North America (IMA-NA), National Stone, Sand & Gravel Association (NSSGA), and SMI, stated that most of their facilities fall under the jurisdiction of the Mine Safety and Health Administration (MSHA) and not OSHA, with OSHA only having jurisdiction over a small number of facilities involved in the blending, product assembly, and packaging of minerals (Document ID 3577, Tr. 560, 618; 3583, Tr. 2287; 2101, p. 3; 2179, p. 1; 2294; 2312, p. 1; 2377, pp. 1-2). As stated in a footnote on MSHA jurisdiction (see previous page), OSHA recognizes that those mining and extraction operations are regulated by MSHA, and this OSHA standard only applies to post-mining operations within the nonmetallic mineral processing industry over which MSHA does not exercise jurisdiction.

[76] The Mine Safety and Health Administration (MSHA) has jurisdiction, which it has exercised, over the mining and extraction of nonmetallic minerals, up to and including beneficiation. Consequently, pursuant to 29 U.S.C. 653(b)(1), OSHA does not have jurisdiction over those operations. This rule applies only to operations within the nonmetallic mineral processing industry that are outside MSHA's exercise of jurisdiction.

Table IV.4.12-A Job Category, Major Activities, and Sources of Exposure of Workers in the Mineral Processing Industry (NAICS 327992, 327999)	
Job Category*	**Major Activities and Sources of Exposure**
Production Worker	Dumping dry materials. • Dust generated during manual breaking and dumping of dry materials. • Dust generated by disposal of empty bags. Transferring, mixing, and packaging dry materials. • Dust from transferring or processing dry materials (e.g., with conveyors, elevators, mixers, blenders, screeners). • Dust from manual mixing or packaging of dry materials. Performing housekeeping duties. • Dust raised by using inappropriate cleaning methods (e.g., dry sweeping, shoveling).
*Job categories are intended to represent job functions; actual job titles might differ, and responsibilities might be allocated differently, depending on the facility. Source: Document ID 1720, p. IV-225.	

4.12.2 Exposure Profile and Baseline Conditions

Exposure Profile and Baseline Conditions for Production Workers

The exposure profile in Table IV.4.12-B incudes 33 full-shift, personal breathing zone (PBZ) exposure samples for production workers in the general industry category of mineral processing. The median exposure is 26 μg/m^3, the mean is 39 μg/m^3, and the range is 12 μg/m^3 to 221 μg/m^3. Table IV.4.12-B shows that, of the 33 samples, 7 (21.3 percent) exceed 50 μg/m^3, and 2 (6.1 percent) exceed 100 μg/m^3.

The samples included in Table IV.4.12-B come from two sources: an OSHA Special Emphasis Program (SEP) inspection report on a facility using mineral raw materials to mix the clays it provides to the pottery industry (Document ID 0108) and a NIOSH Health Hazard Evaluation (HHE) report on a manufacturer producing mineral granules for eventual use by the roofing tile industry (Document ID 1377). Additionally, OSHA Information System (OIS) health sampling data were submitted to the rulemaking record for inclusion in the exposure profile (Document ID 3958). The data and information from these sources provide the basis for the final exposure profile for mineral processing production workers.

The highest exposure of 221 μg/m^3 in Table IV.4.12-B is from an OSHA SEP inspection of a clay manufacturing company for ceramic and pottery clay products where there were noted several issues with dust control. A worker who spent a portion of the shift dumping bags of dry silica-containing material at this station, and spent the remaining portion dry sweeping, experienced the exposure. During the inspection, the dustiest operation OSHA observed was breaking and dumping bags of raw materials into a hopper on an elevated work platform. Although the hopper was partially enclosed and ventilated, the task produced substantial amounts of dust (Document ID 1365, p. 20-7; 0108, pp. 45-49, 64-83).

Two additional workers near the bag dumping station had exposure levels of 80 μg/m^3 and 83 μg/m^3. These workers ran the clay batch operation, which involved dry sweeping, packaging dry product, and moving bags of raw material with an open lift truck. OSHA also noted that product bag-filling areas did not have local exhaust ventilation (LEV) during the inspection, but that mixing and blending containers, and material conveyors and elevators, were enclosed (Document ID 0108, pp. 45-49, 64-83; 1365, p. 20-7).

Following the inspection, the facility made several improvements to its engineering controls including: the installation of ventilated bag-disposal hoppers; a new LEV system with a commercially available dust collector for dry batch operations; improvements to existing LEV ductwork and hoods to improve capture efficiency and exhaust flow; and the addition of high-efficiency particulate air (HEPA) after-filters for two existing dust collectors (Document ID 0108, pp. 137-139, 155-165). After the engineering improvements were completed, three full-shift PBZ follow-up exposure levels were reported at less than 31 μg/m^3 (limit of detection (LOD)), 26 μg/m^3 and 44 μg/m^3 (Document ID 0108, pp. 155-165; 1365, p. 20-8).

NIOSH conducted an HHE at a company that produces roofing granules from nepheline-syenite[77]. The facility processes the raw material into uniform-sized granules by using a system of crushers and production screeners. The granules are then transported by

[77] Although NIOSH indicated that nepheline-syenite is reported to not contain silica, two bulk samples collected during the course of the NIOSH investigation contained 1 to 2 percent silica (as cristobalite). Cristobalite had an existing PEL of 50 μg/m^3.

conveyor to the coloring department where the product is colored, heat cured, and transferred to storage silos (Document ID 1365, pp. 20-2 – 20-3; 1377, p. 2). Six full-shift PBZ samples were collected during the initial visit. Three of those six samples exceeded 50 μg/m^3.[78] A helper in the crushing and screening department who performed general cleaning within the department and assisted with screen changing had the highest exposure at 111 μg/m^3. Two other workers in the crushing and screening department experienced exposures of 58 μg/m^3 (Document ID 1377, pp. 3, 10, PDF 62; 1365, pp. 20-7 - 20-10; 1720, p. IV-227).

Although most processes and conveyors were enclosed, NIOSH investigators observed process leaks and poor housekeeping practices (e.g., piles of dust located throughout the facility) that could expose workers to silica-containing dusts. NIOSH also noted that its monitoring data might not be representative of typical worker exposures at the plant because of upset conditions created by a power failure. Plant management reported that dust concentrations were higher than normal (Document ID 1377, p. 11; 1365, pp. 20-10 - 20-11).

Documents submitted to the rulemaking record indicate that this industry recognizes the need for and uses controls to reduce silica exposures. NISA submitted a copy of its Silicosis Prevention Program (SPP) Guide (Document ID 2195, Appendix A). The guide outlines the seven steps set forth in NISA's SPP to eliminate silicosis among its workforce, including implementation of dust control equipment or processes. During the public hearings, Andrew O'Brien with Unimin Corporation, a NISA member company, stated that "the SPP encourages NISA member companies to undertake a program to anticipate, recognize, evaluate, and control hazardous dust exposures, and to continually monitor the effectiveness of control strategies. It emphasizes that the control of hazards from exposures to respirable crystalline silica and the elimination of silicosis is the primary and single most important reason for developing a comprehensive silicosis prevention program" (Document ID 3577, Tr. 571). NISA

[78] All of the samples which exceeded 50 μg/m^3 contained cristobalite, a type of RCS which forms at the high temperatures associated with mineral processing. When cristobalite was identified in a sample, values were added to the quartz levels to create a total silica result.

recommends that its members implement and manage a comprehensive SPP (Document ID 2195, p. 5). It has received a formal commitment to do so from 15 of its 31 member companies (Document ID 2195, pp. 10-11 n. 12).

The NSSGA submitted a copy of its Occupational Health Program, including the Silica & Dust Control module, to the docket (Document ID 2195, Appendix B). The contents of the silica module include: General Approaches to Silica Exposure Control; Engineering Controls; Work Task Controls; Administrative Controls; Personal Protective Equipment; and Web and Print Resources (Document ID 4026, p. 3). The NSSGA stated that many of its members have been successfully using the Occupational Health Program for decades to measure and control silica exposures (Document ID 2327, Attachment 1, p. 3).

Additionally, the IDPA submitted a copy of the IDPA's Safe Handling Guide to the docket (Document ID 4002, Attachment 3), which provides guidance to diatomite distributors and end users regarding the benefits of engineered ventilation controls, safe work practices, and respiratory protection programs for reducing exposure (Document ID 3577, Tr. 617-619). Although the guide is very general in nature, it shows that the industry recognizes the importance of effective controls for reducing exposure and it supports OSHA's conclusions that these controls are available and can be used to describe baseline conditions in the industry.

Several commenters explained that there is an increasing trend toward automation "of processes that historically were conducted manually" (Document ID 2195, p. 20). Stated another way, "It is not uncommon now * * * for a handful of employees working in a central control room (with a conditioned environment) to perform the tasks previously undertaken by a large crew that was deployed across vast operating areas" (Document ID 2327, Attachment 1, p. 7). Commenters stated that viewing equipment and production processes from a control room, along with automated conveyor systems and mechanical screen vibrators, reduce human intervention and potential dust exposures (Document ID 2327, Attachment 1, p. 7).

Michael Johnson with NSSGA stated, "With respect to the trend of increasing automation in aggregates facilities, the more modern conveying and screening equipment includes designs to reduce maintenance requirements in general and the time it takes to perform maintenance operations. These improvements reduce the opportunity for dust exposures among maintenance and other plant employees" (Document ID 4026, pp. 3-4).

Although not included in the exposure profile because working conditions were not described, the Sorptive Mineral Institute submitted sampling results from 23 production facilities[79] to the rulemaking record (Document ID 4010, pp. 12-18).[80] These samples were taken during MSHA inspections between 2009 and 2014 in accordance with MSHA protocol. The samples were reported using 8-hour time weighted averages (TWA) (Document ID 4010, p. 3). Appendix 2, beginning on page 12, contains 54 samples for Bagging/Packaging workers, with an average exposure of 34 μg/m^3; 11 of those samples were above 50 μg/m^3. There were 32 samples for Kiln/Dryer operators, with an average exposure of 20 μg/m^3; only one sample of 228 μg/m^3 was above the PEL (Document ID 4010, pp. 3, 12-18). While these samples were taken at processing facilities on mine sites, which are not under the jurisdiction of OSHA and sorptive minerals are outside the scope of this final standard, the processes are similar to those in non-mining operations with the scope of the standard. Accordingly, the Agency finds that these data support the conclusion that the PEL of 50 μg/m^3 TWA can be achieved for mineral processing production workers most of the time and can be viewed as showing a representative range of baseline exposures.

During the public hearings, Andrew O'Brien from the Unimin Corporation discussed current exposure among NISA companies and controlling worker exposure to levels below 50 μg/m^3 TWA. Mr. O'Brien stated that "within Unimin, we have an internal target of 50 μg/m^3 for a time-weighted average. And we control to at least below that in order to ensure the lowest likelihood of exceeding 100" (Document ID 3577, Tr. 597). When there is a single exposure above 50 μg/m^3, it conducts a root cause analysis "to

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[79] The Sorptive Mineral Institute (SMI) submitted two separate post hearing briefs to the docket (Document ID 4230; 4010). Appendix 2 of Document ID 4010 included an Excel spreadsheet containing sample data for 23 facilities identified by separate Mine IDs assigned by MSHA. Conflicting information was included in Document ID 4230 on page 8 where SMI states data were collected by 36 SMI mining and processing facilities.

[80] Note that sorptive clays are not included in the scope of this rulemaking, as stated in the regulatory text.

identify what may or may not have contributed to that exposure and to determine whether any corrective actions can be taken to bring exposures back down below the 50" (Document ID 3577, Tr. 598-599). He further added that current exposures are "well below the PEL (of 100 µg/m^3). In fact, well below 50 µg/m^3" (Document ID 3577, Tr. 605).

Mark Ellis, representing the IMA-NA and NISA, stated that "by and large, the members have to control below 50 µg to reliably be below 100 µg where the existing PEL is" (Document ID 3583, Tr. 2322), indicating that many facilities already experience exposures below 50 µg/m^3.

Changes to the Exposure Profile

OSHA made a number of revisions to the exposure profile for Mineral Processing production workers that was presented in the PEA, resulting in the final exposure profile shown in Table IV.4.12-B.

OSHA removed 22 PBZ samples included in NIOSH HETA 91-0091-2418. NIOSH had reported these samples as below the NIOSH recommended exposure limit (REL) of 50 µg/m^3 as an 8-hour TWA. Although NIOSH noted that "most" exposures were below LOD of 20 µg/m^3, the report did not specify how many (Document ID 1377 (p. 10 of Report); 1720, p. IV-227). For all 22 NIOSH samples removed, OSHA had taken the most conservative approach and used an exposure of 50 µg/m^3 in the PEA exposure profile (Document ID 1720, p. IV-227). In the final exposure profile, the Agency has decided to rely on the more precise sample results provided for this industry by OIS.

OSHA added 21 samples from the OIS database to the exposure profile with a range of 12 µg/m^3 to 63 µg/m^3. Nine of the samples added to the profile were below the LOD and were assigned a value of 12 µg/m^3 as described in Section IV-2 – Methodology. Only one sample, which was for a worker in the mixing room of an abrasive product plant, had a result over 50 µg/m^3. General ventilation was used, but no other controls were in place. Worker job titles for the additional OIS data include bagger/blender, mixer/mixing room operator, grinder, soil worker, and maintenance and forklift operator (Document ID 3958).

Nine of the 21 samples came from NAICS codes that are not described as nonmetallic mineral processing. Five samples came from NAICS 325314, Fertilizer (Mixing Only) Manufacturing and the remaining 4 came from 339999, All Miscellaneous Manufacturing. OSHA has included these samples in the exposure profile for Mineral Processing because at the time of sampling, these workers were performing tasks similar to those performed by workers in the mineral processing industry, including blending, bagging, and moving sand (Document ID 3958).

No additional exposure sampling data containing sufficient information as outlined in Section IV-2 – Methodology, were submitted to OSHA for inclusion into the final technological feasibility analysis for mineral processing production workers.

The removal of the 22 NIOSH data points and the addition of the 21 OIS data points resulted in no change to the range of exposures for nonmetallic mineral processing production workers, which remain from 12 μg/m^3 to 221 μg/m^3. The mean exposure declined from 50 μg/m^3 to 39 μg/m^3 and the median declined from 50 μg/m^3 to 26 μg/m^3. In the final exposure profile for this industry, 78.8 percent of the samples (26 out of 33) are below 50 μg/m^3; of the 21.2 percent of samples (7 out of 33), 5 (15.2 percent) are between 50 μg/m^3 and 100 μg/m^3 and 2 (6.1 percent) are over 100 μg/m^3 but below 250 μg/m^3.[81]

Exposure Profile and Baseline Conditions

Based on a review of the available information in the record, OSHA finds that while some facilities may have automated operations and facilities, many do not. Although often the inspector performing the OIS inspection indicated whether there was general and local exhaust ventilation, there were no references to automation. OSHA therefore assumes that automatic controls are not represented in the final exposure profile. Baseline conditions at typical facilities therefore include some form of exhaust ventilation and process enclosures, although these controls might be inadequately maintained and function inefficiently. OSHA concludes that the exposure profile in Table IV.4.12-B is

[81] Without the data OSHA included from NAICS codes 325314 and 339999, the exposure profile would have a mean of 65 μg/m^3. The range of exposure would remain unchanged.

based on the best available data and best represents baseline conditions for production workers in the mineral processing sector of general industry (i.e., excluding mines covered by the Mine Act).

Table IV.4.12-B Personal Respirable Crystalline Silica Exposure Range and Distribution of Results for Workers in the Mineral Processing Industry (NAICS 325314, 327992, 327999, 339999)											
	Exposure Summary			Exposure Range			Exposure Profile				
Mineral Processing Industry	**N**	**Mean (µg/m^3)**	**Median (µg/m^3)**	**Min (µg/m^3)**	**Max (µg/m^3)**		**<25 (µg/m^3)**	**≥25 and ≤50 (µg/m^3)**	**>50 and ≤100 (µg/m^3)**	**>100 and ≤250 (µg/m^3)**	**>250 (µg/m^3)**
Production Worker (Before engineering improvements)	18	42	22	12	221		10 (55.6%)	4 (22.2%)	3 (16.7%)	1 (5.6%)	0 (0%)
Production Worker (With engineering controls)	9	21	15	12	44		6 (66.7%)	3 (33.3%)	0 (0%)	0 (0%)	0 (0%)
Production Worker (other conditions)	6	59	54	30	111		0 (0%)	3 (50%)	2 (33.3%)	1 (16.7%)	0 (0%)
Mineral Processing Industry Total	**33**	**39**	**26**	**12**	**221**		**16 (48.5%)**	**10 (30.3%)**	**5 (15.2%)**	**2 (6.1%)**	**0 (0%)**

Notes: All samples summarized are personal breathing zone (PBZ) results representing 8-hour time-weighted average exposures.
Job categories are intended to represent job functions; actual job titles might differ, and responsibilities might be allocated differently, depending on the facility.
Percentages may not add to 100 percent due to rounding.

Sources: Document ID 1720; 3958; 0108; 1377.

4.12.3 Additional Controls

The exposure profile in Table IV.4.12-B shows that 21 percent (7 out of 33 samples) of production workers in general industry mineral processing facilities have exposures above the final PEL of 50 μg/m^3. Therefore, OSHA finds that additional controls will be necessary to achieve the PEL for these overexposed workers. Appropriate control options include equipping existing bag-dumping stations with well-ventilated enclosures and ventilated bag-disposal equipment; modifying and/or improving maintenance to existing process equipment enclosures and LEV to ensure optimal dust control; and using more diligent housekeeping, in association with low dust producing cleaning methods (i.e., HEPA-filtered vacuuming and wet methods), to reduce dust accumulation.

Local Exhaust Ventilation

The highest exposure level in the industry profile (221 μg/m^3) is associated with bag-dumping and disposal operations at a ceramic and pottery supply company (clay manufacturer). Exposure was reduced by about 80 percent to 44 μg/m^3 after this establishment made engineering improvements to its dry batch operations (Document ID 1365, pp. 20-3—20-8; 0108, pp.137-147, 155-165). Exposure levels for two other workers in the production area of the clay manufacturer were also reduced after the engineering improvements. Full-shift PBZ exposure results for the two workers were initially 80 μg/m^3 and 83 μg/m^3. After improvements were made to control dust from the bag-dumping station and other dry batch process equipment, exposure levels were less than the LOD (in this case 31 μg/m^3) and 26 μg/m^3 (Document ID 1365, pp. 20-5—20-9; 0108, pp. 157-163).

For those facilities with exposures above 50 μg/m^3, LEV that can effectively control dust released during bag opening, emptying, and disposal as reflected above, will need to be installed. This includes ventilated bag disposal hoppers and ventilation systems with dust collectors that service the bag dumping and disposal hoppers, and other dry batch processing equipment (blenders and elevators) (Document ID 1365, pp. 20-15—20-16).

Where further reductions are needed, the addition of HEPA after-filters to dust collectors may improve capture efficiency and exhaust flow, further reducing exposures.

Additionally, installing wet dust collectors intended to remove particles from ventilated air, and internal water sprays, have been shown to reduce exposure (Document ID 1365, pp. 20-15—20-16).

Process Enclosure and Maintenance

Properly enclosed, ventilated, and maintained process equipment (e.g., conveyors, elevators, mixers, blenders, screeners) is necessary to ensure low exposures to silica-containing dusts during material transfer and other process-related operations. OSHA has determined that proper process enclosure and maintenance include (1) implementing a preventive maintenance program to ensure that potential process-related leakage points are inspected and repaired before significant dust emissions occur; (2) designing and testing LEV systems to ensure they are functioning effectively; and (3) replacing process enclosures that are removed for inspection or maintenance purposes as soon as the work is completed to prevent significant (and unnecessary) releases of silica-containing dust into the workplace (Document ID 1365, pp. 20-16—20-18; 1720, p. IV-226).

Housekeeping

Poor housekeeping can contribute substantially to a worker's exposure levels. OSHA has determined that control options for production workers also include performing more diligent housekeeping and using low dust producing cleaning methods such as:

1) Implementing vacuuming as a cleaning method (as opposed to dust producing methods such as dry sweeping and shoveling). Sweeping with hand brooms has been observed to produce noticeable clouds of dust so the use of vacuums with HEPA filters is helpful in reducing dust levels generated during cleaning (Document ID 1365, p. 20-18);

2) Wet sweeping in areas where vacuuming is not practical. Wet sweeping includes the addition of moisture in the form of water or other suitable substances to help minimize the release of dust during cleaning (Document ID 1365, p. 20-20);

3) Implementing procedures that require routine cleaning of all surfaces, including floors, storage bins, and process equipment, and developing and enforcing a program to correctly handle product, contain spills, and perform clean-up (Document ID 1365, pp. 20-18—20-20).

NISA stated that sweeping is widely employed in the aggregates industry for cleaning durable surfaces such as roads, buildings, shop floors, and offices and that sweeping outside of buildings often requires wet-vac sweepers, although this is not always the case. It further acknowledge that sweeping is an important housekeeping activity that helps to maintain a safe working environment (Document ID 2327, Attachment 1, pp. 9-10). OSHA agrees that housekeeping is an important factor in reducing and maintaining lower exposures. Where dust accumulations are prevalent, a thorough cleaning in association with improved housekeeping procedures such as wet methods or vacuum cleaning, as discussed above, may be needed to reduce exposures (Document ID 1365, p. 20-18).

Comments Regarding Additional Controls for Production Workers

Several commenters expressed concern regarding the availability of controls and control implementation.

SMI felt that it was “unclear whether it is technologically feasible for the covered SMI facilities to comply with the Proposed Regulation. SMI members' preliminary analysis suggests that engineering controls may not be available to consistently reduce exposures to * * * the PEL and Action Level set forth in OSHA's Proposal” (Document ID 2377, p. 11). However, SMI did not provide any further detail on why the kinds of controls identified in the PEA would not be technologically feasible. OSHA, therefore, continues to believe that the best available evidence, including the previously described voluntary safe handling guidelines for large segments of the mineral processing industry, demonstrates the feasibility of the standard in this industry.

The National Mining Association (NMA) stressed the importance of properly designing, installing, and maintaining controls stating, “No matter how well you design and install a system, if it is not properly and adequately operated and maintained over time it is as unreliable as a poorly worn respirator” (Document ID 2211, p. 7). NISA stated, “Every work environment is unique so the most effective controls (singularly and combined) are often those designed specifically for the space, machinery, process flow, work schedule and other variables that differ from one work environment to the next.” NISA companies “continually monitor the effectiveness of control strategies” (Document ID 2195,

Appendix A, p. 12). OSHA concurs with both the NMA and NISA that controls must be properly installed in each individual workplace and then continually maintained to ensure their effectiveness in reducing exposures.

The NSSGA expressed concern regarding the introduction of new hazards into the workplace through the implementation of wet methods to the process. It commented, "Using water as a dust suppressant inside of structures such as a maintenance shops could increase electrical safety hazards and potentially violate OSHA electrical safety standards" (Document ID 2327, Attachment 1, p. 11). OSHA acknowledges that additional precautions, such as GFCI in accordance with 29 CFR 1910.304(b)(3) when needed to provide protection for employees, may be necessary when using wet methods around electrical equipment.

4.12.4 Feasibility Finding

Based on the exposure profile in Table IV.4.12-B, OSHA concludes that a substantial majority of the production workers in this industry (78.8 percent) already achieve exposure levels of 50 μg/m^3 or less through the use of process enclosures and ventilation and that the remaining 21.2 percent of workers who are overexposed will require additional controls to reach this level. Based on the other record evidence discussed above, however, OSHA finds that the standard is technologically feasible for most production workers in mineral processing facilities most of the time when baseline and additional controls previously discussed are used.

Evidence submitted to the docket shows that a significant number of facilities already routinely achieve exposures of 50 μg/m^3 or less through the use of engineering controls and work practices, including properly designed and maintained LEV and enclosures, and good housekeeping practices. In fact, the data show that where engineering controls are used the highest exposures experienced is 44 μg/m^3 versus 111 μg/m^3 during upset conditions (a power failure) when engineering controls were not operational.

OSHA received two comments regarding the feasibility of the PEL for the nonmetallic mineral processing industry. Michael Sheahan with Front Range Aggregates stated, "OSHA has underestimated the feasibility, achievability and economics associated with the proposed rule" (Document ID 2225, p. 2). NISA expressed support of the American Chemistry Council's (ACC) position that the proposed standard with a PEL of 50 μg/m^3 is not technologically feasible (Document ID 4208, pp. 3-4).

However, no data or specific information explaining why the rule was not technologically feasible for the mineral processing industry was provided by the ACC, NISA, or Front Range Aggregates. In fact, NISA and its members stated their ability to achieve exposures below 50 μg/m^3 on a consistent basis (Document ID 3577, Tr. 597, 605; 3583, Tr. 2322-2323).

For the reasons stated above, OSHA does not agree that worker exposure to less than 50 μg/m^3 is technologically infeasible for nonmetallic mineral processing facilities. The record evidence relied on by OSHA cited in this section demonstrates that, through the use of LEV, process enclosure and maintenance, and good housekeeping measures, exposures below 50 μg/m^3 can be regularly achieved. Industry data and evidence submitted to the docket support this finding.

Thus, OSHA concludes that most production workers at mineral processing facilities are currently exposed to silica levels below 50 μg/m^3. For workers who are currently exposed above 50 μg/m^3, the engineering and work practice controls described in this section can be implemented to reduce silica exposure levels to 50 μg/m^3 or less in most operations, most of the time. Therefore, OSHA finds that the final PEL of 50 μg/m^3 is technologically feasible for the Mineral Processing industry.

4.13 PAINT AND COATINGS

4.13.1 Description

During the manufacturing of paints and similar products such as stains, powder coatings, glazing compounds, and vitreous enamels; ground quartz and cristobalite are often added for pigment and as a filler component. These products are manufactured by establishments classified in the six-digit North American Industry Classification System (NAICS) code 325510, Paint and Coating Manufacturing. Although the production of specialized vitreous coatings are described in Sections IV-4.14 – Porcelain Enameling and IV-4.15 – Pottery, specialized forms of coatings, glaze and enamels are relevant to the paint-manufacturing industry (Document ID 1720, pp. IV-233, IV-239 – 250, IV-251 – 274). OSHA estimates that one-third of this industry uses silica during paint manufacturing with less than 10 percent of the industry using silica in the form of cristobalite (Document ID 1720, p. IV-233).

OSHA finds that material handlers and mixer operators are the two job categories with the highest potential of exposure in this industry. OSHA's findings are based upon two OSHA Special Emphasis Program (SEP) inspection reports, records associated with two OSHA inspections reported in OSHA's Information System (OIS), and a site visit (Document ID 0105; 0199; 0943; 3958). The handling of powdered silica components, including mixing operations and housekeeping, are believed to create the greatest worker exposures. Table IV.4.13-A summarizes the job categories, major activities, and primary sources of silica exposure of workers in this industry.

There is no evidence of exposure for both material handlers and mixer operators once end products are packaged because they are in a liquid form. The American Coatings Association (ACA) noted in written comments that "[o]nce added to the finished paint or coating product, crystalline silica becomes part of a 'wetted mixture' of resin, pigment and solvent and would not, in and of itself, be considered 'respirable crystalline silica'" (Document ID 2239, Attachment 1, p. 1 (quotations in original)).

Table IV.4.13-A Job Categories, Major Activities, and Sources of Exposure of Workers in the Paint and Coatings Industry (NAICS 325510)	
Job Category*	**Major Activities and Sources of Exposure**
Material Handler	Oversee delivery of raw materials and their transportation through the facility. • Dust from open transferring of silica-containing raw materials (such as sand and clay) manually or by lift truck. • Dust from manual weighing of silica-containing materials. • Dust from sweeping, brushing (housekeeping).
Mixer Operator	Add wet and dry ingredients to milling, mixing, and dispersion equipment. • Dust from opening and manually emptying bags of silica-containing materials into hoppers. • Dust from manual weighing of silica-containing materials. • Dust from sweeping, brushing (housekeeping).
*Job categories are intended to represent job functions; actual job titles might differ, and responsibilities might be allocated differently, depending on the facility. Source: Document ID 1365, Table 9-3 on p. 9-4.	

4.13.2 Exposure Profile and Baseline Conditions

Exposure Profile and Baseline Conditions for Material Handlers

The exposure profile in Table IV.4.13-B includes 11 full-shift personal breathing zone (PB) samples of respirable crystalline silica for material handlers in the paint and coatings industry. All 11 results for material handlers are below 25 μg/m³ (the median exposure is 12 μg/m³, the mean is 12 μg/m³, and the range is 10 μg/m³ to 13 μg/m³). The 11 samples come from 1 air sample result from an OSHA SEP Inspection, 3 results from OSHA OIS files, and 7 analytical results as part of a site visit conducted by the OSHA contractor Eastern Research Group (ERG). OSHA concludes that this exposure profile represents the baseline exposure for material handlers in facilities that use crystalline silica in this industry (Document ID 1365, pp. 9-6 – 9-8; 1720, Table IV.C-30 on p. IV-236; 3958).

Baseline conditions for material handlers include considerable manual handling of packaged and bulk raw materials, including powdered products. Manual handling of silica-containing materials can increase the exposure risk to material handlers but are mitigated by local exhaust ventilation (LEV). Exposure results were less than 12 μg/m³ (the limit of detection) when LEV was used to mitigate material handler exposure at a coatings manufacturing facility identified during the review of OSHA OIS files (Document ID 3958).

Exposure Profile and Baseline Conditions for Mixer Operators

The exposure profile in Table IV.4.13-B includes 12 full-shift PBZ samples for mixer operators in the paint and coatings industry. The median exposure is 13 µg/m³, the mean exposure is 89 µg/m³, and the range is 12 µg/m³ to 413 µg/m³. Table IV.4.13-B shows that, of the 12 samples, 3 (25 percent) are above 50 µg/m³, and those 3 also exceed 100 µg/m³. For the original exposure profile presented in the PEA, OSHA reviewed a total of 10 analytical results: 3 from two OSHA SEP Inspections and 7 air sample results as part of an ERG site visit (Document ID 1720, pp. IV-234-235). To produce the exposure profile in this FEA, OSHA added an additional 2 sample results for mixer operators from OSHA's OIS files (Document ID 3958).

One result of 263 µg/m³ is from a 447-minute sample associated with a mixer operator manually transferring raw materials (emptying 50-pound bags) during a period of ventilation system failure. At that manufacturing site, the plant-wide combination LEV and bag disposal system worked well for the first shift monitored but became clogged (reduced or no airflow) during the subsequent shift during which ERG obtained the elevated result. The other six results from this site were collected while the ventilation system was still functioning and resulted in exposure levels below 25 µg/m³ (Document ID 0199, pp. 6, 8-11).

In 2014, OSHA conducted an inspection of another paint manufacturer, obtaining two personal sampling results for mixer operators who added "sand and other particulate to paint during a mixing process" without the benefit of LEV. This basic information about the plant conditions (general dilution ventilation) surrounding these two sample results are described in OSHA's OIS. One of these two results was greater than 200 µg/m³, indicating that mixer operators in paint plants continue to experience exposure levels more than twice the previous PEL when LEV is absent (Document ID 3958, Rows 237-239).[82]

[82] Lines 237 and 238 were consecutive samples collected on a single employee during a single work shift.

Based on the information in the ERG site visit report, OSHA determined that exposures are due primarily to airborne dust generated when: 1) bags are opened, 2) materials are transferred into hoppers, and 3) empty bags are compressed for disposal; and that exposures are significantly higher when LEV is not available or fails (Document ID 0199, pp. 9-10). Two additional sample results from OIS support this determination regarding the value of LEV (see discussion above, Document ID 3958).

Detailed information on housekeeping practices at the paint manufacturing facility visited by ERG indicate that a mixer operator used a brush to dry sweep into the tank any silica powder that accumulated on tank rims near the bag dumping stations. Another operator at this facility used a hose to wash away powder spilled on the floor. Floors at this facility were also cleaned using a wet vacuum truck that was operated by workers in the material handler job category (Document ID 0199, pp. 4, 9, 12). Workers performing these activities during a shift when the exhaust ventilation system was functioning were among those who experienced exposure levels of less than 25 μg/m^3 (Document ID 0199, pp. 4, 6-8, 9, 12). Routine daily cleaning at this level appears to be a standard practice in this industry, not only to minimize slip hazards created by spilled product and materials, but also to maintain product quality by minimizing the unwanted spread of concentrated color pigments, which can affect product color quality.

Table IV.4.13-B Personal Respirable Crystalline Silica Exposure Range and Distribution of Results for Workers in the Paint and Coatings Industry (NAICS 325510)											
	Exposure Summary			**Exposure Range**			**Exposure Profile**				
Paint and Coatings Industry	**N**	**Mean (µg/m³)**	**Median (µg/m³)**	**Min (µg/m³)**	**Max (µg/m³)**		**<25 (µg/m³)**	**≥25 and ≤50 (µg/m³)**	**>50 and ≤100 (µg/m³)**	**>100 and ≤250 (µg/m³)**	**>250 (µg/m³)**
Material Handler	11	12	12	10	13		11 (100%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)
Mixer Operator	12	89	13	12	413		8 (67%)	1 (8%)	0 (0%)	1 (8%)	2 (17%)
Paint and Coatings Industry Total	**23**	**52**	**13**	**10**	**413**		**19 (83%)**	**1 (4%)**	**0 (0%)**	**1 (4%)**	**2 (4%)**

Notes: All samples summarized are personal breathing zone (PBZ) results and represent 8-hour time-weighted average exposures.
Job categories are intended to represent job functions; actual job titles might differ, and responsibilities might be allocated differently, depending on the facility.
Percentages may not add to 100 percent due to rounding.

Sources: Document ID 1720; 3958; 0105, 0199, and 0943.

4.13.3 Additional Controls

Additional Controls for Material Handlers

Based on the exposure profile in Table IV.4.13-B, OSHA concludes that all material handlers are currently below the final PEL of 50 μg/m^3, and therefore no additional controls are required for material handlers in order to meet the PEL. Additional controls, if needed, could include substitution of materials with less silica content and improved ventilation at weighing stations. The effectiveness of these options is described briefly for mixer operators.

Additional Controls for Mixer Operators

The exposure profile in Table IV.4.13-B shows that 25 percent (3 out of 12 samples) of mixer operators have exposures above the final PEL of 50 μg/m^3. On the other hand, 8 of the 9 samples below 50 μg/m^3 are also below the final action level of 25 μg/m^3. Nevertheless, OSHA finds that additional controls will be necessary to achieve the PEL for the 25 percent of these workers who are overexposed under baseline conditions. In the PEA, OSHA described the primary controls for mixer operators as bag dumping stations equipped with well-ventilated enclosures and bag compactors (also ventilated) (Document ID 1720, p. IV-237). At a site mentioned previously, ERG monitored mixer operator exposure and obtained results of less than 12 μg/m^3 and 13 μg/m^3, the sample limits of detection, while workers produced batches of paint by emptying 50-pound bags of quartz and cristobalite powder into hoppers during periods when the combined exhaust ventilation and bag disposal systems were working properly. These values are 95 percent lower than the result of 263 μg/m^3 obtained during another shift at the same plant when these controls malfunctioned (Document ID 0199, p. 9). Based on that site visit, OSHA estimates that properly functioning and adequate LEV and bag disposal systems will reduce exposures from levels exceeding 250 μg/m^3 to less than the limit of detection of 12 or 13 μg/m^3 (a 95 percent reduction) (Document ID 1720, p. IV-237).

High-efficiency particulate air (HEPA)-filtered vacuums offer an alternative to dry brushing and sweeping in plants where exhaust ventilation is insufficient to control dust during these activities. These vacuums supplement wet washing and wet sweeping that already occur in paint and coatings manufacturing facilities (Document ID 0199, pp. 4, 12).

4.13.4 Feasibility Finding

Feasibility Finding for Material Handlers

Based on the exposure profile in Table IV.4.13-B, OSHA finds the baseline exposure level for all material handlers to be less than 25 μg/m³. This finding is based on the 11 sample results - all less than 25 μg/m³ - included in the exposure profile. Thus, OSHA finds that the standard is technologically feasible for material handlers in paint and coatings manufacturing facilities.

Feasibility Finding for Mixer Operators

Based on the exposure profile in Table IV.4.13-B and other record evidence discussed above, OSHA finds that the standard is technologically feasible for most mixer operators most of the time when baseline and additional controls are used. These controls keep exposures well below the PEL when functioning properly. As previously discussed, paint and coatings facilities will need to provide ventilated bag dumping stations and bag disposal systems (also ventilated) for the 25 percent of mixer operators currently exposed to silica at levels exceeding 50 μg/m³. To eliminate dry brushing until ventilation systems are operating effectively, mixer operators can use HEPA-filtered vacuums to clean tank rims and areas that cannot be washed with water immediately after spills occur.

OSHA received no comments related to technological feasibility of the proposed rule for the operations described above. Although both the Society for Protective Coatings (SSPC) and the American Coatings Association (ACA) commented on other aspects of the proposed rule, neither of these organizations commented on the technological feasibility of reducing silica exposures below the PEL with respect to mixer operators in the paint and coatings industry (Document ID 2120; 2239, see, *e.g.*, pp. 4-5 (confining its remarks to applying paint)). Similarly, the National Automobile Dealers Association (NADA) provided extensive comments related to automotive paints (confining its remarks to the removal of paints and other products such as body fillers by automobile body shop technicians), but it did not comment on the technological feasibility of reducing the PEL for mixer operators in paint manufacturing plants (Document ID 2358; 4197; 4198). The NADA did affirm that "OEM [original equipment manufacturing] and aftermarket automotive paint manufacturers have essentially eliminated crystalline silica" from these paints (Document ID 2358, p. 3). NADA explains that "Historically, the paint systems used on automotive coatings contained small amounts of crystalline silica as a rheology agent. No crystalline silica is used currently in North America on automobile coatings and has been removed from all manufacturers' paint products since at least model year 2000." (Document ID 4198, p. 1).

Overall Feasibility Finding for Paints and Coatings Manufacturing Facilities

OSHA concludes that all material handlers and most mixer operators in paint and coatings facilities are currently exposed to silica levels below 50 μg/m^3. For mixer operators who are currently exposed above 50 μg/m^3, the engineering and work practice controls described in this section can be implemented to reduce silica exposure levels to 50 μg/m^3 or less in most operations, most of the time. Therefore, OSHA finds that the final PEL of 50 μg/m^3 is technologically feasible for the Paint and Coatings industry.

4.14 PORCELAIN ENAMELING

4.14.1 Description

Porcelain enamel is a boro-silicate layer usually applied to metal products as a protective or decorative coating. Porcelain enameling is used in a variety of industries to produce such products as architectural panels, bathtubs, barbeques, boilers, chemical vessels, cookers, heat-exchange panels and tubes, microwave ovens, street signs, water heaters, and washing machines (Document ID 0671, pp. 3-4). Industries that can involve porcelain enameling are classified in the 2007 six-digit North American Industry Classification System (NAICS) codes 332812, Metal Coating, Engraving (except Jewelry and Silverware), and Allied Services to Manufacturers; 332998, Enameled Iron and Sanitary Ware Manufacturing; 332323, Ornamental and Architectural Metal Work Manufacturing; 339950, Sign Manufacturing; and 335211, 335221, 335222, 335224, and 335228, industries involved in household appliance manufacture (e.g., stoves, refrigerators, microwave ovens, water heaters).[83]

Porcelain enamel is produced from ground frit, a silicate glass composed of approximately 50 percent amorphous silicon dioxide, and additive ingredients. For many applications (but not all), these additives include crystalline silica or crystalline silica-containing materials such as feldspar and quartz (Document ID 0740, p. 19; 0959). The application of the enamel on the base material is performed in various ways, including manual or automatic dipping, slushing, flowcoating, manual or automatic spraying, electrostatic wet spraying, electro-deposition, and electrostatic dry powder spraying. For the purposes of this analysis, porcelain enamels can be divided into two categories: 1) clay-containing porcelain enamels that typically include 2 to 10 percent silica, are always applied as a wet slurry, and cannot be applied electrostatically, and 2) porcelain enamels classified as powder coatings, which contain no clay or silica and can be applied by electrostatic/electro-deposition processes (Document ID 0959). This discussion focuses solely on manufacturers of enamels that contain silica.

[83] The applicable 2012 NAICS codes also include 332999, 334519, and 335210

4.14) Porcelain Enameling

Establishments that perform porcelain enameling typically employ enamel preparers who mix the enamel and coatings applicators who apply the enamel to metal products. In facilities with small enameling operations, the same operator might mix the coating and apply it to products. See Table IV.4.14-A for a description of job categories, major activities, and sources of exposure. The processes used for both the porcelain enamel preparation and application are generally similar to those used to produce and apply glazes in the pottery industry, including the preparation of materials, molding, and glaze application procedures. See Table IV.4.15-A, in Section IV-4.15 – Pottery, for detailed descriptions of these processes. The major difference between the porcelain enamel used on metals and the glaze applied to pottery is that metal enamels contain more boron and less silica (2 to 10 percent silica in metal enamels compared with 23 percent in pottery glaze), which allows enamels to fuse at a lower temperature and accommodate the greater thermal expansion of metals (Document ID 1365, p. 15-4).

Table IV.4.14-A
Job Categories, Major Activities, and Sources of Exposure of Workers in the Porcelain Enameling Industry (2007 NAICS 332323, 332812, 332998, 335211, 335221, 335222, 335224, 335228, and 339950)

Job Category*	Major Activities and Sources of Exposure
Enamel Preparer	Combine frit and other raw ingredients; transfer enamel slurry to other areas of the plant. • Dust from milling and/or mixing of silica-containing materials. • Dust from manual weighing and bag dumping of silica-containing materials.
Porcelain Applicator	Apply enamel to products (manually or automated); transfer products between conveyors; perform housekeeping. • Dust from handling products coated in dried enamel. • Dust from dried overspray and dripped slurry from the application process.

*Job categories are intended to represent job functions; actual job titles might differ, and responsibilities might be allocated differently, depending on the facility.
Source: Document ID 1365, pp. 15-1-15-6.

4.14.2 Exposure Profile and Baseline Conditions

The exposure profile in Table IV.4.14-B includes 35 full-shift personal breathing zone (PBZ) samples of respirable crystalline silica for workers in the Porcelain Enameling industry. The median is 44 μg/m^3, the mean is 207 μg/m^3, and the range is 3 μg/m^3 (the limit of detection (LOD)) to 2,300 μg/m^3. Table IV.4.14-B shows that, of the 35 samples, 15 (42.9 percent) exceed 50 μg/m^3.

Only 5 of the samples characterize silica exposures during porcelain enameling. In the absence of more completely documented exposure information for this industry, OSHA has primarily relied on sampling data obtained from its Integrated Management Information System (IMIS) data, and also has relied on the general exposure information provided by a contact within the industry (Document ID 0960). Drawbacks associated with IMIS data include limited documentation of worker activity, sample duration, materials being handled, exposure controls in use at the time, and other or adjacent sources of silica exposure. However, IMIS data remain the best available source of exposure data for workers involved in porcelain enameling. The OSHA contractor ERG searched IMIS data for silica sampling associated with porcelain enameling between 1979 and 2002, and identified three exposure results (as respirable dust containing silica) for enamel preparers and 23 results for porcelain applicators between 1985 and 1992 (Document ID 1365, pp. 15-6 – 15-9). In addition, the International Union of Automobile Workers (UAW) submitted nine respirable silica sample results which have been included in the final exposure profile (Document ID 4031, Attachment F, pp. 4-5). However, because of the scarcity of data for porcelain enameling, OSHA has retained the data presented in the Preliminary Economic Analysis (PEA) from before 1990.[84]

OSHA also reviewed inspection data submitted to the rulemaking record from OSHA's Information System (OIS), but determined that OIS did not include any data for silica sampling associated with porcelain enameling. The exposures summarized in Table IV.4.14-B for enamel preparers and porcelain applicators represent the best available information on the exposure levels associated with these job categories and, in the absence of more detailed information, also represent baseline conditions for enamel preparers and porcelain applicators.

Exposure Profile and Baseline Conditions for Enamel Preparers

The exposure profile in Table IV.4.14-B includes 5 full-shift personal breathing zone (PBZ) samples of respirable crystalline silica for enamel preparers in the Porcelain Enameling industry. The median is 51 μg/m^3, the mean is 71 μg/m^3, and the range is 12

[84] For more information on how OSHA handled data contained in the feasibility analysis, refer to Section IV-2–Methodology.

μg/m^3 (the limit of detection (LOD)) to 190 μg/m^3. Table IV.4.14-B shows that, of the 5 samples, 3 (60 percent) are above 50 μg/m^3. Two of respirable silica samples for enamel preparers (millers, mixers) from the IMIS database measured detectable concentrations of46 μg/m^3, and 56 μg/m^3, while a third was reported as below the LOD (Document ID 1365, p. 15-8). The value for the LOD could not be determined because the sample duration was not provided in the IMIS database, so a value of 12 ug/m3 was used in the exposure profile (see Table IV.4.14-B). Two additional silica samples of 51 μg/m^3 and 190 μg/m^3, submitted by the UAW, were added to the exposure profile (Document ID 4031, Attachment F, pp. 4-5). Limited information provided by NIOSH and from contacts within the industry indicates that most facilities performing porcelain enameling currently use automated systems to move some raw materials (such as frit) to the mixer, but that enamel preparers are most likely to introduce those additives used in smaller quantities (such as silica-containing ingredients) by dumping bags directly into a hopper at the mixer opening (Document ID 1365, p. 15-10; 1682, p. 5; 0959). Some form of exhaust ventilation is often available at the mixer opening or hopper; however, the ventilation does not necessarily offer complete dust control during mixer charging, as evidenced by reports of measurable silica exposure levels during mixer charging (Document ID 1277, 1365, p. 15-4). For example, the Porcelain Enamel Institute (PEI) noted that the industry often uses LEV with baghouses in the bag dumping area (Document ID 2281, p. 3). Although often a relatively brief task requiring approximately one hour per day, mixer charging can be the most significant source of worker silica exposure associated with porcelain enameling (Document ID 1365, pp. 15-4 – 15-5).

OSHA concludes that the exposure profile in Table IV.4.14-B for enamel preparers represents the best available information on the exposure levels associated with this job category. Accordingly, OSHA considers the profile to be representative of baseline conditions for enamel preparers.

Exposure Profile and Baseline Conditions for Porcelain Applicators

The exposure profile in Table IV.4.14-B includes 30 full-shift personal breathing zone (PBZ) samples of respirable crystalline silica for porcelain applicators in the Porcelain Enameling industry. The median is 28 μg/m^3, the mean is 229 μg/m^3, and the range is 3 μg/m^3 (the LOD) to 2,300 μg/m^3. Table IV.4.14-B shows that, of the 30 samples, 12 (40 percent) are above 50 μg/m^3, 6 (20 percent) exceeded 100 μg/m^3, and 2 (6.7 percent) exceeded 1,000 μg/m^3 (Document ID 1365, p. 15-9; 4031, Attachment F, pp. 4-5). The sampled porcelain applicators were primarily employed by appliance manufacturers with job titles such as porcelain sprayer, porcelain applicator, enameler, rework sprayer, and enamel sprayer. The IMIS data indicate that one facility was inspected by OSHA in three different years. Both porcelain applicator results exceeding 1,000 μg/m^3 were obtained in 1985 at the first inspection of this facility, along with two results of 47 μg/m^3 and 91 μg/m^3. At the two subsequent inspections, silica exposures for applicators were controlled below 50 μg/m^3. Results of 3 μg/m^3, 4 μg/m^3, 6 μg/m^3, and 22 μg/m^3 were reported in 1989, and results of 22 μg/m^3 and 23 μg/m^3 were reported in 1992 (Document ID 1698). No information on controls is available for this facility.

At Porcelain Facility A, all air sampling results for workers associated with the porcelain application line were reportedly below 100 μg/m^3 (Document ID 1365, p. 15-10; 0960). These results are associated with exhaust ventilation along the length of the spray application line. Only summary exposure data is available to OSHA from Porcelain Facility A (no individual results).

Regardless of the application method used (e.g., spray, dip, flowcoat), silica-containing porcelain enamels are typically applied as a slurry (Document ID 1365, p. 15-10; 0959). This wet application reduces exposure because silica particles cannot become airborne until dry, and when dry, porcelain enamel adheres tightly to the surface to which it is applied (Document ID 1365, pp. 15-5 – 15-6). Limited information provided by a contact within the industry indicates that ventilation is used extensively while porcelain applicators coat objects and subsequently handle the parts. All application is performed in ventilated booths (e.g., a spray booth) (Document ID 1365, p. 15-5). Written comments received by PEI also implied that the industry uses LEV systems with baghouses in the porcelain application booths (Document ID 2281, p. 3, PDF p. 7). Based on the experiences of other industries, some of the ventilation systems and booths might require maintenance or modification to operate efficiently.[85] Thus, OSHA concludes that baseline conditions for porcelain applicators include wet application methods and use of exhaust ventilation, which might or might not be functioning optimally.

OSHA concludes that the exposure profile in Table IV.4.14-B for porcelain applicators represents the best available information on the exposure levels associated with this job category. Accordingly, OSHA considers them to be representative of baseline conditions for porcelain applicators.

[85] See Sections IV-4.4–Cut Stone, IV-4.8–Foundries and IV-4.18–Refractories.

Table IV.4.14-B **Personal Respirable Crystalline Silica Exposure Range and Distribution of Results for Workers in the Porcelain Enameling Industry (NAICS 332812, 332998, 335211, 335221, 335222, 332323, 335224, 335228, 339950)**											
	Exposure Summary			**Exposure Range**			**Exposure Profile**				
Porcelain Enameling Industry	**N**	**Mean (μg/m³)**	**Median (μg/m³)**	**Min (μg/m³)**	**Max (μg/m³)**		**< 25 (μg/m³)**	**≥ 25 and ≤ 50 (μg/m³)**	**> 50 and ≤ 100 (μg/m³)**	**> 100 and ≤ 250 (μg/m³)**	**> 250 (μg/m³)**
Enamel Preparer	5	71	51	12	190		1 (20%)	1 (20%)	2 (40%)	1 (20%)	0 (0%)
Porcelain Applicator	30	229	28	3	2,300		14 (46.7%)	4 (13.3%)	6 (20%)	1 (3.3%)	5 (16.7%)
Porcelain Enameling Industry Total	**35**	**207**	**44**	**3**	**2,300**		**15 (42.9%)**	**5 (14.3%)**	**8 (22.9%)**	**2 (5.7%)**	**5 (14.3%)**
Notes: All samples summarized are personal breathing zone (PBZ) results representing 8-hour time-weighted average exposures. Job categories are intended to represent job functions; actual job titles might differ, and responsibilities might be allocated differently, depending on the facility. Percentages may not add to 100 percent due to rounding. Sources: Document ID 1720; 1698; 4031, Attachment F											

4.14.3 Additional Controls

Additional Controls for Enamel Preparers

The exposure profile in Table IV.4.14-B shows that 3 of 5 samples, (60%) for enamel preparers have exposures above the final PEL of 50 µg/m^3. Therefore, OSHA finds that additional controls will be necessary to achieve the PEL. Considering this profile to be representative of baseline conditions for enamel preparers, and based on other information in the rulemaking record that this work typically requires a limited amount of time to add the silica-containing materials (generally less than 10 percent of all raw materials) and can be done using ventilated mixers/mill charging equipment, OSHA finds that additional controls will be necessary to achieve the PEL for these overexposed workers and expects that porcelain enameling will be able to reduce exposures to the final PEL of 50 µg/m^3 or less by proper ventilation or by improved design or maintenance of existing ventilation systems at bag dumping and mixer charging stations, process automation, improved housekeeping, and substitution. These controls have proven effective in the porcelain enameling industry and in other industries with analogous job categories, such as those that manufacture pottery or structural clay (see the related Section IV-4.15 – Pottery and Section IV-4.21 – Structural Clay). Coatings preparers in these industries are exposed to silica during transfer and mixing of sand, feldspar, and other coatings or glaze ingredients. Both the pottery and structural clay industries use a substantially greater percentage of silica (also in the form of quartz or feldspar) in product coatings than are used by the porcelain enameling industry. Because of the similarity of the tasks, equipment, and materials, OSHA concludes that control methods employed by coatings preparers in the pottery and structural clay industries will function equally well in the porcelain enamel industry.

Local Exhaust Ventilation

Bag-dumping stations with properly ventilated enclosures, which capture dust release during both bag emptying and bag disposal, have been used successfully in the pottery and structural clay industries to reduce exposures. An example from the pottery industry demonstrates the value of the booth alone. A coatings preparer used a booth and a weigh scale outside the booth to mix glazes. An initial exposure of 143 µg/m^3 was reduced to 51 μg/m^3 after the baghouse ventilation system was repaired. A consultant evaluating the plant on the second (post-repair) sampling date recommended limiting use of compressed air for cleaning to further reduce silica exposure; this recommendation suggests that compressed air was used regularly in the plant (Document ID 0106, p. 55). OSHA concludes that by moving the weigh scale into the booth or adding exhaust ventilation to the scale area, and by reducing reliance on compressed air for cleaning, the exposure of this coatings preparer could be reduced to a level consistently below 50 μg/m^3.

A bag-dumping station with fully functioning local exhaust ventilation (LEV) was found to reduce silica exposure by at least 95 percent in a paint manufacturing facility where workers emptied 50-pound bags of silica-containing materials (Document ID 0199, pp. 7, 8, 11). The station consists of hoppers topped with grates enclosed by LEV hoods. After each bag is emptied, the worker releases it and suction automatically pulls the bag into the ventilation system and transfers it to an enclosed storage area. Other types of bag dumping stations also are effective at reducing respirable dust (Document ID 1369). Ventilated bag dumping stations are readily available from commercial sources (Document ID 0581; 0594; 0680; 1212; 1224). PEI commented that OSHA underestimated the amount of LEV (and the associated costs) required to effectively control exposures to 50 μg/m^3 in porcelain enameling (Document ID 2281, pp. 4-5). OSHA understands that some facilities, including those that use enamel coatings that contain higher concentrations of silica, may need to install LEV with a higher flow rate than other facilities. OSHA has not required a specific flow rate or minimum flow rate and instead is relying on employers to evaluate their exposures and install the appropriate controls based on the findings of an exposure assessment. See Chapter V of this FEA for a discussion on the associated costs.

Process Automation

Although information specific to enamel preparers is not available, the effectiveness of automated systems for transferring silica-containing materials is illustrated by exposure monitoring data obtained for material handlers at two pottery facilities. The exposure for a material handler who was monitoring automated equipment adding silica-containing raw materials to a mixer was almost 66 percent lower (29 μg/m^3 versus 85 μg/m^3) than the exposure of a material handler manually adding bags of raw materials to the mixer. At another facility, OSHA obtained a reading of 23 μg/m^3 for a material handler monitoring automated equipment that transferred dry silica sand from the storage silo and pumped a slurry of ball clay and kaolin into a mixer (Document ID 1365, p. 15-13).

An example from the structural clay industry is also instructive. At a facility inspected by OSHA, an 86 percent reduction in respirable quartz exposure readings occurred after management installed an enclosed, automated sand transfer system, despite having an incorrectly sized conveyor. With tightly sealed components, it is likely that exposures would be reduced further (Document ID 1365, p. 15-13).

Housekeeping

Dust released during mixer charging can contribute substantially to enamel preparer exposure in facilities where poor housekeeping has allowed dust to accumulate. In addition, some cleaning procedures (e.g., dry sweeping) can aggravate the situation by stirring up dust and causing it to become airborne. For those facilities where excessive dust has been allowed to accumulate, an initial thorough cleaning, followed by continuous, improved housekeeping procedures (e.g., use of a high-efficiency particulate air [HEPA]-filtered vacuum) to maintain cleanliness can reduce exposures. An example from the structural clay industry demonstrates the benefit of diligent housekeeping practices on worker silica exposure levels. A dramatic exposure reduction (in some cases a greater than 10-fold reduction) was associated with thorough (professional-level) cleaning to remove dust accumulations on the floor and structural surfaces of raw material handling areas (Document ID 0571).

Surface cleaning with HEPA vacuums instead of compressed air has proven beneficial in the pottery industry (another industry using similar silica-containing mineral powders). In a pottery industry facility, the use of compressed air to clean silica dust from the surface of molds was replaced with the use of a vacuum and abrasive pad (Document ID 0027, pp. 161-191; 1372, p. 7). Using these methods, and despite uneven functioning of the LEV at two workstations, the facility was able to reduce all of its silica exposures to 40 μg/m^3 or below (three results equal to 30 μg/m^3 and single results of 10 μg/m^3, 20 μg/m^3, and 40 μg/m^3) (Document ID 0027, pp. 32, 186, 367). As discussed in the PEA, this reflects a substantial reduction in exposure levels at this facility where 50 percent of samples previously taken by OSHA and 30 percent of results taken by NIOSH were over 50 μg/m^3 (Document ID 0027, pp. 32, 186, 367; 1720, p. IV-245).

Substitution

The use of enamels with reduced crystalline silica content represents an additional control option. By preparing coatings with low-silica ingredients, enamel preparers' exposures to silica would likely be reduced. Coatings producers typically use quartz and feldspar as ingredients in coatings to increase durability and chemical resistance; however, coatings with reduced crystalline silica content can be formulated by replacing quartz with materials such as feldspar (lower crystalline silica content) and frit (amorphous silica), which contain less crystalline silica (Document ID 1365, p. 15-14). Porcelain enamels with less than 3 percent crystalline silica are available (Document ID 0960).

PEI commented that it is not practical to use low-silica ingredients, that there are no proven replacements for mill-added crystalline silica in today's wet-applied enamel systems, and that silica offers technical advantages in finished product quality which cannot otherwise be practically and economically achieved (Document ID 2281, Attachment 1, p. 3). OSHA does not expect substitution to be a suitable control in every situation where high silica ingredients are currently used. However, OSHA continues to be convinced that substitution is a feasible control in other applications, given communication with a porcelain enameling facility that uses enamels containing less than 3 percent crystalline silica (Document ID 0960). PEI did not indicate how frequently these substitutes may be unacceptable for the referenced applications.

Additionally, OSHA considers the wet-application process itself to be a means for exposure reduction. If an establishment disfavors substitution for quality assurance reasons, additional controls, such as process automation during mixing, LEV and housekeeping to remove wet product before it dries are alternative methods for reducing exposure.

Combination of Controls

Using several of the controls discussed above (LEV, process automation, housekeeping, and substitution) simultaneously can lead to greater exposure reductions. Porcelain Facility A (described previously) uses both ventilation and good housekeeping to keep exposures low. At Porcelain Facility A, enamel preparers charge milling equipment for 1 hour per day, then monitor mills and transport the resulting enamel slurry as needed within the facility for the remainder of the shift. Exhaust ventilation holds the milling equipment under negative pressure to minimize dust release during charging and mixing (Document ID 0960; 1365, p. 15–11). In addition to ventilating the milling equipment, Porcelain Facility A uses a vacuum fitted with a HEPA filter for all cleaning. To minimize the generation of airborne dust, workers avoid dry sweeping and only shovel or scrape materials that are damp (Document ID 1365, p. 15–12).

In the PEA, OSHA discussed a report by a company representative from Porcelain Facility A stating that air monitoring conducted by OSHA at this facility found that the 8-hour TWA exposure level of porcelain preparers was controlled below the previous PEL of 100 μg/m^3 (Document ID 1365, p. 15–10; 0960). Airborne silica concentrations could, however, exceed this level during the bag dumping task. Exposures might have been still lower during this task if the bag dumping station had been designed differently and included ventilated equipment to dispose of empty bags (Document ID 1720, p. IV-245).

Additional Controls for Porcelain Applicators

The exposure profile in Table IV.4.14-B shows that 40 percent (12 of 30 samples) of porcelain applicators have exposures above the final PEL of 50 μg/m^3. Therefore, OSHA finds that additional controls will be necessary to achieve the PEL. Available controls include LEV, automation, diligent housekeeping practices, and use of low-silica enamels. Implementation of these controls might involve installing new equipment or improving current equipment.

Local Exhaust Ventilation

A common exposure control option includes the use of well-ventilated, well-enclosed booths for enamel application. In order for the booths to be effective, it is important to follow recommended exhaust rates. The American Conference of Governmental Industrial Hygienists (ACGIH) specifies ventilation designs for both large and small spray booths, including recommended air flow rates across the entire face of the booth (100 to 150 feet per minute) (Document ID 0515, pp. 13-129 – 13-132).

The effectiveness of this method in other industries that use similar, but higher, silica content coatings than the porcelain enamel industry is demonstrated by exposure monitoring data obtained at a pottery manufacturing facility visited twice by NIOSH (Document ID 0209; 0211). After the facility improved booths and LEV systems used for manual and automated spraying operations by repairing holes and openings and increasing airflow rates, median exposure readings were 44 percent, 88 percent, and 67 percent lower on the manual, semiautomatic, and automatic lines, respectively. On the semiautomatic and automatic lines, NIOSH recorded eight results. The highest result was 66 $\mu g/m^3$, the median was 30 $\mu g/m^3$, and the results included four values of 23 $\mu g/m^3$ or lower. On the manual spray line, where exposure levels decreased by only 44 percent and the maximum exposure recorded was 507 $\mu g/m^3$, reports indicate that operators used compressed air hoses to blow dust off prior to applying glaze during both site visits. OSHA concludes that it is possible that exposures on the manual spray line could be reduced further by removing dust from work pieces with vacuums and wet sponges as is done by operators on the semiautomatic spraying line.

In this facility, workers who used automated coatings application equipment had a median silica exposure level 64 percent lower than workers performing manual spraying. When the automated spray equipment is well enclosed and associated with a functioning ventilation system, operator results can be even lower (Document ID 1365, pp. 15-14 – 15-16).

Porcelain applicators should ensure that they are making optimal use of LEV. As discussed in the PEA, Porcelain Facility A encourages workers who apply enamel to avoid positioning themselves between the enamel spray and the ventilation system. During manual spraying, small items are positioned by hand within the booth so the spray is directed into the booth and toward the ventilation take-off. For large items, the facility provides a turntable support that allows porcelain applicators to rotate the item to spray all sides of the object while maintaining the spray direction pointing into the ventilated booth (Document ID 1720, p. IV-246). The workers also use great care to avoid dislodging enamel powder when handling items that are coated with dry porcelain enamel (e.g., when transferring parts to the furnace conveyor line).

Housekeeping

Dust released from dried coatings and coatings residues (e.g., drips, spills, and overspray) can contribute substantially to the silica exposure of porcelain applicators in facilities where poor housekeeping has allowed dust to accumulate. Improper cleaning procedures such as dry sweeping can aggravate the situation by stirring up dust and causing it to become airborne. An initial thorough cleaning in association with improved housekeeping procedures (e.g., use of a HEPA-filtered vacuum) to maintain cleanliness can reduce exposures in facilities where dust has accumulated (Document ID 0571). An example from the structural clay industry demonstrates the benefit of diligent housekeeping practices on worker silica exposure levels. A dramatic exposure reduction (in some cases a greater than 10-fold reduction) was associated with thorough (professional-level) cleaning to remove dust accumulations on the floor and structural surfaces of raw material handling areas (Document ID 0571).

Substitution

As discussed previously, the use of enamels with reduced crystalline silica content represents an additional control option. For further information see the previous section on Substitution under Additional Controls for Enamel Preparers.

Combination of Controls

Using several of the controls discussed above (LEV, housekeeping, and substitution) simultaneously can lead to greater exposure reductions. The aforementioned Porcelain Facility A uses ventilation, good work practices, and diligent housekeeping to keep exposures low (Document ID 1720, p. IV-247; 0960). Porcelain Facility A makes extensive use of ventilation along the entire coatings application line. Both automated and manual spray enamel application are performed inside spray booths fitted with exhaust ventilation designed for the spray booths. At this site, most operations occur in large, ventilated, walk-in spray booths, although porcelain applicators sometimes apply the coating standing outside a smaller ventilated booth (Document ID 1720, p. IV-247). In addition to using ventilated booths, Porcelain Facility A takes several steps to minimize the amount of dust that becomes airborne. Workers remove enamel residue from spray booths while it is still damp, using shovels and scrapers to recover the material for reuse (Document ID 1720, p. IV-247; 1365, p. 15–17; 0960). A company representative notes that no visible dust is generated during this process (Document ID 1365, p. 15–17). Additionally, this facility uses a large HEPA-filtered vacuum to capture any dried porcelain enamel that workers encounter outside the ventilated booths. Sweeping and shoveling dry materials is not permitted and the HEPA-filtered vacuum is used for general housekeeping throughout the facility (Document ID 1720, p. IV—247; 1365, p. 15–17; 0960). A representative exposure levels of porcelain applicators were well below the previous PEL, as calculated based on the OSHA general industry standard for silica in respirable dust (Document ID 1720, p. IV-247; 0960).

4.14.4 Feasibility Finding

Feasibility Finding for Enamel Preparers

Based on the exposure profile in Table IV.4.14-B and other record evidence discussed above, OSHA has determined that 40% of enamel preparers currently have silica exposures at or below the final PEL of 50 μg/m^3, and the remaining 60% are only slightly higher than 50 μg/m^3. For enamel preparers exposed above 50 μg/m^3, their exposure can be reduced using HEPA-filtered vacuums instead of compressed air for cleaning. OSHA has determined that when facilities implement this control, exposure levels of 50 μg/m^3 or less can be achieved for most enamel preparers most of the time.

Where additional controls are required, options for enamel preparers include adding or improving maintenance on bag dumping stations and ventilated bag disposal equipment, process automation, improved housekeeping, and substitution. These methods have reduced exposure levels in other industries that prepare vitreous coatings or use similar materials to form products. OSHA concludes and expects that these methods will be equally effective in the porcelain enameling industry and can reduce the exposure for enamel preparers to levels at or below 50 µg/m^3 for most operations, most of the time. Therefore, OSHA concludes that the PEL of 50 µg/m^3 is feasible for enamel preparers.

Feasibility Finding for Porcelain Applicators

Based on the exposure profile in Table IV.4.14-B and other record evidence discussed above, OSHA has determined that 60 percent of porcelain applicators already experience exposures at or below 50 µg/m^3. Low exposures are attributed to use of low-silica enamels; enclosed, well-ventilated automatic spray equipment; appropriately enclosed and ventilated booths for manual operations; and diligent housekeeping. OSHA concludes that exposure levels for the remaining porcelain applicators (40 percent) can be reduced to 50 µg/m^3 or less using similar, properly implemented and maintained controls.

The two highest exposures for this job category (2,300 µg/m^3 and 2,006 µg/m^3) were both obtained in 1985 at the same facility where OSHA later recorded six silica concentrations between 3 µg/m^3 and 23 µg/m^3 for porcelain applicators, demonstrating that even the highest exposures for this job category have been successfully controlled to levels below 50 µg/m^3. Therefore, OSHA concludes that the PEL of 50 µg/m^3 is technologically feasible for porcelain applicators.

Overall Feasibility Finding for the Porcelain Enameling Industry

Based on the exposure profile in Table IV.4.14-B and other record evidence discussed above, OSHA concludes that the porcelain enameling industry can control the silica exposure to levels of 50 µg/m^3 or less for most operations most of the time. Therefore, OSHA finds that the final PEL of 50 µg/m^3 is technologically feasible for the Porcelain Enameling industry.

4.15 POTTERY

4.15.1 Description

Silica-containing materials are the primary ingredients in the manufacture of pottery products, and they are also sometimes used to prepare glazes that are applied to pottery products. Facilities manufacturing pottery products are classified in the 2007 six-digit North American Industry Classification System (NAICS) codes 327111, Vitreous China Plumbing Fixtures and Bathroom Accessories; 327112, Vitreous China, Fine Earthenware, and Other Pottery Products; and 327113, Porcelain Electrical Supply Manufacturing[86] (Document ID 1365, p. 4-1).

Pottery product manufacture typically begins with the mixing of clay raw material with water in a mill, to create a slurry that is then transferred into molds. After setting, the pottery pieces are removed from the molds and finished, and glazes are mixed and applied to the pottery. The pieces are then fired in kilns and packaged (Document ID 1365, p. 4-2).

Workers in all phases of pottery product manufacture have potential for silica exposure (Document ID 1365, p. 4-2). The primary job categories with potential exposures are material handler, forming line operator, finishing operator, coatings preparer, and coatings operator (see Table IV.4.14-A). Certain workers regularly perform tasks associated with multiple job categories (Document ID 1365, p. 4-2). Details regarding activities performed by workers and the sources of exposure in each job category can be found in a review of General Industry prepared by OSHA's contractor Eastern Research Group (ERG, 2008) (Document ID 1365, pp. 4-1 - 4-33).

[86] The applicable 2012 NAICS code is 327110.

Table IV.4.14-A Job Categories, Major Activities, and Sources of Exposure of Workers in the Pottery Industry (2007 NAICS 327111, 327112, and 327113)	
Job Category	**Major Activities and Sources of Exposure**
Material Handler	Transferring silica-containing raw materials (e.g., clay, silica sand, feldspar) from storage silos to weigh hoppers via front-end loader or forklift; mixing clay slip. • Dust generated from transfer of materials. • Dust from manually opening and dumping bags of silica-containing raw materials.
Forming Line Operator	Transferring slip into molds; removing formed pottery pieces; cleaning molds for reuse; applying mold parting compound. • Dust from cleaning molds. • Dust from applying the mold parting compound.
Finishing Operator	Shaping, smoothing, trimming of dried or fired pottery pieces, and typically using handheld equipment. • Dust from finishing dried pottery pieces.
Coatings Preparer	Transferring silica-containing materials (e.g., clay, silica sand, feldspar) to weigh hoppers or mixers; mixing glazes. • Dust generated from transfer of materials. • Dust from manually opening and dumping bags of silica-containing raw materials.
Coatings Operator	Applying glazes to pieces, typically by hand-dipping or spraying. • Silica-containing aerosol during glaze spraying.
Note: Job categories are intended to represent job functions; actual job titles might differ and responsibilities might be allocated differently, depending on the facility. Source: Document ID 1365.	

4.15.2 Exposure Profile and Baseline Conditions

The exposure profile in Table IV.4.15-B includes 87 full-shift, personal breathing zone (PBZ) samples of respirable crystalline silica for workers in the pottery industry. The median is 40 μg/m^3, the mean is 98 μg/m^3, and the range is 6 μg/m^3 (limit of detection (LOD[87])) to 1,101 μg/m^3. Table IV.4.15-B shows that, of the 87 samples, 38 (43.6 percent) are above 50 μg/m^3 and 13 (14.9 percent) exceed 100 μg/m^3.

To evaluate silica exposures of pottery production workers, OSHA reviewed full-shift personal breathing zone (PBZ) respirable quartz exposure monitoring data from six OSHA Special Emphasis Program (SEP) inspection reports, and one NIOSH site visit report. OSHA also reviewed 12 additional facility reports from the states of Michigan,

[87] LODs are as reported by the original study author. LODs are discussed in further detail in Section IV-2–Methodology.

New Jersey, and Ohio for historical reference. For the final exposure profile, OSHA eliminated all data points that were collected prior to 1990 because those data points likely overestimated current exposures in pottery facilities. The ceramics industry as a whole, including pottery production, has seen marked decreases in respirable dust and silica exposure levels and greater attention to exposure controls since the 1980s (Document ID 1720, p. IV-253).

The U.S. Environmental Protection Agency (EPA) issued a 2007 National Emissions Standard for Hazardous Air Pollutants for Clay Ceramics Manufacturing Area Sources, which includes specific provisions for managing emissions at these facilities, including inspecting and testing ventilation systems associated with pottery kilns and glaze spray booths (40 CFR 63.11435-63.11445, 2007). This rule went into effect in 2007, and OSHA believes that the inspection requirements for ducts, bag houses, and other dust control systems likely has helped to reduce exposures due to problems with ventilation system integrity.

OSHA also identified a more recent NIOSH report describing a small storefront pottery operation with four full-time workers and several part-time assistants (Document ID 0878). Because workers' activities could not be classified by job category (they all encompassed most job categories), exposure information has not been included in the exposure profile. However, the available results indicate that exposures are relatively low at this type of facility despite a lack of local exhaust ventilation (LEV). Only one of the workers evaluated had a measurable full-shift exposure; no results exceeded the final PEL of 50 $\mu g/m^3$ (one result was at 50 $\mu g/m^3$ and the other sample results were below the limit of detection [LOD], (in this case 12 $\mu g/m^3$) (Document ID 0878, p. 5). Although task-based sample results (one to two hours duration) did indicate the potential for exposure to occur during brief periods when workers handle bags of clay and mix clay, workers that perform dusty jobs also perform many other tasks during their shifts (Document ID 0878, p. 6). Thus, their cumulative silica exposure is rarely detectable and did not exceed the PEL of 50 $\mu g/m^3$. NIOSH recommended that the facility improve the building's central ventilation and air circulation and also install exhaust ventilation hoods in the areas where the most dust was generated (Document ID 0878, pp. 14-15).

These samples suggest that the limited amount of materials and equipment used in small shops pose a lower risk than similar activities in a large manufacturing operation. For example, at the storefront facility visited by NIOSH, workers reprocessed clay and mixed glazes from 10-gallon buckets (Document ID 0878, p. 2). In contrast, at a large industrial pottery facility one worker produced four 9,000-pound batches of clay on one shift (Document ID 0143, p. 153).

For each of the job categories listed in Table IV.4.14-A and included in the exposure profile, and for the pottery industry as a whole, OSHA concludes that Table IV.4.15-B represents baseline conditions.

Exposure Profile and Baseline Conditions for Material Handlers

The exposure profile in Table IV.4.15-B includes 11 samples for material handlers in the pottery industry. The median is 41µg/m^3, the mean is 149 µg/m^3, and the range is 20 µg/m^3 to 1,101 µg/m^3. Table IV.4.15-B shows that, of the 11 samples, 5 (45.5 percent) are above 50 µg/m^3 and 2 (18.2 percent) exceed 100 µg/m^3.

Of the six material handler samples with information on engineering control status (local exhaust ventilation (LEV)), three (41 µg/m^3 to 89 µg/m^3) are associated with LEV reported as relatively functional in areas where materials are dumped, both manually and using front-end loaders, and three results (67 µg/m^3 to 1,101 µg/m^3) were associated with no LEV or LEV described as inadequate. An additional two samples (23 µg/m^3 and 29 µg/m^3) made full or partial use of automated processes. Overall, these sample results suggest that exposures in facilities with LEV systems are lower than in facilities without LEV or facilities where the ventilation performs poorly. As shown in Table IV.4.14-A, the silica exposures of material handlers result primarily from airborne dust generated as materials are transferred into hoppers or bins, bags are brushed, empty bags are handled for disposal, and vehicles re-suspend settled dust in the air.

The highest sample for this job category (and also this industry), a value of 1,101 µg/m^3, was obtained when OSHA monitored a material handler shoveling dry clay into a mill that formed clay slip. No ventilation was installed in the mill area, and the material handler also shared the work space with a coatings preparer (another job category with potential to generate substantial silica dust) (Document ID 0174, pp. 69-72). A lower result of 67 µg/m^3 was obtained for a second worker at the same plant. This worker shoveled a different clay (ball clay) in the mill area and controlled the addition of water and other ingredients from silos (Document ID 0174, pp. 27, 241). The available information is insufficient to determine with certainty whether factors other than the clay type caused the results to vary so much.

Most of the facilities for which information is available have some form of ventilation system, though it was not necessarily operating effectively at the time of investigations. Inadequate ventilation systems were characterized by insufficient air flow, leaking ducts, inappropriate hood shape or position, or other factors that make dust collection less efficient.

Exposure Profile and Baseline Conditions for Forming Line Operators

The exposure profile in Table IV.4.15-B includes 36 samples for forming line operators. The median is 31 µg/m^3, the mean is 42 µg/m^3, and the range is 6 µg/m^3 (LOD) to 238 µg/m^3. Table IV.4.15-B shows that, of the 36 samples, 11 (30.6 percent) are above 50 µg/m^3 and 2 (5.6 percent) exceed 100 µg/m^3. All of the samples for forming operators are associated with operations involving wet or liquid (slip) clay mixtures, although many operators also handle dry materials, such as mold coating compounds and dried clay slip residue in molds. Four samples for which engineering control status could be established were associated with the use of LEV (median 25 µg/m^3; mean 25 µg/m^3; range 10 to 40 µg/m^3).

Exposure Profile and Baseline Conditions for Finishing Operators

The exposure profile in Table IV.4.15-B includes 10 samples for finishing operators. The median is 21 µg/m^3, the mean is 26 µg/m^3, and the range is 10 µg/m^3 (LOD) to 55 µg/m^3. Table IV.4.15-B shows that, of the 10 samples, 2 (20 percent) are above 50 µg/m^3 and none exceed 100 µg/m^3. The lowest value for this job category (reported as 10 µg/m^3) was associated with a worker using manual and machine-controlled grinding wheels to square off the bottoms and backs of sanitary ware (e.g., ceramic bathroom fixtures). At least part of this work was conducted in a ventilated booth (Document ID

0106, p. 67). On the same day, two other samples were also obtained for finishing operators at this facility. One of these workers used hand tools and steel wool pads to smooth unfired ceramic pieces, which reportedly generated a lot of visible dust (no booth mentioned), resulting in an exposure level of 53 μg/m^3. Although the other worker used a ventilated booth to perform similar work, that individual also used compressed air to remove the dust, and the consultant taking the samples again noted visible dust in the air, which likely explains the result of 55 μg/m^3 (Document ID 0106, pp. 54, 67, 74-75).

No additional information regarding baseline conditions for finishing operations was submitted to the rulemaking record; therefore, OSHA concludes that baseline conditions for finishing operators are best represented by the data contained in the exposure profile and the range of working conditions under which those samples were collected.

Exposure Profile and Baseline Conditions for Coatings Preparers

The exposure profile in Table IV.4.15-B includes 12 samples for coatings preparers. The median is 82 μg/m^3, the mean is 305 μg/m^3, and the range is 24 μg/m^3 to 983 μg/m^3. Table IV.4.15-B shows that, of the 12 samples, 10 (83.3 percent) are above 50 μg/m^3 and 5 (41.6 percent) exceed 100 μg/m^3. As discussed below, all of the samples for this job category are associated with the manual transfer of dry, silica-containing materials into mixing equipment.

The highest reading, 983 μg/m^3, was obtained for a coatings preparer who manually emptied bags of glaze components into a large, unventilated mixer located in one area of the slip house (Document ID 0174, pp. 27, 84-86, 241). Also in the same space was a material handler whose exposure level of 1,101 μg/m^3 was the highest of the values in the material handler exposure profile (Document ID 0174, pp. 69-72, 81-83). The actions of both workers would have contributed to extremely high silica dust levels in the space.

Exposures are substantially lower when workers prepare coatings at ventilated workstations. OSHA obtained an exposure reading of 86 μg/m^3 for a coatings preparer who mixed three 3,000-pound batches of glaze (Document ID 0143, p. 28). The coatings preparer manually weighed the glaze components in bags or buckets under an LEV hood. The coatings preparer then manually emptied the bags or buckets into an opening in a ball mill (Document ID 0143, pp. 122, 124-125). At another facility, OSHA obtained sample results of 51 μg/m^3 and 41 μg/m^3 for coatings preparers using a LEV system that was only partially functional. These coatings preparers batched glazes by manually weighing materials and then manually loading them into a mixer hopper inside a booth equipped with LEV. However, the scale used for weighing materials was located outside the booth. Additionally, the LEV system did not generate a sufficient exhaust rate (Document ID 0106, pp. 35, 49-54, 57, 74).

Exposure Profile and Baseline Conditions for Coatings Operators

The exposure profile in Table IV.4.15-B includes 18 samples for coatings operators. The median is 53 μg/m^3, the mean is 81 μg/m^3, and the range is 12 μg/m^3 (LOD) to 507 μg/m^3. Table IV.4.15-B shows that, of the 18 samples, 10 (55.6 percent) are above 50 μg/m^3 and 4 (22.3 percent) exceed 100 μg/m^3. All of the samples were obtained while workers used spray methods to apply silica-containing glazes onto pottery pieces. At all facilities from which sample results are available to OSHA, the spray operations took place in LEV-equipped booths; however, some of the booths were documented as performing poorly (Document ID 0106; 0143; 0211; 1365, p. 4-14).

Silica exposure levels are generally higher when workers use manual spray equipment, rather than automated equipment (Document ID 1365, p. 4-15). Automated processes tend to allow the worker to stand at a greater distance from the exposure source. Exposures occur primarily when particles of silica-containing coatings are released by pressurized spray nozzles, but fail to adhere to the pottery pieces and drift into coatings operators' breathing zones.

Table IV.4.15-B
Personal Respirable Crystalline Silica Exposure Range and Distribution of Results for Workers in the Pottery Industry (NAICS 327111, 327112, 327113)

	Exposure Summary			**Exposure Range**			**Exposure Profile**				
Pottery Industry	**N**	**Mean (µg/m³)**	**Median (µg/m³)**	**Min (µg/m³)**	**Max (µg/m³)**		**< 25 (µg/m³)**	**≥ 25 and ≤ 50 (µg/m³)**	**> 50 and ≤ 100 (µg/m³)**	**> 100 and ≤ 250 (µg/m³)**	**> 250 (µg/m³)**
Material Handler	*11*	*149*	*41*	*20*	*1,101*		*3 (27.3%)*	*3 (27.3%)*	*3 (27.3%)*	*1 (9.1%)*	*1 (9.1%)*
Forming Line Operator	*36*	*42*	*31*	*6*	*238*		*15 (41.7%)*	*10 (27.8%)*	*9 (25%)*	*2 (5.6%)*	*0 (0%)*
Finishing Operator	*10*	*26*	*21*	*10*	*55*		*6 (60%)*	*2 (20%)*	*2 (20%)*	*0 (0%)*	*0 (0%)*
Coatings Preparer	*12*	*305*	*82*	*24*	*983*		*1 (8.3%)*	*1 (8.3%)*	*5 (41.7%)*	*1 (8.3%)*	*4 (33.3%)*
Coatings Operator	*18*	*81*	*53*	*12*	*507*		*5 (27.8%)*	*3 (16.7%)*	*6 (33.3%)*	*3 (16.7%)*	*1 (5.6%)*
Pottery Industry Total	87	98	40	6	1,101		30 (34.5%)	19 (21.8%)	25 (28.7%)	7 (8%)	6 (6.9%)

Notes: All samples are personal breathing zone (PBZ) results representing 8-hour time-weighted average exposures.
Job categories are intended to represent job functions; actual job titles might differ, and responsibilities might be allocated differently, depending on the facility.
Percentages may not add to 100 percent due to rounding.
Sources: Document ID 1720; 3958; 0027; 0106; 0143; 0174; 0195; 0211; 1436.

4.15.3 Additional Controls

Material Handlers

The exposure profile in Table IV.4.15-B shows that 45.5 percent (5 out of 11 samples) of material handlers have exposures above the final PEL of 50 μg/m^3. Therefore, OSHA finds that additional controls will be necessary to achieve the PEL for these overexposed workers. These controls include LEV (including well-ventilated process equipment (e.g., mixers) and bag or loader dumping stations equipped with well-ventilated enclosures and, as needed, attached bag compactor); enclosed and ventilated cabs for front-end loaders; improved housekeeping; and automated transfer of silica-containing materials. Implementation of these controls might involve installing new equipment or improving existing equipment.

Local Exhaust Ventilation

Data presented in the exposure profile (Table IV.4.15-B) suggest that ventilated material transfer stations are associated with lower worker exposures. Although some results remain above the PEL of 50 μg/m^3 when workers have access to LEV described as functional, the results are markedly lower (median exposure level 85 μg/m^3) than when workers use material transfer stations where LEV is clearly inadequate or missing (median exposure level 133 μg/m^3). Adjustments that improve the ventilation system, changes in work practices (e.g., crushing empty bags or dumping materials from a loader scoop), and improved housekeeping (as discussed later in this section) will all further reduce material handler exposure levels.

During the first of two visits to a pottery facility, NIOSH noted that coatings preparers compressed bags, generating visible dust (Document ID 0209, p. 34). OSHA considers it likely that it is likely that the same practice was used by other workers, including material handlers, who also handled bags of raw materials in the same facility. Although no data exist for the pottery industry, in a paint manufacturing facility where workers emptied 50-pound bags of silica-containing materials, a bag-dumping station with fully functioning LEV and automated bag disposal was found to reduce silica exposure by at least 95 percent. After each bag is emptied, the worker releases it and suction automatically pulls the bag into the ventilation system and transfers it to an enclosed storage area (eliminating manual bag crushing) (Document ID 0199, pp. 7, 11, 12-13). As an alternative, ventilated bag compactors also eliminate manual bag crushing. Both bag dumping stations and bag crushing equipment are readily available from commercial sources (Document ID 0581; 0594; 0680; 1212; 1213; 1224). Ventilated hoppers for receiving materials transferred by front-end loaders can also be installed. OSHA expects that both types of ventilation systems will control silica exposures when designed according to ACGIH recommendations (Document ID 3883, p. 13-80 (VS-50-10 Bin & Hopper Ventilation).

Additionally, ventilation can be augmented along conveyor systems. Such control methods include covering conveyors and increasing ventilation at existing enclosed transfer points to meet the ACGIH recommended air velocity of 250 fpm/ft^2 across all openings in the enclosures (Document ID 3883, p. 13-81). OSHA has not identified specific examples from the pottery industry; however, in other industries that convey quantities of dusty silica sand, enclosed or pneumatic conveying systems are an effective part of comprehensive respirable dust management, which results in reduced exposure levels (see Sections IV-4.13 – Paint and Coatings and IV-4.21 – Structural Clay).

Enclosed Cabs

The use of well-ventilated cab enclosures for lift trucks or front-end loaders also can reduce exposure for material handlers. Although data documenting the effectiveness of such enclosures at pottery manufacturing facilities are not available, data from other sources suggest a 90 to 99.5 percent reduction in respirable dust (inside compared with outside the cab) with well-sealed, air-conditioned, and filtered cabs (Document ID 1365, p. 4-19). Operators working in heavy equipment cabs designed to meet the American Society of Agricultural Engineers' (ASAE) standard should experience exposure reductions in this general range (Document ID 0719, p. 51). Although these cabs require regular maintenance to function properly and concerns exist regarding the construction standards of new heavy equipment, OSHA expects that appropriately fitted and maintained cabs would offer an exposure reduction of at least 90 percent (the low end reported for larger equipment) for material handlers, including those using front-end loaders (Document ID 1365, p. 4-19).

Housekeeping

Poor housekeeping contributes substantially to worker exposure levels in material handling areas, and a thorough (professional-level) cleaning in association with improved housekeeping procedures (to maintain cleanliness) can reduce exposures where dust has been allowed to accumulate. For one material handler, poor housekeeping was reported as the primary source of silica exposure (Document ID 1436, p. 1). In the structural clay industry, another industry with similar material handling requirements, a thorough cleaning of a brick manufacturing facility dramatically reduced exposure levels (by 90 percent or more in some cases) for workers in areas where raw materials were transported or handled (raw material storage, near grinding equipment and conveyors, during bag dumping, and at raw material hoppers). In these areas, most worker exposures were reduced to less than 50 μg/m^3 without other abatement efforts (Document ID 1365, pp. 3-19—3-20, 4-2; 0571). In addition to regular housekeeping procedures, spillage of raw materials can sometimes be prevented by modifying conveyor belts (e.g., using troughed belts or V-rollers).

Automated Equipment

Samples at pottery manufacturing facilities with both manual and automated material transfer systems illustrate the effectiveness of the automated equipment. In one facility, exposure was almost 66 percent lower (29 μg/m^3 versus 85 μg/m^3) for a material handler tending automated equipment adding silica-containing raw materials to a mixer compared with a material handler manually adding bags of raw materials to the mixer (Document ID 1436, pp. 4, 27-35). Both workers were working in areas with functioning LEV (although the investigator's notation does not mean that the LEV was functioning optimally). At another facility, OSHA obtained a reading of 23 μg/m^3 for a material handler monitoring automated equipment to transfer dry silica sand from the storage silo and pump a slurry of ball clay and kaolin into a mixer (Document ID 0143, pp. 28, 44, 128-131).

Forming Line Operators

The exposure profile in Table IV.4.15-B shows that 30.6 percent (11 out of 36 samples) of forming line operators have exposures above the final PEL of 50 μg/m^3. Therefore, OSHA finds that additional controls will be necessary to achieve the PEL for these overexposed workers. Generally low exposures experienced by many forming line operators can be attributed to the fact that most materials are handled in a wet state and to the wide-spread use of LEV during the production phase. However, additional controls like those described above will reduce exposures for the nearly 31 percent of forming line operators whose exposure levels exceed 50 μg/m^3. Additional controls include improved or added LEV, eliminating the use of compressed air, using vacuums to remove residual clay from molds, and employing equipment that reduces the release of airborne dust when workers apply mold parting compound. A combination of these controls should be more effective in reducing exposures below the PEL than any one control alone.

Eliminating Use of Compressed Air for Cleaning

Changes in controls and work practices were implemented at one work site in order to reduce the exposure of forming line operators. The use of compressed air to clean molds was replaced with the use of a vacuum and abrasive pad. Additionally, the bags previously used to dust molds with talc (a parting compound containing trace amounts of silica) were redesigned to release talc from only one end in the direction of the molds. Primarily through the elimination of compressed air for cleaning, and despite uneven functioning of the LEV at two workstations, the facility reduced silica exposures substantially so that results for workers at these stations were below 40 μg/m^3. The ERG report suggested that exposures would have been lower still if the LEV were more effective (Document ID 0027, pp. 32, 186-189, 367; 1365, p. 4-23).

Finishing Operators

The exposure profile in Table IV.4.15-B shows that 20 percent (2 out of 10 samples) of finishing operators have exposures above the final PEL of 50 μg/m^3. Therefore, OSHA finds that additional controls will be necessary to achieve the PEL for these overexposed workers. Additional controls include improving maintenance of or modifying existing LEV and using wet methods to perform finishing operations, as discussed below.

Local Exhaust Ventilation

OSHA has obtained two sample results of 10 μg/m^3 and 55 μg/m^3 for finishing operators using LEV at a facility manufacturing sanitary ware. These samples represent the highest and the lowest exposures in the profile for this job category. The worker who experienced the exposure of 55 μg/m^3 spent the majority of an eight hour shift finishing greenware (unfired pottery) with steel wool in a ventilated booth. In addition, compressed air was used for dust removal which likely contributed to the elevated exposure (Document ID 0106, p. 74). The other worker used a grinder to square off the bottoms and backs of sanitary ware in a ventilated booth (Document ID 0106, p. 75). A study by NIOSH documented the use of a down-draft hood used in the dry finish of pottery (Document ID 1372). However, elevated results were seen due to the inadequate capture rate and the intensity of the sanding (Document 1372, pp. 6-8). OSHA anticipates that a properly designed and maintained system would have resulted in exposures at or below the PEL.

OSHA did not receive any additional data describing the use of ventilated booths to control exposures for this group of workers; however, exposure monitoring data from the foundry industry for cleaning/finishing operators provide good evidence that properly designed LEV systems can reduce exposure for pottery finishing operators. Like pottery finishing operators, foundry workers that perform similar work also use grinding equipment to remove residual silica material, typically a mixture of sand and clay, from castings. An OSHA SEP inspection report documents respirable quartz readings for foundry industry grinders of 56 μg/m^3, 80 μg/m^3, and 81 μg/m^3 (mean of 72 μg/m^3) (Document ID 0130, pp. 34). After installation of a downdraft dust collection bench, OSHA collected readings of 20 μg/m^3 and 24 μg/m^3 (mean of 22 μg/m^3) for two grinders (Document ID 1365, p. 4-24).[88] The downdraft benches were associated with a 69 percent

[88] OSHA described the system as a two-station Torit Model DDHV-45 Downdraft Bench dust collecting system designed to operate at 4,800 cfm. The system was 99 percent efficient for particles 1 micron or larger, used 51 cotton sateen filter bags, and provided 255 square feet of filter media (Document ID 1365, p. 4-24).

reduction in mean silica concentration. Exposure levels also decreased when the foundry added LEV to bench grinders. ACGIH (2010) typically offers recommended designs for booths and other ventilation-based engineering controls (Document ID 0515, pp. 13-1-13-204.

OSHA did not receive any data that demonstrate the effectiveness of using LEV-equipped tools by finishing operators in the pottery industry. However, based on the successful implementation in other industries, OSHA expects that tool-mounted LEV systems for handheld grinding equipment can be helpful for reducing exposure. In the construction industry, a tool-mounted LEV system operating at 70 cubic feet per minute (cfm) (consisting of a grinder-mounted shroud, a 2-inch diameter flexible hose, and an industrial vacuum equipped with a cyclone and a high-efficiency particulate air [HEPA] filter) reduced silica exposure substantially (Document ID 0613, pp. 3-5). OSHA notes that in this study of handheld grinding in construction both the uncontrolled and controlled silica exposure levels were extremely high during 15-minute periods of intensive grinding. OSHA expects that tool-mounted LEV in the pottery industry, where peak exposures for finishing operators are not as extreme (among the data available to OSHA, 55 $\mu g/m^3$ is the maximum value for this job category), could reduce exposures to the PEL of 50 $\mu g/m^3$ or less even if the same percentage reduction is not attained. Indeed, recent information regarding tuckpointing grinders (angle grinders used to remove mortar between bricks, historically among the construction tasks for which silica dust is most difficult to control) suggests that lower exposure levels (less than 50 $\mu g/m^3$ under certain conditions) can be achieved with these and other tools with LEV when workers are equipped with more powerful vacuums that provide greater LEV airflow and suction over an extended work period than traditional shop vacuums (Document ID 0600; 0731).

Based on this information, OSHA has determined that tool-mounted LEV can provide exposure reductions to levels of 50 $\mu g/m^3$ and less for finishing operators in the pottery products industry when LEV shrouds and vacuum systems are correctly matched to the grinding tools. For additional dust control, tool-mounted LEV can also be used in conjunction with ventilated downdraft tables or booths.

Wet Methods

Exposures also can be reduced by performing finishing operations on pottery pieces that are still slightly damp instead of dry, because silica particles are less likely to become airborne when pieces are wet (Document ID 0209, pp. 23-27, 47; 0106, p. 72). Wet finishing operations can be conducted using sponges and abrasive pads, or by moistening the outer layer of the pottery prior to abrading it. Operators also might perform finishing tasks on a piece that has not completely dried. Exposure levels were more than two times higher when operators finished fully dried pottery pieces compared with partially dried pieces with slight moisture content (Document ID 0106, p. 74 (53 and 55 μg/m^3); 0174, pp. 90-95 (22 μg/m^3)).

The other wet finishing process option, wet sanding of dried pottery, is similar to a process used in the construction industry. Drywall finishers using a damp abrasive sponge experience a 60 percent reduction in respirable dust levels compared with dry sanding (Document ID 1239). OSHA expects that pottery grinders would receive similar benefits in reducing respirable dust and that silica would be reduced proportionally. Although moistened pieces would likely require additional drying time, drying time would still be less than for the original wet casting because only the surface layer of clay would be dampened (Document ID 1365, p. 4-26).

Coatings Preparers

The exposure profile in Table IV.4.15-B shows that 83.3 percent (10 out of 12 samples) of coatings preparers have exposures above the final PEL of 50 μg/m^3; these overexposures came from each of the six facilities evaluated sampled. Therefore, OSHA finds that additional controls will be necessary to achieve the PEL for these overexposed workers. The available information suggests that some LEV is often present at pottery facilities, but in most plants the LEV is applied to only a portion of the potentially dusty operations. As further explained below, control options include consistent use of bag dumping stations equipped with well-ventilated enclosures and ventilated bag disposal equipment, ventilated mixing equipment, and improved housekeeping. Reducing reliance on compressed air for cleaning also will help limit exposures. Implementation of these controls might involve installing new equipment or improving current equipment with ventilation systems.

Local Exhaust Ventilation

To reduce coatings preparer exposure levels to at or below the PEL or, in some cases, to the lowest levels feasible above the PEL, workers must make all raw material transfers within ventilated enclosures or use equipment fitted with effective LEV. The effectiveness of such ventilation controls was demonstrated at a pottery manufacturing plant where a coatings preparer used a ventilated booth (with low airflow) to empty bags of powdered raw materials into a hopper, but also used a weigh scale outside the booth to measure some ingredients. An initial exposure value of 143 $\mu g/m^3$ was reduced to 40 $\mu g/m^3$ and 51 $\mu g/m^3$ after the baghouse ventilation system was repaired (Document ID 106, pp. 41-44). A consultant evaluating the plant during the second (post-repair) sampling date recommended that silica at this facility be reduced to its lowest possible level by taking additional steps such as limiting use of compressed air for cleaning (suggesting that compressed air was still used regularly in the plant after the ventilation system was repaired) (Document ID 0106, pp. 8, 28, 34-40, 71-72). In this example, the workers' exposure levels were reduced to approximately one-third of the original value (i.e., from 143 $\mu g/m^3$ to 40 $\mu g/m^3$ and 51 $\mu g/m^3$) simply by repairing the existing ventilation system (Document ID 0106, p. 54).

OSHA concludes that exposures could have been reduced further if the facility had taken two additional steps: 1) moving the weigh scale into the booth (or adding exhaust ventilation to the scale area), and 2) reducing reliance on compressed air for cleaning. As discussed below, exposure levels can be greatly reduced by both these modifications.

A dramatic reduction in exposure was recorded at a facility where previously OSHA had obtained the highest result for a coatings preparer. At the time of the original sample, this worker manually lifted bags of raw materials and, from a position on a platform, dumped them into an unventilated mixer in an area where another dusty operation also took place (Document ID 0174, pp. 72, 84). As part of a four-part abatement plan, the facility made substantial changes to the way materials were handled during coating production. After hiring engineering consultants to evaluate the areas where OSHA found elevated exposure, the facility installed two new dust collector systems in the glaze-making area. These included one hood under which the worker now filled a portable hopper with measured raw materials and another hood at the hatch of the ball mill into which the materials were poured. To minimize ergonomic stress, the filled hopper was lifted by a mechanical hoist to the overhead platform (level with the mill hatch) and emptied into the mill. Equipment leaking dust in other parts of the plant were also repaired. After these changes had been made (but prior to a planned comprehensive cleaning of the area) a consultant obtained a silica result of 47 $\mu g/m^3$ for a coatings preparer. A general area sample also collected in the glaze-making area resulted in a respirable quartz concentration of 34 $\mu g/m^3$ (Document ID 0174, pp. 234-235, 241, 249, 254).

The value of ventilated bag dumping systems was discussed previously with respect to material handlers where it was noted that workers using a bag-dumping station (with ventilated bag disposal equipment) in a paint manufacturing facility experienced silica exposure reductions of at least 95 percent (from 263 $\mu g/m^3$ to 12 $\mu g/m^3$). A second type of bag-dumping station equipped with an enclosure, empty bag compactor, bag disposal chute, and LEV system also was found by NIOSH to effectively control dust released during bag opening, emptying, and disposal (Document ID 1369, p. 1). As noted previously, ventilated bag-dumping stations and ventilated compactors are readily available from commercial sources (Document ID 0581; 0594; 0680; 1212; 1213; 1224).

Eliminating Use of Compressed Air for Cleaning

As noted in the discussion of additional controls for pottery industry forming line operators, a pottery facility visited by OSHA eliminated use of compressed air for removing dust from pottery pieces, substituting a vacuum instead. Despite uneven functioning of the LEV at two workstations, this modification reduced silica exposures to below 50 $\mu g/m^3$.

Housekeeping

Although there are no data describing the efficacy of housekeeping measures in the pottery industry, exposure monitoring data from the structural clay manufacturing industry provide strong evidence that housekeeping measures can reduce exposures for coatings preparers in the pottery industry. In the structural clay manufacturing and pottery industries, the same exposure reduction challenges arise for workers who transfer and mix sand and other coatings or glaze ingredients. OSHA concludes that coatings preparers in the pottery industry would benefit equally from housekeeping measures, based on the similarity in raw materials used in the structural clay and pottery industries (quartz sand and powdered silica-containing materials).

For example, in the china manufacturing facility at which the highest coatings preparer result was recorded (983 μg/m^3), the four-phase exposure abatement program included a thorough cleaning of all surfaces in the area where workers blend coatings (Document ID 0174, pp. 84-86, 249). This phase had not been completed at the time of the last results available to OSHA from this facility (47 μg/m^3, as presented in the discussion of LEV for coatings preparers) (Document ID 0174, pp. 234-235, 241, 249, 254). Based on the experience in the structural clay manufacturing industry (Document ID 1365, pp. 3-19 - 3-20, 4-2; 0571) OSHA expects that the silica exposure of this pottery industry coatings operator would have been even lower after the planned cleaning.

Coatings Operators

The exposure profile in Table IV.4.15-B shows that 55.6 percent (10 out of 18 samples) of coatings operators have exposures above the final PEL of 50 μg/m^3. Therefore, OSHA finds that additional controls will be necessary to achieve the PEL for these overexposed workers. As explained below, additional controls include the use of low-silica coatings; well-enclosed, well-ventilated booths; and well-enclosed, well-ventilated automated coatings application machinery. Implementation of these controls might involve installing new equipment or improving current equipment to improve enclosure and ventilation.

Local Exhaust Ventilation and Automation

Well-ventilated, well-enclosed booths for coatings application can reduce worker exposure. The effectiveness of this method is demonstrated by exposure monitoring data obtained at a facility visited twice by NIOSH (Document ID 0211; 0209). During the initial site visit, silica sample results of 113 μg/m^3, 125 μg/m^3, 152 μg/m^3, 192 μg/m^3, 195 μg/m^3, 253 μg/m^3, 259 μg/m^3, 319 μg/m^3, and 434 μg/m^3 were obtained for operators on the semiautomatic spraying line (manual spraying of pieces mechanically transported through the booth[s] on this line) (Document ID 0209, pp. 55-56). The facility then improved the booths by repairing holes or openings that could allow particles to escape or decrease the efficiency of the LEV systems by disrupting airflow. After repairs to the booths and ventilation system, silica exposure levels were one reading of 22 μg/m^3 (the LOD in this case), three readings of 23 μg/m^3 (the LOD for these samples), and one reading of 66 μg/m^3 (Document ID 0211, p. 33). The facility also made improvements to the LEV system to increase airflow rates in the booths, which significantly reduced respirable silica exposures. NIOSH returned to evaluate operator exposure and collected five samples. On the same semiautomic spraying line, four of the five results (80 percent) were less than the LOD (less than 25 μg/m^3 in each case), and one result was 66 μg/m^3 (Document ID 0211, pp. 32-33).

The facility made similar repairs to two other spraying lines (one fully manual and the other fully automatic), which also reduced worker exposure levels, generally 70 to 90 percent (Document ID 0211, pp. 9, 21-22, 32-33). However, NIOSH noted that even after ventilation system upgrades on the fully manual line, workers used compressed air to blow dust off pottery pieces prior to applying glaze and likely contributed to worker silica exposure levels (this practice had been eliminated from the semiautomatic line by providing workers with damp sponges to remove dust from the pottery pieces) (Document ID 0211, pp. 9, 21-22). OSHA finds that additional exposure reduction will be possible by eliminating use of compressed air for removing dust from pieces (switching to vacuum system or damp sponges), making additional adjustments to further enclose the spray lines (particularly the fully automated line), reducing overspray through careful work practices and using modern high-volume-low-pressure (HVLP) spray nozzles, and limiting worker exposure while adjusting spray machines.

OSHA found in the technological feasibility analysis for the standard on hexavalent chromium that paint spray booths intended for small and medium-sized parts (including the sizes of pottery pieces, but excluding large objects the size of aircraft) are capable of controlling worker exposure to hexavalent chromium (a component of paint present in some pigment particles) to levels well below that PEL of 5 μg/m^3 (one-tenth the silica PEL of 50 μg/m^3). Spray booths were found to be an effective control even for paint containing greater than 10 percent chromate (Document ID 0934, p. III-142). OSHA finds that well-designed and effectively maintained spray booths are equally effective for silica particles in glazes as they are for chromate-containing paints. In demonstrating the effectiveness of spray booths for silica-containing coatings, OSHA notes that glazes can be 30 or more percent quartz. However, this higher percent silica is offset by the less restrictive PEL for silica compared with hexavalent chromium. Although the level of chromate (hexavalent chromium) in the paints discussed above is three times lower than the amount of silica in the pottery industry coatings, the hexavalent chromium PEL is also 10 times lower than the PEL of 50 μg/m^3 for silica. Thus, OSHA concludes that spray booths will protect pottery industry coating operators from excessive silica exposure at least as well as the booths protect painters from chromates.

Automation offers another exposure control option for coatings operators. As shown in Table IV.4.15-B, among all data available to OSHA for this job category, coatings operator silica exposure levels are dramatically lower for workers tending automated equipment than for those using manual processes. Workers in this job category will also benefit from improved housekeeping.

4.15.4 Feasibility Finding

Based on the exposure profile in Table IV.4.15-B and other record evidence discussed above, OSHA finds that the standard is technologically feasible for the different categories of pottery workers in pottery facilities and additional controls previously discussed are used. OSHA received no comments during the hearings on its preliminary findings presented in the PEA that feasible controls can be implemented in the pottery industry to achieve the final PEL of 50 μg/m^3. Evidence in the rulemaking record, as reflected in Table IV.4.15-B, however, reflects that maximum exposures under baseline conditions for material handlers, forming line operators, finishing line operators, coating preparers, and coating operators in the pottery industry have exceeded the final PEL of 50 μg/m^3, and mean and median exposures for these job categories are also generally above the PEL. Therefore, OSHA has determined that additional controls will be required. As discussed above for each job category, control options include local exhaust ventilation, use of bag dumping stations equipped with well-ventilated enclosures and ventilated bag disposal equipment, ventilated mixing equipment, and improved housekeeping. Reducing reliance on compressed air for cleaning also will help limit exposures. Implementation of these controls might involve installing new equipment or improving current equipment. OSHA concludes that the controls described above can effectively reduce silica exposure levels to 50 μg/m^3 or less for most operations, most of the time, in the pottery production industry.

Furthermore, OSHA concludes that silica exposure levels of 50 μg/m^3 or less are already achieved for most workers at smaller pottery operations that use a relatively small amount of raw materials and clay. The results obtained by NIOSH at such a shop did not exceed the final PEL of 50 μg/m^3 despite the lack of LEV (Document ID 0878). If elevated exposures do occur, the same control methods available to larger facilities, including (LEV, wet methods, and improved housekeeping, can be instituted on a smaller scale to achieve compliance with the final PEL.

Thus, OSHA concludes that, with the exception of coatings preparers and operators, most workers at pottery facilities are currently exposed to silica levels at or below 50 μg/m^3. For workers who are currently exposed above 50 μg/m^3, the engineering and work practice controls described in this section can be implemented to reduce silica exposure levels to 50 μg/m^3 or less in most operations, most of the time. Therefore, OSHA finds that the final PEL of 50 μg/m^3 is technologically feasible for the Pottery industry.

4.16 RAILROADS

4.16.1 Description

Railroad track maintenance-of-way workers are responsible for maintaining the overall surface of the roadbed including the rails, ties, and ballast (crushed rock), and other components associated with the railroad track right-of-way. Potential exposure to silica-containing dust may occur during maintenance activities involving both the manual and automated manipulation of ballast (Document 2318, p. 8). This application group is classified in the six-digit North American Industry Classification System (NAICS) codes as 482111, Line-Haul Railroads, and 482112, Short Line Railroads (Document ID 1365, p. 12-1).

Railroad track is most often supported by a bed of material called ballast. Ballast transmits and distributes the load of the track and rolling equipment evenly across the roadbed; controls movement of the track; helps maintain proper track cross-level, surface, and alignment; and provides drainage for the track. Today, most railroads use crushed stone, especially granite, traprock, and limestone or slag for ballast on main-line tracks. In 2001, granite containing 25 to 40 percent silica accounted for approximately 46 percent of the total crushed stone sold for railroad ballast within the United States (Document ID 1365, p. 12-1). Potential exposure to silica-containing dust occurs when silica-containing ballast is dumped or otherwise manipulated during track maintenance activities (Document ID 2318, p. 8).

The two major functional job categories associated with potential silica exposure during track maintenance are 1) workers known as “ballast dumpers” who work outside cabs of on-track roadway maintenance machines and 2) operators of these machines (Document ID 1365, pp. 12-2 - 12-7). Table IV.4.16-A presents job activities and the major sources of exposure for affected job categories.

As explained in this FEA section on Federal Rules Which May Duplicate, Overlap or Conflict with the Final Rule in Chapter IX, Final Regulatory Flexibility Analysis, OSHA has general regulatory and enforcement authority to address silica exposures of railway workers. The OSH Act, however, precludes the Agency from promulgating standards in areas over which another federal agency exercises statutory authority. Section (4)(b)(1), 29 USC 653. Effective September 26, 2003, the Federal Railroad Administration (“FRA”) amended the Railroad Workplace Safety regulations, 49 CFR Part 214, to require that new and employer-designated existing on-track roadway maintenance machines (“FRA-covered RMM”) be equipped with, among other things, positive pressurized ventilation systems, and be capable of protecting employees in the cabs of the machines from exposure to air contaminants (including silica) in accordance with the OSHA Air Contaminants standard, 29 CFR 1910.1000. 49 CFR 214.505. The FRA did not require retrofitting FRA-covered RMM manufactured before 1991 based on a decision that such retrofitting would be too costly and impose an undue burden on small employers, which are the primary users of such older machines. 68 FR 44405. In contrast to this negative exercise of jurisdiction over "grandfathered" RMMs, the FRA made it clear

> that it is not adopting those OSHA standards that include protection from silica dust for employees not working inside the cabs of on-track roadway maintenance machines covered by this section. The extent of FRA's adoption of OSHA standards in this section reaches only as far as the cab of the covered on-track roadway maintenance machine. As a result, when working inside the cab, workers receive protection from FRA; when working outside the cab, workers receive protection from OSHA.

68 FR 44393-44394. Section 214.501 of 49 CFR states that any working condition involving the protection of railroad employees engaged in roadway maintenance duties but which is not specifically addressed in the subpart continues to be governed by the OSHA regulations (49 CFR 214.501; 68 FR 44391 (2003)).[89] Thus, this feasibility analysis primarily examines protections for worker exposure outside the cab, including ballast handling (e.g., dumping) or other track maintenance or construction activities along right-of-ways.

[89] FRA also clarified that “when OSHA revises the standards, FRA will enforce the revised standards on those machines over which FRA has jurisdiction.” 68 FR 44393.

Table IV.4.16-A Job Categories, Major Activities, and Sources of Exposure in the Railroads Industry (NAICS 482111 and 482112)	
Job Category*	**Major Activities and Sources of Exposure**
Ballast Dumper	Walks alongside moving ballast cars and manually or automatically (via radio remote control) opens hopper doors on moving ballast cars and dumps ballast alongside the track. • Dust generated when dry ballast falls from hopper cars.
Machine Operator	Operates heavy equipment used for track bed surfacing activities. Includes the ballast regulator to level, shape, and dress ballast, the mechanical broom to sweep tracks, tamper machines to pack down ballast under the ties, undercutter machines to lift ties and scoop out existing ballast from underneath, and rotary scarifiers to break up or loosen the track bed surface. • Dust generated during direct manipulation of the ballast.
*Job categories are intended to represent job functions; actual job titles might differ, and responsibilities might be allocated differently, depending on the facility. Source: Document ID 1365, pp. 12-2—12-7; 2318, p. 8; 2366, p. 4; 3583, Tr. 2388	

4.16.2 Exposure Profile and Baseline Conditions

OSHA evaluated the silica exposures of workers in the railroad transportation industry by reviewing full-shift personal breathing zone (PBZ) respirable quartz exposure monitoring data from two NIOSH reports (Document ID 0882; 0884). These monitoring results are presented in the exposure profile Table IV.4.16-B. Full-shift area samples reported in these studies are also discussed. In preparing the FEA, OSHA searched the inspection data recorded in OSHA Information System (OIS) and other information submitted to the rulemaking record, but no additional monitoring data on railroad worker exposures were identified (Document ID 3958). The results presented in Table IV.4.16-B differ from the PEA in that ten sample results for machine operators were adjusted. One ballast dumper experienced cristobalite exposure of 50 μg/m^3 in addition to 90 μg/m^3 quartz exposure, for a total silica exposure level of 140 μg/m^3. Nine other sample results for machine operators were adjusted due to an inconsistency in the method used in the PEA to report the limit of detection (LOD) or limit of quantification (LOQ). These values have been corrected to the appropriate LOD or LOQ value as reported in the original NIOSH reports.

Exposure Profile and Baseline Conditions for Ballast Dumpers

The exposure profile in Table IV.4.16-B includes 26 samples for ballast dumpers. The median exposure is 25 µg/m^3, the mean is 68 µg/m^3, and the range is 11 µg/m^3 (LOD) to 370 µg/m^3. Of the 26 samples, 6 (23.1 percent) are above 50 µg/m^3, and 4 (15.4 percent) exceed 100 µg/m^3. These results come from a single NIOSH report issued in 2001 (Document ID 0884, pp. 13-20).

NIOSH investigators reported that some ballast was wet because the railroad company required that ballast be washed at the quarry before being loaded into hopper cars. Although some ballast was observed to be wet as it was dumped, pockets of dry ballast were still a source of dust. In general, most cars loaded with ballast were observed to be dry, and dust was created when the ballast was dumped (Document ID 0884, p. 4). A contact familiar with the industry (Mine Safety and Health Administration, 2003) reported that ballast material is not typically washed by quarries on a regular basis and washing likely depends on the size of the quarry operation as well as the tonnage of the ballast order (Document ID 0820).

The samples included in Table IV.4.16-B were gathered under a range of conditions and reflects the best available evidence of the exposures of ballast dumpers. The exposure profile reflects all data identified for this sector through literature searches performed in the development of the PEA, and no other data was submitted to the rulemaking record. OSHA considers the exposure profile in Table IV.4.16-B to represent the baseline conditions for ballast dumpers (Document ID 1365, p. 12-8)

Exposure Profile and Baseline Conditions for Machine Operators

The exposure profile in Table IV.4.16-B includes 100 samples for machine operators in railroad yards. The median exposure is 40 µg/m^3, the mean is 73 µg/m^3, and the range is 9 µg/m^3 (LOD to 440 µg/m^3). Of the 100 samples, 38 (38 percent) are at 50 µg/m^3 or above, and 19 (19 percent) exceed 100 µg/m^3. The samples in the exposure profile come from full-shift respirable quartz readings in two NIOSH reports. The exposure data described in the first of these reports were collected in 1991 (Document ID 0882, p. 1). Data described in the second NIOSH report were collected between 1993 and 1997, while the employer was in the midst of implementing a cab retrofit program to control operator exposures to silica (Document ID 0884, pp. ii and 3).

Neither report differentiated between workers who engaged in activities outsides of the cab and operators who worked exclusively inside the cab. The first report (Document ID 0882) describes two sets of workers: Track Maintenance (TM) crews (described as "pick and shovel") and Timber and Surfacing (T&S), which use mechanized equipment. Specific job titles are listed in Table 1, page 25, and correspond to the "machine operator" job description. The report states on page 6 that TM crews often assist T&S crews, and may often perform similar functions as machine operators. In the second report (Document ID 0884), NIOSH states "Although some operators walk with their machines, most are seated upon the machine–many within enclosed cabs." All are classified as "machine operators."

The data in the record do not include sufficient information on which OSHA could distinguish between the levels of exposure for workers inside a cab that is not enclosed as opposed to workers elsewhere on the machine or on the ground, nor does it suggest that the exposures of workers on the ground would be higher or lower than those on the machines without enclosed cabs (other than the possibility that it may be easier for employees on the ground to distance themselves from the source of the exposure). In fact, the maximum and minimum exposures recorded for a ballast dumper, which is defined as a person walking on the ground, are nearly identical to those of the operators of ballast dumper regulator machines who are typically on the machines. The majority of the significant potential exposures to TM or T&S crews on the ground results from the same silica exposure-generating activities to which employees on the machines are exposed. Therefore, OSHA refers generally to the entire group of maintenance of way workers (excluding the ballast dumpers, who are addressed separately) as "machine operators" and divides them into two categories for the purpose of making technological feasibility determinations: exposure while working inside a cab, and exposure while working outside the cab (including in the absence of any cab). Because of FRA jurisdiction over workers inside cabs (as well as workers on "grandfathered" machines without cabs), exposure while working outside cabs is of primary interest for the purposes of this OSHA standard.[90]

In addition to the 100 PBZ samples included in the exposure profile for machine operators, NIOSH also reported results of area samples taken on several types of heavy equipment. Twenty-seven full-shift (i.e., greater than 360 minutes duration) area respirable silica readings were collected during the use of ballast regulators, brooms, tampers, and a scrap buggy. Samples were taken either inside the cab or within approximately three feet of the operator’s PBZ. Results range from below the limit of detection (11 µg/m^3 to 32 µg/m^3, depending on the sample) to 140 µg/m^3, with a median of 50 µg/m^3 and a mean of 54 µg/m^3 (Document ID 0882, pp. 25-30; 0884, pp. 12, 14). Thirteen results (48 percent) exceed 50 µg/m^3 (although four of these were below the limit of quantification) and three results (11 percent) exceed 100 µg/m^3. An additional very high reading of 2,040 µg/m^3 quartz was associated with a less-than-full-shift (225 minute) area sample on a back broom (Document ID 0882, pp. 13, 30). Although these area samples are not direct measures of worker exposure, and are not included in the exposure profile, they illustrate the potential for significant reductions in exposure. The personal samples are much lower than the area samples, indicating that increased distance from the point of exposure reduces the level of the exposure. The NIOSH authors note that the personal sample for the broom operator on this machine was much lower (110 µg/m^3) because the worker attempted to stay upwind of the broom and dust cloud, and that this very high fixed area reading for this machine demonstrates the potential worker exposures that could occur for an operator working on a machine, suggesting that this machine may have been remotely operated (Document ID 0882, p. 13).

A report by Tucker et al. (1995) confirms the potential for overexposure among maintenance-of-way operators of older machines, most of which are likely without enclosed cabs and may therefore provide a more accurate reflection of exposures for operators outside the cabs (even though operators of the older, "grandfathered" machines

[90] While OSHA does not have authority to require retrofit of track maintenance machines with protective cabs, the 50 µg/m^3 PEL will apply, both to workers under OSHA jurisdiction, and those under FRA jurisdiction.

fall within the FRA's jurisdiction). Twenty percent of 81 full-shift PBZ samples collected on ballast regulator and broom operators were greater than 100 μg/m^3 (the American Council for Government Industrial Hygienists Threshold Limit Value (TLV) for respirable silica at that time). The machine type showing the highest percentage of operator exposures exceeding the TLV were track broom operators. While the study authors do not describe the factors that may lead to the high proportion of track broom operators experiencing elevated exposures, they do recommend that these machines be retrofitted for remotely controlled operation to reduce exposures (Document ID 1188, pp. 1083 - 1085).

Upon consideration of the evidence available in the rulemaking record, including the two NIOSH reports, the study by Tucker et al., and comments submitted to the record, OSHA has determined that the NIOSH sampling results are the best available evidence of ballast dumper and machine operator exposures. These results are reflected in the Final Exposure Profile, Table IV.4.16-B below.

Table IV.4.16-B
Personal Respirable Crystalline Silica Exposure Range and Distribution of Results for Railroads (NAICS 482110, 482111, 482112)

	Exposure Summary			Exposure Range		Exposure Profile				
Railroads	**N**	**Mean (μg/m³)**	**Median (μg/m³)**	**Min (μg/m³)**	**Max (μg/m³)**	**< 25 (μg/m³)**	**≥ 25 and ≤ 50 (μg/m³)**	**> 50 and ≤ 100 (μg/m³)**	**> 100 and ≤ 250 (μg/m³)**	**> 250 (μg/m³)**
Ballast Dumper	*26*	*68*	*25*	*11*	*370*	*13 (50%)*	*7 (26.9%)*	*2 (7.7%)*	*2 (7.7%)*	*2 (7.7%)*
Machine Operator (Ballast Regulator)	38	91	45	9	370	8 (21.1%)	13 (34.2%)	8 (21.1%)	4 (10.5%)	5 (13.2%)
Machine Operator (Broom Operator)	21	90	60	10	440	2 (9.5%)	6 (28.6%)	7 (33.3%)	5 (23.8%)	1 (4.8%)
Machine Operator (Tamper Operator)	35	52	40	9	310	13 (37.1%)	14 (40%)	4 (11.4%)	3 (8.6%)	1 (2.9%)
Machine Operator (Other Operator)	6	27	20	20	50	4 (66.7%)	2 (33.3%)	0 (0%)	0 (0%)	0 (0%)
Machine Operator Subtotal	*100*	*73*	*40*	*9*	*440*	*27 (27%)*	*35 (35%)*	*19 (19%)*	*12 (12%)*	*7 (7%)*
Railroads Total	**126**	**72**	**40**	**9**	**440**	**40 (31.7%)**	**42 (33.3%)**	**21 (16.7%)**	**14 (11.1%)**	**9 (7.1%)**

Notes: All samples summarized are personal breathing zone (PBZ) results representing 8-hour time-weighted average exposures.
Job categories are intended to represent job functions; actual job titles might differ, and responsibilities might be allocated differently, depending on the facility.
Percentages may not add to 100 percent due to rounding.
Sources: Document ID 1720; 0882; 0884.

4.16.3 Additional Controls

Additional Controls for Ballast Dumpers

The exposure profile in Table IV.4.16-B shows that 23.1 percent (6 of 26 samples) of ballast dumpers have silica exposures above 50 μg/m^3. Although 50 percent (13 of 26 samples) are exposed at less than 25 μg/m^3, OSHA concludes that additional controls will be needed for the overexposed ballast dumpers. These controls include substitution with low-silica or silica-free ballast material, use of dust suppression, and improved work practices in conjunction with remotely controlled dumping. In testimony during public hearings, Mr. Lamont Byrd speaking on behalf of the Brotherhood of Maintenance of Way Employees Division (BMWED) of the Teamsters Rail Conference (International Brotherhood of Teamsters, IBT) supported the conclusion that implementing these controls was technologically feasible. He stated as follows:

> The BMWED Teamsters believes that engineering controls required for certain roadway maintenance machines, in addition to controls such as wetting down ballast cars prior to unloading and using remote operation dump doors on ballast cars, are feasible controls to reduce silica exposure for all workers in the railroad industry (Document ID 3581, Tr. 1610).

In written comments, he further described "quarrying methods or processes that reduce the overall content of respirable silica in ballast" as an additional feasible control strategy (Document ID 2318, p. 4).

Substitution

The silica released during ballast dumping depends in part on the silica content of the ballast material. Ballast material with high silica content (e.g., granite, sandstone, quartzite) will generate dust with high silica content, whereas ballast material with low silica content (e.g., slag products, low-silica limestone[91]) will generate dust with reduced silica content. Slag products are reported to contain less than 1 percent silica, and the

[91] The silica content in limestone can vary greatly. Low-silica limestone silica content generally ranges from < 1 to 9 percent silica, while high-silica limestone silica general ranges from 9 to up-to 67 percent (Document ID 1365, p. 12-2).

FRA specifically permits crushed slag as a suitable material for ballast (Document ID 0388; 0693, pp. 5.56, 6.47).[92]

Objecting to the use of limestone as a substitute ballast material, the Association of American Railroads (AAR) and the American Short Line and Regional Railroad Association (ASLRRA) jointly commented that the use of limestone as a substitute would create safety hazards:

> Limestone is not nearly as strong as granite and limestone ballast does not drain as well as granite ballast. Prior use of limestone ballast by one AAR member, dating back to the late 1970's, produced unsatisfactory results, due to poor drainage (i.e., mud and cementing) which necessitated yearly resurfacing of the track bed. Additionally, a more frequent resurfacing program creates additional potential exposure of employees to silica * * * Poor drainage also affects walking conditions, creating potential hazards for rail employees to sustain injuries from slipping, tripping, and falling. Finally, a weakened track structure could jeopardize the safe operation of trains, which * * * can cause derailments * * * (Document ID 2366, p. 6).

AAR and ASLRRA comments imply that OSHA proposed the removal and replacement of granite ballast that is currently in place on railway road beds, and go on to describe the costs of replacing the granite ballast that is currently installed (Document ID 2366, pp. 6-7). In fact, OSHA proposed only that lower silica alternatives to granite be considered for ballast installed after the standard's effective date. Limestone and other materials already account for a significant percentage of ballast. In 2001, limestone accounted for 16 percent of crushed stone sold for railroad ballast, while granite accounted for less than half (Document ID 1365, p. 12-2). An additional 26 percent of ballast used in 2001 was composed of other low silica crushed stone, namely, traprock and dolomite (Document

[92] A NIOSH-sponsored study evaluated the dust generated when various materials (including several types of slag) were used as grit for abrasive blasting. This study concluded that, while low in silica, the dust from slags "have substantially higher levels of some other health-related agents (metals), as compared to silica sand" (Document ID 0773, pp. iii and, 90). Because ballast-handling can also generate airborne dust, OSHA notes that when low-silica aggregates such as slag are used as ballast, employers must evaluate the need to protect workers from other contaminants.

ID 1365, p. 12-2).[93] OSHA is not suggesting that limestone can safely be used for all installations. However, these data clearly demonstrate that the use of certain low-silica limestone and other low silica ballast is currently in use and therefore feasible in a great many instances, without compromising track safety.

Engineering Controls in Conjunction with Work Practices

Remote operation of hydraulic dump doors on ballast cars has the potential to limit worker exposure to silica during ballast dumping, as well as reducing the risk of personnel injury. Radio remote controls for ballast cars are commercially available (Document ID 0583; 0584; 0884, pp. 3-4). However, this control does not eliminate the dust at its source, and is only effective when workers are able to maintain distance from the dumping operation, and stay upwind in order to avoid dust clouds generated during dumping. NIOSH noted that this may be challenging in narrow right-of-ways (Document ID 0884, p. 4). However, no comments were received in the record indicating that worker distancing and remotely controlled ballast dumping operations are not technologically feasible. OSHA concludes that workers should almost always be able to move up or down the length of the track to avoid the dust source, and can, with proper controls, become proficient at remote monitoring of ballast dumping operations from an increased distance.

In hearing testimony, BMWED described remote operation of ballast dump doors, as well as wetting down of ballast cars prior to unloading, as "feasible * * * to reduce silica exposure for all workers in the railroad industry" (Document ID 3581, Tr. 1610). Industry representatives did not so much contest the feasibility of the dust control method as the cost. Ms. Yurasko, representing AAR and ASLRRA, noted in written comments that "some of the Class I railroads utilize GPS technology to conduct ballast dumping operations remotely, virtually eliminating employee exposure to silica dust for these

[93] 1,400,000 metric tons of limestone, and 4,090,000 metric tons of granite were used that year. This figure includes both high silica and low silica limestone. However, since the ASLRRA / AAR comments do not draw any distinction between the suitability of high versus low silica limestone, OSHA concludes that use of low silica limestone is suitable. Several other types of crushed stone were also reported to be used in 2001, including two with lower silica content than granite - traprock (1,940,000 tons, 1-12 percent silica), and dolomite (355,000 tons, 0-3 percent silica) (Document ID 1365, p. 12-2).

operations" (Document ID 2366, Attachment 1, pp. 2-3). But, Ms. Yurasko noted, the GPS technology for remotely controlled dumping is not widely used by smaller railroads due to its cost; one railroad representative estimated a cost of $6,000 per day to contract the use of a GPS ballast train (Document ID 2366, p. 3, 5).

No quantitative exposure reduction data regarding worker positioning in relation to ballast dust are available in the record. Nonetheless, OSHA concludes that upwind positioning from dust caused by dumping ballast is often feasible and that exposures will be reduced when workers do not position themselves within or downwind of silica-containing dust clouds (see also Document ID 1720, p. IV-281; 1365, p. 12-17).

Dust Suppressants

Washing ballast before it is loaded into hopper cars reduces the amount of fine particulate matter generated during dumping. In other industries like asphalt paving products (see Section IV-4.1 – Asphalt Paving Products) the use of washed sand results in silica exposures that are generally lower than when sand is not pre-washed, and increased moisture content decreases the amount of dust generated. Water sprays should be applied to material before it reaches a transfer point so that the dust has time to absorb the water. Washing ballast would help achieve both of these goals, i.e., reducing the amount of fine (respirable) particulate present in the ballast, and suppressing airborne dust generated during dumping (Document ID 1365, p. 12-16).

Since ballast wetted at the supplier's site might dry prior to reaching the dumping site, one option to reduce evaporation is to apply an additional layer of blanketing foam or other sealing chemical suppressant to the top of the rail car at the load-out station. This chemical sealant system has been used effectively by a quarry to eliminate dust emissions during transit, and is commercially available for sealing open rail cars in the United States (Document ID 0635; 0809, p. 2). A number of other types of long-acting chemical suppressants have been used effectively for dust suppression in other industry sectors, such as mining, abrasive blasting, and on unpaved roadways (Document ID 1360, pp. 1-2; 0773, p. 45; 0516, pp. 109 - 110; 1540, pp. 64-65, 253-256). Water with surfactant could be used effectively at the point of ballast dumping (Document ID 1360, pp. 1-2).

Although OSHA is unaware of commercially available original equipment options including spray systems that are specifically designed for dumping ballast from rail cars, mobile rock-crushing and mining equipment, are equipped with spray nozzles and connectors are commercially available (Document ID 0770, p. 2). OSHA estimates that a directional mist applied during dumping activities could reduce exposures by over 70 percent (Document ID 1365, pp. 12-16 – 12-17). The NIOSH Dust Control Handbook for Industrial Minerals Mining and Processing provides schematics for water spray application for "typical loader dump dust control application" and also describes electronically controlled self-contained water delivery systems that can automatically adjust the liquid flow rate in response to changes in dust loading, to optimize dust control (Document ID 1540, pp. 69, 71).

Similarly, in brick manufacture, NIOSH described use of a citrus-based foam surfactant suppressant system installed on a conveyor supplying shale to a loading hopper (Document ID 0239, p. 8). Anthony Bodway of the National Asphalt Pavement Association noted that, for asphalt milling machines, water spray treated with surfactant are effective, and described a study showing that water treated with a foaming agent that reduced exposures four to five times more than water aerosol alone. Mr. Bodway concluded that when water spray is used with a surfactant, "silica exposures can be consistently maintained below the PEL without the use of respirators" (Document ID 2181, pp. 10-11, 16). While these situations are not identical to ballast dumping, they all involve the transfer of large quantities of silica-containing materials. OSHA concludes that the processes are similar enough to suggest that the technology could be readily adapted to allow for wetting or application of other suppressants to ballast prior to dumping.

Industry representatives expressed various environmental and safety concerns over chemical or water dust suppressants:

> [S]praying the ballast with chemicals could * * * trigger the need for a National Pollutant Discharge Elimination System (NPDES) permit * * *. [S]praying water spray * * * could affect walking conditions around the roadbed, creating additional opportunities for employee injury.

> Additionally, spraying liquid on ballast will have limited, if any, effectiveness given that, depending upon the ambient temperature, the water or chemical spray could evaporate before or after coming in contact with the ballast or freeze upon application. OSHA should not require the rail industry to spray water or chemicals on ballast, as it unnecessarily creates environmental and safety hazards to railroad employees and the public (Document ID 2366, pp. 7-8).

The NIOSH Dust Control Handbook for Industrial Minerals Mining and Processing (2012) discusses suppressant options for mining haul roads. This handbook addresses environmental concerns when it describes options such as polymers and petroleum emulsions that are nontoxic or of low toxicity, and maintain their effectiveness over extended time periods because they do not evaporate or wash away after a rainstorm (Document ID 1540, pp. 255- 256). Addo and Sanders note that many dust suppressants, particularly chloride salts, are used in much greater quantity for road de-icing than as suppressants, and that when used as suppressants, they "stay mostly at one place in the road surface" instead of being immediately washed off as snow and ice melt, so that the environmental effects of suppressants are overshadowed by their use as deicers (Document ID 0516, p. 32). In regard to freezing conditions, Addo and Sanders (1995) describe a number of chloride salts used as chemical suppressants that can be used in freezing conditions and, in fact, are effective in lowering the freezing point of water, to as low as -60F (Document ID 0516, pp. 119 – 122). Regarding the concern that use of wet suppressants may contribute to slippery walking and working surfaces, OSHA notes that misting was found to be effective in controlling silica exposures during concrete breaking (jackhammer operation), "without adding a substantial amount of water to the work site" (Document ID 1431, p. 3-48).

OSHA acknowledges that wet methods or chemical suppressants may not be practical in all circumstances. Nevertheless, OSHA concludes that these methods can be used effectively in many cases, as they have been successfully implemented in other sectors such as mining and construction.

Additional Controls for Machine Operators and Other Employees Working Outside the Cab

The exposure profile in Table IV.4.16-B shows that 38 percent (38 of 100 samples) have exposure above the final PEL of 50 μg/m^3. Although the exposure profile does not distinguish clearly between exposures to machine operators inside and outside of cabs, OSHA concludes that additional controls will be required for those operators who experience silica exposures above 50 μg/m^3. In addition to the substitution described above for ballast dumpers, OSHA has identified several controls and methods appropriate to protect maintenance of way employees working outside the cab. As noted earlier, because FRA exerts jurisdiction over employees exposed to silica while working inside machine cabs (as those on older, pre-2004 machines that were not required to be retrofitted with cabs), OSHA uses the term “operator” in this context generally to represent the group of employees (excluding ballast dumpers) who could be exposed to silica as the result of activities on the ground.

Dust suppression kits

An engineering control option to protect workers outside the cabs is the use of dust control kits. These kits use local exhaust ventilation and air filtration to reduce the amount of ballast dust released during track maintenance and they are currently available from equipment manufacturers. For example, dust control kits are available for new brooming equipment, although information regarding their effectiveness is not available (Document ID 1365, pp. 12-19 - 12-20). However, AAR and ASLRRA noted that “one of AAR's member railroads has utilized equipment with a dust collection system, but discontinued the practice after the results were determined to be unsatisfactory” (Document ID 2366, p. 5). It is not clear from this statement the nature of the dissatisfaction, how long ago this experience occurred, and whether more recent technology that would produce a more satisfactory result is now available.

AAR and ASLRRA also stated that OSHA’s suggestion to use dust suppression kits as an alternative to protective cabs “exceeds the scope of OSHA's jurisdiction over the railroad employees working inside the cabs of this equipment” (Document ID 2366, p. 4). The commenter misconstrues the purpose of these controls. They are intended to reduce exposures for employees working *outside* the cabs in the area that, as explained earlier, the FRA has clearly reserved for OSHA jurisdiction; OSHA is not requiring them for employers or machines covered by the FRA regulations. While the dust suppression kits may have the secondary effect of also reducing operator exposure when working inside a cab that is not enclosed, OSHA is evaluating this control method as a means of protecting workers working outside the cab in the vicinity of the equipment, like the ballast dumpers or track maintenance crews. This standard does not mandate the use of any specific controls. Employers are free to use any combination of these and other control strategies to meet the PEL.

Another option for broom operators, who have the greatest potential for elevated exposure, would be remotely controlled operation. Existing equipment can be retrofitted for remote control, automating brooming operations (Document ID 1365, p. 12-19).

Wet dust suppression methods are also an option. Water or chemical suppressants applied during dumping will provide dust suppression for activities performed days or weeks afterwards. But, if necessary, the track area can be re-wetted or re-coated with dust suppressant, for example, if maintenance operations are being performed months or years after the last aggregate dump (or substantial rainfall). Although no data are available for the railroad industry, the available data for construction (see IV-5.3 Heavy Equipment Operators) and materials handlers (IV-4.3 Concrete Products) suggest that the use of water and/or chemical dust suppressants applied to the yard or aggregate piles can reduce exposure to respirable silica-containing dust for machine operators and other maintenance of way employees working outside of cabs (Document ID 1365, pp. 5-10, 5-15 – 5-19; 1431, p. 3-36).

Worker positioning

In most cases, the controls and practices capable of reducing silica exposures for ballast dumpers will also reduce exposures to other maintenance of way workers on the ground. One of those practices is ensuring that there is a greater distance between the source of the silica exposure and the worker. As with ballast dumpers, no quantitative exposure reduction data regarding worker positioning in relation to dust are available in the record.

Nonetheless, for the reasons discussed with respect to ballast dumpers, OSHA concludes that exposures will be reduced when workers do not position themselves within or downstream of silica-containing dust clouds.

4.16.4 Feasibility Findings

Feasibility Finding for Ballast Dumpers

The exposure profile in Table IV.4.16-B shows that 77 percent of ballast dumper exposures are already at or below 50 µg/m^3, and the median for this job category is 25 µg/m^3 (13 of 26 ballast dumpers sampled were below the 25 µg/m^3 action level). Based on the exposure profile and other information in the rulemaking record described above, OSHA concludes that the silica exposures of ballast dumpers in the railroad industry can be reduced to 50 µg/m^3 or less most of the time. Additional controls will be needed for the 23 percent of ballast dumpers who currently have exposures above 50 µg/m^3. Employers who provide low silica content ballast and dust suppressants (e.g., wet methods), and who require that employees use safe work practices will reduce ballast dumpers' silica exposure to at or below 50 µg/m^3. Safe work practices include administrative controls that require ballast dumpers to stand at a distance from the dump point (also a good practice to avoid physical injury) and modifying ballast car doors for remote operation, a feature already commercially available to this industry (Document ID 0584). OSHA thus finds that the standard is technologically feasible for ballast dumpers when baseline and additional controls are used.

Feasibility Finding for Machine Operators and Other Employees Working Outside the Cab

Based on the exposure profile in Table IV.4.16-B and information in the rulemaking record discussed above, OSHA concludes that the silica exposures of machine operators and other maintenance of way workers working outside the cab (excluding ballast dumpers), can be reduced to levels of 50 µg/m^3 or less most of the time. This conclusion is based in part on the finding that 62 percent of machine operator exposures were already at or below this level (see Table IV.4.16-B) prior to the 2004 FRA requirement that operative positive pressurized ventilation systems be provided to new on-track-roadway maintenance machines (RRMs). Additional controls will be necessary for machine operators who currently experience exposure levels above 50 µg/m^3 while working outside cabs. When additional controls are needed, employers can reduce these employees' silica exposure to 50 µg/m^3 or less through use of one or more of the following controls: low silica content ballast, dust suppressants, and/or automated broom machines. Therefore, OSHA finds that the standard is technologically feasible for maintenance operators and other employees working outside cabs (and hence coming within OSHA, not FRA jurisdiction), when baseline and additional controls are used.

Overall Feasibility Finding

OSHA concludes that most exposures to silica dust in the railroad track maintenance industry covered by this standard are currently at or below the PEL of 50 µg/m^3. Where such exposures are currently above the PEL, OSHA finds that feasible control methods described above exist to reduce exposures to respirable crystalline silica to levels at or below the PEL for most operations most of the time in this industry. Therefore, OSHA finds that the final PEL of 50 µg/m^3 is technologically feasible for the Railroad industry.[94]

[94] OSHA is not making any feasibility finding with respect to operators working exclusively inside a cab on a machine that the FRA chose to exempt from its requirements in 49 CFR 214.505 for environmentally controlled cabs. The FRA has reserved jurisdiction over the protection of these workers but has not mandated any exposure limits tied to OSHA's PEL with respect to these employees, so there is no need for OSHA to evaluate the feasibility of protecting these employees.

4.17 READY MIX CONCRETE

4.17.1 Description

Ready-mixed concrete refers to concrete that is delivered to the customer in a freshly mixed and unhardened state (Document ID 1365, p. 13-1; 2318, p. 5). Ready-mixed concrete is typically comprised of Portland cement containing aggregates and water. Silica-containing materials are used as fine and coarse aggregate ingredients in the manufacture of ready-mixed concrete. The most commonly used silica-containing aggregates include sand, gravel, and crushed stone (Document ID 1203, p. 1). Ready-mixed concrete can be created inside of a delivery truck barrel (dry batch) or come from a central facility that mixes concrete (wet batch). At dry batch facilities, the raw materials (cement and aggregate) and water are added directly to the truck barrel with contents mixed in the truck mixer in the plant yard, while driving to the job site, or at the job site. At wet batch plants, the concrete is prepared in a plant mixer and then discharged after blending into a truck for delivery to the job site (Document ID 1365, pp. 13-1 – 13-2; 0923, pp. 4-5).

Concrete batch plants are dispersed nationally and are usually located in areas convenient for the delivery of raw materials (cement and aggregates). A typical facility includes storage areas for the raw materials; tanks and conveyors for holding, mixing, and dispensing raw materials; a computerized control room to weigh, mix, and load materials into trucks; a dispatch room to schedule pickups and deliveries; a yard area to wash and park trucks; a maintenance garage; and offices (Document ID 1365, p. 13-2; 1405, p. 2). Ready-mixed concrete facilities are classified in the six-digit North American Industry Classification System (NAICS) 327320, Ready-Mixed Concrete Manufacturing.

Workers are potentially exposed to silica at both dry and wet batch concrete plants. The job categories with potential for exposure to silica include:

- material handler, responsible for overseeing the transfer of aggregates and cement to bins, hoppers, or storage silos;

- batch operator, operates controls to weigh the aggregates and cement, which are then sent either to an agitator truck or an on-site mixer for blending with a premeasured quantity of water;
- quality control technician, responsible for collecting and testing samples of raw materials and prepared concrete;
- maintenance worker, performs intermittent, non-routine tasks, primarily involving equipment maintenance and repair; and
- truck driver, responsible for (1) checking and filling the water and additive (admixture) tanks that are attached to the truck; (2) checking and adjusting the concrete slump when the truck is fully loaded and prior to discharge; (3) operating the drum rotation speed according to the concrete specifications and mixing instructions; and (4) hosing down the truck (inside and/or outside) when fully loaded, after the mixer is completely discharged (Document ID 1365, p. 13-3; 0214, pp. 2-4; 0966).

Table IV.4.17-A summarizes the major activities and primary sources of silica exposure in this industry.

4.17) Ready Mix Concrete

Table IV.4.17-A
Job Categories, Major Activities, and Sources of Exposure for Workers in the Ready-Mixed Concrete Industry (NAICS 327320)

Job Category*	Major Activities and Sources of Exposure
Material Handler	Transferring dry aggregate and cement to bins, hoppers, and storage piles. • Dust from transferring silica-containing raw materials by open material handling equipment, conveyor, or bucket elevator. • Dust from outside piles of aggregates (yard dust).
Batch Operator	Controlling release, weighing, and transfer of aggregates, cement, and water to mixers (plant and/or truck) and discharging of central mixed concrete into haul trucks. • Dust from manual batch operations (approximately 10 percent of ready-mixed concrete facilities have manual batch operations).
Quality Control Technician	Collecting and testing samples of dry raw materials (such as sand and gravel) and concrete. • Dust from collecting and testing samples of raw materials and prepared concrete. • Dust from outside piles of aggregates (yard dust). • Dust from recirculation of settled dust at the plant and construction sites.
Truck Driver/Specialty Contractor	Occasionally (e.g., twice per year) entering and cleaning interior of mixer drum to remove hardened concrete.** • Dust from removing hardened concrete from mixer drums using pneumatic chippers.
Maintenance Operator	Performing maintenance and repair on equipment throughout plant; in some cases using hand tools (such as sledgehammers) to remove residual concrete from inside plant mixing drum. • Dust from changing parts or maintaining equipment in aggregate conveyors and batch plant. • Dust from cleaning cement chute and removing residual concrete from plant mixer.

*Job categories are intended to represent job functions; actual job titles might differ, and responsibilities might be allocated differently, depending on the facility.
**Truck mixer drum cleaning is completed by only a small number of truck drivers. This task is increasingly performed by contractors who specialize in removing hardened concrete from ready-mixed truck drums (Document ID 0922, p. 11; 2024, p. 2; 2305, p. 7). Instead of infrequent exposure, contractors receive regular silica exposure from this activity, perhaps on a daily basis.

Sources: Document ID 1365, pp. 13-3 – 13-5, 13-6; 0924; 0923; 0922, p. 11.

4.17.2 Exposure Profile and Baseline Conditions

The exposure profile in Table IV.4.17-B includes 33 full-shift personal breathing zone (PBZ) samples of respirable crystalline silica for workers in the Ready-Mixed Concrete industry. The median is 13 μg/m^3, the mean is 338μg/m^3, and the range is 10 μg/m^3 (the limit of detection (LOD)) to 9,804 μg/m^3. Table IV.4.17-B shows that, of the 33 samples, 8 (24.2 percent) exceed 50 μg/m^3.

The following sections describe the baseline conditions and respirable crystalline silica (RCS) exposure levels for each affected job category based on two NIOSH research reports, two OSHA Special Emphasis Program (SEP) inspection reports, and unpublished consultant data obtained from the Georgia and Illinois state consultation programs (Document ID 0214; 0245; 0198; 0095; 1226; 3732, Attachment 3). In addition, OSHA reviewed the OSHA Information System (OIS) compliance sampling data submitted to the docket and identified an additional 12 samples from Ready-Mixed concrete facilities that were added to increase the number of measurements in the exposure profile from 21 in the PEA, to 33 samples presented in Table IV.4.17-B in this section (Document ID 3958).

For each of the job categories listed in Table IV.4.17-A and included in the exposure profile, and for the Ready-Mixed Concrete industry as a whole, OSHA concludes that Table IV.4.17-B represents baseline conditions.

Exposure Profile and Baseline conditions for Material Handlers

The exposure profile in Table IV.4.17-B includes 13 full shift personal breathing zone (PBZ) samples of respirable crystalline silica for material handlers in the Ready-Mixed Concrete industry. The median is 14 μg/m^3, the mean is 31 μg/m^3 and the range is 10 μg/m^3 (the limit of detection (LOD)) to 131 μg/m^3. Table IV.4.17-B shows that, of the 13 samples, 3 (23 percent) exceed 50 μg/m^3.

The 13 full-shift samples obtained were from workers whose job functions include material handling equipment operators, such as front-end loaders operators, of which three were greater than 50 μg/m^3. Of the remaining 10 respirable silica exposure samples, one was between 25 and 50 µg/m^3, and the rest were below 25 µg/m^3 (Document ID 0095, p. 193; 1226, p. 31; 3958).

Of the 13 samples collected for this job category, there are two samples associated with enclosed cabs, two samples that OSHA has assumed are associated with open cabs, and the rest are associated with various or unspecified conditions (Document ID 1720, p. IV-289; 3958). OSHA considers the results summarized in Table IV.4.17-B to represent exposure levels for this job category.

As discussed in other FEA technological feasibility sections, higher exposures to silica can occur if material handling equipment is operated without completely enclosed, sealed, and properly maintained cabs (e.g., one or more cab windows is left open, or ineffective filters are used in a cab air conditioning system). Some material handlers perform other yard-related tasks in addition to the transfer of dry aggregate. Such tasks can include operating a hopper or material conveyor. Depending on the task and the level of dust control, somewhat higher silica exposures can occur. However, OSHA has concluded that these exposures are represented in the overall profile and as discussed below, these exposures can be controlled with water and other dust suppressants within and around the plant.

Post hearing comments submitted by the National Ready-Mixed Concrete Association (NRMCA) are consistent with and support OSHA’s findings that most material handlers currently have a TWA exposure level at or below the new PEL (Document ID 3732, Attachment 4). The NRMCA’s written comments stated that the majority of exposures were currently below the proposed PEL as follows:

> Industry monitoring data from a large ready mixed concrete company with ready mixed concrete plants throughout the Southern and Midwest regions from 2003 through 2012 show . . . [e]xposure for batch plant operators was only 20% of the proposed PEL, maintenance operators was 26%, and material handlers was 32 (Document ID 2305, pp. 9-10).

However, OSHA did not include the industry monitoring data in the Final Exposure Profile since the sample results did not provide sufficient detail on the activities of the workers sampled.

OSHA concludes that the exposure profile in Table IV.4.17-B for material handlers represents the best available information on the exposure levels associated with this job category. Accordingly, OSHA considers the profile to be representative of baseline conditions for material handlers.

Exposure Profile and Baseline conditions for Batch Operators

The exposure profile in Table IV.4.17-B includes 8 full-shift personal breathing zone (PBZ) samples of respirable crystalline silica for batch operators in the Ready-Mixed Concrete industry. The median is 14 μg/m^3, the mean is 22 μg/m^3, and the range is 11 μg/m^3 (the limit of detection (LOD)) to 76 μg/m^3. Table IV.4.17-B shows that, of the 8 samples, 1 (12.5 percent) exceeds 50 μg/m^3.

According to industry contacts, about 90 percent of batch operations are automated, and the associated operator exposure is believed to be minimal (Document ID 1365, p. 13-3; 0966). Although manual batch operations may still occur at some ready-mixed facilities, OSHA was not able to obtain information regarding potential operator exposure to silica during manual batch mixing. An area sample collected beneath a dry-loading hopper considered by the researcher to represent the "worst case" for batch mixers (as well as truck drivers) for a 296-minute sample was 19 μg/m^3 (Document ID 1227), suggesting that silica exposure during manual batch mixing is low.

Using information obtained in NIOSH studies, OSHA SEP inspection reports, and unpublished consultant reports, OSHA finds that baseline conditions for ready-mixed batch operators include working within an enclosed booth or office and that their exposure to silica is typically not detectable or very low (Document ID 0214; 0198; 1226).

NRMCA agreed with OSHA's assessment. NRMCA provided exposure sample results for a large Southeast NRMCA member company, which reflected that all exposures including exposures for batch operators were below 50 µg/m^3 (Document ID 3732, Attachment 4)[95].

OSHA concludes that the exposure profile in Table IV.4.17-B for batch operators represents the best available information on the exposure levels associated with this job category. Accordingly, OSHA considers the profile to be representative of baseline conditions for batch operators.

Exposure Profile and Baseline conditions for Quality Control Technicians

The exposure profile in Table IV.4.17-B includes 4 full-shift personal breathing zone (PBZ) samples of respirable crystalline silica for quality control technicians in the Ready-Mixed Concrete industry. The median is 12 µg/m^3, the mean is 12 µg/m^3, and the range is 11 µg/m^3 (the limit of detection (LOD)) to 12 µg/m^3. Table IV.4.17-B shows that, of the 4 samples, no samples exceeded 50 µg/m^3.

The exposure characterization for quality control technicians is based on two samples reported in one NIOSH-case study (Document ID 0214) and two sample results from OSHA's OIS database. The quality control technician's work tasks included performing office work (100 percent of the work shift on the first day of sampling), dry sweeping the office area, collecting aggregate samples (70 percent of the work shift on the second day of sampling), and conducting offsite visits to construction sites (Document ID 0214, pp. 6, 8). At the construction sites, technicians work primarily with samples of wet or already-cured concrete. Similarly, the two sample results from OIS were below 25 µg/m^3, although the conditions and controls were not reported.

Task-related exposure for quality control technicians is expected to be limited because silica- dust producing activities are often conducted inside a laboratory fume hood (aggregate and concrete testing) or minimized through the use of wet methods, that is, the use of water and other dust suppressants to minimize dust created from yard traffic and other dust generated adjacent to or by the quality control technician. In a NIOSH survey

[95] OSHA assumes that batch operator activities would be represented by either the job category plant operator or loader operator in the data submitted.

of six ready-mixed plants, no silica was detected in a 234-minute area sample obtained in the laboratory of one plant. Road dust from the plant lots was the only apparent source of silica (Document ID 0905, pp. 3, 8). Based on these findings, and considering that baseline conditions include local exhaust ventilation (LEV) in the laboratory and controlling adjacent sources of dust, OSHA has determined that quality control technicians are not likely to be exposed to respirable silica at concentrations that exceed 50 μg/m^3.

OSHA concludes that the exposure profile in Table IV.4.17-B for quality control technicians represents the best available information on the exposure levels associated with this job category. Accordingly, OSHA considers the profile to be representative of baseline conditions for quality control technicians.

Exposure Profile and Baseline conditions for Truck Drivers (when cleaning hardened concrete from mixer)

The exposure profile in Table IV.4.17-B includes 3 full-shift personal breathing zone (PBZ) samples of respirable crystalline silica for truck drivers in the Ready-Mixed Concrete industry. The median is 370 μg/m^3, the mean is 3,467 μg/m^3 and the range is 170 μg/m^3 (the limit of detection (LOD)) to 9,804 μg/m^3. Of the 3 samples, all (100 percent) exceeded 50 μg/m^3.

Truck drivers spend most of the shift on the road delivering concrete, and thus their exposure from sources at the concrete plant or construction sites is normally minimal.[96] However, truck drivers occasionally perform maintenance to remove hardened concrete from the inside of the concrete truck mixing drums. This activity is typically performed

[96] Based on the assumption that truck drivers spend more than 75 percent of the shift (6 of every 8 hours) making deliveries away from the plant, OSHA estimates that typical exposure levels for normal work shifts that do not involve truck drum cleaning would be less than 25 percent of the levels experienced by material handlers in this industry. As indicated in Table IV.4.17-B, the maximum exposure level for material handlers is 57 μg/m^3; 25 percent of that value results in an estimated maximum daily exposure level of about 14 μg/m^3 for truck drivers. While it is possible that some truck drivers occasionally experience some silica exposure at customer sites delivering concrete, OSHA expects that these exposure levels are also minimal because concrete delivery trucks spend only a few minutes at the site (although they might need to wait on an adjacent road until they can be unloaded), and they are typically on the perimeter of the site where construction dust levels are lowest.

twice per year (Document ID 0922, p. 11),[97] but on those occasions, the activity subjects truck drivers to extremely high silica exposure levels. The exposure profile for truck drivers includes only results associated with truck drum cleaning.

Industry representatives agreed with OSHA's conclusion that truck drivers usually would only experience silica-dust exposures during drum chipping. During hearing testimony, Robert Garbini of the NRMCA testified that "the drum chipping is the major area where any worker would be exposed" (Document ID 3589, Tr. 4337). In addition, industry contacts indicate that there is a growing trend for ready-mixed companies to subcontract drum cleaning to outside contractors that specialize in the removal of hardened concrete. Therefore, subcontract employees might be exposed to substantial levels of respirable crystalline silica on nearly a daily basis (Document ID 0922, p. 11; 2024, p. 2; 2305, p. 7).

The exposure profile for truck drivers/specialty contractors is based on three full-shift PBZ samples obtained from a NIOSH research report and unpublished consultant data from the Georgia onsite consultation program (Document ID 0245, pp. 9-10; 1226, p. 31). All three of the sample results exceeded 100 μg/m^3. The highest result (9,804 μg/m^3) was associated with a driver who used a pneumatic chisel to chip (break up) hardened concrete inside a truck mixer for 362 minutes (Document ID 1226, p. 31). Two additional full-shift sample results (170 μg/m^3 and 340 μg/m^3)[98] were based on approximately 90 minutes of chipping time inside truck mixers with a jackhammer (pneumatic hammer) (Document ID 0245, pp. 9-10).

OSHA also reviewed a large number of partial-shift exposure samples, that is, samples conducted for less than 360 minutes, for workers cleaning truck mixers (Document ID 1365, p. 13-3; 1157, pp. D122-D123). The 33 partial-shift sample results range from 69 μg/m^3 to 7,740 μg/m^3, with a median of 770 μg/m^3. Assuming no additional exposure

[97] Results of a 2008-NRMCA benchmarking survey (Document ID 0922, p. 11) showed that mixing truck drums were typically cleaned every 6.7 months (average for more than 6 dozen establishments in the ready-mixed concrete industry that responded to the survey).

[98] The full shift exposure calculations – employee #1 (1,820 x 90 minutes)/480 minutes = 340 and employee #2 full shift calculation (910 x 90 minutes)/480 = 170.

throughout the remainder of the work shift, the 8-hour TWA exposures for the partial-shift samples range from 11 µg/m^3 to 4,894 µg/m^3, with a median of 148 µg/m^3. Seventy-six percent (25 samples) of the 8-hour TWAs exceed 50 µg/m^3, and 67 percent (22 samples) exceed 100 µg/m^3 (Document ID 1365; 1157). These partial-shift results generally support the exposure profile in indicating that most results are well above 50 µg/m^3.

Contactors who perform drum cleaning are included in this exposure profile. Similar to the partial-shift exposure samples discussed above, the workers whose full-shift exposure results of 170 µg/m^3 and 340 µg/m^3 represent only about 90 minutes chipping time inside truck mixers with a jackhammer (Document ID 1226, p. 31). If these workers were to perform this activity throughout the day, at the same exposure level measured during the 90 minute sample, the employee exposures could have been as high as 910 µg/m^3 and 1,820 µg/m^3 (Document ID 1365, p. 13-3).

Truck drivers who remove hardened concrete from inside truck mixer drums rarely use any dust controls (Document ID 1365, p. 13-17; 1157, pp. D122-D123). If mechanical ventilation is used, it usually consists of a fan placed over the charge hopper or within the concrete discharge chute to exhaust air out of the mixer drum (Document ID 1365, p. 13-17). However, daily truck rinsing (after the mixer is completely discharged and again at the end of the day) is an indirect baseline control that affects the amount of concrete buildup and the resulting airborne silica concentrations when truck drivers do eventually chip concrete from mixer drums. All three results in the exposure profile are associated with baseline conditions, including the practice of rinsing the drum to some extent every day (Document ID 1365, p. 13-24). Therefore, OSHA concludes that the median exposure for truck drivers engaged in such hardened-concrete removal and cleaning presented in Table IV.4.17-B (370 µg/m^3) represents the baseline condition for this job category.

OSHA concludes that the exposure profile in Table IV.4.17-B for truck drivers who remove hardened concrete from inside tuck mixer drums represents the best available information on the exposure levels associated with this job category. Accordingly, OSHA considers the profile to be representative of baseline conditions for these truck drivers.

Exposure Profile and Baseline conditions for Maintenance Operators

The exposure profile in Table IV.4.17-B includes 5 full-shift personal breathing zone (PBZ) samples of respirable crystalline silica for maintenance operators in the Ready-Mixed Concrete industry. The median is 11 μg/m^3, the mean is 27 μg/m^3, and the range is 11 μg/m^3 (the limit of detection (LOD)) to 58 μg/m^3. Table IV.4.17-B shows that, of the 5 samples, 1 (20 percent) exceeded 50 μg/m^3.

No silica was detected in three of the five full-shift sample results for maintenance workers. The other two full-shift sample results are somewhat higher (43 μg/m^3 and 58 μg/m^3), but less than 100 μg/m^3 (Document ID 1365, pp. 13-16 – 13-17; 0214, p. 8). These two values reflect work conducted inside the in-plant mixer to remove hardened concrete (with a sledgehammer) during a portion of the work shift.[99] From the information presented in Table IV.4.17-B, OSHA concludes that approximately 20 percent of maintenance workers are exposed to silica at levels exceeding 50 μg/m^3 during such activities. This percentage could be higher if pneumatic tools are used, especially pneumatic chippers and chisels; however, the relative convenience of both rinsing and chipping in-plant mixing equipment (compared with truck drums) means less dusty manual methods often suffice for the in-plant equipment.

Based on information obtained from NIOSH-EPHB 247-19 (2001) and Wickman (2004), OSHA finds that maintenance workers also have the potential for silica exposure while working in the plant yard; while working on or near the aggregate conveyors and batch plant; and during the routine removal of hardened concrete inside the plant mixer (Document ID 1365, pp. 13-16—13-17; 0245; 1227, pp. 2-3). Baseline exposure controls include using water and other dust suppression methods to control adjacent sources of

[99] Facilities use in-plant mixers to mix concrete that is then delivered by many trucks, so an in-plant mixer regularly mixes many more batches than does an individual mixing truck. Furthermore, the in-plant mixers have a more open, accessible design than mixing truck drums (although both can meet the criteria for confined spaces). Maintenance operators tend to chip hardened concrete from the in-plant mixers and while they have potential for short term moderate exposure 90 percent of the time is normally spent in plant areas with far less potential for exposure (Document ID 0214, p. 3).

dust; using LEV at the loading point of the concrete batch mixing drum; and scheduling preventive maintenance activities for nonproduction intervals. No engineering controls are used while removing concrete residues from inside the mixing drum (Document ID 1365, pp. 13-16, 13-20—13-21). All three samples in the exposure profile are associated with these baseline conditions. Therefore, OSHA concludes that the median exposure level for maintenance operators presented in Table IV.4.17-B represents the baseline condition for this job category. OSHA did not receive comments on the potential exposures of maintenance workers at ready mixed facilities.

OSHA concludes that the exposure profile in Table IV.4.17-B for maintenance workers represents the best available information on the exposure levels associated with this job category. Accordingly, OSHA considers the profile to be representative of baseline conditions for maintenance workers.

The following Final Exposure Profile reflects the best data on exposures available to OSHA for workers in the Ready-Mixed Concrete industry.

Table IV.4.17-B
Personal Respirable Crystalline Silica Exposure Range and Distribution of Results for Workers in the Ready-Mixed Concrete Industry (NAICS 327320)

	Exposure Summary			Exposure Range		Exposure Profile				
Ready-Mixed Concrete Industry	**N**	**Mean (μg/m³)**	**Median (μg/m³)**	**Min (μg/m³)**	**Max (μg/m³)**	**<25 (μg/m³)**	**≥25 and ≤50 (μg/m³)**	**>50 and ≤100 (μg/m³)**	**>100 and ≤250 (μg/m³)**	**>250 (μg/m³)**
Material Handler	13	31	14	10	131	9 (69.2%)	1 (7.7%)	2 (15.4%)	1 (7.7%)	0 (0%)
Batch Operator	8	22	14	11	76	7 (87.5%)	0 (0%)	1 (12.5%)	0 (0%)	0 (0%)
Quality Control Technician	4	12	12	11	12	4 (100%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)
Truck Driver (when cleaning hardened concrete from mixer)	3	3,467	370	170	9,804	0 (0%)	0 (0%)	0 (0%)	1 (33.3%)	2 (66.7%)
Maintenance Operator	5	27	11	11	58	3 (60%)	1 (20%)	1 (20%)	0 (0%)	0 (0%)
Ready-Mixed Concrete Industry Total	**33**	**338**	**13**	**10**	**9,804**	**23 (69.7%)**	**2 (6.1%)**	**4 (12.1%)**	**2 (6.1%)**	**2 (6.1%)**

Notes: All samples summarized are personal breathing zone (PBZ) results and represent 8-hour time-weighted average exposures.
Job categories are intended to represent job functions; actual job titles might differ, and responsibilities might be allocated differently, depending on the facility.
Percentages may not add to 100 percent due to rounding.

Sources: Document ID 1720; 3958; 0095; 0198; 0214; 0245; 1226.

4.17.3 Additional Controls

Additional Controls for Material Handlers

The baseline conditions for this job category are associated with a median exposure level of 14 μg/m^3; however, Table IV.4.17-B indicates that 23 percent of material handlers at ready mixed concrete plants experience exposures greater than the new PEL of 50 μg/m^3 and will require additional controls to meet this level. Additional controls for material handlers include the use of properly enclosed, ventilated cabs with air conditioning in conjunction with the use of dust suppression methods. Research conducted by NIOSH of exposures of employees working in these types of cabs in the ready-mixed concrete industry as well as other industries where there were similar material handling tasks found that the use of these cabs reduced respirable dust or silica exposures to levels at or below 50 μg/m^3, that is, by 90 to 97 percent (Document ID 0589, p. 1; 0590; 0214, p. 5; 0898, p. 10; 0884, p. 14).

Some commenters indicated that the use of enclosed cabs was difficult due to communication issues (e.g., Document ID 4217, p. 29). However, during hearing testimony, Robert Garbini further explained how his company effectively uses enclosed cabs and avoids issues with the use of enclosed cabs inhibiting workplace communication by using alternate means of communication. He stated, “What they’re using is the Nextel phones, also hand signals up to the operator and back from the operator down to the closed cab. And a lot of them use walkie-talkies” (Document ID 3589, Tr. 4348). David Bosarge of MMC Materials, Inc., in a post-hearing statement wrote, “MMC Materials strongly encourages all employees to operate their equipment with all windows in a closed position so to minimize their exposure to silica and respirable particulate via this potential route of exposure” (Document ID 2024, p. 3).

Where material handlers perform other yard-related tasks, the use of effective dust suppression methods can reduce silica exposures to at below the PEL. Exposure observations of material handlers at concrete manufacturing facilities that implemented yard-dust management controls, e.g., dust suppressants, wetted yard dust, and/or power sweeping, show that levels substantially below 50 μg/m^3 can be achieved in almost all cases (Document ID 1365, p. 13-19; 0220, pp. 5-10; 0234, pp. 5-6). As shown in Table IV.4.17-B, the highest result for material handlers is 131 μg/m^3. Therefore, OSHA concludes that improvement in cabs, that is, ensuring proper sealing and ventilation, and dust management will achieve material handler exposure levels at or below the PEL of 50 μg/m^3.

Additional Controls for Batch Operators

The baseline conditions for batch operators are associated with median exposure of 14 μg/m^3 and 7 of the 8 full-shift PBZ exposure sample results available for batch operators are below the individual sample LODs and well below 50 μg/m^3. OSHA does not expect that the routine activities of batch operators will result in exposure to silica concentrations in excess of 50 μg/m^3 because the batch operator's workstation, which is usually a booth or office that is typically isolated from plant operations. Therefore, no additional exposure controls are required for most batch operators. (Document ID 1365, p. 13-16).

For batch operators who use manual batching processes (not automated) experience elevated exposures (at approximately 10 percent of facilities)[100], silica levels can be reduced by automating the batching process (including adding an operator's booth) and installing engineering controls such as LEV at the mouth of the concrete batching drum and spray bars on conveyors.[101] As noted previously, automation is the norm for this industry and is already incorporated into the vast majority of plants, approximately 90 percent. Automation and LEV used together, as at a concrete ready-mixed wet/dry batch plant described in NIOSH ECTB 233-101c (1999), reduced batch operator silica exposures to levels less than the LOD (reported as 11 μg/m^3) on two sampling dates, each covering the entire 8- to 9-hour shift. Automation permitted the operator to spend most of

[100] As discussed in the Preliminary Economic Analysis (Document ID 1720, p. IV-291), OSHA estimated the percentage of facilities with automated processes. This was based on industry contacts and supported by the industry profile. OSHA did not receive any comments disputing this assertion.

[101] The LEV system is described as an unflanged, tapered hood (32 inches by 32 inches) with an average face velocity of 480 feet per minute [3400 cubic feet per minute]. The system is powered by a 40-horse power squirrel cage fan and connected to a bag house containing 48 4-inch bags with a reverse pulse jet cleaning system. The bags are changed annually, but inspected for leaks daily (Document ID 0214, p. 5).

the shift in the booth. However, silica results obtained for other workers at this plant suggest that the engineering controls also adequately controlled dust: most silica results for all job categories were below the respective LODs (all 13 μg/m^3 or less) and just one result exceeded the PEL of 50 μg/m^3 (58 μg/m^3 for the maintenance operator who chipped hardened concrete from the in-plant mixer barrel) (Document ID 0214, pp. 5, 7-8).

Additional Controls for Quality Control Technicians

All 4 samples in the exposure profile for quality control technicians are 12 μg/m^3 or less. The data and information available to OSHA suggest that the exposure levels of quality control technicians are currently well below 25 μg/m^3. Additional controls are therefore not required for this job category.

Additional Controls for Truck Drivers/Specialty Contractors

The exposure profile for truck drive/specialty contractor contains 3 samples, all of which exceed 100 μg/m^3, with a median of 370 μg/m^3. The exposure data available to OSHA suggest that most truck drivers who remove hardened concrete inside ready-mixed truck mixers have silica exposure levels greater than 100 μg/m^3 on the rare occasions when they perform this task (e.g., twice per year).[102] Many of these exposures are of short duration and high intensity with some exposures approaching 10,000 μg/m^3. Additional controls are required to reduce the exposures or truck drivers or contractors, who specialize in the removal of hardened concrete while they remove hardened concrete from inside truck mixers with pneumatic tools. As further discussed below, these controls currently include: 1) wet methods, 2) mechanical ventilation, 3) a combination of wet methods and mechanical ventilation, and 4) administrative controls.

OSHA has determined that the truck drivers' activities other than drum chipping do not generate appreciable exposures to silica. For example, over the past 10 years, MMC Materials, which subcontracts out 100 percent of drum chipping to specialty contracts, found that their employees who were monitored for their exposure to respirable silica (as

[102] Contractors that perform this work would experience the same exposures more frequently.

quartz) and respirable particulate had TWA exposures below the laboratory's level of quantification and thus the corresponding OSHA PEL (Document ID 2024, p. 2). OSHA has therefore determined that additional controls are only necessary for the removal of hardened concrete inside ready-mixed truck mixers. The control options for this activity are discussed in the paragraphs below.

Wet Methods

Wet methods for dust control during mixer cleaning include spraying the drum interior with water before and during cleaning and/or using a pneumatic tool equipped with a water spray nozzle. Exposure reductions associated with this method of control range from 70 to 98 percent and are discussed in detail in the report by OSHA's contractor ERG (2008), which reviewed the literature. ERG also discussed the possible constraints associated with the use of wet methods such as freezing weather, slip hazards, and electrical hazards (Document ID 1365, pp. 13-20 – 13-23). In response to a question inquiring about the availability and prevalence of the use of water nozzled chipping hammers to remove harden concrete from mixer trucks by NRMCA members, Robert Garabini of the NRMCA agreed their use was prevalent (Document ID 3589, Tr. 4331).

The Illinois Ready Mixed Concrete Association (IRMCA) Industrial Hygiene Study reported that a handheld pneumatic chipper equipped with a water supply hose and spray nozzle reduced worker exposure to silica by 70 percent during concrete truck drum cleaning (Document ID 3732, Attachment 3, p. 14). Workers periodically sprayed the interior surface of the drum and had a continuous water spray directed at the chisel point during chipping. The operator adjusted the water flow rate, which was described as a controlled mist that did not generate excess water. Williams and Sam further reported that workers were very comfortable using the water-equipped chipper and that all workers noticed a substantial reduction in dust during chipping (Document ID 1136, p. 2). When using this technique, all electrical cords connected to lights or fans near the drum must be plugged into a ground-fault circuit interrupter (Document ID 3723, Attachment 3).

The use of high pressure and ultra-high pressure water-blasting (or water-jetting) is an optional cleaning procedure that could be an effective alternative for some ready-mixed concrete companies. High-pressure pump manufacturers market water-jetting cleaning applications for the interior and exterior of concrete mix trucks (Document ID 1247; 0695). Additionally, a single-operator, ultra-high pressure-water-wash system for removing hardened concrete inside mixer drums was recently commercialized (Document ID 0556). The boom-mounted washer is operated wirelessly from a work platform. No human entry into the mixer drum is required, eliminating the dangerous and labor-intensive job of chipping away dried concrete by hand (Document ID 0556). Limited PBZ sampling conducted by the company in 2009 demonstrated that use of this system substantially reduced silica exposures from cleaning the interior of mixer drums. Six partial-shift PBZ dust samples (three total dust and three respirable dust samples with sampling durations of 60, 80, and 95 minutes) obtained during demonstration tasks, which represent moderate-to-worst case potential daily exposure, yielded no detectable amounts of silica on any of the samples (Document ID 0557).[103] OSHA observes that the maximum concentration of respirable dust of 150 µg/m^3 measured during these test periods suggests that even if silica had been present on the sample filter as a relatively high percentage (e.g., 25 percent)[104] of the respirable dust, the maximum concentration of silica would have been 38 µg/m^3 during periods of intensive drum cleaning.

In their comments, the NRMCA described a process of truck cleaning which eliminates the need for entering the mixer to chip dried concrete. Instead, a specially designed water spray nozzle can be inserted into the mixer to remove dried cement with high pressure water (Document ID 3589, Tr. 4338).

Mechanical Ventilation

Investigators have evaluated various types of mechanical ventilation (LEV, general exhaust ventilation, forced dilution ventilation, and LEV in combination with general

[103] OSHA notes that although silica was not detected, depending on the method used to obtain the samples, the LOD could be as high as 100 µg/m^3 for the samples with the shortest duration.

[104] The hypothetical “worst case” value of 25 percent silica in the sample is approximately twice the level reported in respirable dust during truck drum cleaning. NIOSH found 7 to 13 percent silica in respirable dust air samples obtained over 6 days for truck drivers chipping concrete from mixing truck barrels on two dates (Document ID 0245). Strelec (2008) reported 7.6 and 16 percent silica in respirable dust samples obtained during truck drum cleaning (Document ID 1157, p. D123).

exhaust ventilation) alone or in combination with wet methods. For example, in an evaluation of ventilation techniques for cleaning residual concrete from ready-mixed truck drums, NIOSH investigators found that workers who used general exhaust ventilation alone reduced silica concentrations by 25 percent (from 970 $\mu g/m^3$ to 730 $\mu g/m^3$) (Document ID 0245, p. 11).

The most substantial silica reductions obtained using exhaust ventilation are associated with test scenarios that provided workers with: 1) a combination of LEV-equipped chipping tools and general exhaust ventilation, which achieved a 78 percent reduction in geometric mean, from 970 $\mu g/m^3$ to 220 $\mu g/m^3$ (Document ID 0245, p. 12); or 2) forced dilution ventilation alone, which resulted in an 81 percent reduction in the median respirable quartz level (reduced from 5,378 $\mu g/m^3$ to 1,029 $\mu g/m^3$ as calculated from results obtained by Wickman et al. [2003]) (Document ID 1226, p. 31; 1365, p. 13-22).[105] The median respirable silica reading obtained for three samples (3,401 $\mu g/m^3$, 5,378 $\mu g/m^3$, and 7,677 $\mu g/m^3$) where no controls were used was 5,378 $\mu g/m^3$. Sample durations were 315, 210, and 306 minutes, respectively. When forced dilution ventilation was evaluated, the median respirable quartz reading obtained for four samples was 1,029 $\mu g/m^3$ (493 $\mu g/m^3$, 997 $\mu g/m^3$, 1,061 $\mu g/m^3$ and 1,301 $\mu g/m^3$). Sample durations for the forced dilution ventilation samples were 277, 71, 289, and 62 minutes, respectively (Document ID 1365, p. 13-22). However, the placement of fans was critical and is not effective if air flow direction moves contaminated air across workers' breathing zones (Document ID 3732, Attachment 3). As discussed below, while there was a substantial reduction in exposures with the use of mechanical ventilation, OSHA concludes that it is highly unlikely that the use of this control exclusively will reduce exposures to at or below the PEL.

Combined Control Methods

Strelec (2008) described a ready-mixed concrete facility where a combination of engineering controls, including a water misting device and a push/pull ventilation system, reduced breathing zone silica results (Document ID 1157, p. D123). Although the silica

[105] The respirable silica exposure was calculated by multiplying the total respirable dust TWA by the percent silica in the sample.

level decreased from 1,264 μg/m^3 to 128 μg/m^3, the result still exceeded OSHA's previous general industry PEL. At the time of OSHA's initial inspection (exposure levels 1,264 μg/m^3), the facility, which employed 33 truck drivers, had hired two workers from a local temporary employment agency to remove concrete from multiple truck drums (Document ID 1157). These exposures were those of the temporary workers. Based on information presented by the author, OSHA estimates that the engineering controls, the reduced level of silica in the dust, and other worksite factors contributed in equal measure to the change in silica exposure level.[106] OSHA estimates that the use of controls discussed above reduced the total dust exposures by approximately 78 percent.

The report further recommends the use of the following methods to minimize employee exposure when chipping the drum:

1) Hatch of drum open
2) Place box fan horizontally in hopper
3) Set on high speed and exhaust the air flow out of the drum
4) Use chipping hammer equipped with water spray nozzle
5) Initially spray the entire inner surface of the drum with water
6) Adjust the water spray so that it is aimed at the point of the chisel
7) Ensure water sprays at all times when the chipper is in operation
8) If during the cleaning procedure, concrete surfaces dry to the point that dust is being generated while chipping, the surface should be re-sprayed with water (Document ID 3732, Attachment 3, p. 9)

Illinois Ready Mixed Concrete Association (IRMCA) presented data that indicated that the use of the combination of controls listed above (including water spray nozzle attached to the chipper) can reduce workers' exposures to at or below the PEL of 50 μg/m^3.

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[106] OSHA calculated the 8-hour TWA concentration of the workers' silica exposure based on the 8-hour TWA respirable dust concentration and the percent quartz in the respirable dust, both provided by Strelec (2008). Before controls, respirable dust was 7,900 μg/m^3 (7.9 mg/m^3) containing 16 percent quartz (1,264 μg/m^3 silica). After controls were initiated, respirable dust was 1,690 μg/m^3 (1.69 mg/m^3) containing 7.6 percent quartz (128 μg/m^3 silica). The percent reduction of exposure to total dust is 78 percent ((7,900-1,690)/7,900) (Document ID 1157, p. D123).

However, this is dependent on the percent silica in the concrete and the duration of the task being less than 2 hours (Document ID 3732, Attachment 3, p. 16).

The IRMCA Industrial Hygiene Study indicates that the truck mixer drums meet OSHA's definition of a confined space as defined by 29 CFR 1910.146 (Document ID 3732, Attachment 3). The OSHA *Pocket Guide Worker Safety Series Concrete Manufacturing (No. 3221)* states that ready-mix trucks have confined spaces that pose safety risks for workers. Employers will need to assess how the standard applies to their specific situation including the appropriate procedures, PPE, respirators, and ventilation. However, the controls discussed in this section to reduce exposures to silica are compatible with §1910.146.

Administrative Controls

Administrative controls primarily include implementing good mixer drum rinsing procedures and increasing the frequency of rinsing to prevent or reduce the amount of concrete buildup. Good drum rinsing procedures include a rinse after each load is poured and a triple rinse at the end of each work shift (Document ID 3732, Attachment 3, p. 9). Additionally, Williams and Sam (1999) reported that construction site conditions can cause a driver to pour concrete from the truck slowly, which can result in excess concrete beginning to harden on the drum wall. In that case, three-quarters-inch aggregate loaded into the drum and rotated for 30 minutes will scour the hardening concrete from the inner surface of the drum and reduce the amount of buildup (the aggregate can then be used in the next batch of concrete) (Document ID 1365, p. 13-24).

OSHA concludes work practices that reduce the amount of concrete buildup in drums will reduce the amount of time required later to remove the hardened concrete from the drum. All other factors being equal, a shorter period of drum cleaning during the shift will result in a correspondingly lower full-shift silica exposure level.

Additional Controls for Maintenance Operators

Although the exposure data available to OSHA suggest that 80 percent of maintenance operators in this industry have silica exposures less than 50 $\mu g/m^3$, as discussed above, one situation in particular can result in higher levels. Additional controls are required where maintenance operators experience elevated exposures while removing hardened concrete from inside plant mixer drums. The controls available for in-plant concrete mixers are similar to those for concrete mixer trucks. Such controls include the use of polyurethane drum liners, good rinsing procedures to remove residual concrete before it dries and builds up, increasing the frequency of mixer cleaning, wet methods, and various types or combinations of mechanical ventilation when hardened concrete must be chipped from drums. Wet methods and mechanical ventilation controls applicable to maintenance operators are described in the earlier discussion on truck drivers (see discussion under the heading Additional Controls for Truck Drivers/Specialty Contractors) (Document ID 1365, p. 13-23).

Polyurethane drum liners are available for plant mixers and reportedly reduce the buildup of hardened concrete. Industry sources indicate that polyurethane-lined drums generally require weekly rather than daily clean out. Reducing the amount of concrete buildup should reduce worker exposure to silica during cleaning because less time will be required to remove the buildup (Document ID 1365, p. 13-26). OSHA was unable to obtain exposure data demonstrating the potential reduction in silica exposure that might be achieved from use of polyurethane-lined drums in plant mixers.

As noted with truck mixer drums, increasing rinse frequency and using good drum rinsing procedures (e.g., rinsing mixers with high pressure water after each batch of concrete) minimizes concrete buildup and the amount of cleaning required to remove hardened concrete (Document ID 1365, p. 13-24). In turn, the reduced cleaning time should reduce exposure to silica.

Depending on the method utilized, the additional controls described for truck drivers reduced silica exposures by 25 to 98 percent during drum cleaning. For example, in an evaluation of ventilation techniques for cleaning residual concrete from ready-mixed truck drums, NIOSH investigators found that workers who used general exhaust ventilation alone reduced silica concentrations by 25 percent, from 970 μg/m^3 to 730 μg/m^3 (Document ID 0245, p. 11). Assuming that this control would reduce exposure to maintenance operators cleaning plant mixers by a similar amount, OSHA expects that the highest levels reported in the exposure profile for maintenance operators removing hardened concrete with a sledge hammer (43 μg/m^3 and 58 μg/m^3) would be reduced by 25 percent to values at or below 50 μg/m^3 (32 μg/m^3 and 44 μg/m^3, respectively).

4.17.4 Feasibility Finding

In written comments, Robert Garbini, the President of NMRCA, described the management practices currently used to minimize exposure to silica dust in their industry as follows:

> To further ensure a safe and healthy work environment, common and best management practices at ready mixed concrete plants consist of wetting aggregates and driveways, keeping truck and loader cabs in good condition, closed building and vehicle windows with air conditioners and heaters, minimal sweeping, dust ventilation systems, strict adherence to confined space regulations, PPE and frequent worker training (Document ID 2305, p. 10).

Sampling data submitted to the record by the NRMCA to characterize worker exposure to crystalline silica at a large southeast ready-mix concrete producer indicated exposure to at or below the PEL. Out of approximately 90 samples comprising the defined position descriptions of Loader, Mechanic, Operator and Driver, no sample was above the final PEL (Document ID 3732, Attachment 4).

Feasibility Finding for Material Handlers

Based on the available information, OSHA finds that most material handlers (69 percent) in this industry are currently exposed to silica at levels less than 25 μg/m^3. Only 23 percent of the 13 samples in the exposure profile exceed the revised PEL of 50 μg/m^3. For these workers, OSHA concludes that the primary option for reducing exposure to levels at or below the PEL is the use of enclosed operator cabs that are well sealed and ventilated with positive pressure and filtered air. An additional option that will reduce exposures to levels at or below 50 μg/m^3 is the application of effective dust suppression methods in yards and during raw material handling, exclusively or in conjunction with enclosed operator cabs.

As discussed above, NIOSH research indicates that the use of enclosed operator cabs reduced respirable dust or silica exposures to levels at or below 50 µg/m^3, (Document ID 0589; 0590; 0214; 0898; 0884). Exposure observations for material handlers at concrete manufacturing facilities that implemented yard dust management controls show that levels substantially below 50 µg/m^3 were achieved in almost all cases (Document ID 1365, p. 13-19; 0220; 0234).

Upon OSHA's final review of exposure data and baseline conditions for material handlers including associated engineering and administrative controls, OSHA concludes that material handlers can achieve exposures at or below 50 µg/m^3 most of the time with the control methods described in this section.

Feasibility Finding for Batch Operators

The available exposure data indicate that most batch operators are not exposed to silica levels in excess of 25 µg/m^3. Seven of the 8 samples in the exposure profile were less than 25 µg/m^3. Additional exposure controls do not appear to be necessary for this job category. However, in the event that a batch operator is exposed to elevated levels of silica, for example, because of dust levels at the central mix area or dust tracked into the batch operator's work station, the facility can achieve exposures of 25 µg/m^3 or less for that worker by improving housekeeping and seals on the operator's booth or by improving maintenance on dust controls in the central mix area.

Upon OSHA's final review of exposure data and baseline conditions for batch operators including associated engineering and administrative controls, OSHA concludes that batch operators can achieve exposures of less than 50 µg/m^3 most of the time with the control methods described in this section.

Feasibility Finding for Quality Control Technicians

Based on the available information, OSHA does not expect that the routine activities of quality control technicians will generate exposures that exceed 25 µg/m^3. Additional exposure controls do not appear to be necessary for this job category. However, if technicians are exposed to silica while obtaining samples in the raw materials storage areas, their exposure will be reduced when exposures in other job categories are controlled. Other control options for these workers include: implementing administrative policies that allow quality control technicians to avoid dusty plant process areas until dust subsides and adding LEV (e.g., a laboratory fume hood) in the laboratory.

Upon OSHA's final review of exposure data and baseline conditions for quality control technicians including associated engineering and administrative controls, OSHA concludes that quality control technicians can achieve exposures of less than 50 μg/m^3 most of the time with the control methods described in this section.

Feasibility Finding for Truck Driver/Specialty Contractors

As indicated in Table IV.4.17-B, the silica levels of all truck drivers are greater than 100 μg/m^3 only on the rare occasions (e.g., twice per year) when the truck drivers chip hardened concrete from their truck mixing drums. However, it is much more common for this work to be conducted by contractors who move from plant to plant chipping concrete from truck drums as reflected in the comment described above (Document ID 2024, p. 2).

OSHA concludes that the exposure levels of most truck drivers engaged in chipping cement off the inside walls of mixing drums can be reduced to silica levels that fall between approximately 100 μg/m^3 and 500 μg/m^3 when this activity is performed over an entire shift This range of exposure levels has been achieved by several investigators using various combinations of controls for workers who spent at least half of the sampling period (and usually the entire period) chipping concrete from inside truck mixing drums. The combination of controls described here will reduce most workers' exposures during truck drum cleaning but will not eliminate the need to provide supplemental respiratory protection to reduce exposures to at or below the PEL.

Examples of controls used to controls dust while chipping out hardened concrete from truck drums and the associated exposure levels are as follows:

- LEV-equipped chipping tool plus general exhaust ventilation: Silica levels reduced to 220 μg/m^3 (Document ID 0245, p. 12).

- Water misting device and push/pull ventilation system: Silica levels reduced to 128 µg/m^3 (Document ID 1157, p. D123).
- Periodic spraying of the interior surface of the drum and directing continuous water spray at the chisel point during chipping kept silica levels reduced to less than 100 µg/m^3 or somewhat less (Document ID 1365, pp. 13-21, 13-25).

IRMCA showed that with the use of a combination of administrative controls to minimize the build up of hardened concrete from the truck-mixing drum and the use of a combination controls as discussed above, including forced air dilution ventilation, for short duration jobs (under 2 hours), can reduce truck driver exposures to at or below 50 µg/m^3 (Document ID 3732, Attachment 3, p. 16). Alternative cleaning techniques, such as high- or ultra-high-pressure water blasting, which is available from a single-source supplier, might also be effective under some circumstances.

OSHA concludes that the same controls that will reduce the exposures for truck drivers will reduce exposures for specialty contractors while chipping hardened concrete from the truck mixing drums. However, due to the increase duration of performing this activity, specialty contractors may experience higher exposures then the truck drivers who may perform this activity for short durations and may need respirators in addition to engineering controls to reduce exposures to at or below the PEL.

OSHA concludes that most truck drivers that only occasionally (e.g., twice per year) enter and clean the interiors of mixer drums to remove hardened concrete can achieve exposure at or below the 50 µg/m^3 PEL if the job is less than two hours. However, for specialty contractors or truck drivers that spend a larger portion of their shift chipping hardened concrete from the truck mixing drum, the use of supplemental respiratory protection may be necessary.

Upon OSHA's final review of exposure data and baseline conditions for truck drivers and specialty contractors including associated engineering and administrative controls, OSHA concludes that truck drivers and specialty contractors can achieve exposures of less than 50 µg/m^3 most of the time with the control methods described in this section.

Feasibility Finding for Maintenance Operators

OSHA finds that the exposure levels of 80 percent of maintenance operators are currently well below 50 µg/m^3. By using one or more of the additional controls described in this section, the remaining operators will achieve results at or below 50 µg/m^3. Appropriate controls include using polyurethane drum liners, employing good rinsing procedures to remove residual concrete before it dries and builds up, increasing the frequency of mixer cleaning (to reduce the amount of hardened concrete that needs to be removed), using forced dilution or general exhaust ventilation, and using pneumatic tools equipped with LEV or a water spray. Alternative cleaning techniques, such as high- or ultra-high-pressure water blasting, also might effectively control worker exposures to silica during in-plant mixer cleaning and eliminate the need to send workers inside the mixer to manually remove hardened concrete buildup. Substantially higher exposure levels that might be associated with the use of pneumatic tools to clean in-plant mixers would require the same controls or combinations of controls as outlined for truck drivers.

Upon OSHA's final review of exposure data and baseline conditions for maintenance operators including associated engineering and administrative controls, OSHA concludes that maintenance operators can achieve exposures of less than 50 µg/m^3 most of the time with the control methods described in this section.

Overall Feasibility Finding

Based on OSHA's analysis of the available monitoring data and industry comments, OSHA concludes that material handlers, batch operators, quality control technicians, and maintenance operators can achieve exposures of less than 50 µg/m^3 most of the time with the controls described in this section. OSHA also concludes that most truck drivers that only occasionally (e.g., twice per year) enter and clean the interior of a mixer drum to remove hardened concrete can achieve exposure to at or below the PEL if the job is less than two hours through the use of a combination of administrative controls (minimizing the amount of harden concrete) and engineering controls such as LEV and water spray as described above. However, for specialty contractors or truck drivers that spend a larger portion of their shift chipping hardened concrete from the truck mixing drum, the use of supplemental respiratory protection may be necessary.

The available monitoring data presented in Table IV.4.17-B indicate that overall 76 percent of the samples are already at or below the PEL of 50 $\mu g/m^3$. For the workers currently exposed above 50 $\mu g/m^3$, the engineering and administrative control measures described in this section can, in most cases, reduce exposures to 50 $\mu g/m^3$ or less. Accordingly, OSHA finds the final PEL of 50 $\mu g/m^3$ is technologically feasible in the Ready-Mixed Concrete industry.

4.18 REFRACTORIES

4.18.1 Description

Facilities manufacturing refractory products are classified in the 2007 six-digit North American Industry Classification System (NAICS) codes 327124, Clay Refractory Manufacturing, and 327125, Nonclay Refractory Manufacturing.[107] Silica-containing materials are used in these industries to produce a wide range of heat-resistant products. Refractory products include oven and furnace linings, materials used for casting molten substances (metals and glass), and insulation for high-temperature processes and equipment.

The manufacturing facilities in this industry typically produce one or more of the following three distinct product forms: 1) pre-formed refractory items such as fire bricks and custom shapes; 2) glass-like refractory ceramic fibers (RCF);[108] and 3) unshaped powder products, called monolithic refractories. The monoliths are typically sold in sacks and intended to be either cast in place or applied as mortars or coatings at customer facilities (Document ID 1365, p. 14-1; 0965, p. 1; 1392, pp. 25, 31-32).

Within each of these general forms, a variety of product types exist, including refractories based on compounds of silica, aluminum, chromium, magnesium, or other minerals. Some examples of common raw ingredients for refractory materials include aluminum silicate clays, aluminum oxide ore, chromium compounds, ceramic frit, ground quartz, and calcined materials (the calcining process can convert any amorphous silica to cristobalite).[109] Refractory materials contain silica either as a key component or as a minor contaminant depending on the temperature the refractory material needs to withstand. For example, high silica-based refractory products, often referred to as high-

[107] The applicable 2012 NAICS code is 327120, Clay Building Material and Refractories Manufacturing.

[108] Refractory ceramic fiber production accounts for approximately 1 percent (80 million pounds per year) of the total U.S. man-made vitreous fiber manufacture. In total, about 800 workers are involved in RCF manufacturing (Document ID 0965, p. 2).

[109] Cristobalite is a type of crystalline silica with an existing PEL equivalent to 50 μg/m^3 (29 CFR 1910.1000 Table Z-3).

duty brick, can contain upwards of 50 percent silica and are able to withstand higher temperatures. High aluminum clay refractory products, often referred to as low-duty brick, might only contain a fraction of a percent of silica (Document ID 1365, p. 14-1; 0266, pp. 4-5).

One commenter noted that her company produced a low duty, or low temperature, refractory brick using clay that contained 29 percent quartz (i.e., silica). She commented that this brick was made of clay only and was no different from clays used in clay brick manufacturing. OSHA notes that during the public hearings representatives from the structural clay brick industry confirmed that structural brick typically contains "10 through to 30-odd percent" free silica (Document ID 3577, Tr.704). She further noted that their low duty refractory brick does "not contain additional additives such as pitch, chromium, resins, or other organic additives that higher temperature-performance refractory brick typically include[s]" (Document ID 3731, p. 1).

Additionally, this industry recycles a substantial amount of fired refractory material for use in new product. The fired refractory material may add additional amounts of silica in the form of cristobalite. As a result of this wide variability in composition, silica exposure can be variable from day to day and product to product within an individual production facility (Document ID 1365, pp. 14-1 – 14-2).

Workers are potentially exposed to silica throughout all phases of production: when they manually manipulate and mix silica-containing raw ingredients; use dry casting methods to form bricks and shapes; finish cast shapes with grinders and saws; charge or tend melting furnaces used to form ceramic fibers; and package dry powdered refractory materials. See Table IV.4.18-A for a description of the major activities and sources of exposures for affected job categories (material handler, forming operator, finishing operator, ceramic fiber furnace operator, and packaging operator). OSHA notes that the raw materials, job activities, and production methods used in this industry are similar to those employed by the Structural Clay Products, Concrete Products, Glass Products, and Pottery Products industries (also described in the respective sections of this report: IV-4.21, IV-4.3, IV-4.9, and IV-4.15).

4.18) Refractories

Table IV.4.18-A **Job Categories, Major Activities, and Sources of Exposure of Workers in the Refractories Industry** **(2007 NAICS 327124 and 327125)**	
Job Category*	**Major Activities and Sources of Exposure**
Material Handler	Operating forklifts and loaders to transport materials; transferring, weighing, and dumping raw materials by hand or using automated equipment; charging and operating mixing and milling machines. • Dust from manual emptying of bags of silica-containing materials into batch bins, hoppers, mixers, and milling machines. • Dust disturbed during transfer of silica-containing materials using open conveying equipment. • Dust released while operating unventilated, open mixing, or blending equipment.
Forming Operator	Transferring dry or wet mixed ingredients into molds and compacting using automated or manually operated equipment; removing formed product from molds; cleaning molds. • Dust that becomes airborne during compacting of dry silica-containing ingredients using vibrating machinery or mechanical presses. • Dust disturbed during cleaning of molds, surfaces, and floors using brooms or compressed air. Using automated processes to extrude and cut refractory clay brick. • Dust from spilled clay and handling dried bricks (unfired).
Finishing Operator	Cutting, shaping, and grinding products by hand or with semi-automated equipment. • Dust from grinding and sawing fired products by hand or with automated equipment. • Dust disturbed during cleaning of floors and surfaces using brooms or compressed air.
Ceramic Fiber Furnace Operator	Charging melting furnaces with silica-containing ingredients and raking raw materials; operating fiber production equipment; performing housekeeping in the furnace area. • Dust released while charging furnaces with raw materials.[110] • Dust disturbed during cleaning of floors and surfaces using brooms or compressed air.
Packaging Operator	Filling bags with loose, dry powder or aggregate products using automated or semi-automated equipment; handling filled bags manually or using automated equipment. • Dust escaping from bag packing equipment. • Dust emitted from newly filled bags during stacking and palletizing activities. • Dust disturbed during cleaning of floors and surfaces using brooms or compressed air.
*Job categories are intended to represent job functions; actual job titles might differ, and responsibilities might be allocated differently, depending on the facility. Source: Document ID 1365, pp. 14-3 – 14-6.	

[110] Newly manufactured RCF contain little or no silica. Thus, handling raw ingredients presents the greatest opportunity for exposure to silica. Once the raw ingredients are melted (to the amorphous form), silica exposure is unlikely to occur.

In a follow-up response to questions asked during the public hearings, one small business noted that approximately 70 percent of its work force performed tasks that would be subject to the proposed rule. These employees were categorized as grinders, kiln firemen, unloaders, maintenance workers, shippers, blenders, press operators, and plant supervisors. This commenter also noted that they tumble fired brick (a process that involves "running the bricks through a rotating cylinder so they bump against the sides and each other," to give them an "old world appearance") and crush out-of-spec brick (Document ID 3731, pp. 1-2). OSHA believes that each of these duties would fall within the job categories described in Table IV.4.18-A. OSHA received no other comments regarding job categories or activities that present the potential for silica exposures in this industry.

For each of the job categories listed in Table IV.4.18-B and included in the exposure profile, and for the refractories industry as a whole, OSHA concludes that Table IV.4.18-B represents baseline conditions.

4.18.2 Exposure Profile and Baseline Conditions

The exposure profile in Table IV.4.18-B includes 63 full-shift personal breathing zone (PBZ) samples of respirable crystalline silica for workers in the refractories industry. The median is 23 $\mu g/m^3$, the mean is 47 $\mu g/m^3$, and the range is 10 $\mu g/m^3$ to 526 $\mu g/m^3$. Table IV.4.18-B shows that, of the 63 samples, 14 (22.2 percent) are above 50 $\mu g/m^3$ and 7 (11.1 percent) exceed 100 $\mu g/m^3$.

OSHA's exposure profile in the PEA for the refractories application group included monitoring data from OSHA Special Emphasis Program (SEP) inspection reports and NIOSH reports on silica exposure in refractory product manufacturing facilities and analogous operations. Each of the facilities covered in these reports produces multiple product forms (e.g., shapes or bricks, ceramic fibers, packaged monolithic refractory materials) (Document ID 1365, pp. 14-6 – 14-7; 0193, pp. 5-6; 0089, p. 29; 0266, p. 3; 1720, pp. IV-305-310). In the final exposure profile presented in Table IV.4.18-B, OSHA supplemented this data with 12 sample results at three facilities from the OSHA Information System (OIS) for material handlers (3 samples), forming operators (8 samples), and packaging operators (1 sample) (Document ID 3958, Rows 525-531,822, 824, 960-962).[111] Exposure monitoring data for each job category are discussed in detail below.

Exposure Profile and Baseline Conditions for Material Handlers

The exposure profile in Table IV.4.18-B includes 30 samples for material handlers in the refractories industry. The median is 32 μg/m^3, the mean is 71 μg/m^3, and the range is 12 μg/m^3 to 526 μg/m^3. Table IV.4.18-B shows that, of the 30 samples, 12 (40 percent) are above 50 μg/m^3 and 6 (20 percent) exceed 100 μg/m^3.

The 30 samples were obtained at five facilities (the three facilities included in the Preliminary Economic Analysis (PEA) exposure profile, as well as two of the three facilities covered in the OIS data) during manufacture of a variety of products (shapes, bricks, fibers, aggregate) (Document ID 1365, p. 14-8; 0193, pp. 25-27, 36, 58; 0089, pp. 43-46, 53-57, 63-67, 72; 0266, pp. 14-15; 3958).

The 6 samples above 100 μg/m^3 were obtained from three separate facilities and are associated with manual bag dumping (Document ID 0089; 0193; 0266). These 6 samples range from 120 μg/m^3 to 526 μg/m^3, with a median of 164 μg/m^3 and mean of 220 μg/m^3. Quartz values were reported for all of these samples, but 1 sample contained cristobalite as well. The result for this sample was 170 μg/m^3 of total silica;[112] however, the report offered no information on the percentages of these types of silica in the materials that this worker handled. Total respirable dust concentrations associated with these 6 elevated samples range from 3.0 mg/m^3 to 11.0 mg/m^3, suggesting incomplete dust control during the bag dumping task at all three facilities (Document ID 1365, pp. 14-8 – 14-9; 0193, p. 58; 0089, p. 72; 0266, p. 14). At one of the facilities, NIOSH indicated that the “area was equipped with a dust control ventilation system,” but that its use was “not a regular occurrence,” and that “dust was dispersed from holes in the duct elbows” that had been

[111] One sample was excluded from the exposure profile because the worker was performing unrelated tasks (Document ID 3958, Row 823).

[112] Sample was composed of respirable cristobalite at 100 μg/m^3 and respirable quartz at 70 μg/m^3. Where cristobalite and quartz are identified in a sample, values are added together to create a total silica result.

worn through by abrasion. The report did not, however, indicate which samples (if any or all) were associated with local exhaust ventilation (LEV) at the workstation (Document ID 0266, p. 6).

Although several silica samples below 25 μg/m^3 were obtained for workers dumping bags at some of the same workstations where elevated samples were obtained, these values were generally associated with handling of materials with very low silica levels (i.e., silica levels below the limit of detection (LOD), which was less than 1 percent in the sample) and lower total respirable dust concentrations (between 1.0 mg/m^3 and 3.0 mg/m^3) (Document ID 1365, pp. 14-8 – 14-9; 0193, p. 35; 0089, pp. 63-67, 72; 0266, pp. 14-15). These findings likely represent variations in work practices or respirable-size silica content of materials dumped.

Two respirable silica samples from a separate facility (included from the OIS data) were also for material handlers dumping bags into the hopper or adding materials into the blend. Both samples were below the LOD of 12 μg/m^3. While information was not available regarding the silica content of the material, both were associated with lower total respirable dust concentrations (0.230 mg/m^3 and 2.3 mg/m^3 compared to 3.0 mg/m^3 to 11.0 mg/m^3 mentioned above) indicating that the operations were generally not dusty or were well controlled (Document ID 3958). Other silica samples below 25 μg/m^3 in the exposure profile for material handlers include operating transportation equipment (e.g., forklift, mullite dump truck), overseeing automated material conveyance, and working at a brick crusher (Document ID 1365, p. 14-9; 0266, p. 14; 3958).

Three of the five facilities had LEV installed for some of their mixing and charging operations (the other two facilities provided general dilution ventilation for all but one of the observed operations). The 4 samples for material handlers definitively associated with LEV are less than or equal to 14 μg/m^3 (the LOD), 36 μg/m^3, 53 μg/m^3, and 87 μg/m^3 (Document ID 0089, pp. 53-57, 63-67, 72; 0193, pp. 25-32).[113] However, the LEV air

[113] Results reported as “none detected” are assigned a value equal to the LOD. The LOD is determined individually for each sample based on the volume of air sampled and the method used to analyze the sample, therefore, the limit of detection varies between samples. See Section IV-2–Methodology for additional information on LODs.

velocity provided at one of the facilities was below that recommended by ACGIH (2010) (Document ID 1365, p. 14-14; 3997; 0089, pp. 53, 63). The 2 OIS samples associated with general dilution ventilation were both below the LOD of 12 μg/m^3.

The only information OSHA received regarding baseline conditions for material handlers during the public comment period was a follow-up response to questions asked during the public hearings. One small refractory brick manufacturer noted that its material handler also crushes "out of spec" brick. Although the commenter did not provide exposure data or a detailed description for this task, they did note that the task was done under a water spray, which was monitored due to EPA requirements (Document ID 3731, p. 2).

Based on the available data, OSHA has determined that baseline conditions for material handlers include routine manual bag dumping, and operating forklifts and loaders to transport materials. Ventilation systems for mixing and dumping equipment, if available, have been observed to function sub-optimally (Document ID 1365, pp. 14-14 – 14-16; 0089, pp. 19, 27-33, 133-139; 0266, pp. 6, 8, 10-13). Although OSHA requested additional exposure data for material handlers in refractories industries during the public comment period, it did not receive any. OSHA has determined that the exposure profile for material handlers summarized in Table IV.4.18-B, which was obtained from the best available evidence, and shows a range of exposures from 12 to 526 μg/m^3, with a median of 32 μg/m^3, represents baseline conditions for this job category.

Exposure Profile and Baseline Conditions for Forming Operators

The exposure profile in Table IV.4.18-B includes 8 samples for forming operators in the refractories industry. The median is 35 μg/m^3, the mean is 37 μg/m^3, and the range is 12 μg/m^3 to 71 μg/m^3. Table IV.4.18-B shows that, of the 8 samples, 1 (12.5 percent) is above 50 μg/m^3 and none exceed 100 μg/m^3.

Due to limited exposure data, OSHA used surrogate exposure data derived from analogous operations for forming operators in the structural clay, pottery products, and concrete products manufacturing industries to characterize the exposure profile for forming operators in the refractories manufacturing industries in the PEA (Document ID 1720, pp. IV-307 – IV-308). Data contained in OIS, however, provide 8 full-shift, time weighted average (TWA) samples for forming operators at two refractory manufacturing plants (Document ID 3958, Rows 525-531, 824). Although OSHA believes the surrogate data used in the PEA provided a credible exposure profile for refractory manufacturing forming operators in the absence of industry specific data, OSHA has concluded that 8 samples from OIS provide the basis for a more appropriate, industry-specific exposure profile. These 8 samples, summarized in Table IV.4.18-B, have a median silica exposure of 35 μg/m^3, a mean of 37 μg/m^3, and range from 12 μg/m^3 to 71 μg/m^3. One sample (12.5 percent) exceeded 50 μg/m^3, all others (87.5 percent) were below 50 μg/m^3 (Document ID 3958).

This exposure profile is consistent with, but slightly lower than, the profile based on the surrogate data presented in the PEA: the median and mean exposure levels were similar, with a median of 30 μg/m^3 and a mean of 47 μg/m^3. While the percentage of samples that exceeded 50 μg/m^3 was about half (12.5 percent compared to 27 percent), 7 of the 8 samples from OIS were for workers performing tasks with LEV which may explain this decrease in exposure levels. The surrogate data used in the PEA contained sample results from a manufacturing facility where the exhaust ventilation system did not fully capture visible dust at any of the product lines, and the ventilation system was disconnected entirely at one press where the most visible dust was released, resulting in higher exposure values (Document ID 1720, p. IV-308; 0202, pp. 15-20, 22).

OSHA concludes that LEV and general dilution ventilation are baseline conditions for forming operators at most refractory product manufacturing facilities. Although OSHA requested additional exposure data for forming operators in refractories during the public comment period, it did not receive any. In the absence of additional data, OSHA concludes the exposure levels summarized in Table IV.4.18-B for forming operators accurately reflect as a baseline condition a median exposure level of 35 μg/m^3.

Exposure Profile and Baseline Conditions for Finishing Operators

The exposure profile in Table IV.4.18-B includes 8 samples for material handlers in the refractories industry. The median is 13 μg/m^3, the mean is 13 μg/m^3, and the range is 13 μg/m^3 to 14 μg/m^3. Table IV.4.18-B shows that, of the 8 samples, none are above 50 μg/m^3 and none exceed 100 μg/m^3.

Eight full-shift finishing operator samples were identified for a refractory products manufacturing facility visited by NIOSH. On the days that sampling was conducted, finishing operators performed manual grinding on low-temperature fire brick (hydrous aluminum silicate clay and plaster) at ventilated grinding stations. All eight exposures were below the LOD (13 μg/m^3 to 14 μg/m^3) (Document ID 1365, p. 14-11; 0266, pp. 11-12, 14-15).

These samples for finishing operators are associated with LEV, which was present on all the manual grinding stations. The adjacent automated grinding machines, drill presses, and saws (not operated during the evaluation) were also fitted with LEV. At the time of sampling, NIOSH determined that air velocity for the LEVs at the manual grinding stations an inch from the 36-inch grinding wheels was 300 feet per minute, with half the grinder/LEV stations operating (volumetric airflow was not provided) (Document ID 0266, p. 8). However, settled dust in the area and high respirable dust sample results suggest that the LEV did not completely capture grinding dust (Document ID 0266, p. 6). Dust control is further reduced when workers manually open dampers to the remaining grinding stations when those other machines are also in use. In addition, NIOSH noted that these workers spend a portion of their shift performing clean-up activities and that dry sweeping also contributes to the workers' dust exposure (Document ID 1365, p. 14-11; 0266, pp. 4, 8). LEV or ventilated enclosures and wet methods were also associated with grinders at a second refractory brick manufacturing plant evaluated by NIOSH, but for which no PBZ silica samples were obtained (Document ID 0909, p. 22-Encl 2).

OSHA received one comment regarding baseline conditions for finishing operators in a follow-up response to questions asked during the public hearings. One small refractory brick manufacturer noted that its finishing operators tumble fired brick as part of their finishing process and that the dust from the tumbling operation is controlled by a dust collector, which is monitored as required in the manufacturer's EPA Title V operating permit (Document ID 3731, p. 2). The commenter did not provide any exposure data associated with this task so OSHA could not include the data in its exposure profile for finishing operators, but this information supports OSHA's conclusion that LEV is typically used in finishing operations.

Based on the presence of LEV for finishing operations in these manufacturing facilities discussed above, OSHA concludes that the use of LEV represents baseline conditions in the finishing areas of refractory product manufacturing facilities. Although OSHA requested additional data exposure for finishing operators in refractories, it did not receive any. In the absence of additional data, OSHA concludes that the exposure levels summarized in Table IV.4.18-B for finishing operators accurately reflect as a baseline condition a median exposure level of 13 μg/m^3.

Exposure Profile and Baseline Conditions for Ceramic Fiber Furnace Operators

The exposure profile in Table IV.4.18-B includes 4 samples for ceramic fiber furnace operators in the refractories industry. The median is 14 μg/m^3, the mean is 13 μg/m^3, and the range is 12 μg/m^3 to 14 μg/m^3. Table IV.4.18-B shows that, of the 4 samples, none is at or above 50 μg/m^3.

Four samples were identified for ceramic fiber furnace operators. Although limited, these represent the best data available to OSHA for ceramic fiber furnace operators in the refractory products industry. NIOSH collected these air samples on two consecutive days at a facility that manufactured refractory fibers (Document ID 0266, pp. 6-7, 11-12). The 4 samples for the furnace operator and production assistant all were less than or equal to the limits of detection (12 μg/m^3 to 14 μg/m^3), despite the fact that silica sand quartz accounted for 50 percent of the ingredients added to the furnace (Document ID 0266, p. 6-7, 14-15). The furnace operator spent 75 percent of the time in a control room and occasionally checked on equipment or collected samples outside the booth (Document ID 0266, pp. 6, 11). The production assistant spent both shifts working and cleaning around the furnace and fiber production equipment. The furnace was equipped with a low-volume ventilation system (suggesting that the system was designed to remove heat rather than air contaminants) (Document ID 1365, 4-12; 0266, p. 9). The production assistant, referred to at this facility as a shot-man, charged the furnace by dumping silica flour into the charge hopper from 2-ton sacks suspended from a pallet jack (Document ID 1365, p. 14-12; 0266, p. 12).

The high-quality sand required for the delicate process of vitreous fiber production is one factor that might contribute to the low silica exposure of furnace operators. Clean, uniform sand particles optimize melting and minimize impurities that can cause problems in the production process or reduce product quality (Document 1365, p. 14-12). NIOSH indicated that the silica flour used in spun ceramic fibers was of mesh number 140 or less, meaning approximately 100 µm or less maximum particle size (Document ID 1365, p. 14-12; 0266, p. 6). Sand particles are also routinely separated to limit the lower particle size, so it is possible that the flour used contained minimal particles in the respirable range (Document ID 1365, p. 14-12; 0205, pp. 4-5).

The glass manufacturing industry typically uses automated equipment to charge melting furnaces (see Section IV-4.9 – Glass Products). However, at the refractory product facility visited by NIOSH, the shot-man spent a portion of the shift emptying large bags of sand into the furnace hopper (Document ID 1365, p. 14-12; 0266, p. 12). OSHA received no comments on the type of controls used at the refractory product facilities for furnace operators, but assumes, consistent with the conditions that applied to its collected data, that baseline conditions for furnace operators include a control booth for the operator and only heat extraction ventilation on the furnace. Silica ingredients for fiber production are typically sized larger than the respirable range, which might limit respirable-size particles fed to the furnace (Document ID 1365, p. 14-12; 0205, pp. 4-5; 0266, p. 6).

Although OSHA requested during the comment period additional exposure data for ceramic fiber furnace operators in refractories industries, it did not receive any. In the absence of additional data, OSHA concludes that the exposure levels summarized in Table IV.4.18-B for ceramic fiber furnace operators accurately reflect as a baseline condition a median of 14 µg/m^3.

Exposure Profile and Baseline Conditions for Packaging Operators

The exposure profile in Table IV.4.18-B includes 13 samples for packaging operators in the refractories industry. The median is 23 µg/m^3, the mean is 30 µg/m^3, and the range is 10 µg/m^3 to 118 µg/m^3. Table IV.4.18-B shows that, of the 13 samples, 1 (7.7 percent) is above 50 µg/m^3 and 1 (7.7 percent) exceeds 100 µg/m^3. Seven of the remaining 13 samples (53.8 percent) are 25 µg/m^3 or less (Document ID 1365, pp. 14-12 – 14-13; 0193, pp. 55, 58; 0089, pp. 38-42, 47-52, 58-62, 69, 72; 0266, pp. 14-15; 3958).

The highest exposure, 118 µg/m^3, was associated with a worker who spent the 8-hour shift alternating between tending a bag-packing machine and charging blending equipment with the ingredients needed for the next product to be packaged by the bag-packing machine. This latter activity involved manually dumping bags of raw materials into the ventilated charge hopper. A significant source of exposure for this worker was an adjacent bulk bag filling station, which leaked a substantial amount of dust that was subsequently pulled through the worker's breathing area by the charge hopper ventilation (Document ID 1365, p. 14-13; 0089). Operators at other unventilated bag-packing stations who did not charge hoppers had exposures of 23 µg/m^3, less than or equal to 30 µg/m^3 (LOD), and 41 µg/m^3 (Document ID 1365, p. 14-13).[114] OSHA recommended that the employer add LEV to all packing stations.

NIOSH and OSHA sample results from two other facilities also suggest that bag dumping and mixing activities are a greater source of exposure than packaging. NIOSH reported 4 packaging operator samples (bag-packing only) (one at 19 µg/m^3, and three below the LOD), while OSHA reported 1 packaging operator sample (bag packing only) (12 µg/m^3). However, a supervisor at the facility visited by NIOSH, who also managed the mixing area, had an exposure of 38 µg/m^3, twice that of highest packaging operator sample result (Document ID 1365, p. 14-13; 0266, p. 14; 3958).

[114]At this facility, ingredients for the products the workers packaged could contain up to 50 percent quartz, but bulk sampling indicated actual concentrations were in the range of 1.0 to 5.0 percent quartz (Document ID 1365, p. 14-13; 0266, pp. 5-6).

4.18) Refractories

Although OSHA requested additional exposure data for packaging operators in the refractories industries during the public comment period, it did not receive any. In addition, OSHA received no comments on its description of baseline conditions for refractory packaging operators in the PEA. Based on this and on the information described above, OSHA concludes that baseline conditions for packaging operators in this industry typically include unventilated bag-packing equipment and potential exposure from adjacent uncontrolled or inadequately controlled processes. The majority of the sample results summarized in the exposure profile in Table IV.4.18-B were obtained under these conditions. As a result, OSHA concludes that the exposure levels summarized in Table IV.4.18-B for packaging operators accurately reflect as a baseline condition a median exposure level of 23 $\mu g/m^3$ and a mean of 30 $\mu g/m^3$.

Table IV.4.18-B
Personal Respirable Crystalline Silica Exposure Range and Distribution of Results for Workers in the Refractories Industry (2007 NAICS 327124, 327125)

	Exposure Summary			Exposure Range		Exposure Profile				
Refractories Industry	**N**	**Mean (µg/m^3)**	**Median (µg/m^3)**	**Min (µg/m^3)**	**Max (µg/m^3)**	**< 25 (µg/m^3)**	**≥ 25 and ≤ 50 (µg/m^3)**	**> 50 and ≤ 100 (µg/m^3)**	**> 100 and ≤ 250 (µg/m^3)**	**> 250 (µg/m^3)**
Material Handler	30	71	32	12	526	12 (40%)	6 (20%)	6 (20%)	5 (16.7%)	1 (3.3%)
Forming Operator	8	37	35	12	71	2 (25%)	5 (62.5%)	1 (12.5%)	0 (0%)	0 (0%)
Finishing Operator	8	13	13	13	14	8 (100%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)
Ceramic Fiber Furnace Operator	4	13	14	12	14	4 (100%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)
Packaging Operator	13	30	23	10	118	7 (53.8%)	5 (38.5%)	0 (0%)	1 (7.7%)	0 (0%)
Refractories Industry Total	**63**	**47**	**23**	**10**	**526**	**33 (52.4%)**	**16 (25.4%)**	**7 (11.1%)**	**6 (9.5%)**	**1 (1.6%)**

Notes: All samples summarized are personal breathing zone (PBZ) results and represent 8-hour time-weighted average exposures.
Job categories are intended to represent job functions; actual job titles might differ, and responsibilities might be allocated differently, depending on the facility.
Percentages may not add to 100 percent due to rounding.

Sources: Document ID 1720; 3958; 0089; 0193; 0266.

4.18.3 Additional Controls

Additional Controls for Material Handlers

The exposure profile in Table IV.4.18-B shows that 40 percent (12 out of 30 samples) of material handlers have exposures above the final PEL of 50 μg/m^3. Therefore, OSHA finds that additional controls will be necessary to achieve the PEL for these overexposed workers. Additional controls include improved ventilation at bag dumping stations and associated ventilated bag compactors, and increased use of automated equipment to charge hoppers and mixing equipment.

One control option that would reduce exposures to at or below 50 μg/m^3 involves bag dumping stations with properly ventilated enclosures, which capture dust released during both bag emptying and bag disposal. A bag dumping station with fully functioning LEV was found to reduce silica exposure by at least 92 percent (Document ID 0199, pp. 6-13). The stations consisted of hoppers topped with grates that were enclosed by LEV hoods. After each bag is emptied, the worker releases it, and suction automatically pulls the bag into the ventilation system and transfers it to an enclosed storage area. Although no exposure information was identified for refractory products facilities using such bag dumping stations, comparable respirable quartz exposure monitoring data exist for workers using bag dumping stations to empty 50-pound bags of silica-containing materials at a paint manufacturing facility (Document ID 0199, pp. 6-12). Other similar types of bag dumping stations (e.g., systems incorporating enclosures, empty bag compactors, bag disposal chutes, LEV) also have been proven effective (Document ID 1365, pp. 14-14 – 14-15; 1681). Ventilated bag stations are readily available from commercial sources (Document ID 0581; 1429; 0680; 1212; 1224).

Automated material transfer equipment can also help reduce dust released as hoppers are filled. A sample result below the LOD (13 μg/m^3) was obtained for a material handler monitoring the automated transfer of raw materials (Document ID 1365, p. 14-15; 0266, pp. 10, 14-15). Although the value of this sample result is limited by the low silica content of the respirable dust sample (less than 1 percent, the LOD), sample results obtained in similar industries further demonstrate the value of automated equipment for reducing exposure. For example, at a structural clay facility inspected by OSHA, an 86-percent reduction in respirable quartz exposure readings (from 501 μg/m^3 to 70 μg/m^3) occurred after management installed an enclosed, automated sand transfer system (Document ID 1365, p. 14-15; 0161, pp. 183, 424-427, 1059-1060). The inspection report noted that sand leaked from the conveyor leading to the hopper because it was not the correct size. With tightly sealed components, exposures could be reduced further.

Additional Controls for Forming Operators

The exposure profile in Table IV.4.18-B shows that 12.5 percent (1 out of 8 samples) of forming operators have exposures above the final PEL of 50 μg/m^3. Therefore, OSHA finds that additional controls will be necessary to achieve the PEL for these overexposed workers.

As noted above, OSHA has determined that the exposures above 50 μg/m^3 for forming operators in the refractory products industry are associated with activities without ventilation or with ventilation that is not operating properly. OSHA believes that in such cases, forming operator exposure levels would be reduced to 50 μg/m^3 or less by controlling dust released from adjacent operations (bag dumping and mixing performed by material handlers), improving maintenance on existing LEV at forming stations, installing new LEV systems, and/or using wet methods or a high-efficiency particulate air (HEPA)-filtered vacuum rather than compressed air to clean molds (Document ID 1365, p. 14-16; 0266, p. 13; 1720, p. IV-311).

In particular, combination “push-pull” ventilation—designed to exhaust contaminated air near the source while supplying a similar amount of clean air behind or above the worker’s head—has been demonstrated to be very effective. Experimental data from Heinonen et al. (1996) during the simulated manual weighing of flour additive powder showed that compared with general ventilation alone, breathing zone total dust concentrations were reduced by 98 percent (from 42 mg/m^3 to 1.0 mg/m^3 or less) when the work surface was fitted with exhaust ventilation (at the front, side, or as a downdraft) in combination with local clean air supply above the workers head (Document ID 1393, pp. 357, 360). Although there are no data on the use of this type of system in refractory product facilities, OSHA expects this type of “push-pull” ventilation system would be similarly effective for reducing levels of respirable silica for refractory products forming operators that work at specific stations (Document ID 1393, p. 360).

As noted previously, some of the highest silica exposures reported in the surrogate data discussed in the PEA were associated with poorly functioning LEV. Improved maintenance on the existing LEV (reconnecting and repositioning exhaust ducts) would improve dust control at individual presses. Further control options focus on limiting dust emitted from the mold cleaning process, which occurs every few seconds. For example, better enclosure of the area around the mold and increased exhaust ventilation rate will capture more of the dust disbursed during mold cleaning. Alternatively, use of a HEPA-filtered vacuum brush to clean residual clay from the molds (rather than compressed air) would reduce airborne concentrations of silica, a control strategy that would require changes to the automated press design (Document ID 1720, p. IV-311).

Additional Controls for Finishing Operators

The exposure profile in Table IV.4.18-B shows that none of the finishing operators has exposures above the final PEL of 50 μg/m^3. Therefore, OSHA finds that no additional controls will be necessary to achieve the PEL for these workers.

The exposure profile indicates that finishing operators’ silica sample results are well below 50 μg/m^3. However, OSHA has determined that the exposure profile might underestimate the potential for exposure for finishing operators in the refractory products industry because all of the data in the exposure profile were collected at a single facility during work with alumina-based refractory products that contained only a small percentage of silica. If operators work on materials containing a modestly higher proportion of silica, the existing exhaust ventilation systems will continue to maintain exposures at or below 50 μg/m^3. However, at the limited number of facilities where finishing operators cut or grind high-quartz or high-cristobalite materials, used especially for shaped products such as fire bricks (no data available for the exposure profile), exposures are likely to be significantly higher. At these facilities, additional controls might be required. Appropriate engineering controls associated with finishing equipment include LEV and water-fed equipment (Document ID 1365, p. 14-17).

Although no data are available for cleaning/finishing operators in the refractory products industry, exposure monitoring data from the foundry industry (using grinding equipment to remove residual refractory mold material, typically a mixture of sand and clay, from metal castings) provide good evidence for the effectiveness of LEV. In analogous foundry operations, the use of downdraft benches was associated with a 69-percent reduction in mean silica concentration for grinders (Document ID 1365, pp. 4-24 – 4-25; 0130).

Similarly, limited data are available to support the use of water-fed equipment with refractory products. OSHA reported a silica concentration of 18 μg/m^3 in the breathing zone of a construction worker using a water-fed stationary masonry saw to cut refractory fire brick during a 340-minute sampling period (less than full shift) (Document ID 1365, pp. 14-17; 0102, pp. 3, 7-10, 40).[115] Based on this information from similar processes in other industries, such as the concrete products industry, OSHA has determined that LEV and wet methods can also be effectively used to control exposure when cutting refractory brick in the refractory products industries. For further discussion of both water-fed (dust suppression) and LEV (dust capture) dust control for finishing equipment, see Section IV-4.3 – Concrete Products.

To further reduce exposures, combinations of controls have been effective. LEV combined with wet methods was used with grinders at a second refractory brick manufacturing plant evaluated by NIOSH (Document ID 0909, pp. 21-Encl 2 - 22-Encl 2). There, the grinders were enclosed in a ventilated cabinet, and water or oil was used during grinding to keep dust down. Although no PBZ silica samples were obtained at this facility, OSHA SEP inspection reports from the stone and stone products industry suggest that a combination of controls can reduce silica levels. For example, the median full-shift PBZ silica exposure level was 31 μg/m^3 for eight sawyers at four facilities that

[115] Sample values were reported in Document ID 0161 as 0.20 mg/m^3 and differ slightly due to data handling. See Section IV-2–Methodology for more detailed information.

implemented housekeeping in combination with other control measures, such as enclosing the saw in a booth with a fan, pre-washing stone, managing slurry, increasing water flow for wet processes, and controlling dust from adjacent processes (Document ID 1365, pp. 11-17; 0046, p. 76; 0157, p. 340; 0176, pp. 93, 96; 0180, pp. 3, 13, 52, 56).

Additional Controls for Ceramic Fiber Furnace Operators

The exposure profile in Table IV.4.18-B shows that none of fiber furnace operators has exposures above the final PEL of 50 μg/m^3. Therefore, OSHA finds that no additional controls are required.

The data in the Table IV.4.18-B suggest that the exposure levels of furnace operators handling quartz-containing batch mixes are less than 25 μg/m^3. The exposure results summarized in the exposure profile were obtained using sized ingredients that minimized the amount of respirable particles. Furthermore, a chemical glass manufacturing facility also reported sample results below the LOD during delivery and transport of size-separated bulk quartz that included a uniform range of particles considerably larger than respirable size (Document ID 1365, p. 14-18; 0949). Thus, where raw materials containing larger-than-respirable-size particles are used additional controls would not be required for this job category.

Additional Controls for Packaging Operators

The exposure profile in Table IV.4.18-B shows that 7.7 percent (1 out of 13 samples) of packaging operators have exposures above the final PEL of 50 μg/m^3. Therefore, OSHA finds that additional controls will be necessary to achieve the PEL for these overexposed workers.

As shown by Table IV.4.18-B, most packaging operator exposure levels are at or below 50 μg/m^3. Slightly more than ninety-two percent of packaging operators in the refractory products industry already experience exposures at or below the PEL. However, the sample results for 7.7 percent of the workers in the job category (1 of 13) exceed this level. As discussed in the baseline conditions section, exposure levels of most of these workers will be reduced when silica emissions from adjacent operations (e.g., material handling) are better controlled (Document ID 1365, pp. 14-19 – 14-21; 0089). In some cases, the bag-packing equipment might also require additional controls, which can include adding to and improving existing ventilation at bag filling equipment and hoppers, installing a dual nozzle system on bag filling equipment, and using effective bag valves (Document ID 1365, p. 14-19 – 14-21; 1326, pp. 754, 759; 1689, p. 8).

The only packaging operator sample that exceeded 50 μg/m^3 (118 μg/m^3), involved a worker who was adjacent to unventilated and leaking bulk bag filling equipment. This worker also manually dumped bags of silica-containing material to charge the bag filling equipment. OSHA recommended that the employer add ventilation to the bag filling equipment (Document ID 1365, p. 14-19; 0089). Additional sources of exposure at typical bag-packaging equipment, noted in a report on the concrete products industry, can include dust generated while bags are being filled; when filled bags are dropped and impact the conveyor; and when workers use compressed air to clean their clothing (Document ID 1365, p. 14-19; 1689, p. 8). Recommendations for reducing exposures included repairing leaks in the LEV system, installing LEV hoods on the fill nozzles, reducing the distance that filled bags must fall to the conveyor, and prohibiting the use of compressed air to clean clothing.

OSHA SEP inspection results illustrate the effectiveness of well-designed LEV for analogous packaging tasks. At a concrete products facility, installation of a more powerful fan motor and new filter bag for the bag filling machine, LEV, and moving the hoods closer to the packaging operator's position reduced respirable dust exposure by 92.5 percent (Document ID 1365, p. 14-19 – 14-20; 0126). After these improvements, a packaging operator had a full-shift silica exposure of less than or equal to 11 μg/m^3 (LOD) (Document ID 1365, p. 14-20; 0126). An inspection at another facility obtained a full-shift exposure reading of 12 μg/m^3 (LOD) for a worker who operated a dry concrete mix bagging machine equipped with a dust collection system (Document ID 1365, p. 14-20; 0073). Another type of ventilation for bag filling operations, an overhead air supply island system (OASIS), has been shown to reduce respirable dust exposure by 98 percent and 82 percent for packaging operators at two mineral processing facilities (Document ID 0161, pp. 1549-1554; 1326, p. 754). OSHA expects that OASIS would be similarly effective at reducing silica exposures of packaging operators in the refractory products industry.

A dual nozzle system for bag filling machines can also reduce exposures for packaging operators. This system consists of an inner fill nozzle (to load the bag with material) surrounded by an outer nozzle (to depressurize the filled bag and remove dust from the bag valve, thereby preventing dust release). This type of system has been shown to reduce respirable dust levels by 83 percent at a mineral processing facility (Document ID 1365, p. 14-20; 1326, p. 754). The use of bag valves that seal effectively and prevent product leakage from filled bags is another way to control exposure. Respirable dust exposures were reduced by more than 60 percent with the use of 6-inch extended polyethylene valves compared with standard paper valves, and by more than 45 percent with the use of 4-inch foam valves (Document ID 1365, pp. 14-20 – 14-21; 1326, p. 759). Based on this information, OSHA expects that a dual nozzle system and effective bag valves can be effectively used to reduce silica exposures of packaging operators in the refractory products industry.

Finally, the bag quality or use of inappropriate bags for the product could also be a significant source of exposure. Bags that break during filling can be a notable source of silica dust and can contribute to operator exposures of two to three times the preceding permissible exposure limit (PEL). On a busy production line, improperly handled or low-quality bags might break frequently, up to 10 to 20 times per two hours (Document ID 1365, p. 14-21; 0587, p. 2). In addition, leakage from bags which are inappropriate for the product type can also be a major source of exposure. In one dry concrete bagging facility, changing the type of bag used in packaging from a three-ply bag perforated throughout to a two-ply bag perforated only on the inner layer reduced respirable dust by 83 percent (Document ID 0766). Workers should be trained on proper techniques for filling and handling bags as well as provided with high-quality bags of a type recommended for the product type, filling equipment, and subsequent handling requirements to control for these types of bag failures (Document ID 1365, p. 14-21; 0587, p. 2).

4.18.4 Feasibility Findings

Based on the exposure profile in Table IV.4.18-B and other record evidence discussed above, OSHA finds that the standard is technologically feasible for the different categories of refractories workers in refractory industries and additional controls previously discussed are used.

OSHA received comments from two small refractory manufacturers arguing that a PEL of 50 μg/m^3 was not technologically feasible; both expressed a similar belief that "it may not be possible to attain lower levels than 100 μg/m^3 in a given process, even with significant process and engineering controls" (Document ID 2056, p. 1; 3731, p. 1). Neither commenter provided exposure data or any supporting detail.

OSHA's inspection database reflects facilities that are both well-controlled and facilities that have poor or no controls at all, indicating that exposures can be significantly reduced with the appropriate engineering controls and work practices. As a result, OSHA disagrees with these comments and believes that the available data summarized above demonstrate that exposure levels for 77.8 percent of the workers in this industry are already at or below the PEL and exposure levels can be controlled to at or below the PEL for the remaining workers in the industry with existing, effective control technologies.

Feasibility Finding for Material Handlers

Based on the exposure profile in Table IV.4.18-B and other record evidence discussed above, OSHA finds that more than half (60 percent) of all material handlers in this industry already achieve exposure levels of 50 μg/m^3 or less. OSHA finds that by improving or adding ventilation at bag dumping stations and adding ventilated bag compactors, as well as by enclosing and ventilating mixing equipment, the exposure levels for most material handlers can be reduced to at or below 50 μg/m^3 most of the time. This conclusion is based on sampling results from the paint manufacturing industry, previously discussed under additional controls for material handlers, which indicate that a well-functioning ventilation and bag disposal system at manual charge hoppers can reduce exposures by 92 percent or more (Document ID 0199, pp. 6-13). A similar reduction in the refractory products industry would yield a maximum exposure well below the PEL of 50 µg/m^3.

Based on the information included in this section, OSHA concludes that the enclosure and ventilation controls alone will effectively reduce the exposure level of material handlers to 50 µg/m^3. However, when material handlers work with specific refractory materials with very high silica content, further controls, such as automated material transfer equipment, may be necessary. An 86-percent exposure reduction (observed in the structural clay industry for an enclosed, automated sand transfer system) would reduce all but the highest exposure to 50 µg/m^3 or less (Document ID 1365, p. 3-26; 0161).

Feasibility Finding for Forming Operators

Based on the exposure profile in Table IV.4.18-B and other record evidence discussed above, OSHA finds that most forming operators (87.5 percent) already experience exposure levels at or below 50 µg/m^3. OSHA finds that by controlling dust released during adjacent material-handling activities, increasing maintenance on existing LEV systems in the forming area, and using wet methods to clean molds, exposure levels at or below 50 µg/m^3 can be achieved for most forming operators most of the time.

Feasibility Finding for Finishing Operators

Based on the exposure profile in Table IV.4.18-B and other record evidence discussed above, OSHA finds that finishing operator exposures are already well below the PEL of 50 µg/m^3. Even if the exposure profile underestimates the exposures for workers who may cut or grind high-quartz materials, their exposure levels can be maintained at or below 50 µg/m^3 through improved LEV on saws and grinders, wet methods, or a combination of controls, as recommended by ACGIH (Document ID 3997).

Feasibility Finding for Ceramic Fiber Furnace Operators

Based on the exposure profile in Table IV.4.18-B and other record evidence discussed above, OSHA finds that the exposure of all ceramic fiber furnace operators is already less than 50 µg/m^3. Thus, additional controls are not required. However, if higher exposure levels are encountered, the use of sized ingredients can limit the number of respirable particles.

Feasibility Finding for Packaging Operators

Based on the exposure profile in Table IV.4.18-B and other record evidence discussed above, OSHA finds that, most (92.3 percent) packaging operators are already exposed at or below 50 µg/m^3. For the remaining packaging operators, OSHA finds that improved workstation ventilation can control exposure to levels of 50 µg/m^3 or less. If further controls are required, a dual-nozzle filling system and/or the use of effective bag valves can reduce exposures. In some cases, the exposure levels of packaging operators will be reduced when facilities control adjacent sources of airborne silica associated with other job categories.

Overall Feasibility Finding

Based on the exposure profile in Table IV.4.18-B and other record evidence discussed above, most workers sampled (77.8 percent) in the refractory products manufacturing industry are exposed to 50 µg/m^3 or below. Thus, OSHA concludes that most workers at refractory facilities are currently exposed to silica levels at or below 50 µg/m^3. For workers who are currently exposed above 50 µg/m^3, most notably material handlers, forming operators, and packaging operators, the engineering and work practice controls described in this section can be implemented to reduce silica exposure levels to 50 µg/m^3 or less in most operations, most of the time. Therefore, OSHA finds that the final PEL of 50 µg/m^3 is technologically feasible for the Refractory industry.

4.19 REFRACTORY REPAIR

4.19.1 Description

Refractory materials, also known as refractories, are typically used to line furnaces or other equipment where commercial production processes exceed temperatures of 1,000 degrees Fahrenheit. Refractories are produced with raw materials that include silica-containing minerals such as quartz, cristobalite, bauxite, and fireclay. Refractory materials are used in the construction of furnaces, boilers, cupolas, hot gas stacks, ladle linings, smelting pits, and incinerators. High-temperature applications requiring refractory equipment occur in a wide range of industries, including brick and pottery manufacturing, glass manufacturing, metal casting (foundries), smelting operations, steel production, chemical plants, and waste incineration.

While some facilities utilize their own maintenance workers to repair and replace refractory materials, others subcontract this work to firms that specialize in refractory repair. In-plant foundry workers who handle refractory material are covered in Section IV-4.8 – Foundries (Metal Casting). Other industries (as well as most foundries planning to completely reline furnaces) are more likely to use the services of contractors. Workers who repair and replace refractory materials as their primary activity are typically employed by refractory repair and replacement services contractors; up to 75 percent of all companies across all industries use a contract service to reline their furnaces (Document ID 1159, p. 1). These workers travel to customers' facilities, or, less frequently, customers' equipment is brought to them for refractory relining. Workers who specialize in refractory repair are classified under the six-digit North American Industry Classification System (NAICS) code 423840, Industrial Supplies Merchant Wholesalers. Refractory workers employed by refractory product suppliers are likely to service a range of industries and work with diverse refractory materials (Document ID 1365, p. 16-3).

Refractory workers typically perform a variety of activities during a work shift, such as set up, tear out, installation, and cleanup (Document ID 1365, p. 16-5). Table IV.4.19-A summarizes, under the single job category of contract refractory worker, the major activities and primary sources of silica exposure for workers performing refractory repairs. The relining process involves two basic steps: 1) removal and demolition of the old or damaged lining (or portion thereof), and 2) installation of new or replacement refractory material. Demolition of refractory is the activity that has the most potential to produce elevated exposures as silica-containing material becomes airborne due to the mechanical energy of demolition tools.[116] Workers rarely remove, or demolish, refractory material for a full shift; up to 2 hours per day is more typical, particularly if the job is small (Document ID 1161; 0121, p. 27). However, workers may also perform demolition activities for longer than two hours, and large jobs can take up to an entire shift. One report indicated that the removal of an old refractory took 60 minutes and the entire relining operation could be completed efficiently in five hours (Document ID 0121, p. 10).

The refractory materials are chipped and torn out using hammers, jackhammers, pneumatic chisels (handheld or mounted on wheeled equipment), and rakes. Refractory workers then use shovels, brooms, buckets, and cranes to transfer the resulting waste materials to waste bins (Document ID 1365, pp. 16-3—16-5; 0793, pp. 46-47; 1161, p. 1). Although refractory workers use remote mechanical removal processes (e.g., hydraulically controlled chisels attached to a small tractor) for as much as 70 percent of their work, some refractory removal jobs require work with handheld tools (Document ID 1162). Workers use hand tools exclusively in tight spaces and around delicate portions of the equipment (Document ID 1365, p. 16-3).

New linings are applied by various methods; the method depends on the type of lining being installed. In some cases, workers pour and ram (i.e., compact using gas- or electric-powered vibrating equipment) low-moisture powdered refractory materials. These materials also can be blown into place using air guns that introduce a small amount of water into the spray as a “shotcrete”-type operation. Alternatively, refractory workers (sometimes classified as masons) position prefabricated refractory ceramic shapes, bricks, bats, or tiles and use refractory mortar (mixed from powdered product received in

[116] OSHA expects that the other activities performed by refractory repair workers do not generate as much airborne dust as demolition activities, which are responsible for the highest recorded exposures (Document ID 0050).

sacks) to seal the spaces between the shapes (Document ID 0969, p. 1). Other lining materials are mixed (in a bucket or tote) from powder and liquid ingredients by refractory workers who then trowel or pour the resulting “plastic” paste into position, in processes similar to plastering or casting concrete. Workers typically perform much of refractory installation work manually, within arm’s length of the worker’s breathing zone and often within the enclosed confines of the furnace or oven (which might be classified as a confined space) (Document ID 1365, p. 16-4; 1390).

The North American Insulation Manufacturers Association (NAIMA) agrees with OSHA’s characterization of these operations. NAIMA stated that repairs or rebuilds have two components: the removal of the refractory brick or lining, and the installation of new refractory material (Document ID 2348, Attachment 1, p. 4). NAIMA further explained:

> The demolition phase results in potential worker exposure to dust as the silica-containing refractory is removed. Although some refractory blocks can easily be removed with pry bars, others may require the use of jackhammers, air chisels, and other tools. During rebuild operations all or part of the existing furnace, channel, and forehearth is demolished and then rebuilt. The demolition process may be performed by the manufacturer’s employees or a construction contractor’s employees or a combination of both.
>
> The installation of new refractory, or the rebricking phase, results in potential worker exposure to silica as the refractory brick and preformed pieces may need to be cut and adjusted during installation. Silica exposure similarly occurs with refractory repair work performed between furnace rebuilds. During repairs, workers have to remove the refractory brick and replace it with new refractory brick that may have to be cut and formed on an urgent basis. New refractory brick is typically cut with wet sawing techniques that would greatly limit dust from the sawing process and the finished piece. Silica exposure, above the proposed [permissible exposure limit] PEL and action level would more likely occur during demolition or removal of spent refractories (Document ID 2348, Attachment 1, pp. 4-5).

The Glass Association of North America (GANA) similarly commented that employees and contractors have exposure to silica when doing furnace rebuild or repair work, such as tearing out old refractories, replacing them with new refractories, hauling away waste refractories, cleaning used refractory bricks for recycling, and cleaning furnace control equipment (Document ID 2215, p. 4).

Table IV.4.19-A Job Categories, Major Activities, and Sources of Exposure of Workers in the Refractory Repair Industry (NAICS 423840)	
Job Category*	**Major Activities and Sources of Exposure**
Contract Refractory Worker	Removing/demolishing old or damaged refractory material from furnaces and other equipment. • Dust generated by using handheld or hydraulically controlled demolition tools (e.g., chisels, jackhammers, rakes). • Preparing new refractory materials for installation. • Dust released when mixing dry ingredients. • Dust generated by dry cutting bricks with saw. Installing new dry refractory materials. • Dust released by emptying sacks of product. • Dust raised by compacting product with vibrating tools. • Dust released by applying product with air gun. Installing new refractory brick or precast shapes using refractory mortar or grout to seal surfaces and cracks. • Dust raised when handling dry, powdered mortar. • Performing cleanup and housekeeping activities. • Dust raised from dry sweeping, shoveling, and transporting silica-containing debris and materials.
*Job categories are intended to represent job functions; actual job titles might differ, and responsibilities might be allocated differently, depending on the facility. Source: Document ID 1720, p. IV-318.	

Table IV.4.19-B summarizes the available exposure information for refractory workers. OSHA concludes that Table IV.4.19-B represents baseline conditions.

4.19.2 Exposure Profile and Baseline Conditions

The exposure profile in Table IV.4.19-B includes 6 full-shift personal breathing zone (PBZ) samples of respirable crystalline silica for workers in the refractory repair industry. The median is 33 µg/m^3, the mean is 63 µg/m^3, and the range is 12 µg/m^3 (i.e., LOD) to 196 µg/m^3. Table IV.4.19-B shows that, of the 6 samples, 2 (33.4 percent) are above 50 µg/m^3 and one (16.7 percent) exceeds 100 µg/m^3. Five of these samples were obtained from two OSHA Special Emphasis Program (SEP) inspection reports, and one sample was obtained from the OSHA Information System (OIS) database (Document ID 0164; 0037; 3958). These limited results include four exposures (67 percent) less than or equal to 50 µg/m^3.

Two samples below 50 µg/m^3 were collected while workers relined a furnace at a customer's facility. During the refractory removal process, the workers used a jackhammer and shovel to chip the lining and collect debris. One worker used a crane to transport refractory waste to a trash receptacle, while the other used a "wet vacuum" (and changed the vacuum filter). The samples were also analyzed for cristobalite, but none was detected in any of the samples (Document ID 0037, pp. 4, 132-139). Two samples, 90 μg/m^3 and 196 μg/m^3 (cristobalite was not analyzed), were obtained at a refractory service provider's work site where workers were reconditioning a furnace. These elevated results are associated with two workers who used a jackhammer and crowbar to remove the refractory furnace lining during the entire shift (Document ID 0164, pp. 70-77).

Samples from the foundry industry also show that exposures occur during refractory removal. As presented in Section IV-4.8 – Foundries (Metal Casting) of this analysis, exposure data from refractory removal and relining activities by in-plant workers at foundries show that exposures may exceed 200 μg/m^3 and exceed the levels identified for refractory workers providing contract services. However, OSHA has reason to believe that the most elevated foundry results might not be typical of the highest exposures likely to be experienced by contract refractory workers. Contract refractory service providers perform the same work on a daily basis and, compared with foundry workers, are more experienced and better equipped to reduce exposure levels during removals by using engineering controls and installing refractory materials in a manner that is less likely to generate dust (Document ID 1720, p. IV-321).

Silica exposures are not expected to occur during installation of refractory ceramic fibers (RCF), but could be possible during removal activities after the material has been in service as reflected in two studies revealing that elevated silica exposures can (but do not always) occur during removal of RCF (Document ID 1414, p. 361; 1389, p. 532). Data from a 1998 study by Maxim,et al., suggest that silica exposure above 50 μg/m^3 based on task sampling is not common during RCF removal (demolition) work (mean concentration was 43 μg/m^3). These data were excluded from the exposure profile because they predate 1990 (Document ID 0793, p. 51).[117]

[117] See Section IV-2–Methodology for sampling data criteria.

NAIMA submitted a summary of exposure results to the docket. These results were not incorporated into the exposure profile because they are summary results and not individual PBZ samples, and three of the samples are area samples while the other eleven samples do not have a characterization of sample type (Document ID 3999, Attachment 1, pp. 2, 4). NAIMA provided summary results from fourteen exposure samples for refractory repair, obtained from its wool manufacturing members (Document ID 3999, Attachment 1, pp. 2, 4). NAIMA submitted two tables containing exposure results during furnace demolition and rebuild. The first table identifies the geometric mean of 11 samples taken during furnace demolition and rebuild operations as 21.92 μg/m^3. Although it is not clear from its submission, it is likely that these measurements were from personal breathing zone samples since NAIMA included area sample results on a different table (Document ID 3999, Attachment 1, p. 2). There were three area samples for furnace demolition and repair activities, which ranged from 29 to 30 μg/m^3 (Document ID 3999, Attachment 1, p. 4). In its earlier submission to the rulemaking record, NAIMA stated that its furnace demolition, cleanup, and rebuild exposure data ranged from 4.6 to 62 μg/m^3 (Document ID 2348, Attachment 1, p. 17).

GANA acknowledged the use of engineering controls, wet methods, and ventilation during furnace rebuild operations. It commented, however, that personal protective equipment (PPE) to limit exposures to silica dust was needed because it was not feasible to use engineering controls alone to control dust exposures (Document ID 2215, pp. 4, 6-7.)

OSHA reviewed several reports that describe engineering controls currently being used for refractory repair work. Based on published literature and information from industry members, OSHA has determined that up to 70 percent of refractory work is performed using hydraulically controlled tools mounted on equipment outside the furnace and a few feet away from the point where dust is generated (Document ID 1162). Another semi-remotely controlled process involving a hydraulic “pusher” system is increasingly common for removing refractory lining from cylindrical induction furnaces. Manufacturers now build this capability into all induction furnaces over 4 tons and sell approximately 50 percent of new furnaces with this option (Document ID 1269; 0687).

Facilities for which OSHA has process information rarely report that exhaust ventilation is used to reduce the spread of silica (or refractory ceramic fibers). Thus, OSHA concludes that few refractory workers operate with the benefit of local exhaust ventilation (LEV) installed on the furnaces (Document ID 1365, pp. 16-11– 16-12).

Some refractory workers use vacuums for cleanup (Document ID 0576, p. 719-720; 0037, p. 134). Other sources report at least occasional use of wet dust control methods during refractory demolition or installation. OSHA therefore concludes that water-fed masonry saws are typically used for cutting firebrick (Document ID 0576, p. 719-720; 1365, p. 16-12).

NAIMA also stated that the mineral wool industry has implemented many of the engineering and work practice controls identified in the PEA for furnace rebuilds where practicable (Document ID 2348, Attachment 1, p. 22). NAIMA described the exposure control strategy its members currently employ:

> For rebuilds, where potential exposures to crystalline silica and other deleterious materials occur, mineral wool manufacturers have specified safety and health precautions to be followed to minimize worker exposures. These include but are not limited to: 1) restricting access to the furnace demolition and rebuild area to only those workers or contractors directly engaged with the project; 2) using respirators, protective clothing (*e.g.*, Tyvek suits), and other PPE to minimize airborne exposures and protect against other safety related hazards; 3) use water mist, other wetting means or dust suppressants to control dust generation; 4) vacuum clean-up of spilled mixed batch from the area prior to demolition; 5) where possible, removal of preformed refractory block by pry-bar rather than by powered air-chisels; and 6) air monitoring to better understand the airborne exposures and thus select appropriate PPE (Document ID 2348, Attachment 1, p. 22).

Based on a review of inspection reports, published literature, industry contacts, and submissions to the rulemaking record, OSHA has determined that refractory workers most commonly perform a combination of manual processes and semi-remote mechanical processes in areas with general ventilation in many cases, or with dedicated LEV in atypical cases (Document ID 1720, p. IV-322; 2348, Attachment 1, pp. 12, 13, 21; 1365, pp. 16-11 - 16-12). Additionally, baseline conditions include the use of other engineering controls such as automation, substitution, wet methods, and work practices by some employers (Document ID 2348, Attachment 1, p. 21; 1365, pp. 16-11–16-12). The median exposure for this job category (33 μg/m^3), presented in Table IV.4.19-B, is based on six samples obtained while workers repaired and replaced refractory materials. OSHA considers these results, although limited in number, to be representative of baseline conditions for contract refractory repair workers.

Table IV.4.19-B Respirable Crystalline Silica Exposure Range and Distribution of Results for Workers in the Refractory Repair Industry (NAICS 423840)											
	Exposure Summary			**Exposure Range**			**Exposure Profile**				
Job Category	**N**	**Mean ($\mu g/m^3$)**	**Median ($\mu g/m^3$)**	**Min ($\mu g/m^3$)**	**Max ($\mu g/m^3$)**		**<25 ($\mu g/m^3$)**	**≥25 and ≤50 ($\mu g/m^3$)**	**>50 and ≤100 ($\mu g/m^3$)**	**>100 and ≤250 ($\mu g/m^3$)**	**>250 ($\mu g/m^3$)**
Refractory Worker	6	63	33	12	196		2 (33.3%)	2 (33.3%)	1 (16.7%)	1 (16.7%)	0 (0%)
Total	**6**	**63**	**33**	**12**	**196**		**2 (33.3%)**	**2 (33.3%)**	**1 (16.7%)**	**1 (16.7%)**	**0 (0%)**

Notes: All samples summarized are personal breathing zone (PBZ) results representing 8-hour time-weighted average exposures.
Job categories are intended to represent job functions; actual job titles might differ, and responsibilities might be allocated differently, depending on the facility.
Percentages may not add to 100 percent due to rounding.

Sources: Document ID 1720; 3958; 0037; 0164.

4.19.3 Additional Controls

The exposure profile in Table IV.4.19-B shows that 33.3 percent (2 out of 6 samples) of material handlers have exposures above the final PEL of 50 µg/m^3. Therefore, OSHA finds that additional controls will be necessary to achieve the PEL for these overexposed workers. The exposure profile, based on results from 4 of the 6 exposure samples, suggests that 67 percent of all contract refractory workers are currently exposed to silica levels at or below 50 µg/m^3. The remaining 33 percent will require additional controls. The exposure profile, however, may overestimate exposures in light of the NAIMA data, which reflect a geometric median of 21.92 µg/m^3 (Document ID 3999, Attachment 1, p. 2).[118]

Some stakeholders commented that the engineering controls presented are not capable of reducing exposures to or below 50 µg/m^3 for all workers (see, e.g., Document ID 2215, Attachment 1, p. 7; 2348, Attachment 1, pp. 25-26). GANA requested that the Flat Glass Manufacturing Industry be permitted to continue using respirators, wet spray, and other work practices during rebuilds (Document ID 2215, Attachment 1, pp. 7-8). This standard for general industry is performance-based and adopts OSHA's standard hierarchy of controls, under which respirators are viewed as a last resort after engineering and work practice controls; as such, respirators are neither mandated nor prohibited as part of an employer’s control strategy for refractory repair workers that limits their exposure to the PEL or below. Based on the information in the record, however, OSHA has concluded that there are feasible engineering and work practice controls that can consistently reduce most workers’ exposure to – and often well below – 50 µg/m^3 most of the time.

Additional controls include use of low-silica-content refractory materials, use of pre-formed materials, local exhaust ventilation, and wet methods; increased use of semi-remote or automated removal processes; improved work practices; and additional worker training. In describing these controls, OSHA has drawn from the experiences of industries such as mineral wool manufacturing, glass manufacturing, and foundries, whose workers perform work that is similar to contract refractory repair workers. OSHA

[118] OSHA did not incorporate NAIMA's data into the final exposure profile because it included only summary information and not individual sample results.

expects that these controls will be effective for controlling silica exposure during refractory demolition and installation, which is the source of most and highest silica exposures for this application group.

Several stakeholders have stated in response to the PEA that these engineering controls are not capable of reducing exposures to or below the PEL to all workers. GANA stated:

> During rebuild operations, the Flat Glass Manufacturing Industry currently uses various engineering controls and PPE to limit exposure to various materials, including silica dust, during the demolition. However, there are no identified feasible engineering controls that alone will reduce exposure levels to at or below the proposed PEL for all workers in all manufacturing facilities (Document ID 2215, p. 7).

Additionally, NAIMA argued that its analysis shows that engineering controls are not feasible:

> There is no evidence in the record identifying specific engineering controls or work practices that would lead to these workers' slightly elevated exposures being reduced below the PEL. Given the sporadic nature of these exposures and the physical characteristics of the furnace and hot end portion of the manufacturing plants, the only feasible option will be to increase use of PPE. The Final Rule should permit such use (Document ID 2348, Attachment 1, p. 32).

Both NAIMA and GANA argued that, because of the lack of feasible controls, its members should be permitted the flexibility to use engineering controls and work practices of their choosing.

OSHA is not limiting employer flexibility to meet the standard or requiring any specific control to the exclusion of an alternative effective control, but expects as a general matter that "slightly elevated exposures" can be reduced to the PEL or below with the use of additional controls. As the evidence presented in this section shows, there are feasible engineering controls capable of significantly reducing workers' silica dust exposures. As shown by the exposure profile and summary data submitted by NAIMA, most exposures to silica are already below the PEL of 50 μg/m^3. Based on the record, OSHA therefore concludes that controls exist to reduce worker exposure below the PEL most of the time during refractory repair and replacement.

Reduced-Silica Refractory Materials

Refractory materials with low silica content (5 to 10 percent silica compared with 90 percent silica) are readily available from commercial sources, although each low-silica refractory material is not necessarily compatible with every application for which refractory materials are used (Document ID 0691, p. 1; 1365, p. 16-12).

NAIMA argued that reduced silica refractory materials are not technologically feasible, and that using low-silica refractories would greatly reduce furnace life and result in more frequent furnace rebuilds (Document ID 2348, Attachment 1, p. 25). Similarly, Verallia stated that using a standard low silica refractory would shorten the furnace life dramatically, and that transitioning to low-silica refractory would add about 10 times to the cost (Document ID 3584, Tr. 2847).

OSHA understands that refractories are designed for specific purposes, and that substitution to reduced-silica refractory materials is not possible in every situation. However, the record shows that using low-silica refractory materials is viable for many refractories. For example, an OSHA inspection demonstrated that substitution provides an effective way to reduce exposures and also increase the furnace utility cycle. The Agency performed an inspection at a foundry where silica exposures were reduced by 90 percent after implementing a comprehensive exposure control program that included switching to a low-silica refractory applied to furnace walls by means of spray guns. The replacement refractory material was stronger and lasted longer, permitting refractory workers to use less material during cupola repair operations (Document ID 0121, pp. 2, 8-9, 13).

OSHA is not imposing specific requirements in the final rule requiring the use of alternative refractory material. Nevertheless, using lower silica-containing refractory material is a feasible control in some situations.

<u>Automated and Remotely Controlled Processes</u>

Automated refractory demolition and installation methods can reduce the number of workers exposed, the duration of exposure, and the exposure levels of refractory workers. A "pusher" system installed in coreless induction furnaces allows refractory linings to be automatically removed by push plates installed in furnace bottoms. The refractory materials are pushed or extruded out of the furnace, which has been tipped to lie horizontally. Waste falls directly into a disposal bin positioned at the furnace mouth (Document ID 0684). New induction furnaces fitted with push equipment are commercially available, accounting for 50 percent of new furnace sales, and all larger induction furnaces (over 4-ton capacity) have built-in push capability (Document ID 1269, p. 1; 0687). Additionally, existing furnaces might be retrofitted (Document ID 1269).

Although the evidence shows the push process to be quite dusty, it requires fewer workers and substantially less time than traditional removals. For properly equipped induction furnaces, a "push" removal can be completed in 15 to 30 minutes, while traditional methods might take up to two full days of using chipping hammers operated by foundry workers standing or crouching inside the furnace (Document ID 0684; 1358; 0686; 0713). No data are available to quantify the exposure reduction that a pusher system provides; however, a rough estimate can be made by comparing the relative time spent on the task under each removal method. Assuming that each method generates comparable breathing zone silica concentrations, a 30-minute push process would expose the worker for just 6 percent of a 480 minute shift; thus, exposure would be 94 percent lower for workers using the push process. In reality, it is also likely that some additional cleanup would be necessary for both removal methods.

For furnaces that cannot be fitted with pusher systems, large amounts of refractory material can be removed using chipping equipment attached to a hydraulically controlled articulated arm commonly available on some types of construction equipment. The operator remains outside the furnace and manipulates the arm from inside the equipment cab. The arm can be fitted with a camera to allow the worker to see the work area. Although this method is not suitable for very small furnaces or work around delicate instrument controls, one company that uses such methods estimates that 70 percent of large-scale lining removal jobs are performed this way (Document ID 1162). Although no data are available for the refractory repair industry, researchers have shown that well-ventilated cabs fitted and maintained to minimize dust can reduce in-cab dust levels by more than 90 percent (Document ID 1563, p. 4). OSHA concludes that the increased distance between the source of the dust and the worker's breathing zone and a well-ventilated cab would each substantially reduce worker exposure.

Automation also is an option for reducing exposures during furnace relining. A study described an automated system for installing dry rammable refractory material in coreless induction furnaces (Document ID 1390, pp. 6-7, 9-11). With this system, 70 percent fewer workers are required to complete the job, and the reported exposure levels during furnace relining ranged from less than or equal to 10 $\mu g/m^3$ to 20 $\mu g/m^3$ at five foundries using the automated equipment (Document ID 1367, pp. 10-11).

Precast Refractory Materials

Relining of induction and other furnace types also might be accomplished using precast refractory materials that are set in place as units, with minimal risk of exposure. Precast refractory materials can look like typical construction bricks, or they can have more sophisticated geometries that facilitate installation.

For example, curved shapes can be cast that sit flush against the furnace wall. The custom-made precast materials are sealed with refractory grout, mixed from a powder (Document ID 0713; 0969). When appropriate for a particular application, preformed refractory shapes can reduce installation labor, improve performance, and provide a longer service life compared with some brick and poured materials. When repairs are required, standard shapes mean that replacement parts can be kept on hand and that repairs can be isolated to the worn section of the lining, eliminating the need for complete tear-out and extended the period of time workers are exposed during demolition and relining (Document ID 1179). Because of these and other advantages, companies are more frequently using precast shapes instead of powdered products (monolithics) for certain applications (Document ID 0713).

NAIMA commented that these materials will not completely eliminate exposures nor will companies have a full inventory of precast materials for every repair. NAIMA also noted that not all furnace designs are amenable to precast shapes when the best design is simple refractory brick (Document ID 2348, Attachment 1, p. 26). Although precast refractory materials will not always be appropriate, there is evidence demonstrating that precast materials are being used more frequently than monolithic refractory materials (Document ID 0713). Using precast refractory materials can reduce exposures during installation and removal applications and can also result in longer overall refractory service life, reducing the time workers are potentially exposed to silica during replacement and repair (Document ID 1179).

Local Exhaust Ventilation (LEV)

The ventilation systems installed on furnaces to remove the heat and fumes generated during normal operation of the furnace cannot be considered an effective control for refractory workers. These ventilation systems are designed to exhaust rising fumes or gas during heating and are inadequate to control silica dust generated during periodic refractory replacement activities. The overhead design that is most effective for capturing rising heat exhaust is inappropriate for capturing dust generated on the walls and floor of the furnace because it pulls contaminated air through the worker's breathing zone (Document ID 3883, pp. 6-31 – 6-32).

LEV is an effective option to control dust generated when refractory workers chip or apply refractory linings inside the furnace. A company that provides refractory overhaul services developed a method for installing temporary LEV in a gas-fired furnace. This method is used for complete lining removals, but also is applicable to smaller patching jobs. The method, associated with silica exposures between 50 $\mu g/m^3$ and 100 $\mu g/m^3$, involves company-built exhaust fans fitted with air filters (three filters of increasing efficiency in series) (Document ID 1161; 1365, p. 16-15). Plastic sheeting is used as necessary to ensure that fresh air enters the furnace only from the most advantageous point, causing clean air to flow past the worker's breathing zone. Fan/filter boxes are set into the opposite and lower end of the furnace to exhaust dusty air from near the chipping point. Placement of the boxes should be carefully considered to obtain optimum performance (Document ID 1162). LEV also is a dust control option for refractory workers who empty bags or mix refractory powders (Document ID 1720). For smaller jobs, workers who dump bags of silica-containing materials can empty the bags into a movable hopper or other receptacle and then use a flexible sleeve to guide material from the hopper to the distribution point (e.g., a furnace bottom). A portable exhaust trunk (preferably with a semicircular slot or flanged hood) positioned near the bag dumping hopper can capture a portion of the dust released during that activity. Because additional silica exposure can occur when workers compress empty bags, this task also should be located near a portable exhaust trunk. Bag dumping for large jobs can sometimes be eliminated by obtaining powdered materials in bulk bags (e.g., 1-ton sack) filled by the supplier with the predetermined amount of product required for the job. As a standard feature, bulk bags come fitted with a sleeve through which material is dispensed. Bulk bags and sleeves are used for installing high-silica rammable refractory powder in induction furnaces. Maintaining the bottom of the sleeve, which releases material, at a level just below the surface of deposited material can keep dust emissions to a minimum (Document ID 0691, p. 2; 1367, p. 4).

Workers who mix high-silica refractory materials also would benefit from the use of a portable exhaust hood which is similar to the portable exhaust trunk discussed above (both are forms of LEV). The hood is able to capture some of the dust released while workers mix materials. Information from IV-4.17 – Pottery shows that the silica exposure of a coatings preparer (mixes silica-containing material) was reduced from 983 $\mu g/m^3$ to 47 $\mu g/m^3$ after exhaust ventilation was installed at the raw material hopper and the ball mill hatch (ball mill is a type of mixing equipment), and dust leaks were sealed elsewhere in the plant (Document ID 0174, pp. 98, 241). See also IV-4.15 – Paints and Coating (citing Document ID 0199, p. 9).

NAIMA and GANA commented that LEV control for furnaces and portable LEV for the other operations mentioned above are not feasible during demolition and rebuild operations. They objected that when the furnace or smelter is shut down, some of the associated engineering controls that help reduce exposure, including bag houses, collection chambers, and exhaust stacks, are also shut down (Document ID 2215, p. 7;

2348, Attachment 1, p. 26). Considering the evidence and testimony presented in this and in Section IV-4.8 – Foundries (Metal Casting), OSHA understands that while there may be challenges to installing efficient ventilation controls, particularly for large furnaces, other types of controls exist to mitigate workers' exposures, like automatic and ventilated chipping tools, which are discussed below. Ventilation systems are commercially available, or could also be designed by facilities based on their needs with readily available materials (Document ID 1162).

Ventilated Chipping Tools

The chipping of refractory materials in demolition is similar to chipping concrete, another silica-containing material. The tool-mounted systems used for controlling silica in other industries (e.g., construction and the ready-mixed concrete industries) can also be used in furnace demolition. NIOSH tested two tool-mounted LEV shrouds for handheld pneumatic chipping equipment (impact drills): one custom built, the other a commercially available model. Comparing multiple short-term samples, NIOSH found that rock-drill shrouds reduced total respirable dust to 870 $\mu g/m^3$, a 58 percent reduction, and custom-made shrouds reduced respirable dust to 1,120 $\mu g/m^3$, a 46 percent reduction from 2,060 $\mu g/m^3$ with no controls (Document ID 0865, p. 9).

In a separate evaluation, NIOSH showed that this type of LEV system controls dust equally well for larger chipping equipment. NIOSH collected short-term samples while workers used 25- or 30-pound jackhammers to chip concrete from inside concrete mixer truck drums. During 90- to 120-minute periods of active chipping, mean silica levels decreased 69 percent (from 970 $\mu g/m^3$ to 300 $\mu g/m^3$) when the workers used a tool-mounted LEV shroud in these enclosed spaces (Document ID 0862, p. 10). Although exposures in this NIOSH study are higher than exposures during demolition of refractory material (as the exposure profile shows), the control methods used would also work in reducing exposures during refractory demolition.

NIOSH also evaluated a combination of ventilation controls as part of the same study. The tool-mounted LEV shroud plus general exhaust ventilation provided an additional exposure reduction compared with uncontrolled conditions, resulting in a 78 percent decrease in silica readings (from 970 μg/m^3 to 220 μg/m^3) and a 69 percent decrease in respirable dust levels (from 7,760 μg/m^3 to 2,420 μg/m^3); the difference was due to a lower percentage of silica in the respirable dust sample associated with the combined control (Document ID 0862, pp. 10-12). These ventilated chipping tools reduce worker exposures from both impact drills and jackhammers used to chip refractory materials.

Wet Methods

Wet methods can be successfully used to control silica exposures in a number of operations, including chipping, sawing, spraying, and handling dusty refractory materials, and are currently being used by some in the refractory repair service industry (Document ID 2348, Attachment 1, p. 22).

Studies have quantified the benefit of using wet methods to control respirable dust generated during chipping with handheld equipment. NIOSH investigated a water spray dust control used by construction workers breaking concrete with 60- and 90-pound jackhammers (Document ID 0865). A spray nozzle was fitted to the body of the chipping tool, and a fine mist was directed at the breaking point. Using both a direct reading instrument and a high-flow cyclone and filter media, NIOSH collected 10-minute readings with and without the spray activated, and found respirable dust concentrations were between 72 percent and 90 percent lower when the water spray was used (Document ID 0865, p. 6). NIOSH completed another study evaluating water spray devices to suppress dust created while jackhammering. The study reported a 77 percent reduction in exposures, from 380 μg/m^3 to 85 μg/m^3 (Document ID 0867, p. 8, 17).

Tool-mounted water spray devices can be manufactured using materials obtained from a hardware store and include a garden spray nozzle, tubing, clamps, and a control valve (Document ID 0741; 0838; 0914).

Two more sources also show the effect that water misting devices have on dust control. One study examined dust suppression using misting nozzles to reduce silica while brick cutting using a stationary saw (Document ID 0549, p. 505). Water-fed saws are readily available and effectively control dust during sawing of concrete, stone, and bricks. In comparison with free-flowing water, the respirable mass fractions of dust were reduced by 63 percent with the mist on low, 67 percent on medium, and 79 percent on high (Document ID 0549, p. 509). In another study, the use of a bench-top water-fed masonry saw was associated with a less-than-full-shift (340 minutes) result of 18 μg/m^3 for a worker cutting refractory brick (Document ID 0113, pp. 6, 9, 10).[119]

Water spray also is useful for suppressing dust during cleanup. One employer uses a garden mister to wet refractory debris in the bottom of the furnace, after chipping is completed (Document ID 1162). This step helps control dust as the waste is removed from the furnace. The same employer also tested high-pressure water blasting as a refractory removal method; the process controlled dust, although workers found it difficult to manage the amount of water released in the process (Document ID 1162). This method could be effective in cases where water can be captured effectively.

Workers must use caution when introducing water into a furnace. Some refractory materials crumble and become muddy or slippery when wet with excessive amounts of water (Document ID 1414, p. 366; 1161; 1365, p. 16-18). During partial furnace rebuilding, wetting un-removed brick may introduce a safety hazard. According to the United Automobile Workers (UAW), using water for cutting bricks could cause an explosion when firing a furnace because the bricks absorb too much moisture (Document ID 3582, Tr. 1843-1846). OSHA concludes that wet method controls, while not suitable for every furnace repair situation, may be the best option to control silica during total furnace rebuilds because all the material will be new and dry but other controls such as LEV for demolition and vacuuming for cleanup may be more suitable for partial repairs.

Work Practices

Work practices, such as limiting the number and location of operators working in a furnace at one time, can reduce refractory worker exposures during removal activities. NAIMA noted that its members restrict access to the furnace demolition and rebuild area to only those workers or contractors directly engaged with the project (Document ID 2348, Attachment 1, p. 22).

[119] This value is not included in the exposure profile because it was less than full shift.

Another beneficial work practice is modifying the use of equipment during demolition activities. A study reported a higher silica exposure level for a refractory worker operating in a position closer to the point of operation than a second refractory worker within a 1,100-pound holding furnace for molten aluminum. The worker who experienced higher exposure levels reportedly bent over to grab and toss the pieces of refractory material debris while the other worker operated the jackhammer. This put the lower worker's breathing zone closer to the jackhammer's point of operation and dust generation than the breathing zone of the jackhammer operator. The employer installed ventilated partial enclosures that reduced the workers' exposures substantially (Document ID 1178, pp. 508-509). This study shows that performing these demolition activities can produce elevated exposures, especially if the worker's breathing zone approaches the point of operation, which in this case was the jackhammer tip. Allowing for a pause in demolition for the second refractory worker to collect and discard demolished refractory material would also obviously reduce the amount of airborne silica in the worker's PBZ.

Regular maintenance of equipment and controls can also reduce refractory workers' exposures. For example, workers experienced an exposure reduction of approximately 90 percent when a foundry initiated several control measures, including a preventive maintenance program to ensure proper function of air guns and related equipment used to spray refractory furnace lining materials (Document ID 0121, p. 15). Preventive maintenance programs can also ensure that workers are not exposed to high levels of silica because of faulty equipment. In another foundry, a worker's silica exposure level decreased after a foundry replaced the missing tool restraint on a pneumatic chipper used to remove the refractory lining from a large ladle. The tool restraint eliminated the need for this worker to lean into the ladle where dust was generated to hold the chipping blade in place (Document ID 0576, pp. 719-720). This improvement to the tool, in conjunction with other controls, reduced the worker's exposure by 70 percent.

Combined Control Methods

Depending on the sources of respirable dust, a combination of control methods can reduce silica exposure levels more effectively than a single method. A routine cupola relining (removal and replacement) in the ferrous foundry industry demonstrates the benefit of a combination of controls by achieving a 92 percent reduction in the median exposure (Document ID 1365, p. 16-21). Before implementing controls, OSHA collected samples for three workers with 8-hour TWA results of 324 μg/m^3, 456 μg/m^3, and 583 μg/m^3 (Document ID 0121, pp. 43-47). This facility then implemented control measures to reduce exposures that included substitution of a refractory material with reduced silica and greater moisture content, improvement in equipment and materials to reduce malfunction and task duration, wetting of refractory material before removal, and assigned a consistent team of trained workers to the task. After the foundry made these changes, additional monitoring was conducted during three relining events. Four of five samples measured exposures between 30 μg/m^3 and 50 μg/m^3, with one exposure of 62 μg/m^3. The median was reduced from 456 μg/m^3 to 37 μg/m^3, a reduction of 92 percent (Document ID 0121, pp. 2, 5-7, 9, 12, 42-47).

A second report on a facility performing refractory relining also demonstrates the benefits of a combination of control measures (Document ID 0576, pp. 718-720). A full-shift silica result of 215 μg/m^3 was obtained while a worker chipped away the old refractory lining using faulty equipment, and then mixed the replacement refractory material (Document ID 0576, p. 719). According to the manufacturer's material safety data sheet, the ladle lining contained 56 percent silica. This report noted that the "pneumatic chipper lacked a tool retainer, requiring the worker to hold the chipping bit, putting the worker much closer to the source of the exposure than would have been necessary had the pneumatic chipper been equipped with a retainer" (Document ID 0576, p. 718). The foundry responded by holding a training meeting and seeking worker input on abatement actions, implementing a water control system to reduce dust generated during the pneumatic chipping process, purchasing and using chisel retainers (thereby eliminating the need for the worker to reach into the ladle during chipping), and purchasing and using a vacuum to remove dust and debris from the ladle (Document ID 0576, pp. 719-720). With these changes in place, exposure was reduced to 74 μg/m^3, representing a 66 percent reduction (Document ID 0576, p. 720).[120] OSHA has reason to believe that this

[120] The 8 hour TWA exposure was .67 mg/m^3, equal to 670 μg/m^3, and the sample contained 11 percent crystalline silica. The silica exposure was therefore 670 * .11 = 73.7 μg/m^3.

facility might have achieved still lower silica exposure levels by using LEV or tool-mounted vacuum suction to capture dust, or by managing fresh air flow past the worker's breathing zone.

4.19.4 Feasibility Finding

Based on the exposure profile in Table IV.4.19-B and other record evidence discussed above, OSHA concludes that exposure levels of 50 μg/m^3 or less have already been achieved for 66 percent of refractory-repair workers by implementing a combination of engineering and work practice controls.

The remaining refractory-repair workers will require additional controls to meet this level. These controls include:

- Increased reliance on remote and semi-automated methods for removing and replacing refractory materials.
- Use of portable exhaust ventilation units configured to capture dust as it is generated and design of ventilation to direct fresh air flow past the workers' breathing zone.
- Use of chipping equipment fitted with water mist nozzle or LEV-exhaust hood on the tool.
- Use of upgraded spray guns that allow workers better control of the refractory/water mix during spray application.
- Improved worker training.
- Substitution of high-silica refractories with low-silica-content refractory materials, or materials with a higher moisture content, or precast refractory shapes that minimize airborne silica exposures.

OSHA recognizes that in some instances respiratory protection may be needed, for example, when workers have to go inside furnaces to remove refractory materials by hand or where there is not enough room around the furnace to use automated methods.

OSHA concludes that refractory repair services can achieve silica exposure levels of 50 μg/m^3 or less for most refractory repair workers most of the time by using a combination of the controls described in this section. Accordingly, OSHA finds that the final PEL of 50 μg/m^3 is technologically feasible for the Refractory Repair industry.

4.20 SHIPYARDS (MARITIME INDUSTRY)

4.20.1 Description

The maritime industry encompasses the shipbuilding and repair industry (shipyards) as well as the marine cargo handling industry.[121] Abrasive blasting with silica-containing abrasive is a widely-recognized source of silica exposure in the maritime industry (Document ID 1144, p. 1; 1145; 0852, p. 3; 1365, p. 10-1). Other processes performed in the maritime industry that can result in worker exposure to silica are either construction-related activities or foundry operations, both of which are covered elsewhere in this technological feasibility analysis. Examples of such activities include milling road pavement; grinding, drilling, and sawing concrete or masonry structures; and using jackhammers and impact drills on concrete.

Facilities that repair ships and build boats are classified under the North American Industry Classification System (NAICS) codes 336611 (Ship Building and Repairing) and 336612 (Boat Building). Shipyard workers who repair and build ships/boats generally use abrasive blasting to clean rust, paint, and adhesions from metal surfaces and to etch such surfaces in order to leave a profile or anchor pattern for paint and coating adhesion.

In shipyards, abrasive blasting is the most effective and efficient means of surface preparation. In general, across all U.S. industries, the use of silica sand in abrasive blasting has declined substantially, from 1,500,000 metric tons in 1998 to 579,000 metric tons in 2008 (Document ID 1679, p. 17; 1211, p. 12). In the maritime industry, silica sand has been replaced with other abrasive media in many shipyard applications (Document ID 1427, p. 8). This move away from silica sand abrasive is not universal. While many larger shipyards, including those operated by the U.S. Navy, have switched to non-silica media, some smaller shipyards continue to use sand (Document ID 1680, p. 3; 1365, p. 10-2).

[121] OSHA does not anticipate silica exposure in maritime operations related to the operation of shipping lines for commercial use such as loading and unloading cargo ships.

Workers who perform abrasive blasting are classified as painters under the Bureau of Labor Statistics (BLS) Standard Occupational Classification (SOC) system. Attendants who assist abrasive blasters are classified as painter's helpers (Document ID 1706). In shipyards, these are the primary job categories in which employees are exposed to silica during abrasive blasting with silica-containing abrasive. However, any workers near such abrasive blasting operations have potential for substantial silica exposure. As in other industries that conduct abrasive blasting, maritime industry workers sometimes perform abrasive blasting in enclosed areas, such as in the ballast or bilge tanks or in the ship's holds. On other occasions the work is performed on the ship exterior, semi-enclosed in a dry dock.

Table IV.4.20-A
Job Categories, Major Activities, and Sources of Exposure of Workers in Shipyards (Maritime Industry) Industry (NAICS 336611, 336612)

Job Category*	Major Activities and Sources of Exposure
Painter	Using abrasive blasting equipment to remove paint and clean and etch surfaces to leave a surface profile for paint adhesion. • Dust generated from the use of silica-containing abrasive blast media. • Dust generated from abrasive blasting of silica-containing paint. Using abrading equipment to remove paint and rust and prepare surfaces for application of paint. • Dust generated from sanding silica-containing paint.
Painter's Helper	Dry sweeping residue generated from abrasive blasting operations. • Dust raised by sweeping spent abrasive material (housekeeping).

*Job categories are intended to represent job functions; actual job titles might differ, and responsibilities might be allocated differently, depending on the facility.
Sources: Document ID 0852; 0507; 1365; 1720, p. IV-334.

4.20.2 Exposure Profile and Baseline Conditions

The exposure profile in Table IV.4.20-B includes 9 full-shift personal breathing zone (PBZ) samples of respirable crystalline silica for workers in the maritime industry. The median is 85 μg/m^3, the mean is 511 μg/m^3, and the range is 12 μg/m^3 (limit of detection (LOD)) to 3,100 μg/m^3. Table IV.4.20-B shows that, of the 9 samples, 5 (55.6 percent) are above 50 μg/m^3 and 4 (44.4 percent) exceed 100 μg/m^3.

To evaluate maritime workers' silica exposures, OSHA reviewed 7 personal breathing zone (PBZ) respirable silica exposure monitoring samples available from a NIOSH report on abrasive blasting in a shipyard (Document ID 0852, p. 7). OSHA inspection data from OSHA's Information System (OIS) provide 2 additional samples in NAICS code 336611 – one sample for "blasting and painting" and one for a "sandblaster" (Document ID 3958, lines 217, 332).[122] OSHA requested, but did not receive, additional exposure data for this industry. Thus, the limited exposure data in the record constitute the best available evidence on which OSHA can base the exposure profile for the maritime industry (shown in Table IV.4.20-B). OSHA notes that these pieces of data are generally consistent with the profile presented in Section IV-5.1 – Abrasive Blasters of this Final Exposure Analysis (FEA), after accounting for the differences in length of exposure and the type of media that is generally used.

The NIOSH report describes a facility engaged in the business of constructing marine vessels for oceanographic research (Document ID 0852). The company employs 1,000 workers, 2 to 20 of whom are exposed to silica daily. Painters perform sandblasting with beach sand and typically spend the balance of their shifts painting. The designated areas for abrasive blasting and painting movable parts have a hoisted screen curtain and rails to position pieces to be blasted. While NIOSH did not observe controls in place during its assessment, the facility indicated that the designated abrasive blasting/painting areas were selected so that prevailing winds would carry the generated aerosol away from the workers (Document ID 0852, pp. 3, 5). OSHA notes that the working conditions described in the NIOSH report, and the associated silica exposures, may not be representative of shipyard workers overall. Workers at this facility used beach sand containing a high percentage of crystalline silica, a practice also described by EPA at a small marine yard servicing boats averaging 125 feet in length (Document ID 0852, p. 4; 1202, pp. 38-39). In contrast, maritime workers in larger naval shipyards and facilities

[122] As noted in Section IV-2–Methodology, all sample results included in the exposure profile are 8-hour time-weighted averages (8-hour TWAs) calculated based on the assumption that the exposure continued at the same rate during any unsampled portion of the shift.

working under navy contracts do not use blast media with silica content greater than 1 percent (Document ID 1201, p. 43).

Workers employed by small, marina-based shipyards are more likely to have diverse duties, with abrasive blasting constituting only a small portion of their work shifts. These smaller maritime facilities typically service fishing vessels requiring routine repair and maintenance (Document ID 1202, p. 9). The U.S. Coast Guard estimates that 79,000 vessels could be engaged in fishing activities. Of these, 20,000 weigh 5 gross tons (GT) or more, and 59,000 are less than 5 GT (Document ID 0761).

Exposure Profile and Baseline Conditions for Painters

The exposure profile in Table IV.4.20-B includes 6 samples for painters in the maritime industry. The median is 31 μg/m^3, the mean is 679 μg/m^3, and the range is 12 μg/m^3 (limit of detection (LOD)) to 3,100 μg/m^3. Table IV.4.20-B shows that, of the 6 samples, 2 (33.3 percent) are above 50 μg/m^3 and 2 (33.3 percent) exceed 100 μg/m^3.

Existing OSHA standards applicable to shipyards require that abrasive blasters be provided with hoods and air-line respirators, or positive pressure air helmets, when blasting in enclosed spaces, or in the open with abrasives containing at least 1 percent silica; other suitable respiratory protection is required for other blasting activities (29 CFR 1915.34(c)(3)). Where blasting enclosures are used, they must be ventilated as described in 29 CFR 1910.94(a)(3). Based on these existing requirements and the NIOSH shipyard evaluation, OSHA finds that the use of compressor powered equipment with dry silica containing abrasive blast media and abrasive blasting respirators represent baseline conditions for blasters/painters in shipyards. OSHA also finds that the use of isolation by distance and partial screens around unventilated blasting areas are baseline controls for these workers (Document ID 0852, pp. 3-5). Painters typically perform abrasive blasting for 50 percent or less of every shift (Document ID 0852, p. 3).

Table IV.4.20-B summarizes the available silica exposure data for painters who perform abrasive blasting at maritime facilities. The data include four samples from the NIOSH report and two sample results from two recent OSHA inspections at maritime facilities (Document ID 3958). The median silica exposure for painters is 31 μg/m^3, and the mean is 679 μg/m^3, with a range of 12 μg/m^3 to 3,100 μg/m^3. The highest silica exposure occurred at the shipyard studied by NIOSH on a day when the painter spent 45 percent of his time sandblasting, 25 percent of his time preparing for sandblasting, and 20 percent of his time painting. The lowest exposure at this facility, 26 μg/m^3, occurred for the same painter on the following day when he spent 10 percent of his time sandblasting, 20 percent of his time preparing for sandblasting, and 70 percent of his time painting. The two other NIOSH sample results (36 μg/m^3 and 890 μg/m^3) involved a second painter who spent 70 percent of the shift sandblasting, 15 percent of his time preparing for sandblasting, and 15 percent of his time painting on both days (Document ID 0852, pp. 7, 9). The higher exposure level occurred on the second day, when 50 percent more silica sand was used. The amount of sand used on the second day was more representative of typical conditions at the facility (Document ID 0852, p. 5). Both painters performed sandblasting outdoors within a screen enclosure intended to decrease the spread of silica dust to other areas. Tasks and controls for the two OIS data points were described as, "blasting and painting, process enclosed," and "sandblaster, work performed in open air" (Document ID 3958, Rows 217, 332). Both OIS sample results were below the limit of detection (LOD) of 12 μg/m^3 and the type of blasting media used was not identified.

Exposure Profile and Baseline Conditions for Painters' Helpers

The exposure profile in Table IV.4.20-B includes 3 samples for painters' helpers in the maritime industry. The median is 160 μg/m^3, the mean is 175 μg/m^3, and the range is 85 μg/m^3 to 280 μg/m^3. Table IV.4.20-B shows that, of the 3 samples, 3 (100 percent) are above 50 μg/m^3 and 2 (66.7 percent) exceed 100 μg/m^3.

Painters' helpers perform dry sweeping of residue between the painters' abrasive blasting and painting activities. These tasks are performed wherever painting will occur, including in enclosed or confined spaces (e.g., a vessel engine room or tank) and outdoors on the deck of a ship (Document ID 0852, p. 6). Painters' helpers wear dust filtering respirators while dry sweeping (Document ID 0852, pp. 5-6).

The painters' helpers evaluated in the NIOSH report spent their entire shifts dry sweeping and using a hand brush (Document ID 0852, p. 6). The three sampling results for painters' helpers are summarized in Table IV.4.20-B. The median silica exposure for painters' helpers is 160 µg/m^3, and the mean is 175 µg/m^3, with a range from 85 µg/m^3 to 280 µg/m^3. The lowest exposure level was associated with the worker who swept the deck. The two higher values were obtained for two helpers who spent all or part of their shifts dry sweeping in an enclosed engine room (Document ID 0852, pp. 6-7).

Table IV.4.20-B
Personal Respirable Crystalline Silica Exposure Range and Distribution of Results for Workers in the Shipyards (Maritime) Industry (NAICS 336611, 336612)

	Exposure Summary			Exposure Range			Exposure Profile				
Shipyards (Maritime) Industry	**N**	**Mean (μg/m³)**	**Median (μg/m³)**	**Min (μg/m³)**	**Max (μg/m³)**		**<25 (μg/m³)**	**≥25 and ≤50 (μg/m³)**	**>50 and ≤100 (μg/m³)**	**>100 and ≤250 (μg/m³)**	**>250 (μg/m³)**
Painter	6	679	31	12	3,100		2 (33.3%)	2 (33.3%)	0 (0%)	0 (0%)	2 (33.3%)
Painter's Helper	3	175	160	85	280		0 (0%)	0 (0%)	1 (33.3%)	1 (33.3%)	1 (33.3%)
Shipyards (Maritime) Industry Total	**9**	**511**	**85**	**12**	**3,100**		**2 (22.2%)**	**2 (22.2%)**	**1 (11.1%)**	**1 (11.1%)**	**3 (33.3%)**

Notes: All samples summarized are personal breathing zone (PBZ) results and represent 8-hour time-weighted average exposures.
Job categories are intended to represent job functions; actual job titles might differ, and responsibilities might be allocated differently, depending on the facility.
Percentages may not equal 100 percent due to rounding.

Sources: Document ID 1720, p. IV-336; 3958; 0852.

4.20.3 Additional Controls

The exposure profile in Table IV.4.20-B shows that more than half (5 out of 9 samples) of painters and painter's helpers in the maritime industry have exposures above the final PEL of 50 μg/m^3. Therefore, OSHA finds that additional controls will be necessary to achieve the PEL for these overexposed workers. As the exposure profile indicates, painters and painters' helpers performing abrasive blasting operations using silica-containing abrasive in shipyards are potentially exposed to levels of silica well above 50 μg/m^3 unless additional controls are used. Additional controls are required not only to protect these workers, but also any workers adjacent to the blasting operation.

Additional Controls for Painters

Painters are potentially exposed to very high levels of silica when performing abrasive blasting using silica-containing abrasive. Since workers in this job category spend varying amounts of time performing blasting, exposures can range from below 50 μg/m^3 to above 3,000 μg/m^3. Thirty-three percent (two) of the six sample results for painters in Table IV.4.20-B are above 50 μg/m^3 and will require additional controls. The remaining 67 percent (four) of the six sample results are less than 50 μg/m^3. Workers who use silica-containing media to perform abrasive blasting in maritime industry facilities will benefit from the following exposure control options, which are outlined in IV-5.1 Abrasive Blasters and repeated here for convenience.

- Low-silica and silica-free abrasive blasting media substitutes that are less toxic than silica sand.
- Abrasive blasting with wet methods, dust suppressants, or other processes that reduce or eliminate dust generation.
- Automated and/or enclosed (shrouded) abrasive blasting equipment.
- Abrasive blasting cabinets for small and medium-sized parts.
- Enclosures, such as containment structures (which protect adjacent workers only).
- Local exhaust ventilation (LEV) of enclosures (with proper filtration to protect adjacent workers).
- Respiratory protection.

Use of Alternative Abrasive Media

To eliminate the hazards posed by using silica sand as the abrasive media, employers can select alternative blasting media that do not contain crystalline silica. For shipboard use, low-silica substitutes and silica-free blasting media, which are less toxic than silica sand, offer an important option for exposure control, particularly in areas where automated and semi-automated methods are impractical (for example, in most interior spaces and in spaces with small surface areas, multiple fittings, or corners and angles) (Document ID 0852, p. 5).

OSHA received many comments related to the use of alternatives to silica sand in abrasive blasting. Those comments are described more fully in IV-5.1 Abrasive Blasters. Ms. Peg Seminario, Director, Safety and Health Department of the AFL-CIO, urged OSHA to implement a ban on the use of silica sand in abrasive blasting (Document ID 4204, p. 76). Mr. Ian Bennitt, Manager, Government Affairs for the Shipbuilders Council of America (SCA), described efforts to reduce silica exposures in the shipbuilding and repair industry, stating that alternatives to dry abrasive blasting are effective in some circumstances:

> Within the shipbuilding and repair industry, there has been a concerted effort to eliminate occupational exposure to silica. In practice, shipyards have reduced or eliminated respirable crystalline silica from production processes, products, and services. A prime example of this has been the adoption of alternative media components for blasting operations…. Blasting techniques such as water blasting, dustless blasting, dry ice blasting and others have been tested and implemented in many shipyards (Document ID 2255, pp. 1-2).

Mr. Bennitt also noted, however, that “in some cases these alternative methods have proven unsuccessful in keeping up with production demands and providing competitive costs” (Document ID 2255, p. 2).

Many types of alternative abrasive blasting media are available for use as a substitute for silica sand in abrasive blasting. Alternative abrasive media containing less than 1 percent silica include garnet, staurolite, aluminum oxide, and slags of copper, coal, or nickel

(Document ID 3747, p. 14). Flynn and Susi (2004) suggest that crushed glass, specular hematite, and dolomite may be low-hazard alternatives to silica sand (Document ID 1717, p. 682). The International Safety Equipment Association (ISEA) describes steel shot as a safer, effective, and economical substitute for silica sand (Document ID 2212, Attachment 1, p. 4).

Some shipyards are already using alternatives to silica to meet customer specifications. For instance, in 1996, the U.S. Navy banned the use of silica sand, or any abrasive media containing more than 1 percent silica by weight, for abrasive blasting of ship hulls (see military specification MIL-A-22262B(SH) Amendment 2 (Document ID 1365, p. 10-2)).[123] Moreover, the American National Standards Institute (ANSI) Z9.4-1997 design standard on exhaust systems for abrasive blasting operations at fixed location enclosures prohibits the use of silica sand as an abrasive blasting agent in such operations (Document ID 0528, p. 1).

Ms. Sally Greenberg, Executive Director of the National Consumers League, noted that, in addition to the U.S. Navy, the Air Force, the Coast Guard, 23 state departments of transportation, and other countries (such as Great Britain, Germany, Sweden, and Belgium) have all banned the use of silica sand in abrasive blasting (Document ID 3588, Tr. 3752). Paul Mellon of Novetas Solutions testified regarding the growing use of alternative blasting media, noting that the annual tonnage of silica sand used for abrasive blasting operations decreased 67 percent from 1996 to 2007, primarily due to the use of alternative blasting media and high-pressure water-jet techniques (Document ID 3545, p. 4).

Evidence in the record suggests that several of the alternatives to silica sand may pose their own health hazards. Studies on abrasive blasting have noted that even blasting operations using media with low silica content, such as garnet, copper slag, and non-siliceous substrates, can result in elevated airborne concentrations of silica. In a NIOSH-sponsored study, 17 of 52 respirable samples showed detectable silica concentrations

[123] This specification supersedes one dated April 1993 restricting the use of abrasive blasting media containing greater than 1 percent silica.

when blasting on steel plate with garnet, with results as high as 6,800 µg/m^3; however, the geometric mean concentration (200 µg/m^3) was about 2 percent of the geometric mean concentration associated with blasting with silica sand (8,800 µg/m^3) (Document ID 0772, p. 117). This study did note that all respirable quartz samples were below the limit of detection for crushed glass, coal slag, nickel slag, olivine, specular hematite, copper slag with dust suppressant, and steel grit (Document ID 0772, p. 82). In this same study, 3 of 32 samples involving blasting with copper slag media showed detectable silica, with concentrations as high as 740 µg/m^3 (Document ID 0772, p. 83); however, the geometric mean level (140 µg/m^3) was 59 times lower than the geometric mean level associated with blasting with silica sand (8,800 µg/m^3) (Document ID 0772, p. 114).

In a follow-up study, all four samples involving blasting with garnet showed detectable silica, with concentrations ranging from 870 µg/m^3 to 7,280 µg/m^3, while no detectable silica concentrations were associated with copper slag media; blasting with silica sand led to silica concentrations ranging from 9,910 µg/m^3 to 50,052 µg/m^3 when blasting with silica sand (Document ID 0773, p. 45). This study found that the alternative media studied (coal slag, nickel slag, staurolite, copper slag, garnet, and steel grit) each resulted in higher geometric mean concentrations of at least four of ten toxic metals studied (arsenic, beryllium, cadmium, chromium, lead, manganese, nickel, silver, titanium, and vanadium), as compared to silica sand (Document ID 0773, pp. iii and 90). However, this study noted that only one abrasive from each generic category was studied, and that the potential for variability in toxic metals exposures between individual abrasives within a general category must be considered (Document ID 0773, pp. 89-90).

In another study, investigators measured geometric mean silica concentrations of 5,000 µg/m^3 and 6,900 µg/m^3 in the breathing zones of abrasive blasters removing paint from foot bridges using recycled coal slag or steel grit. The paint contained 5.9 percent to 9.6 percent silica by weight (Document ID 0802, p. D81 - D82). This study also indicated the presence of other toxic substances, even in clean abrasives (Document ID 0802, p. D-82).

Based on the studies in the record, OSHA has determined that while alternative blast media can be effective in reducing worker exposures to silica, alternative blast media must be carefully selected and evaluated for health hazards.

OSHA acknowledges that not every silica alternative will be practical in every circumstance. OSHA also recognizes, as described above, that many of the silica sand substitutes may increase levels of toxic dust other than silica. Based on its consideration of relevant comments and the information available to OSHA, the agency has determined that a ban on the use of silica sand is not warranted. Nonetheless, OSHA concludes that, in a great many cases, further reductions in silica exposures can be achieved through the use of alternative blasting media, and finds that substitutes can be an effective control in some situations. When employers are selecting appropriate controls for abrasive blasting operations, they must consider all potentially feasible controls – including substitution.

Wet Methods

Wet abrasive blasting methods will reduce the silica exposure levels of maritime workers who use silica sand. Wet abrasive blasting methods have proven to be effective in the construction sector. The exposure profile in Section IV-5.1 – Abrasive Blasters shows a median silica exposure of 251 μg/m^3, with a range of 12 μg/m^3 to 29,040 μg/m^3, for abrasive blasting operators performing dry, uncontrolled blasting without a booth or cabinet. In contrast, for abrasive blasting operators performing wet blasting without a booth or cabinet, the median silica exposure is 125 μg/m^3, and exposure levels range from 36 μg/m^3 to 407 μg/m^3. These values demonstrate the extent to which wet blasting can reduce exposure levels. It should be noted, however, that the construction industry data for both dry and wet abrasive blasting include samples collected under a variety of conditions, including some results obtained while workers used low-silica or silica-free abrasive blast media while blasting on silica-containing substrates, such as concrete.[124] The maritime exposure profile includes sample results associated with dry silica-containing blast media, which may be more typical of smaller shipyards and marinas.

[124] The construction industry abrasive blasting data represent 8-hour TWA exposure levels, calculated with the assumption that no additional exposure occurred during any unsampled portion of the shift.

Although there are some differences between the construction and maritime industries, the results from the construction industry showing the effectiveness of wet methods can offer valuable insight into the potential benefits of using wet abrasive blasting in the maritime industry.

Use of Dust Suppressant Additives

Dust suppressants are another control strategy that can be effective in reducing silica exposures when silica sand is used for abrasive blasting. NIOSH noted that a shipyard safety director described a 40 percent reduction in respirable silica exposures when abrasive sand containing dust suppressant materials was used. However, use of this control was discontinued, perhaps due to the increase in cost (from $20 to $26 per ton of blasting sand) (Document ID 0852, p. 5). Dust suppressant additives provide a limited amount of dust control during blasting with silica sand. For instance, during a study evaluating several types of abrasive media, silica sand abrasive was used to blast the side of an unpainted, rusted steel coal barge (Document ID 0773, p. 1). Silica exposures ranged from 9,910 µg/m^3 to 50,522 µg/m^3, with a geometric mean of 27,959 µg/m^3 (Document ID 0773, p. 45). When a dust suppressant was used with the silica sand abrasive, silica levels in four readings had a geometric mean of 19,040 µg/m^3 (ranging from 9,180 µg/m^3 to 28,200 µg/m^3), about 68 percent of the mean associated with the use of untreated silica sand (Document ID 0773, p. 45). Although these levels are still excessive, dust suppressant methods used in combination with other measures, such as ventilation and work practices, can help to reduce silica exposures when silica sand must be used as the blasting agent. Effective dust suppressant additives will also help reduce silica exposures when workers (e.g., painter’s helpers) handle abrasives before and after the actual abrasive blasting. OSHA did not receive comments or exposure information on dust suppressant additives and finds that they (in combination with other control measures) are useful in reducing workers’ exposure to silica.

Alternative Methods to Dry Abrasive Blasting

Many of the alternative methods for dry abrasive blasting (listed in Table IV.4.20-C, Alternative Controls) have been tested in shipyards, where the large expanses of near-flat surfaces available on ship decks and hulls provide optimal surfaces for comparative trials. Many of these methods effectively remove paint and eliminate worker exposure to silica by completely enclosing or eliminating the use of silica-containing blasting media or by eliminating the process of abrasive blasting (substituting another process, such as grinding paint off the surface).

Some of the alternative abrasive blasting methods also offer some reduction in airborne exposure to other contaminants (e.g., metals) from the surface coating being removed. For example, Flynn and Susi (2004) reviewed vacuum blasting and automated, robotic systems for removing lead-containing paint (Document ID 1717). Vacuum blasting demonstrates the potential value of a well-enclosed and well-ventilated process. Using this technology, worker lead dust exposures were controlled to a considerable extent, from a geometric mean of 4,200 μg/m^3 during open blasting to 55 μg/m^3 during vacuum blasting (a 98.6 percent reduction) (Document ID 1717, p. 685). Although these lead results cannot be translated directly to silica exposure levels, they suggest that much of the dust contaminated air was captured during the abrasive blasting. The exhaust ventilation on vacuum blasting systems would be expected to be even more effective in capturing respirable size particles (as compared to total dust), as respirable particles are smaller and are captured at a lower velocity and at a greater distance from the exhaust hood (Document ID 4149, p. 9; 3883, pp. 6-18 – 6-27).

Furthermore, automated and semi-automated versions of hydroblasting, centrifugal wheel blasting, and vacuum blasting equipment offer quality cleaning of flat or gently curved surfaces (such as exterior hulls) while allowing the workers performing the blasting to stand a good distance away from the surface being blasted. Each of these automated methods are challenged by corners, fittings, and sharp bends in the surface, where workers must still use mechanical stripping (needle gunning, grinding) or traditional abrasive blasting to finish the job (Document ID 0852, p. 6; 1365, p. 10-5). Additionally, these alternate methods result in different anchor patterns on the bare metal than traditional abrasive blasting, so workers require technical expertise to match alternate surface cleaning methods to the surface metal and paint system to be applied (Document ID 1717, p. 683).

Table IV.4.20-C, Alternative Controls Examples of Alternatives to Dry Abrasive Blasting	
Name	**Description/Comments**
Wet Abrasive Blasting	Can be used in most instances where dry abrasive blasting is used. Includes: 1) compressed air blasting with the addition of water into the blast stream before the abrasive leaves the nozzle, and 2) water jetting with the addition of abrasive into the water stream at the nozzle. Additives and rust inhibitors might be used.
Hydroblasting	High Pressure Water Jetting: Uses pressure pump, large volume of water, and specialized lance and nozzle. Pressures range from 3,000 to 25,000 pounds per square inch (psi). Can remove loose paint and rust; will not efficiently remove tight paint, tight rust, or mill scale. Can be used in most instances where abrasive blasting is used. Primary application is for an older surface rusted in a saline environment rather than for new steel. Rust inhibitors could be required to prevent flash rusting. Ultra-High-Pressure Water Jetting: Similar to high-pressure water jetting. Uses pressurized water from 25,000 to 50,000 psi. Removes tight paint and rust, but not mill scale.
Centrifugal Wheel Blasting	Uses a rotating wheel assembly inside an enclosure equipped with a dust collector. Abrasive is propelled outward from the rotating wheel and removes rust, paint, and mill scale. Abrasives are recycled and include steel shot, steel grit, cut wire, and chilled iron grit. Generates no airborne dust or high velocity particles.
Vacuum Blasting	Uses standard blast nozzle inside a shroud (head) that forms a tight seal with the work surface. Vacuum is applied inside shroud during blasting to remove dust and debris. Abrasives are recycled and include aluminum oxide, garnet, steel shot, steel grit, and chilled iron grit. When used properly, cleans effectively with minimal dust.
Dry Ice Pellets	Dry ice blast cleaning with solid carbon dioxide. Waste is minimized and includes paint chips and rust. Storage and handling costs can be substantial.
Thermal Stripping	Uses a flame or stream of superheated air to soften paint, allowing for easy removal. Generates one waste stream (i.e., waste paint). Effective for small parts; not suitable for heat-sensitive surfaces. Very labor intensive.
Chemical Stripping	Uses hazardous chemical strippers such as methylene chloride-based or caustic solutions. Effective for small fiberglass, aluminum, and delicate steel parts. Requires adequate ventilation and other safety measures. Generates multiple waste streams (i.e., contaminated rinse water and waste strippers).
Mechanical Stripping	Involves chipping, grinding, sanding, or scraping the coating off small parts or surfaces through the use of needle guns, chipping hammers, sanders, and grinders. Generates paint waste and airborne dust. Some power tools are equipped with dust collection systems.
Sources: Document ID 1202; 0775, pp. 4-5; 0575, pp. 36-37, 40-41, 43.	

A NIOSH study (ECTB 233-110) noted that switching to factory pretreated steel in the mid-1990s eliminated the need for some shipyard abrasive blasting. To reduce the need to remove yard corrosion by abrasive blasting, the shipyard purchased steel that had been coated with a zinc antioxidant after treatment in a steel shot blast machine. The resulting steel requires less abrasive blasting at the shipyard (Document ID 0852, p. 5).

As described above, a variety of technologies are available as alternatives to open air dry abrasive blasting. Available literature, also described above, leads OSHA to conclude that these methods are feasible and effective in reducing exposures to respirable crystalline silica in many instances.

Enclosures and Local Exhaust Ventilation (LEV)

Enclosing blasting operations is a common technique for preventing exposures among workers not directly involved in blasting operations. The NIOSH shipyard evaluation described the use of partially enclosing screens to reduce bystander exposures (Document 0852, pp. 3-5). Similarly, one of the OSHA shipyard inspections reported in OIS noted that process enclosure was used for abrasive blasting (Document ID 3958, Row 217).

When enclosures are used, they must be properly ventilated to avoid extremely high silica exposures for the person performing the abrasive blasting. For example, in an evaluation of bridge repair, NIOSH found elevated short-term airborne silica results of 820 $\mu g/m^3$, 1,730 $\mu g/m^3$, and 2,960 $\mu g/m^3$ (with sample durations of 93, 96, and 93 minutes, respectively) for area samples collected inside an unventilated enclosure used to confine dust generated during the blasting process (Document ID 0910, p. 5). OSHA's existing Ventilation Standard at 29 CFR 1910.94 contains requirements for abrasive blasting in shipyards. Among other things, the standard includes specifications for blast-cleaning enclosures, exhaust ventilation systems, air supply and air compressors, and operational procedures.

The record supports OSHA's determination that enclosures and LEV reduce silica exposure. NIOSH researchers found that when blasting ceased, ventilation rapidly reduced the high levels of dust that had been produced by abrasive blasting in ventilated enclosures (Document ID 0212, p. 15). And while the exposure data in the record do not provide precise measurements of the extent to which silica exposures associated with abrasive blasting are reduced in ventilated enclosures, evidence in the record, coupled with basic ventilation principles, indicates that use of ventilated enclosures results in reduced exposures among operators that work within the enclosures. In hearing testimony, Ms. Lauren Bailey of the National Automobile Dealers Association (NADA) described the use of LEV with spot abrasive blasters:

> It is not uncommon for dealership auto body shops to use ventilated spot blasters for dust control purposes regardless of the media being used since such devices offer the advantage of abrasive capture and recycling and have a cleaner workplace environment. The use of ventilated blasters, like ventilated sanders, helps to minimize any potential dust exposures (Document ID 3587, Tr. 3722).

Similarly, the AFL-CIO submitted a World Health Organization document on airborne dust to the record, which explains that enclosures are usually coupled with exhaust ventilation to remove contaminants from the workplace (Document ID 4072, Attachment 15, p. 97).

Portable blast-cleaning equipment and temporary containment structures must have sufficient exhaust ventilation to: 1) prevent a build-up of dust-laden air and reduce the concentrations of hazardous air contaminants, 2) prevent any leakage of dust to the outside, and 3) provide prompt clearance of dust-laden air from the enclosure when blasting has ceased (Document ID 0528, pp. 5, 9; 3883, p. 13-142). Exhaust ventilation systems must be constructed, installed, inspected, and maintained according to 29 CFR 1910.94. The exhaust air from blast-cleaning equipment must be discharged to the outside (away from other workers and the public) through an appropriate dust collector to protect the workplace, the environment, and the surrounding community from hazardous air contaminants. The dust collector should be set up so that the accumulated dust can be emptied and removed without contaminating other working areas.

Additionally, another control method for workers who abrasively blast smaller, removable parts is the use of ventilated enclosures (e.g., ventilated abrasive blasting cabinets), which will isolate the abrasive blasting media and limit (or eliminate) worker exposures to silica.

Respiratory Protection

OSHA recognizes that, even with implementation of feasible engineering and work practice controls, respiratory protection may be necessary in some circumstances to protect abrasive blasting operators in the maritime industry from silica exposures above 50 µg/m^3. Maritime employers following 29 CFR 1915.34(c)(3)(i) protect abrasive blasters from a wide range of hazards by equipping these workers with hoods and NIOSH-certified airline respirators or positive-pressure air helmets. In contrast, when abrasive blasters are working in the open and using synthetic abrasive blasting media that contains less than 1 percent silica, employers may use appropriate filter type respirators in accordance with 29 CFR 1915.154 (which states that respiratory protection for shipyard employment is covered by the general industry Respiratory Protection Standard at 29 CFR 1910.134). Employers will need to consider the silica PEL of 50 µg/m^3 when determining whether a respirator offers adequate protection. Ms. Julie Tremblay of 3M noted in written comments that blasting respirators come with assigned protection factors (APFs) of 25 and 1000. Emphasizing the importance of proper respirator selection in accordance with OSHA's Respiratory Protection Standard, she stated that "without considering the performance (APF) of the respirator, some workers could be overexposed to silica" (Document ID 2313, p. 1). OSHA agrees with Ms. Tremblay's concern that a respirator with an APF of 25 or higher may be needed for abrasive blasting operations in some cases, depending on factors such as the silica content of the media, the task duration, and whether the blasting is performed in the open or in an enclosed area.

Additional Controls for Painters' Helpers

As presented in the exposure profile in Table IV.4.20-B, all three sample results for painters' helpers exceed 50 µg/m^3; therefore, additional controls will be necessary to reduce exposures among painters' helpers. In the PEA, OSHA estimated that the same controls for, and alternatives to, dry abrasive blasting with silica sand outlined for painters would benefit the painters' helpers (regardless of the helpers' duties) to at least the same extent as those methods benefit the painters themselves. No comments were received in the rulemaking record disputing this estimate. Automated, enclosed (e.g., isolating), or shrouded dry abrasive blasting methods, which employ some form of vacuum suction device to capture the media, will produce less dust and debris, resulting in less cleaning by the helpers. Wet methods, such as wet abrasive blasting, will limit the spread of dust and prevent silica dust from becoming airborne to the extent that the helpers can clean up the spent media while it is still damp. Low-silica substitutes and silica-free blasting media that is less toxic than silica sand will generate dust with lower silica content and reduce painters' helpers' exposures during cleaning.

Improved housekeeping methods are of critical importance to reduce exposures among painters' helpers. The dry sweeping of spent abrasive blasting media and debris can be a significant source of silica exposure for painters' helpers. For example, the NIOSH shipyard evaluation found exposure levels of 85 $\mu g/m^3$, 160 $\mu g/m^3$, and 280 $\mu g/m^3$ for workers who spent the entire sampling period dry sweeping material from surfaces, using a hand broom or a whiskbroom (Document ID 0852, p. 3). Dry sweeping material will create higher airborne dust levels than other methods (such as vacuums, shovels, and scrapers); indeed, NIOSH recommended the use of a filtered vacuum system rather than dry sweeping (Document ID 0852, p. 6).

Using vacuums, shovels, and scrapers to clean surfaces introduces less dust into the air than dry sweeping. A study of Finnish construction site workers (Riala (1988)) compared the silica exposures for workers dry sweeping with exposures for workers using alternate cleaning methods (Document ID 1163). When compared with dry sweeping, worker exposures were approximately three times lower when the workers used squeegees to scrape surfaces and approximately five times lower when workers used vacuums (Document ID 1163, p. 217). Additionally, when wet abrasive blasting is implemented as a control, moisture in the abrasive media will continue to suppress dust as long as workers dispose of or recover the abrasive before it dries. OSHA expects that exposure reductions seen in the construction industry can be replicated in shipyards.

Based on the information presented here and in IV-5.1 – Abrasive Blasters, OSHA concludes that silica exposure levels among painters' helpers can be reduced by providing high-efficiency particulate air (HEPA)-filtered vacuums for cleaning. NIOSH recommends vacuuming with an approved HEPA-filtered vacuum, or using wet cleaning methods, to minimize worker exposures to hazardous air contaminants (such as asbestos, silica, and heavy metals) during housekeeping activities in numerous industries (Document ID 1365, pp. 19-25, 23-6). Furthermore, as discussed previously, when vacuum blasting was used for an abrasive blasting task, lead exposure levels among painters were reduced by 98.6 percent (Document ID 1717, p. 685). A HEPA-filtered vacuum uses similar suction and filtration technology without an internal blasting component so will capture settled dust even more efficiently. Even if a HEPA vacuum is assumed to capture dust only 85 percent effectively, it would reduce the highest painters' helper's silica exposure level from 280 μg/m^3 to 42 μg/m^3.

4.20.4 Feasibility Findings

OSHA has determined that a PEL of 50 μg/m^3 is technologically feasible for the maritime industry. Although it is not feasible to reduce painters' exposures to 50 μg/m^3 when conducting abrasive blasting operations most of the time without the use of respirators, evidence in the record demonstrates that it is feasible to reduce painters' helpers' exposure to 50 μg/m^3 most of the time with HEPA-filtered vacuums. As noted above, workers in the maritime industry may also be exposed during foundry activities; as explained in Chapter 4.8.4 – Captive Foundries, OSHA has determined that it is feasible to reduce exposures during most operations in captive foundries to 50 μg/m^3, most of the time. The record evidence indicates that shipyard foundries face similar issues controlling silica as other typical small foundries (e.g., cleaning the cast metal) and that shipyard foundries cast items in a range of sizes, from small items like a ship's plaque to large items like the bow structure for an aircraft carrier (Document ID 1145; 3584, Tr. 2607). OSHA did not receive comments indicating that foundries in shipyards would require any unique controls to reduce exposures, and therefore believes that exposures in shipyard foundries can also be reduced to 50 μg/m^3 in most operations, most of the time. Accordingly, OSHA has determined that 50 μg/m^3 is feasible for most silica-related activities performed in the maritime industry.

Even if captive foundries are excluded from consideration, OSHA considers the standard to be feasible for shipyards with the use of respirators by painters doing abrasive blasting. OSHA recognizes that, consistent with its hierarchy of controls policy for setting methods of compliance, respirator use is not ordinarily taken into account when determining industry-wide feasibility. Neither this policy nor the "most operations most of the time" formulation for technological feasibility is meant to place OSHA in a "mathematical straitjacket" (*Indus. Union Dep't, AFL-CIO v. Am. Petroleum Inst.*, 448 U.S. 607, 655 (1980) ("*Benzene*") (stated with respect to the "significant risk" finding, which the Supreme Court recognized is "based largely on policy considerations" (*Benzene*, 448 U.S. at 655 n.62)). No court has been confronted with a situation where an industry has two operations (or any even number), of which one can achieve the PEL through engineering controls and the other (or exactly half) can achieve it most of the time only with the use of respirators. However, the same court that formulated the "most operations most of the time" standard "also noted that '[i]nsufficient proof of technological feasibility for a few isolated operations within an industry, or even OSHA's concession that respirators will be necessary in a few such operations, will not undermine' a showing that the standard is generally feasible" (*Amer. Iron & Steel Inst. v. OSHA*, 939 F.2d 975, 980 (D.C. Cir. 1991) (*Lead II*), (quoting *United Steelworkers of Am., AFL-CIO-CLC v. Marshall*, 647 F.2d 1189, 1272 (D.C. Cir. 1980) ("*Lead I*")). It further recognized the intended pragmatic flexibility of this standard by stating that "[f]or example, if 'only the most technologically advanced plants in an industry have been able to achieve [the standard] — even if only in some of their operations some of the time,' then the standard is considered feasible for the entire industry" (*Lead II*, 939 F. 2d at 980 (quoting *Lead I*, 647 F.2d at 1264)). In this instance, OSHA has determined that it makes sense to treat painters performing abrasive blasting in shipyards as an outlier for which the PEL established for all other covered industries is feasible, even conceding that respirators will be necessary. If abrasive blasting were the predominant activity that occurs in shipyards, there might be justification to set a separate, higher PEL for shipyards. But as in construction (for which supplemental respirator use is also contemplated for abrasive blasting operations), abrasive blasting is one of many activities that occurs; substitution of non-silica blasting materials is an option in many cases; few, if any, painters spend entire days or weeks doing blasting operations and thus needing respirators for the duration; and lowering the standard from 250 μg/m^3 to 50 μg/m^3 does not threaten the economic viability of the industry. Under these circumstances, OSHA concludes that it may find the standard feasible for shipyards rather than raise the PEL for this single industry because it can only achieve the uniform PEL with respirators or, alternatively, not be able to revise the previous PEL of 250 µg/m^3 at all.

4.21 STRUCTURAL CLAY

4.21.1 Description

Silica-containing materials are the primary ingredients in the manufacture of structural clay products, which include bricks, clay tiles, and ceramic tiles. Facilities manufacturing structural clay products were classified in the 2007 six-digit North American Industry Classification System (NAICS) codes: 327121, Brick and Structural Clay Manufacturing; 327122, Ceramic Wall and Floor Tile Manufacturing; and 327123, Other Structural Clay Product Manufacturing. OSHA analyzed the facilities classified in NAICS codes 327121, 327122, and 327123 together, based on the similarity of materials, processes, and worker activities associated with potential exposure to silica throughout the majority of these facilities.[125]

Structural clay products manufacturing typically begins with crushing, grinding, and screening silica-containing raw materials such as clay and shale. Traditionally, there are three ways to form and shape structural clay products: extrusion, molding, and dry-pressing. For molding and extrusion, the processed raw materials are mixed with water in a mill to form wet clay or slurry. Next, the wet clay is either pressed into a mold or, more commonly, extruded through a die and cut into shape with a wire-cutter. Dry pressing, an alternate method for forming high-density products (e.g., floor tiles), uses clay slurry that is spray-dried to a low-moisture compactable powder, then compressed in a mold (Document ID 1365, p. 3-2).

Regardless of the forming method, the resulting clay products can be coated or glazed with silica-containing coating mixtures at various stages in the shaping process depending on the final appearance of product desired. For example, a sand mixture is sometimes applied directly to the mold and is often sprayed or sprinkled on the formed product shape. The formed products are dried, fired in kilns, and then packaged. Structural clay products typically require no further processing after the forming, coating, and firing steps are complete. Workers do not normally cut, grind, sand, or saw the

[125] The applicable 2012 NAICS code is 327120, Clay Building Material and Refractories Manufacturing (which consolidates the three codes 327121, 327122, and 327123 into a single NAICS code).

finished products, except perhaps to separate units cast as groups (Document ID 1365, p. 3-6).

The Whitacre Greer Company stated that the following employee types would be directly affected by the rule; grinders, kiln firemen, unloaders, maintenance, shipping and blending, press operators, and plant supervision (Document ID 3731, p. 1). OSHA agrees and has determined that based on the comments received, available literature and exposure monitoring data presented in site visit reports, NIOSH reports, and OSHA Special Emphasis Program (SEP) reports, workers in all phases of structural clay products manufacture have potential for silica exposure (Document ID 1365, p. 3-2).

The primary job categories with potential for exposure are: material handler, grinding operator, and forming line operator. To evaluate the exposure conditions effectively, these job categories have been further broken down into subcategories. Material handlers are split into three categories—loader operator, production line handler, and post-production handler—depending on the type of material handled (raw material, shaped but unfired product, or fired product). Forming line operators are split by job activity into three categories as well: pug mill operators, coatings blenders, and formers.[126]

Material Handlers

Material handlers classified as *loader operators* oversee the transfer of the raw materials from both off site to storage piles or bins and within the facility to the processing equipment. Typically this work is done with the use of a front end loader although some facilities utilize pneumatic conveyor systems for the transfer of raw material from storage silos. Additionally, these workers may use forklifts to transfer bulk bags of materials (Document 1365, p. 3-5).

After products are formed, *production line handler*s transfer unfired product to racks or kiln cars which move the product through the kiln and dryers.[127] After firing and drying is

[126] In the exposure profile contained in Table IV.4.21-B, formers have been further divided into the subcategories of clay powder formers, wet clay formers, automated coatings applicators and manual coatings applicators.

[127] This process is often referred to as hacking in the brick industry.

complete, *post-production handlers* remove the products from the kiln cars and/or racks[128] either by hand or with the use of lifts and automated equipment; and oversee the product through the inspection and packaging process. Post production works may also utilize forklifts to transport finished products throughout the facility (Document 1365, p. 3-5).

Grinding Operators

Grinding operators oversee the automated machinery responsible for the crushing, grinding and screening of raw materials. Typically these workers monitor equipment from enclosed and ventilated control rooms; however, grinding operators enter the process area multiple times a shift to maintain equipment, to clear jams caused by rocks and debris, to ensure that storage bins and hopper are full, and to clean spillage in the area (Document 1365, p. 3-5).

Forming Line Operators

Forming line operators perform several functions perform several functions. Those classified as *pug mill operators* monitor the equipment, commonly called a pug mill that blends and mixes the raw materials together with water. For this process, raw clay or shale is typically transferred from the grinding process to the milling area by conveyor belts. When needed for dry-press molding, the pug mill operator will also spray dry the clay mixture. After milling, the processed material exits by conveyor to the forming area (Document 1365, p. 3-5 – 3-6).

Coatings blenders prepare crystalline silica-containing coatings by manually emptying bags or boxes of sand into mixer hoppers, then operating sand driers, mills, and mixers to create the coatings applied on the production line. These workers also often spend a portion of their shift performing tasks associated with the formers' job category on the production line (Document 1365, p. 3-6).

Workers in the *formers* category are responsible for shaping the product. At most brick manufacturing and some tile manufacturing facilities *wet-clay formers* oversee equipment

[128] This process is often referred to as de-hacking in the brick industry.

that forces mixed clay through a die to form an extruded column that is cut by an automated wire-cutter. At other facilities, operators known as *clay powder formers* oversee machinery that presses wet or powdered clay into molds. Some formers also shape specialty products by hand. After the product is formed, *coatings applicators* monitor coatings application equipment; which applies a silica-containing mixture or slurry onto the product surface (Document 1365, p. 3-6).

See Table IV.4.21-A for a description of the job categories, major activities, and sources of silica exposure for workers in the structural clay products industry.

4.21) Structural Clay

Table IV.4.21-A Job Categories, Major Activities, and Sources of Silica Exposure of Workers in the Structural Clay Industry (2007 NAICS 327121, 327122, 327123)	
Job Category	**Major Activities and Sources of Exposure**
Material Handler	
Loader Operator	Transferring raw materials (e.g., clay, shale) from storage piles to processing equipment or storage bins via front-end loader. • Dust from open transfer of silica-containing raw materials via front-end loader. • Dust re-suspended by passing traffic (e.g., spilled materials, settled dust). • Dust from conveyors and drop points.
Production Line Handler	Transferring unfired, shaped products within the production line (e.g., to dryers, kilns) using manual, power assisted, or automated processes. • Dust generated by spilled or broken product crushed under wheels. • Dust released from products during handling. • Dust from adjacent processes (e.g., forming line operators, sand coating application).
Post-Production Handler	Transferring finished, fired products through post-production inspection, packaging, and yard areas manually or using lifts and automated equipment. • Dust released during open transfer of products manually or by lift truck. • Dust disturbed by passing traffic (e.g., spilled materials, settled dust, yard dust).
Grinding Operator	
	Operating and maintaining raw material processing equipment, such as crushers, grinders, screens, and driers; performing housekeeping activities. • Dust generated during manual maintenance and operation of crushers, grinders, screens, and raw material driers. • Dust from housekeeping activities (e.g., dry sweeping, shoveling silica-containing materials).
Forming Line Operator	
Pug Mill Operator (including all raw clay-finishing processes)	Mixing dry clay with water to form wet clay to be extruded or molded; spray-drying clay slurry to create compactable clay powder. • Dust from transferring dry material into pug mills and related equipment. • Dust from spray-drying of clay and associated conveyors.
Coatings Blender	Preparing and transferring sand-based coatings to add pigment and texture to bricks. • Dust disbursed during open, manual emptying of bags of silica-containing materials into hoppers. • Dust generated by sand drying, mixing, and milling equipment used to create coatings.
Former (including manual and automated Coatings Applicators, Clay Powder Formers and Wet Clay Formers)	Forming product by hand or machine (molded or extruded products); applying coatings to products manually or monitoring automated application equipment • Dust released during manual or automated application of silica-containing coatings (e.g., sand) to products. • Dust that becomes airborne while sand-coating bags are emptied and compacted for disposal.
Note: Job categories are intended to represent job functions; actual job titles might differ, and responsibilities might be allocated differently, depending on the facility. Source: Document ID 1365, p. 3-4; 1720, p. IV-346; 3731, p. 1.	

4.21.2 Exposure Profile and Baseline Conditions

<u>*Introduction*</u>

The exposure profile in Table IV.4.21-B includes 135 full-shift personal breathing zone (PBZ) samples of respirable crystalline silica for workers in the structural clay industry. The median is 46 µg/m^3, the mean is 97 µg/m^3, and the range is 10 µg/m^3 (limit of detection (LOD)) to 1,028 µg/m^3. Table IV.4.21-B shows that, of the 135 samples, 64 (47.4 percent) are above 50 µg/m^3 and 36 (26.7 percent) exceed 100 µg/m^3.

To evaluate silica exposures of structural clay production workers, OSHA reviewed monitoring data on full-shift personal-breathing-zone (PBZ) respirable quartz exposure from five OSHA SEP inspection reports[129] on brick manufacturing facilities and three NIOSH control technology and exposure assessment reports on brick manufacturing (Document ID 0161;0137; 0232; 0239; 0235). In addition, OSHA reviewed one report from a site visit to a ceramic tile manufacturing facility (Document ID 0202).[130]

The exposure profile for the structural clay industry includes 135 samples, three of which were added from OSHA's OIS database (Document ID 3958).[131] The addition of these data points did not change the distribution of the samples in a significant way. As a result, the conclusions drawn from the exposure profile are not appreciably different from the conclusions presented in the PEA.

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[129] OSHA SEP Inspection Reports 300530805, 302005772, and 302547674, are all contained within OSHA SEP Inspection Report 300523396 (Document ID 0161).

[130] As noted in Section IV-2–Methodology, all results included in the exposure profile are 8-hour time-weighted averages (8-hour TWAs) derived from samples of 6-hours or longer, assuming the exposure concentration during any unsampled portion of the shift was the same as the concentration during the period sampled. Unless explicitly stated otherwise, all results discussed in the additional controls section meet the same criteria. Assumptions made in calculating 8-hour TWAs are discussed in Section IV-2–Methodology.

[131] A total of 17 samples for 2007 NAICS 327122 appear in the OIS data. Five samples from Frost Tile & Marble Co., (inspections 626738 and 900993) were excluded because the job tasks performed were more closely associated with the cut stone industry. Summitville Tiles, Inc., had four samples collected and analyzed for cristobalite, quartz and tridymite, which resulted in 12 individual data points. All of the cristobalite and tridymite values were zero; therefore, they were not included as individual results, only the quartz values were added. Of those four samples, one worker was performing task unrelated to brick manufacturing, resulting in only three samples being added to the exposure profile (438.1 µg/m^3, 75.9 µg/m^3, 12.0 µg/m^3).

Baseline conditions include the numerous activities at structural clay facilities that produce silica dust, which can be re-suspended in the air and contribute to workers overall exposure. Dust arises while workers handle quantities of dry, dusty raw materials (clay, sand, and other minerals), use equipment for grinding raw materials and finishing clay (mills, mixers, spray driers), mix coatings and tend clay coating processes, and move unfinished and finished products through the plant.[132] Dust becomes airborne during production processes, and then settles on surfaces.

For each of the job categories listed in Table IV.4.21-B and included in the exposure profile, and for the structural clay industry as a whole, OSHA concludes that Table IV.4.21-B represents baseline conditions.

Exposure Profile and Baseline Conditions for Material Handlers

The exposure profile in Table IV.4.21-B includes 64 samples for material handlers. The median is 21 μg/m^3, the mean is 42 μg/m^3, and the range is 10 μg/m^3 (limit of detection (LOD)) to 258 μg/m^3. Table IV.4.21-B shows that, of the 64 samples, 17 (26.5 percent) are above 50 μg/m^3 and 6 (9.4 percent) exceed 100 μg/m^3. Loader operators and material handlers working on the production line tend to have higher maximum and median exposure levels than material handlers working in post-production areas, who handle finished goods. The three subcategories within the material handler's job category (loader operators, production line handlers, and post-production handlers) are discussed in the following subsections. All three subcategories can be subject to silica exposure when passing vehicles crush spilled raw materials or broken product and disturb settled dust.

[132] NIOSH collected 38 samples at a brick manufacturing facility, 16 of which exceeded 50 μg/m^3. Seven of these results also exceeded 100 μg/m^3. NIOSH listed the primary sources of exposure as traffic passing over ground clay and shale in the grinding plant, loader dumping and spillage in the same area, conveyor spillage, dry broom sweeping of kiln cars, and various activities associated with the sand applied to bricks for texture and pigment. NIOSH described the strengths and weaknesses of housekeeping at this facility as follows: "Extensive efforts were made at housekeeping in this facility. The notable exception was in the C plant grinding area, which had significant accumulations of settled dust. [In the other areas] dry sweeping with brooms and shovels was common, with the powered sweeper used in some plant areas and the yard. Hi-Vac systems (Model 230) were installed in both the B and C plants for the cleaning of kiln cars. The vacuum systems were not equipped with [high-efficiency particulate air] HEPA filters. Workers used shovels to remove the largest pieces of brick, followed by dry sweeping, and then vacuuming of the cars" (Document ID 0235). This facility had also installed a number of engineering controls.

Exposure Profile and Baseline Conditions for the Loader Operators Subcategory

The exposure profile in Table IV.4.21-B includes 7 samples for loader operators in the structural clay industry. The median is 56 µg/m^3, the mean is 58 µg/m^3, and the range is 11µg/m^3 (limit of detection (LOD)) to 157 µg/m^3. Table IV.4.21-B shows that, of the 7 samples, 4 (57.1 percent) are above 50 µg/m^3 and one (14.3 percent) exceeds 100 µg/m^3. The highest exposure, 157 µg/m^3, is associated with a loader operator in a ceramic tile facility who dumped dry materials into a hopper and monitored a partially enclosed and ventilated conveyor. Visible dust was released from the loader bucket, hopper, and conveyors, and the worker performed operations with the loader windows open for a portion of the sampling period (Document ID 0202, p. 9). In contrast, exposures of 14 µg/m^3 and 10 µg/m^3 were obtained for loader operators at another facility moving crushed shale and schist from storage piles to hoppers. The floor was wet from the rain and visible dust was not “particularly evident” which may have contributed to the lower exposures (Document ID 0232, p. 4).

In the PEA, OSHA preliminarily determined that while front end loader operators frequently work in enclosed cabs, the cab enclosures are not always properly maintained or consistently used as an exposure control measure. For example, at three facilities, workers operated cabs with ventilation systems turned off or windows left open, or allowed dust to accumulate in cabs (Document ID 1365, p. 3-15). A loader operator working in an area where a dust suppressant foam system blanketed raw materials on conveyors had an exposure level of 56 µg/m^3 (Document ID 0239, pp. 6, 8, 14). NIOSH noted an accumulation of dust on the loader cab interior, suggesting that results could be lower (e.g., at 50 µg/m^3 or less) if the cab interior had been kept clean (Document ID 0239, p. 7).

Additionally, loader operators frequently spend a portion of the shift outside the cab as they monitor raw material conveyor systems. These partially enclosed conveyors can emit silica dust when facilities have not enclosed and ventilated transition points, applied dust suppressant, or adjusted for optimal dust control. In addition, nearby raw material processing equipment (crushers, hammer mills, dry-pans, and screens) is typically partially open, allowing silica dust to escape, despite some effort to provide exhaust ventilation for the equipment (Document ID 1356, p. 3-15).

OSHA did not receive comments specifically disputing the assessment of baseline conditions. Therefore, in this final economic analysis (FEA) OSHA concludes that baseline conditions for loader operators in this industry typically involve ventilated, but poorly maintained or improperly used cab enclosures on all front-end loaders and that dust from nearby processes can contribute to elevated exposures when monitoring conveyor systems. Thus, OSHA anticipates that lower exposure levels can be attained by improving/upgrading controls that are already in place.

Exposure Profile and Baseline Conditions for the Production Line Handlers Subcategory

The exposure profile in Table IV.4.21-B includes 20 samples for production line handlers. The median is 42 μg/m^3, the mean is 69 μg/m^3, and the range is 12 μg/m^3 (limit of detection (LOD)) to 258 μg/m^3. Table IV.4.21-B shows that, of the 20 samples, 9 (45 percent) are above 50 μg/m^3 and 4 (20 percent) exceed 100 μg/m^3. The highest concentrations occurred when workers moved dry, unfired product (Document ID 1365, p. 3-9; 0137, p. 103). During the transportation of unfired brick product throughout the kiln area, the wheels on the forklift (or squeeze lift) crushed a mixture of high-silica spilled and broken product, which became suspended in the air causing a significant source of exposure (Document ID 1365, p. 3-9; 0137, pp. 48, 80, 103).

At a different facility, NIOSH observed silica exposures of 80 μg/m^3 and 64 μg/m^3 for a production material handler who also transported products into and out of kilns with a forklift (Document ID 1365, p. 3-9; 0239). The floors were covered with washed limestone pea gravel (a low-quartz aggregate) and aluminum plates to reduce crystalline silica dust generation. However, dust was still generated by brick breakage during firing (Document ID 1365, p. 3-9; 0239, p. 8).

Workers with low exposures include those controlling the flow of bricks from the molding machine (12 μg/m^3 and 21 μg/m^3) and transfer car operators moving bricks between the manufacturing area and the kilns and drying ovens (four exposures ranging from 17 µg/m^3 to 21 µg/m^3). At this facility the product was sprayed with water from manual or automatic nozzles and the material handlers performed this work either by hand or using automated equipment (Document ID 1365, p. 3-10; 0232, p. 7).

Belden Brick Company submitted data that they shared with OMB and SBA in 2010, to the docket (Document ID 2378, p. 5). For manual hacking, 68.2 percent of samples had exposures over 50 µg/m^3 with 50.0 percent above 100 µg/m^3; and for machine hacking 66 percent of the samples were above 50 µg/m^3 with 19.8 percent falling between 50 and 100 µg/m^3. The data submitted did not contain any individual sampling values nor did it include any description of the working conditions and controls in place; therefore, OSHA was not able to incorporate these results into the exposure profile. However, these exposures are consistent with the baseline working conditions for production line handlers reflected in the final exposure profile in Table IV.4.21-B, which shows that 45 percent of the production line handlers have exposures above 50 µg/m^3.

In the PEA, OSHA reported that production line handlers typically work without task-specific exposure controls. Local exhaust ventilation (LEV) is sometimes associated with nearby processes, such as conveyor belts and coatings application; however, dust control is incomplete, and those processes still contribute to silica exposure of production line handlers (Document ID 1365, p. 3-16). No comments were received disputing this finding; therefore, OSHA finds that baseline conditions for production line handlers in this industry typically involve work near processes with incomplete dust control.

Exposure Profile and Baseline Conditions for the Post-Production Handlers Subcategory

The exposure profile in Table IV.4.21-B includes 37 samples for post-production handlers. The median is 15 µg/m^3, the mean is 25 µg/m^3, and the range is 10 µg/m^3 (limit of detection (LOD)) to 119 µg/m^3. Table IV.4.21-B shows that, of the 37 samples, 4 (10.8 percent) are above 50 µg/m^3 and 1 (2.7 percent) exceed 100 µg/m^3. Silica exposure levels tend to be lower for workers handling kiln-fired structural clay products than for the other two material handler subcategories. After firing, the clay is substantially harder than in earlier parts of the manufacturing process, and thus handling creates less dust (Document ID 1720, p. IV-351; 1365, p. 3-10).

The exposure profile represents a variety of operations that are typical for post-production workers in this application group. Nine workers (24 percent) monitored automated unloading or packaging equipment. These workers had consistently low exposures, ranging from 12 μg/m^3 to 29 μg/m^3. Another 19 workers (51 percent) manually unloaded fired bricks. These workers generally had higher exposures, ranging from 10 μg/m^3 (the LOD) to 119 μg/m^3, with four results exceeding 50 μg/m^3. Finally, nine post-production workers (24 percent) operated forklifts or other heavy equipment to move stacks of fired and packaged bricks around the yard. Exposures for these forklift operators were all below 50 μg/m^3, ranging from 12 μg/m^3 to 44 μg/m^3 (Document ID 0137, p. 122; 0202, p. 11; 0232, p. 11; 0235, pp. 13-14; 0239, p. 14).

A report by NIOSH found that a forklift operator using an enclosed, ventilated cab in addition to yard dust management, had an exposure of less than or equal to 12 μg/m^3 (LOD) (Document ID 1365, p. 3-10; 0235, p. 6). Another facility that frequently sprayed water in the plant yard reduced all of its forklift operator exposures to below 50 μg/m^3 (four results less than or equal to the LOD [16 μg/m^3] and one result of 43 μg/m^3) (Document ID 1365, p. 3-10; 1720, p. IV-351; 0239, p. 8, 12). Additionally, forklift speed was restricted at this facility reducing the amount of dust disturbed by traffic (Document ID 1365, p. 3-10; 0239, p. 9). Many facilities occasionally sprinkle water on heavily traveled routes through outdoor brickyards to suppress dust (Document ID 1365, pp. 3-10, 3-17).

Of the 19 results for workers manually unloading bricks, 12 (63 percent) are associated with some type of additional control (water spray nozzles, fans to remove dust on bricks prior to reaching the operator, or clean air supply blown in the worker's PBZ) (Document ID 0202, p. 11; 0232, p. 11; 0235, p. 13). However, using these controls for manual operations was not always effective; an unloader supplied with clean air had an exposure of 119 μg/m^3. NIOSH reported that the ducts blew clean air into workers breathing zones, but nearby fans may have disturbed the airflow patterns (Document ID 1365, p. 3-10;

0235, p. 13). The post-production handler results associated with automated processes in place (including some obtained in areas where wet methods are also used) are all below 50 μg/m³.

Exposure for post-production handlers in some plants may also occur when tumbling brick. This process is used to give the brick the appearance of being aged or reclaimed. However, the use of this process varies by plant. During the public hearings, Belden Brick stated that it does not do any post-fired tumbling at all. Their brick is only molded (Document ID 3586, Tr. 3481). Brian Ogle with General Shale reported that they tumble fired brick but explained that it was a very dusty operation and that LEV must be set up to remove dust around the kiln tunnel after tumbling fired brick (Document ID 3586, Tr. 3480). Representatives from the Whitacre Greer Company stated that like General Shale, they tumble brick after it has been fired using an old cement mixer with dust controls on it (Document ID 3586, Tr. 3480-3481).

According to the data submitted by Belden Brick Company, 58.5 percent of workers manually unloading (dehacking) kiln cars had exposures over 50 μg/m³ and 26.9 percent were above 100 μg/m³ (n=171), while only 23.3 percent of the samples for dehackers, which OSHA assumes is other than manual dehacking and therefore the worker has less interaction with the process,[133] were above 50 μg/m³ (Document ID 2378, p. 5). The data submitted did not contain any individual sampling values nor did it include any description of the working conditions and controls in place that would allow OSHA to determine whether these exposure results are representative of baseline working conditions for post-production handlers. However, these summary data suggest that OSHA's exposure profile may underestimate the baseline exposures of post-production materials handlers.

During the public hearings, representatives from the brick industry testified that plant workers in arid climates occasionally experience elevated exposures due to dust storms (Document ID 3577, Tr. 714; 3586, Tr. 3465-68). Presumably, the storms would affect

[133] OSHA bases this assumption on similar results between the manual hackers and the machine hackers at the same facility. Where the 50 percent of the workers who manually load (hacking) had exposures above 100 μg/m³ while only 19.8 percent of samples for machine loading was above 100 μg/m³.

only those workers working outdoors. No information, however, was submitted to the docket explaining the frequency of storms, the typical time duration these storms last, the levels of respirable silica dust experienced in these storms, or any existing modification to work practices when dust storms occur. Although Acme Brick described a storm resulting in zero visibility, it seems unlikely that work would still continue under those circumstances (Document ID 3755, Tr. 714). General Shale admitted that they have never sampled to determine what the final exposures for an 8-hour shift where a dust storm occurs might be (Document ID 3586, Tr. 3465-68).[134] Because the final exposure profile reflects a variety of conditions, including low exposure levels in facilities with conscientious dust controls even in the yard areas, OSHA concludes that the profile reflects a range of weather conditions and that no adjustment is required for dust storms.

Based on this information, OSHA has determined that baseline conditions for post-production workers typically include the use of automated equipment, and that most post-production handler's work with some type of task-specific engineering control. However, these controls are often not well implemented. In addition, some facilities use water in the yard and on heavily traveled routes through outdoor brickyards to suppress dust.

Overall Exposure Profile and Baseline Conditions for All Material Handlers

In the PEA, OSHA determined that across the industry, the baseline conditions are best represented by the cross section of facilities reviewed for the exposure profile. No comments were received disputing this determination. Therefore, in the FEA, OSHA concludes that the best description of current baseline exposures includes all results summarized for this job category in Table IV.4.21-B; and the median of 21 μg/m^3, a mean of 42 μg/m^3 for all material handlers and a range of 10 μg/m^3 (LOD) to 258 μg/m^3 represent their baseline exposure.

Exposure Profile and Baseline Conditions for Grinding Operators

The exposure profile in Table IV.4.21-B includes 17 samples for grinder operators. The median is 91 μg/m^3, the mean is 162 μg/m^3, and the range is 12 μg/m^3 (limit of detection

[134] Refer to section FEA Chapter X - Environmental Impacts for a more detailed discussion of environmental factors which affect exposures.

(LOD)) to 628 μg/m^3. Table IV.4.21-B shows that, of the 17 samples, 12 (70.5 percent) are above 50 μg/m^3 and 8 (47 percent) exceed 100 μg/m^3. These values are based on 17 readings for grinding operators obtained from four OSHA SEP inspection reports (Document ID 0137; 0161),[135] three NIOSH reports (Document ID 0232; 0235; 0239) and the OSHA Information System (OIS) (Document ID 3958).

Three of the highest full-shift exposure levels (628 μg/m^3, 410 μg/m^3, and 362 μg/m^3) were all associated with a single production plant and remained high despite efforts on the part of the facility to enhance dust collection at the grinder and improve ventilation and housekeeping in the control room (Document ID 0161). The results might have been influenced by newly installed milling equipment, which reportedly generated more dust and finer particles than had been evident before the installation. OSHA, however, does not have access to results from the period before the new mill was installed for comparison. Additionally, OSHA reported elevated sample levels for workers in all three job categories (10 out of 11 samples were over 100 μg/m^3) suggesting that dust was poorly controlled throughout this facility (Document ID 1365, p. 3-11; 0161). The fourth exposure of 438 μg/m^3 taken at another facility is also associated with a grinder with inadequate ventilation (Document ID 3958, Row 610).

Two of the lowest exposures for grinder operators of ≤18 μg/m^3 (LOD) and 24 μg/m^3, taken on two different days, were associated with one operator who worked from an enclosed, ventilated control room for 90 percent of the shift (Document ID 0235, pp. 10, 13-14; 1365, p. 3-36). For the remaining 10 percent of the time, the operator monitored machinery, removed material from the grinder teeth and performed dry sweeping under the conveyors (Document ID 0235, p. 10; 1365, pp. 3-11 – 3-12). The facility had a troughed conveyor system with raised edges designed to reduce the amount of spillage (Document ID 0235, p. 7). A second operator at the same facility had an exposure result of 169 μg/m^3 while operating additional enclosed grinding and screening equipment in a separate building where substantial spillage occurred. Although a control room was available, this second operator spent most of the shift (85 percent) cleaning the grinding

[135] OSHA SEP Inspection Report 300523396 also contains inspections 302005772 and 302547674, which were conducted at the same facility (Document ID 0161).

machinery by manually removing rocks and shoveling debris in the area. NIOSH noted several exposure sources in the second area including conveyor spillage and re-suspension of settled dust by front end loaders (Document ID 0235, pp. 4, 9-10, 14; 1365, p. 3-12).

Grinding operators at six manufacturing facilities used for this exposure profile performed tasks within the grinder area. Typical conditions associated with this job category include the use of ventilated control rooms for the grinding operator for at least part of the shift, open conveyors, and enclosed and ventilated grinding equipment (Document ID 1365, p. 3-5). The most substantial exposures occur when grinding operators exit control rooms and approach the grinder equipment to clean and maintain equipment and perform housekeeping activities (e.g., manually remove rocks from grinder teeth, and sweep or shovel spilled debris from floors). In the PEA, OSHA made the assumption that grinding operators perform these tasks intermittently (up to eight times per day) and respirable quartz levels in the grinding area often are elevated to extreme levels and thus are the primary source of exposure for grinder operators. This assumption was supported by comments from the brick industry. Acme Brick and the Brick Industry Association stated that their grinding operators are in and out of the control booth all day and spend approximately 50 percent of their time outside of the control room (Document ID 3577, Tr. 733-34, 743; 3586, Tr. 3450). It was further explained that exposures are elevated in this area due to the raw materials sticking to conveyor belts and that dust levels can remain high in spite of extensive dust collection (Document ID 3577, Tr. 742; 3586, Tr. 3449). Poorly constructed control rooms can also obviously become contaminated with silica and contribute to worker silica exposures.

The Belden Brick Company submitted summary sampling data for grinder operators in their facilities (Document ID 2378, p. 5). Over 58 percent of the samples from grinding operators had exposures greater than 50 $\mu g/m^3$ and 17.8 percent were above 100 $\mu g/m^3$. The data submitted did not contain any individual sampling values, nor did it include any description of the working conditions and controls in place that would allow OSHA to determine whether these exposure results are representative of baseline working conditions for grinding operators. However, these summary data are consistent with

OSHA's exposure profile which indicates that approximately 70 percent of the grinders have exposures greater than 50 µg/m^3 and 47 percent were above 100 µg/m^3.

Based on supplemental information, and the conditions described for this job category described above in this subsection, OSHA has determined that the baseline conditions for grinding operators across this industry are best represented by the range of results summarized in the exposure profile (Document ID 2378; 3577). Thus, their baseline exposure level is represented by the median exposure for this job category (91 µg/m^3), ranging from 12 µg/m^3 (the LOD) to 628 µg/m^3.

Exposure Profile and Baseline Conditions for Forming Line Operators

The exposure profile in Table IV.4.21-B includes 54 samples for forming line operators. The median is 76 µg/m^3, the mean is 142 µg/m^3, and the range is 12 µg/m^3 (limit of detection (LOD)) to 1,028 µg/m^3. Table IV.4.21-B shows that, of the 54 samples, 35 (64.9 percent) are above 50 µg/m^3 and 22 (40.8 percent) exceed 100 µg/m^3. Four of the 54 results (501 µg/m^3, 690 µg/m^3, 794 µg/m^3, and 1028 µg/m^3, all from the same facility) also exceed 500 µg/m^3. Silica exposures primarily occur when workers perform open transfer of clay and coatings ingredients into hoppers and mills, operate mixing and milling equipment, and apply sand-based coatings to products.

Exposure Profile and Baseline Conditions for the Pug Mill Operators Subcategory

The exposure profile in Table IV.4.21-B includes 7 samples for loader operators. The median is 226 µg/m^3, the mean is 312 µg/m^3, and the range is 41 µg/m^3 (limit of detection (LOD)) to 1,028 µg/m^3. Table IV.4.21-B shows that, of the 7 samples, 6 (85.8 percent) are above 50 µg/m^3 and 5 (71.5 percent) exceed 100 µg/m^3. The highest value among the data available to OSHA for this industry (1,028 µg/m^3) was obtained for a forming line operator monitoring a pug mill equipped with a poorly maintained exhaust-ventilated enclosure (Document ID 1365, pp. 3-12, 3-37; 0161). The inspection report noted that the enclosure doors did not seal properly and there was no exhaust ventilation in place (Document ID 0161, p. 56). After the inspection, the facility repaired the enclosure around the primary pug mill, installed a second pug mill with a better-sealed exhaust-ventilated enclosure and added a greater quantity of water to the clay mix to reduce dust emissions (Document ID 0161, pp. 602, 1048). During a later inspection, an exposure of 214 µg/m^3 was observed for an operator monitoring this second mill (an exposure 79 percent lower than the first reading). The report also noted that the old pug mill still continued to be a major source of silica dust due to the lack of improved ventilation at that source and may have contributed to the elevated exposure for the worker at that mill (Document ID 0161, pp. 1048-1049, 1052).

Two silica exposure results (226 µg/m^3 and 337 µg/m^3) were obtained for ball mill and spray drier operators at a ceramic tile manufacturing facility who prepared clay powder to be compressed into tiles (Document ID 1365, p. 3-13; 0202, p. 9). These workers had adjacent workstations in the same room where visible dust occasionally entered when the ball mill was charged with fired tile scrap. Dust also entered when the operator brushed spilled material away from the mill hatch. Furthermore, an automatic LEV system associated with the storage hoppers functioned improperly, and the spray-drying equipment constantly emitted fine dust into the surrounding room as the clay powder was sized (sorted in a cyclone-type separator), transferred, and conveyed through the process.[136] Dust release from vertical conveyors adjacent to the spray drier was reduced with enclosures. Air samples obtained in other production processes suggested that dusty air leaking from this area (through doors and open conveyor passages through the walls) contributed to worker exposure farther down the production line (e.g., material handlers and forming line operators). Although a control room was available, and the spray-drier operator spent 10 percent of the shift there, the door was frequently open and the room was unventilated. The floor, walls, windows, and equipment inside the control room were coated with a light layer of dust (Document ID 1365, pp. 3-13; 0202, pp. 9, 24- 26).

Detailed information is not available for the two lowest results (41 µg/m^3 and 70 µg/m^3) associated with the pug mill operator subcategory; however, these workers may have

[136] At times, the airborne dust was sufficient to reduce visibility. Furthermore, the facility provided information indicating that 30 percent of the particles in the milled clay processed through the drier were less than 4 µg in size, suggesting that a substantial portion of the clay particles were in the respirable size range (Document ID 0202, p. 9).

spent a portion of their shift performing other task such as brick cutting (Document ID 0137, p, 129-130, 158).

Exposure Profile and Baseline Conditions for the Coatings Blenders Subcategory

The exposure profile in Table IV.4.21-B includes 10 samples for coating blenders. The median is 77 μg/m^3, the mean is 97 μg/m^3, and the range is 17 μg/m^3 (limit of detection (LOD)) to 225 μg/m^3. Table IV.4.21-B shows that, of the 10 samples, 8 (80 percent) are above 50 μg/m^3 and 3 (30 percent) exceed 100 μg/m^3. The highest exposures (225 μg/m^3 and 190 μg/m^3) are associated with a worker operating a sand dryer and coatings mixer in a brick coatings preparation room. LEV was present at the dryer and at transition points between the particulate screen, bucket elevator, and weight bin; at the bag dumping station for the mixer; and at the transfer point between the mixer and skid tub (Document ID 0235, p. 13). However, the dryer LEV was poorly aligned with the hopper and operated at air velocities less than one-half of the 250 feet per minute recommended by the American Conference of Governmental Industrial Hygienists (ACGIH) for toxic materials (Document ID 1365, p. 3-13; 1607). At the same facility, another worker dumping bags and mixing coatings for a different production line had a much lower exposure of only 17 μg/m^3 (Document ID 0235, p. 13). Although information on the controls associated with this other production line is not available, NIOSH noted that this sand preparation area was smaller, serving only one production line with a part-time operator, while the first served two production lines (Document ID 1365, p. 3-13; 0235, p. 5). A respirable silica exposure result of 68 μg/m^3 was obtained for an employee dumping bags of glaze ingredients under similar conditions at a ceramic tile manufacturing facility (Document ID 1365, p. 3-14; 0202, p. 11). LEV on the bag dumping station was judged inadequate as settled dust obstructed air flow through the slotted hood (Document ID 0202, p. 19).

Exposure Profile and Baseline Conditions for the Formers Subcategory

As Table IV.4.21-B indicates, the 37 exposure samples for formers, the subcategories of forming line operators (Clay Powder Formers, Coating Applicators- Automated, Coatings Applicators – Manual, and Wet Clay Formers) who spend the entire shift at forming stations (without milling or mixing materials), range from 12 μg/m^3 to 794 μg/m^3, with a median of 70 μg/m^3 and a mean of 122 μg/m^3. Twenty-one samples (56.7 percent) exceed 50 μg/m^3, and 14 samples (37.8 percent) exceed 100 μg/m^3.

The exposure profile in Table IV.4.21-B includes 10 samples for Forming Line Operators (Wet Clay Formers). The median is 19 μg/m^3, the mean is 27 μg/m^3, and the range is 13 μg/m^3 (limit of detection (LOD)) to 78 μg/m^3. Table IV.4.21-B shows that, of the 10 samples, 1 (10 percent) is at or above 50 μg/m^3 and none exceed 100 μg/m^3. The formers who primarily work with wet clay only (molding and extrusion processes, no coatings application), identified as Forming Line Operators (Wet Clay Formers) on Table IV.4.21-B have the lowest range of exposures. The exposure profile in Table IV.4.21-B includes 3 samples for Forming Line Operators (Clay Powder Formers). The median is 144 μg/m^3, the mean is 158 μg/m^3, and the range is 141 μg/m^3 (limit of detection (LOD)) to 188 μg/m^3. Table IV.4.21-B shows that, of the 3 samples, 3 (100 percent) are above 50 μg/m^3 and 3 (100 percent) exceed 100 μg/m^3. In contrast, the three exposure samples for formers dealing with pressing dry clay powder (pressing operations, no coatings application), identified as Forming Line Operators (Clay Powder Formers) on Table IV.4.21-B, worked at a ceramic tile facility; they had higher exposures, ranging from 141 μg/m^3 to 188 μg/m^3. An automated air jet that blew residual clay powder from the molds several times per minute resulted in substantial silica in the air, contributing to these workers' exposures (Document ID 1365, p. 3-14; 0202, p. 27). Data are not available to determine whether clay powder pressing operations have elevated exposures in the absence of air spray cleaning; however, formers making specialty shapes also had substantial exposure from frequent dry sweeping/brushing of the work table and dry unfired tiles (Document ID 1365, p. 3-14; 0202, p. 27).

According to the summary data submitted by Belden Brick Company, 80.7 percent of samples for machine brick molder had exposures over 50 μg/m^3 (n=114), and 49.1 percent were above 100 μg/m^3. Fifty-two percent of extruded brick operators experienced exposures over 50 μg/m^3 (n=185), while 70.6 percent who hand-molded brick were over 50 μg/m^3. As noted previously, the data submitted did not contain any individual sampling values nor did it include any description of the working conditions and controls in place; thus OSHA is unable to determine whether these exposures data are representative of baseline working conditions for formers (Document ID 2378, p. 5). Although these summary data suggest that OSHA's exposure profile may underestimate the exposures of formers, there is no means of determining the extent of the possible underestimation

Coatings application operations (especially sand coating) are associated with some of the highest exposures in this industry (only pug mill operators have higher exposure levels). The exposure profile in Table IV.4.21-B includes 15 samples for Forming Line Operators (Coating Applicators - Manual). The median is 102 μg/m^3, the mean is 199 μg/m^3, and the range is 12 μg/m^3 (limit of detection (LOD)) to 794 μg/m^3. Of the 15 samples, 10 (66.7 percent) are above 50 μg/m^3 and 8 (53.3 percent) exceed 100 μg/m^3. The four lowest exposures for manual coatings application were associated with manual slurry application rather than dry mix coatings (Document ID 0232, pp. 4-5, 11-12; 0235, pp. 5-6, 11). Not surprisingly, higher exposures were reported for workers dumping bags of dry silica-containing materials, especially sand. Formers using automated coatings equipment experienced somewhat lower exposures, but seven of the nine samples (77.8 percent) still exceeded 50 μg/m^3 (Document ID 0202, p. 11; 0232, pp. 11-12; 0235, pp. 13-14). Based on this information, OSHA finds that, except for workers primarily handling (wet) clay slurry, all forming line workers routinely experience high exposure levels (greater than 50 μg/m^3), principally from working with dry sand or dry clay (Document ID 1720, p. IV-354; 1365, pp. 3-13 – 3-14).

Formers typically work near local exhaust ventilation hoods, which are generally associated with the automated dry coatings application equipment. Other engineering controls are not normally present on the forming line (Document ID 0232, p. 6; 0573). For example, in contrast to coatings blending areas, the hoppers along the forming line into which workers dump dry coating materials are not fitted with exhaust ventilation. LEV is not normally available at the workstations where formers apply coatings by hand, either to molds or to product (Document ID 0161, pp. 22, 56). In addition, due to the warm conditions in facilities operating drying ovens and kilns, workers often use pedestal or ceiling fans for comfort, which can disturb settled dust and disrupt the function of ventilation systems (Document ID 0232, pp. 2, 5; 0572). Workers also commonly (at least daily) clean the forming line floors by dry sweeping and using shovels to clean up spilled material as necessary which can contribute to exposures (Document ID 1365, pp. 3-12 – 3-14; 3-37 – 3-41).

Overall Exposure Profile and Baseline Conditions Forming Line Operators

The exposure profile in Table IV.4.21-B includes 7 samples for Forming Line Operators (Pug Mill Operators). The median is 226 μg/m^3, the mean is 312 μg/m^3, and the range is 41 μg/m^3 to 1,028 μg/m^3. Table IV.4.21-B shows that 6 of the samples (85.7 percent) exceed 50 μg/m^3, 5 (71.4 percent) exceed 100 μg/m^3 and 3 (42.9 percent) exceed 250 μg/m^3.

Forming line operators work under various conditions depending on the work practices and control technology at the facility. OSHA has determined that across the industry, baseline conditions are best represented by the cross section of facilities reviewed for the exposure profile. OSHA finds that the best description of current baseline exposures of forming line operators includes the full dataset available to OSHA for this job category (summarized in Table IV.4.21-B). Therefore, the median of 76 μg/m^3 for all forming line operators represents their baseline exposure.

Table IV.4.21-B Personal Respirable Crystalline Silica Exposure Range and Distribution of Results for Workers in the Structural Clay Industry (2007 NAICS 327121, 327122, 327123)											
	Exposure Summary			**Exposure Range**			**Exposure Profile**				
Structural Clay Industry	**N**	**Mean (μg/m³)**	**Median (μg/m³)**	**Min (μg/m³)**	**Max (μg/m³)**		**< 25 (μg/m³)**	**≥ 25 and ≤ 50 (μg/m³)**	**> 50 and ≤ 100 (μg/m³)**	**> 100 and ≤ 250 (μg/m³)**	**> 250 (μg/m³)**
Material Handlers Subtotal	*64*	*42*	*21*	*10*	*258*		*37 (57.8%)*	*10 (15.6%)*	*11 (17.2%)*	*5 (7.8%)*	*1 (1.6%)*
Material Handler (Loader Operators)	7	58	56	11	157		3 (42.9%)	0 (0%)	3 (42.9%)	1 (14.3%)	0 (0%)
Material Handler (Production Line Handlers)	20	69	42	12	258		8 (40%)	3 (15%)	5 (25%)	3 (15%)	1 (5%)
Material Handler (Post-Production Handlers)	37	25	15	10	119		26 (70.3%)	7 (18.9%)	3 (8.1%)	1 (2.7%)	0 (0%)
Grinding Operators	*17*	*162*	*91*	*12*	*628*		*4 (23.5%)*	*1 (5.9%)*	*4 (23.5%)*	*4 (23.5%)*	*4 (23.5%)*
Forming Line Operators Subtotal	*54*	*142*	*76*	*12*	*1,028*		*12 (22.2%)*	*7 (13%)*	*13 (24.1%)*	*15 (27.8%)*	*7 (13%)*
Forming Line Operators (Pug Mill Operators)	7	312	226	41	1,028		0 (0%)	1 (14.3%)	1 (14.3%)	2 (28.6%)	3 (42.9%)
Forming Line Operators (Coatings Blenders)	10	97	77	17	225		2 (20%)	0 (0%)	5 (50%)	3 (30%)	0 (0%)
Forming Line Operators (Clay Powder Formers)	3	158	144	141	188		0 (0%)	0 (0%)	0 (0%)	3 (100%)	0 (0%)
Forming Line Operators (Coatings Applicators - Automated)	9	87	73	33	160		0 (0%)	2 (22.2%)	4 (44.4%)	3 (33.3%)	0 (0%)
Forming Line Operators (Coatings Applicators - Manual)	15	199	102	12	794		4 (26.7%)	1 (6.7%)	2 (13.3%)	4 (26.7%)	4 (26.7%)
Forming Line Operators (Wet Clay Formers)	10	27	19	13	78		6 (60%)	3 (30%)	1 (10%)	0 (0%)	0 (0%)
Structural Clay Industry Total	**135**	**97**	**46**	**10**	**1,028**		**53 (39.3%)**	**18 (13.3%)**	**28 (20.7%)**	**24 (17.8%)**	**12 (8.9%)**
Notes: All samples summarized are personal breathing zone (PBZ) results representing 8-hour time-weighted average exposures. Job categories are intended to represent job functions; actual job titles might differ, and responsibilities might be allocated differently, depending on the facility. Percentages may not add to 100 percent due to rounding. Sources: Document ID 1720; 3958; 0137; 0161; 0202; 0232; 0235; 0239.											

4.21.3 Additional Controls

Additional Controls for Material Handlers

The exposure profile in Table IV.4.21-B shows that 26.6 percent (17 out of 64 samples) of material handlers have exposures above the final PEL of 50 μg/m^3. Therefore, OSHA finds that additional controls will be necessary to achieve the PEL for these overexposed workers. Information presented in the exposure profile (Table IV.4.21-B) indicates that the median exposure level for all material handlers is 21 μg/m^3, and these data range from 10 to 258 μg/m^3. The data summarized for material handlers are not distributed equally across all three subcategories. Although Table IV.4.21-B shows that less than 30 percent of material handlers in this industry experience exposure levels of more than 50 μg/m^3, 57 percent of loader operators and 45 percent of production line handlers currently have silica exposures exceeding 50 μg/m^3 and therefore require additional controls. Among data for post-production handlers less than 14 percent exceeded that level.

Brian Ogle with General Shale stated that their company does not have any problem with controlling exposures when handling the finished product on the packaging end, and that exhaust ventilation normally suffices; however, LEV is not enough to consistently control exposures during raw material processing alone (Document ID 3586, Tr. 3450). OSHA agrees that a single control alone may not adequately reduce exposures. It is through the use of a combination of controls (enclosures, housekeeping, etc.) that the Agency believes that exposures for material handlers can be reduced to below the PEL in most instances.

The following paragraphs describe additional controls suitable for material handlers. Since the sources of exposures may vary depending on the processes being used, a facility may find that some of the engineering controls discussed will not be applicable to their specific needs.

Local Exhaust Ventilation and Enclosed Conveyor Systems

To obtain reductions in silica levels in raw material handling areas, the primary control methods target dust emissions from hoppers, conveyors, and transfer points associated with material handlers' duties. Such control methods include covering conveyors and augmenting ventilation at existing enclosed transfer points to meet the ACGIH recommended air velocity of 150 to 300 feet per minute (fpm) across all openings in the enclosures (Document ID 3883, pp. 10-67; 1365, pp. 3-21, 3-24; 0202, p. 14; 0161, pp. 56, 1550-1555; 1607).[137] NIOSH described an enclosed conveying system associated with grinding equipment, pug mills, silos, and mixers at a brick manufacturing facility with ventilation at the transfer points (Document ID 0235, pp. 7-9). During an inspection at a brick manufacturing facility OSHA observed elevated exposures to silica dust during material transfer in the grinding plant (Document ID 0161, pp. 409, 936). The sole source of exposure for the worker in the grinding plant was three conveyors in the rear of the machine (Document ID 0161, p. 590). An enclosed conveyance system was installed and has substantially reduced exposures (Document ID 0161, p. 183).

Enclosed conveyors with exhaust ventilation have been implemented effectively on similar conveyor systems in the foundry industry for the movement of sand and clay used for mold material in metal casting processes. Because of the similarities in the process (equipment, material type and flow), OSHA has determined that these systems can be equally effective in the structural clay industry (Document ID 0018, pp. 52, 93). Foundry sand systems operators working in areas where sand transport systems were enclosed and where machines that process sand and clay (materials also used by the structural clay industry) were fitted with exhaust ventilation, experienced some of the lowest exposures in the foundry industry, e.g., two exposures of 13 μg/m^3 (LOD) for a sand-systems operator (sand mullor) controlling equipment that had both the belts and sand elevator fully enclosed (Document ID 0018, pp. 52, 93).

[137] ACGIH (2010, Chapter 13.50) recommends a minimum air flow of 150 feet per minute (fpm) across bin and hopper openings for manual loading operations; however, ACGIH also recommends air velocity of one-and-a-half to two times that rate (i.e., 225 fpm to 300 fpm) when conditions create conditions more dusty than during manual loading. The need for increased air velocity depends on the material flow rate (a front-end loader will add materials at a much greater material flow rate than manual transfers), dustiness (the material at this site was apparently very dusty), and the height the material falls (influenced both by hopper design and by material handler work practices). Furthermore, ACGIH recommends that the enclosure be "large enough to accommodate the 'splash' effect." For some dust controls, ACGIH suggests increasing the baseline air flow rate from 150 fpm to 250 fpm when the materials handled include toxic dusts.

NIOSH and OSHA evaluated pneumatic and enclosed systems to isolate the storage and transport of dry sand in two foundries. The four exposures for the molder job category from these foundries include two results of 13 μg/m³ (LOD) and one each of 20 μg/m³ and 23 μg/m³ (Document ID 0268; 0501, p. 6).[138] At another foundry, OSHA reported a 65 to 70-percent reduction in exposures (from 140 μg/m³ to 50 μg/m³ and 42 μg/m³) after the facility made improvements to sand delivery systems and exhaust ventilation systems throughout the facility (Document ID 0132, pp. 104-109, 113-118, 138-146, 163-172, 181, 192-195, 197-199, 238, 242-243). Based on these findings OSHA expects that the addition of enclosures and ventilation at dust emission points would provide for similar reductions in the structural clay industry.

If exposure levels remain elevated, another type of ventilation system is available for material handlers who spend a portion of the shift at a fixed location. A combination "push-pull" ventilation system—designed to remove (pull) contaminated air from near the source, while supplying (push) a similar amount of clean air behind or above the worker's head—has been demonstrated to be very effective for other types of dust. Heinonen et al., determined in an experimental study (using dusty flour) that compared with general ventilation alone, breathing zone total dust concentrations were reduced by 98 percent from 42,000 μg/m³ to 1,000 μg/m³ or less when the work surface was fitted with exhaust ventilation (at the front, side, or as a downdraft) in combination with local clean air supply above the worker's head (Document ID 1365, pp. 3-21 – 3-22; 1393). Although this study tested high concentrations of total dust, OSHA expects this type of "push-pull" ventilation system, which is a common form of LEV, would be similarly effective for reducing levels of respirable silica dust in the breathing zone of structural clay workers (in this case, to be considered "clean air," the air provided to the area around the worker would be free of silica). OSHA notes that for such a system to function, competing air from pedestal fans (often used for cooling workers in hot

[138] In the ERG contractor report, molder activities are described as monitoring and operating equipment in which the sand molds are produced, manually handling cured sand mold sections and working near sand transport systems. This sand often contains 100 percent quartz. (Document ID 1365, pp. 2-27 – 2-29).

climates) must be eliminated; however, the temperature (e.g., air-conditioning) of the provided air can be adjusted for worker comfort.

A system similar to this was used on the packaging line (and also at a forming station) at a facility evaluated by NIOSH. Reported exposures had a median of 62 μg/m^3 for stackers in the packaging line and 70 μg/m^3 for formers. NIOSH noted that the prohibition of dry sweeping materials would further reduce exposures (Document ID 0235, pp. 6, 8, 12).

Reduced Spillage and Adhesions Associated With Conveyors

Conveyor belts, even if not fully enclosed, can be modified with raised sides (e.g., using troughed belts or V-rollers) to reduce spilled material that also can contribute to silica exposure levels. In addition to the benefit of reducing occupational exposures, less spillage also translates to minimizing the loss of product or raw material and increased productivity for the employer. NIOSH reported that the brick manufacturing facility that used LEV on various milling, mixing, and storage equipment (mentioned previously) also used alternative trough conveyors to reduce the amount of raw materials lost from the conveyor belts associated with the raw material grinding equipment. At this facility, the "B Plant" grinding room conveyors were equipped with a ¾ inch raised edge that minimized material spillage. Workers in this area who spent only a small portion of the shift (10 percent) performing clean-up activities had exposures below the PEL (≤15 (LOD) and 24 μg/m^3) and (Document ID 0235, pp. 6-7, 10). A second worker in a separate grinding area in the same facility, which did not have this type of conveyor installed, had a sample result of 144 μg/m^3. This worker spent a larger portion of their shift, almost 85 percent, cleaning up material (Document ID 0235, pp. 6, 10).

A second facility visited by NIOSH installed full-width belt scrapers on its feed belt conveyors, which carried screen clay through the production facility to the pug mill (Document ID 0239, p. 8). The scrapers, in addition to water sprays, prevented the clay from clinging to the belt, drying out and continuing to be a source of silica exposure as the conveyor moved. Troughing idlers were also added to prevent spillage of the screen clayed as it moved overhead (Document ID 0239, p. 8). Although sampling results exceeded the PEL, the overexposures could have been due primarily to shoveling spilled clay from the floor. NIOSH recommended using a vacuum to further reduce exposures, an additional control discussed at more length below (Document ID 0239, p. 12).

Dr. Garth Tayler, Technical Director, Acme Brick Company agreed with OSHA that material frequently sticks to the conveyor belts during material transfer resulting in spillage and accumulation on the ground (Document ID 3577, Tr. 742; 3586, Tr. 3447-3449). OSHA expects that the installation of belt scrapers to reduce the amount of material that clings to the belt will reduce material spillage or re-suspension. Use of these scrapers prevents the clay from drying out on the belts and re-aerosolizing as the conveyor continues to move (Document ID 0235, p. 8). Although the benefit of this control method by itself has not been quantified, it can be part of the overall control package used to limit silica exposures, as demonstrated by the fact that just 1 of 32 samples (3 percent) exceeded 100 μg/m^3 in the plant (compared with 28 percent for the industry as a whole, as indicated by Table IV.4.21-B) (Document ID 0235, p. 8).

Housekeeping

Poor housekeeping can contribute substantially to worker exposure levels in all material handling areas. Housekeeping that minimizes the amount of spilled materials and settled dust in areas of vehicular traffic reduces silica exposure that occurs when those sources are crushed or disturbed by passing traffic (including machinery operated by material handlers).

In one facility evaluated by NIOSH, exposures in the two separate grinding rooms were substantially less for operators in the grinding area that had good housekeeping practices (Document ID 0235). The “C plant” had what NIOSH described as “major accumulations (2 to 3 inches) of settled dust on the floor” and was associated with an exposure result of 144 μg/m^3 (Document ID 0235, p. 5). Grinding operators at the same facility in the “B Plant” had substantially lower results of ≤15 (LOD) and 24 μg/m^3 (Document ID 0235, pp. 6-7).

At a different facility evaluated by NIOSH, the grinding room operator spent a portion of the shift sweeping and shoveling (40 percent). NIOSH noted that the facility had implemented a number of various engineering controls and work practices already but suggested that replacing the broom with a vacuum cleaner equipped with a filter selected based on the particle size of the dust would eliminate this as a source of silica dust and further reduce exposures (Document ID 0239, pp. 7, 10, 12).

Thorough initial cleaning in association with improved housekeeping procedures to maintain cleanliness and prevent the accumulation of dust can reduce exposures. For example, a thorough cleaning in a brick manufacturing facility removed "several inches" of dust from floors, as well as from all structural and equipment surfaces (Document ID 1365, pp. 3-19 – 3-20; 0571). Post-cleaning air samples indicated a "dramatic" decrease in exposure levels (in some cases, a greater than 90-percent reduction, to levels less than 50 μg/m^3) for workers in areas where dusty materials were transported or handled. This thorough cleaning also allowed the facility to identify and prioritize specific sources of dust for future control efforts (Document ID 0571).

Enclosed Cabs

For facilities where elevated exposures persist for material handlers using vehicular material handling equipment (e.g., loader operators), well-sealed, air conditioned cabs maintained under positive pressure with filtered air provide an effective control option. The information summarized in the ERG contractor report suggests that most front-end loaders used in this industry are equipped with cabs (Document ID 1365, p. 3-16). During the public hearings, Bill Latham and Tom Brown with Acme Brick confirmed the availability of environmental cabs on front-end loaders in the structural clay industry. They commented that their loader operators use front-end loaders with enclosed cabs that are air conditioned and equipped with HEPA filters (Document ID 3586, Tr. 3442). Although Acme Brick did not submit any sampling data to the docket, Mr. Brown stated that the majority of their employees currently experience exposures below 50 μg/m^3 (Document ID 3577, Tr. 760-761).

Enclosed cabs have been shown to be highly effective in agriculture and mining industries as reflected in data from Hall et al. (Document ID 0719). Agricultural workers are routinely exposed to respirable dust and the agricultural industry has an interest in protection against respirable and total dust. Hall et al., tested two cabs manufactured or retrofitted to comply with the controls recommended by the American Society of Agricultural Engineers'[139] S525–*Engineering Control of Environmental Air Quality* (ASAE S525) standard criteria. The data from Hall et al., suggest that a 94 to 98.5-percent reduction in respirable dust[140] (inside, compared with outside the cab) can be achieved on tractors (a type of heavy equipment) fitted with well-sealed, air-conditioned, and filtered cabs (Document ID 0719, p. 51).[141]

Operators working in heavy equipment cabs designed to meet ASAE S525 standards should experience exposure reductions in the same general range as described by Hall et al. OSHA estimates that for the loader operators currently experiencing exposures between 50 and 100 $\mu g/m^3$ (approximately 40 percent of all operators in this industry), use of well-controlled cabs would reduce exposures to levels at or below 50 $\mu g/m^3$; while operators currently exposed to average concentrations between 100 and 200 $\mu g/m^3$ (approximately 14 percent of loader operators) would achieve exposure levels of less than 100 $\mu g/m^3$. Lighter equipment, such as forklifts, might achieve a lower reduction, but a functional air conditioning system and careful maintenance should offer exposure reductions, in OSHA's judgment, of at least 50 to 90 percent as compared with the 94 to 98.5 percent reductions described above .This estimation was used in the PEA (citation), and no commenters disputed it.

OSHA's estimate of percentage reductions is buttressed by studies of enclosed cabs in the mining industry. The Mine Safety and Health Administration (MSHA) found that for

[139] In 2005, the American Society of Agricultural Engineers (ASAE) changed its name to the American Society of Agricultural and Biological Engineers (ASABE).

[140] The cabs were found to offer exposure reductions of 98.5 percent (manufacturer's factory-made cab) and 94 percent (retrofit cab) for particles smaller than 1.0 µm. When tested against particles 3.0 µm and larger, the cabs were found to provide even greater protection. Although more than half of the mass of respirable particles is usually particles greater than 3 µm, a portion of respirable particles are often smaller. Therefore, OSHA has used the reductions for the smaller particles to ensure workers are fully protected, although this means that OSHA is underestimating the benefit these tractor cabs likely offer workers exposed to respirable particles.

[141] "At least three criteria must be met for a cab to fulfill properly its function: pressurization, minimum penetration with respect to the main pollutants, and cleaned airflow rate."" (Document ID 0550, p. 3). The precise reduction depends on cab pressurization to exclude particles, particle penetration through filters, and clean airflow rate.

loaders, bulldozers, and trucks used by the surface and underground mining industry, where workers were exposed to high levels of mineral dust containing silica, sealed cabs reduced (total) silica exposure levels by 42 to 99 percent (original equipment or retrofit). In most cases, when a loader or truck cab had a filtered ventilation system meeting the requirements of ISO standard 10623, silica exposure reduction was 91 percent (Document ID 0821, pp. 3-6).[142] Cabs offered less effective dust control (less than 80 percent reduction) when seals were poorly maintained or air filtration inadequate; that is, metal mesh filters rather than higher efficiency paper filters were used in the cab air filtration system (Document ID 0871, pp. 2, 6). However, MSHA concluded that "a cab without additional controls provides some additional protection to the worker, because it protects the worker from peak concentrations" (Document ID 0821, p. 4). MSHA also concluded that housekeeping practices should include vacuuming or wet wiping the cab interior daily (Document ID 0871, p. 4). Some loaders tested by MSHA (Caterpillar models 992G, 992C and 980F) were similar to the model used by a structural clay facility evaluated by NIOSH (Caterpillar model 950F), demonstrating that these filtration systems can be implemented for equipment used in the structural clay industry (Document ID 0235).

Although these cabs require regular maintenance to function properly, OSHA estimates that appropriately fitted and maintained cabs would offer an exposure reduction of at least 90 percent (the low end reported for larger equipment) for material handlers, including those using front-end loaders (Document ID 1365).

Using Low-Silica Gravel on Floors

Use of low-silica materials on floors driven on by equipment can reduce silica exposures. In the kiln area of one structural clay facility, the wheels on a lift that was transporting product crushed a mixture of high-silica gravel floor covering and spilled broken product. Plant personnel reported that the material on the floor contained up to 98 percent silica content, which became a source of exposure when dust from the crushed material became airborne. The highest result (258 μg/m^3) for material handlers is attributed to this

[142] ISO standard 10623 provides for a 50 Pascal (0.20 inches of water) cab pressure and a minimum 25 cfm of intake airflow into the cab (Document ID 0821, p. 1).

exposure source (Document ID 0137, PDF p. 115). Another facility, described by NIOSH, used “washed limestone pea gravel” (a low-silica stone) on kiln floors, instead of the original brick chips and dust, as the wheels on mobile equipment tend to pulverize the material and were contributing to worker silica exposure in the enclosed kiln (Document ID 0239, p. 8). Workers covered the pea gravel with aluminum plates to provide thermal protection, improve forklift traction, and reduce dust. Results of 57 to 60 $\mu g/m^3$ were associated with material handlers who worked on the pea gravel surface but also performed dry sweeping and spent half the shift handling unfired dry clay (two additional sources of silica exposure). NIOSH commented that the potential for silica exposure remained, due to bricks that broke during firing (Document ID 0239, p. 8). OSHA notes that it might be necessary to replace the pea gravel frequently to avoid increasing amounts of broken product accumulating in the gravel where it will be crushed by passing in-plant vehicles.

Wet Methods, Dust Suppressants, and Conducting Operations on Damp Clay

When possible, wet methods are a particularly effective means of controlling silica, as water spray can help capture airborne dust, and damp surfaces release less dust than dry surfaces.

Brian Ogle with General Shale expressed concern regarding the use of wet methods due to the physical specifications of the product and machinery, stating “because of the nature of that raw material, we're forced to utilize heaters and devices that displa[ce] [*sic*] large volumes of air at high velocity just so we can process our raw material and make brick. The slightest change in moisture content changes the maintenance related activities, the settings and even the exposure limits in those areas. This is a fancy and complicated way of saying that if we increase moisture content of the raw material; we're not going to be able to make brick” (Document ID 3586, Tr. 3380).

OSHA acknowledges that wet methods may not be appropriate to use in all circumstances such as the pre-production material handling described by Mr. Ogle. Where appropriate, however, their implementation has been shown to reduce exposures. In addition, water sprays are most effective at particle capture when the droplet size and dust particle diameter match, which also results in minimal water usage (see Section IV-4.11 – Landscaping Services for further discussion of the use of wet methods to control dust).

In the structural clay industry, use of wet methods has been shown to reduce respirable silica dust exposures well below the PEL. A NIOSH study demonstrates the effectiveness of wet methods. This study reported six exposure results, all less than 30 µg/m^3 (ranging from 11 µg/m^3 (the LOD) to 29 µg/m^3) for four post-production material handlers who operated *automated* product handling equipment equipped with spray nozzles to unload fired products from kiln cars (Document ID 1365,p. 3-22; 0232, pp. 5, 7, 8, 11). At the same facility, NIOSH also collected an additional six samples indicating similar exposure levels (ranging from 11 µg/m^3 (the LOD) to 36 µg/m^3) for material handlers working in an area where directional water-spray nozzles were used to reduce dust released from fired products before the products were *manually* unloaded (Document ID 1365, p. 3-22; 0232, pp. 5, 7, 8, 11). The spray heads could be triggered by the material handlers or set to operate automatically. An additional water hose with hand sprayers also was available for manual dust control. This report demonstrates how facilities can use both automatic and manual water sprays to optimize dust control and achieve modest exposure results to control dust from fired products (Document ID 1365, p. 3-21; 0232, pp. 5, 7, 8, 11).

Wet methods also can reduce exposures where silica-containing dust in the yard contributes to the overall exposure levels of material handlers. Dust suppressants or frequent wetting using a water spray truck can limit the amount of dust that becomes airborne. For example, a brick manufacturing facility sprayed the yard (product storage area) with water five times per day. Five of the six results obtained for material handlers operating in the area were below the LOD (16 µg/m^3 in this case), while one result was 43 µg/m^3 (Document ID 1365, p. 3—10; 0239, pp. 8-14). Another example that suggests that wet methods can significantly reduce exposures, exposures of 14 µg/m^3 and 10 µg/m^3 were obtained for loader operators at another facility moving crushed shale and schist from storage piles to hoppers. The floor was wet from the rain and visible dust was not “particularly evident” which may have contributed to the lower exposures (Document ID 0232, p. 4).

Dust suppressants, such as foam sprays, can also be applied to hoppers and conveyors to prevent silica dust from becoming airborne as raw materials are transferred between work areas. This method is in use at a structural clay facility visited by NIOSH. A foam suppression system with four spray heads was installed on the conveyor supplying the loading hopper of the pre-crusher. The loader operator working in the area had a silica result of 56 μg/m^3, despite visible dust accumulations in the loader cab which may have contributed to the exposure (Document ID 0239, pp. 6-8, 11, 14).[143]

Another way to reduce exposures to silica dust, while transporting unfired clay is to transport or manipulate the clay objects while they are still slightly damp rather than fully dried. For example, if bricks are handled (to transfer or further process them) while still slightly damp, they will be less dusty, and material handlers (and other production workers) will experience less silica exposure. A review of the data available to OSHA shows that airborne silica concentrations for damp clay operations range from less than or equal to 12 μg/m^3 (LOD) to 77 μg/m^3, with a median exposure of 22 μg/m^3. In contrast, manual operations of dried clay are associated with exposures ranging from 64 μg/m^3 to 215 μg/m^3, with a median exposure of 104 μg/m^3 (Document ID 1720; 0235; 0239). These results support the conclusion that work involving dried clay is dustier than work involving damp clay. OSHA acknowledges that even when workers can perform manual operations on damp clay, the clay eventually must be allowed to dry (e.g., prior to kiln firing). At a site visited by NIOSH, however, wet bricks were stacked onto the kiln carts and allowed to dry in place before firing, eliminating the need to transfer them dry (Document ID 0239, p. 5). Furthermore, spilled damp clay must be cleaned up before it dries and becomes an ongoing source of exposure.

Automation

Automated material handling and transfer equipment will also mitigate exposures. Another review of the exposure data available to OSHA (see Table IV.4.21-B) shows that post-production material handlers performing the tasks of unloading kilns and stacking

[143] The foam application system consisted of “a drum of citrus-based surfactant, a control panel, hoses, a manifold, and four spray heads. This system worked by blanketing the surface of the conveyed material with foam, preventing the generation of silica-containing aerosols” (Document ID 0239, p. 8).

finished structural clay products had lower exposure levels when they used automated material handling equipment (all nine results less than 50 μg/m^3, with eight of those results also less than 25 μg/m^3) than did workers performing this work by hand (Document ID 1365, p. 3-23; 1720, p. IV-359; 0202, p. 11; 0239, p. 11). For manual work, 21 percent of 19 total results exceeded 50 μg/m^3 and one exceeded 100 μg/m^3. Automatic material handling tools include kiln unloading equipment, automated transfer, and stacking and bundling or strapping equipment (Document ID 1720, p. IV-359). OSHA acknowledges that retrofitting to accommodate automating material handling in existing facilities may not be feasible in all cases.

Additional Comments Regarding Controls

General Shale expressed concern that adjacent worksites and non-asphalt roads can be very dusty and can contribute to exposures (Document ID 3586, Tr. 3465-68). Implementation of the controls listed above, such as enclosed cab for workers in vehicular equipment, misting and fogging systems and yard wetting practices which may need to extend to roadways, will control exposures. OSHA understands that workers may continue to be exposed to dust from outside sources, but expects that those sources will not contribute significantly to respirable silica dust exposures in the workplace. For rare instances such as dust storms in arid climates, workers may need to be placed in respiratory protection or if possible adjust the workload to avoid the storm. Please refer to the discussion in FEA Chapter X – Environmental Impacts.

Additional Controls for Grinding Operators

The data summarized in Table IV.4.21-B show that 29 percent of grinding operators' exposures are already at or below 50 μg/m^3. OSHA finds that additional controls are needed to reduce the exposures of the remaining 71 percent of grinding operators in the structural clay products industry. Those controls as discussed further below include well-enclosed and well-ventilated control rooms; enclosures, LEV, and water sprays on grinding equipment, conveyors and storage units; and regular cleaning of the grinding areas using HEPA vacuums.

Eliminating the Use of Compressed Air for Cleaning

As discussed in the PEA, using compressed air for cleaning is an ongoing source of silica exposure for grinder operators. No comments from the structural clay industry were received on the use of compressed air for cleaning. Accordingly, for reasons discussed below, OSHA has reaffirmed its conclusion that facilities eliminating the use of compressed air for cleaning can reduce the exposure levels of grinder operators in the structural clay industry.

NIOSH consistently cites the elimination of compressed air for cleaning when recommending methods to reduce silica exposures in this and other industries, such as the concrete products, refractory products, and foundry industries, which also use substantial quantities of sand and clay- and concrete-based materials (Document ID 0232, p. 10; 0236, pp. 6, 10; 0266, p. 13; 0898, p. 14; 1381, p. 10).

The use of compressed air was shown to have a significant impact on worker silica exposure levels in foundries (Document ID 1365, pp. 2-29 - 2-36, & *passim*). Due to the large number of results available for foundry cleaning/finishing operators, it was possible for the OSHA contractor ERG to examine exposures associated with the use of compressed air on exposure levels (Document ID 1365, pp. 2-69 - 2-70). ERG found that 26 results for cleaning/finishing operators working at five foundries where NIOSH or OSHA had observed the use of compressed air to blow sand and clay molding material (similar to the silica-containing mineral dust found in structural clay facilities) off metal castings or equipment were associated with exposure levels having a median of 487 μg/m^3 compared with a median of 72 μg/m^3 for all finisher/operators. Furthermore, all 26 results (100 percent) were 230 μg/m^3 and higher (Document ID 1365, p. 2-75). In light of the ERG and the NIOSH analyses and recommendations, OSHA concludes that the use of compressed air contributes to high exposures above the preceding and final PEL.

Acme Brick along with the concrete product industry commented that there are locations where vacuums and brooms cannot be utilized and that “the only alternative in these locations is compressed air to blow material out to where it can be collected” (Document ID 2023, p. 5). Acme acknowledges that this approach generates significant dust but that it occurs "on a very periodic basis,* * *. is necessary, and there is currently no engineering control available to address this situation" (Document ID 2023, p. 5). Although Acme Brick's comment appears to be primarily concerned with the cost of the vacuums, OSHA agrees that there may be places, for example, under certain pieces of equipment and in tight spots that cannot be easily accessed by vacuums. As reflected by Acme Brick's comment, however, these circumstances are "periodic" and not therefore usual. Work practices could be implemented during the period compressed air is required that would protect workers, including moving workers not involved with cleaning away from the area, and protecting the workers using compressed air with respirators. The area could then be vacuumed to collect any dust dispersed by blowing before normal activities resumed. Additionally, some of the locations where vacuuming is not possible may be appropriate for the limited use of wet methods to move the material where it can be swept up damp or vacuumed.

OSHA therefore has determined that vacuuming using appropriately filtered vacuums in all or almost all circumstances instead of the use of compressed air will substantially reduce exposures among grinding operators during cleanup activities.

Housekeeping

Another control is diligent housekeeping using HEPA-filtered vacuums and dust suppressants to prevent settled dust from accumulating in grinding areas and control rooms, reducing the likelihood of the dust being re-suspended. The use of HEPA-filtered vacuums and dust suppressants to clean in the grinding areas rather than dry sweeping and shoveling will also reduce the airborne re-suspension of silica-containing dust. A NIOSH report indicates that dry sweeping and shoveling of "fine material" in the grinding area is a notable exposure source that can be eliminated by using a vacuum cleaner equipped with an appropriate filter (Document ID 0239, p. 10; see also Document ID 0232, p. 10; 0236, pp. 6, 10; 0266, p. 13; 0898, p. 14; 1381, pp. 10, 12). Where the facility has allowed significant quantities of dust to accumulate, as previously described under additional controls for material handlers, a thorough initial cleaning can dramatically reduce exposures (Document ID 0571). At the facility described previously, the exposure level of most workers was reduced dramatically, in some cases by over 90 percent, to levels of 50 μg/m^3 or less (Document ID 0571).

While industry representatives agree that vacuum systems can reduce exposures to silica during cleaning activities, their use is not widespread. As one industry representative commented, "[d]espite the obvious value of vacuum systems, only 25 percent of responding companies * * * have implemented those as a control strategy. This limited reliance on vacuum systems is likely due to the fact that they typically collect from only individual discreet areas of an operation" and because "dust/debris is not limited to one or two locations in the plant, fixed location vacuum collection points are not realistic" (Document ID 2023, p. 4). However, some companies use mobile vacuum systems to address this concern. According to Acme Brick, "a few producers * * * have reported the implementation of HEPA semi-mobile central vacuum systems (Demarco or similar) that are used daily between and during shifts as needed" (Document ID 2023, p. 4).

Additionally, modified work practices for housekeeping can be beneficial for further reducing exposures. Acme Brick stated that they have modified their work practices (including housekeeping) so that they do not conduct cleanup activities while the plant is operating. "We know that silica takes a long time to settle, so we normally don't do any clean up or anything until way after the shift is completed" (Document ID 3577, Tr. 742-743). This practice allows the operator to remain in the control booth for the majority of the shift, reducing the likelihood of exposures from the operating equipment.

Operator Control Booth

Operator control booths (or rooms) can limit silica exposures to low levels (often below the LOD) during the time that the operator spends in the booth (Document ID 1365, pp. 3-23 – 3-24). Control booths are widely used for grinder operators in the structural clay industry; however, these booths are not necessarily maintained optimally to limit worker silica exposure levels. As explained below, to provide a low-exposure environment, a control booth must be well-sealed, supplied with clean air, under slight positive pressure to help keep dusty air out, and regularly cleaned to remove any dust that is tracked in.

At a structural clay facility visited twice by OSHA, an area sample collected inside a ventilated control room used by the grinder operator resulted in an average silica concentration of 116 μg/m^3 (Document ID 0161, p. 452). Before OSHA's next visit, the facility sealed gaps around the main entrance door to the control room, which reduced airborne silica levels inside the room to one-tenth the original level. A 6-hour area sample taken on the second visit showed an average respirable quartz concentration of 11 μg/m^3 inside the control room, suggesting that the room provided a substantial level of protection for any worker inside (Document ID 0161).

During the two visits, OSHA also collected personal samples for the grinder operator. The silica exposure level of the grinder operator was 362 μg/m^3 during OSHA's initial visit and fell to 101 μg/m^3 during OSHA's second visit, a 72 percent reduction.[144] Although the report does not indicate the relative amount of time the operator spent in the control room on the two sampling dates, the report attributes this reduction in the grinder operator exposure level to the improvements in the control booth (Document ID 0161, pp. 219, 1285).

Exhaust Ventilation

The use of effective exhaust ventilation systems for clay grinding machines is another option for reducing worker exposures. Although no information specific to the structural clay industry is available, OSHA identified two studies that evaluated exhaust ventilation systems for activities analogous to grinding operations, that is, rock crushing, which often involves a similar action to this type of grinding, and raw clay processing in mining activities, which is as dusty as structural clay. A LEV system installed at a rock crushing plant processing rock containing as much as 60 percent silica was associated with reductions of silica ranging from 20 to 79 percent (Document ID 1365, pp. 3-24 – 3-25). In another study by the U.S. Bureau of Mines, a total mill ventilation system for a clay processing facility that performed crushing and screening operations was associated with an average respirable dust reduction of 40 percent throughout the facility. OSHA expects

[144] On the first sampling date the grinder operator exposure is assumed to have been concurrent with the area sample in the control room. The second grinder operator sample is known to have been obtained concurrently with the second area sample collected in the control room (Document ID 0161).

that similar reductions (approximately 40 percent) in respirable dust levels in structural clay products facilities would result in reduced silica exposures for grinding operators (Document ID 1365, p. 3-25).

Commenters expressed skepticism about the feasibility of LEV. During the public hearing, a representative for General Shale stated, without explanation, that their raw material processing buildings where the grinding operators work “do not provide for the practical use of local exhaust ventilation” or “bag houses” in the raw material processing areas (Document ID 3586, Tr. 3379-3380). He acknowledged, however, that LEV was effective in the mill and final packaging areas (Document ID 3586, Tr. 3450). Other participants at the hearing discussed their use of ventilation in the grinding areas to reduce exposures. Brian Ogle of General Shale testified that “maybe a 50,000 cfm bag house might work in these buildings” but they had not yet looked into it (Document ID 3586, Tr. 3357, 3380). He also stated that “local exhaust ventilation is about what you're going to do” to reduce exposures (Document ID 3586, Tr. 3486-3487). These types of controls for grinding are not uncommon as Rami Katrib representing United Steelworkers (USW) quoted from employers “ … processes typically have point source exhaust systems to collect particulates containing the crystalline silica. In addition, we use work practices such as misting …” (Document ID 3584, Tr. 2537).

Others commented that dust control technologies, including bag house dust collectors, cartridge filter dust collectors, and even mobile units, are used to reduce dust in grinding areas (Document ID 3577, Tr. 743; 3586, Tr. 3450; 2363, p. 2).

Combination of Engineering Controls

In the PEA, OSHA opined that most facilities would need to implement a combination of properly implemented and maintained controls to reduce exposures to at or below the PEL of 50 μg/m^3 for grinding operators (Document ID 1720, p. IV-365). A NIOSH evaluation describes a combination of engineering controls that reduced worker exposure during grinding operations (Document ID 0232). At the facility evaluated, troughed conveyors reduced the spillage of raw materials as the materials were transferred to the grinding equipment; enclosed grinding machinery minimized dust release during the grinding process; a covered conveyor reduced dust release from ground materials as they were transferred to storage silos; and sealed bins prevented dust release from the storage units (Document ID 0232, pp. 4, 6-7). This facility also used raw materials with a higher water content (20 percent) (Document ID 0232, p. 4) than the facilities described in other NIOSH reports (9 percent to 13 percent) (Document ID 235, p. 4; 0239, p. 7). NIOSH obtained exposure readings of 67 $\mu g/m^3$ and 13 $\mu g/m^3$ for the grinding operator at this facility (Document ID 0232, pp. 5, 11-12). These values are substantially lower than the median of 98 $\mu g/m^3$ for this job category (see Table IV.4.21-B). Although the report does not indicate conditions that would explain the difference between these two readings, it recommends against the use of compressed air, suggesting that compressed air was used for cleaning and that its use contributed to worker silica exposures (Document ID 0232, pp. 8, 10). The information presented in this section regarding the use of compressed air. OSHA finds that both these levels would likely have been lower and less than 50 $\mu g/m^3$ if the workers had not used compressed air for cleaning.

Another control that can be implemented in combination with other controls is conveyor belt scraper, which removes material that sticks to the conveyor belts during material transfer. NIOSH observed the use of full-width belt scrapers at a facility where the feed belt conveyors carried screened clay through the production facility to the pug mill (Document ID 0239, p. 8). As discussed earlier, the use of the belt scrapers, in addition to water sprays, prevented clay from clinging to the belt and drying out, preventing it from being a source of silica exposure as the conveyor moved the raw materials (Document ID 3577, Tr. 742; 3586, Tr. 3449).

The use of a combination of controls to reduce exposures was supported by representatives from the brick industry during the public hearings. “No one solution is a fix,” stated one representative. “Basically we develop solutions through engineering, containment, suppression, collection, ventilation, best management practices, education, and training.” He added, “When you have an issue, depending on what it is, you might end up having to put an enclosure over this portion, a fogging system here, ventilation at this end, because you can't just do one thing because it's not going to fix the problem.

And, that is why our engineering department is part" of the team developing controls (Document ID 3577, Tr. 710-711, 745-746).

Although five to twenty percent of Acme Brick grinders experienced higher exposures during the period May 2003 to June 2007 at one of its plants, the industry representative commented that through the use of a combination of controls it was able to control the majority of its employees' exposures to at or below 50 μg/m^3 (Document ID 3577, Tr. 760-61; 3730, pp. 1-2).

In light of the studies and comments, OSHA has concluded that using a combination of controls, the structural clay industry will be able to limit exposure to most grinders at structural clay facilities to at or below the PEL most of the time.

Additional Controls for Forming Line Operators

The exposure profile in Table IV.4.21-B shows that 64.8 percent (35 out of 54 samples) of forming line operators have exposures above the final PEL of 50 μg/m^3. Therefore, OSHA finds that additional controls will be necessary to achieve the PEL for overexposed workers. While General Shale commented that exposures in its mill rooms where forming line operator work are typically below 100 μg/m^3 due to the use of local exhaust ventilation and the existence of moisture in the material (Document ID 3586, Tr. 3450), OSHA's exposure profile represents that exposures of Forming Line Operators substantially exceed the PEL. The final exposure profile, Table IV.4.21-B, reflects that only 35 percent of forming line operators currently experience exposure levels at or below 50 μg/m^3. As is the case for material handlers, the data for this job category are not equally distributed across all three subcategories; only 14 percent of pug mill operators, 20 percent of coatings blenders, and 0 percent of clay powder formers, experience exposures at or below 50 μg/m^3. The only forming line operators that consistently have exposures at or below 50 μg/m^{3}are the wet clay formers with 90 percent of their exposures below 50 μg/m^3.

Since only 35 percent of Forming Line Operators experience exposures at or below the PEL, additional controls are needed to reduce the exposures of the majority of the workers in this job category. Additional controls include enclosed and automated transfer of crystalline silica-containing materials, well-ventilated bag dumping stations, well-enclosed and well-ventilated milling and mixing equipment, and the use of a combination of supply and exhaust ventilation systems in the coatings application areas.

Similar to other job categories in this application group, the use of a combination of controls will be necessary to reduce exposures for forming line operators. Acme Brick reports using fogging systems,[145] suppression surfactant, ventilation, enclosures over the conveyors, belt scrapers and adjusting belt speeds to reduce exposures to at or below 50 μg/m^3 (Document ID 3577, Tr. 743,745-746). This testimony supports OSHA's conclusion that a combination of controls will be most effective.

Local Exhaust Ventilation

Ventilated, sealed, bag dumping stations can capture silica dust during coatings preparation activities performed by some forming line operators (coating preparers and formers). To be effective, the stations require properly ventilated enclosures, which capture dust released during both bag emptying and bag disposal. OSHA has not identified any structural clay products facilities using bag dumping stations that effectively controlled dust generated by bag emptying and disposal. Comparable respirable quartz exposure monitoring data exist, however, for workers using bag dumping stations to empty 50-pound bags of silica-containing materials at a paint manufacturing facility (Document ID 0199, pp. 12-13). The activities and bags dumped are similar to those existing at structural clay facilities. A bag dumping station with fully functioning LEV was found to reduce silica exposure by at least 95 percent (from 363 μg/m^3 to 12 μg/m^3) (Document ID 0199, pp. 7-8). The stations consisted of hoppers topped with grates enclosed by LEV hoods. After each bag was emptied, the worker released it, and suction automatically pulled the bag into the ventilation system and transferred it to an enclosed storage area. Bag dumping stations with other types of ventilated bag disposal equipment should be equally effective as long as they capture dust as the bags are compressed. Ventilated bag dumping and bag disposal stations are readily

[145] Fogging nozzles produce a very fine water mist (a droplet size distribution ranging from submicron to micron) (Document ID 1596,; 3472).

available from commercial sources (Document ID 1224; 0581; 0594; 1429; 0680 and 1212).

These types of controls have been successfully implemented as demonstrated by Acme Brick who reports that in extrusion areas they have enclosures and LEV (Document ID 3586, Tr. 3449).

Automated Coatings Transfer System

Automated material transfer equipment can also help reduce dust released as hoppers are filled (e.g., hoppers that hold sand coatings distributed onto bricks along forming lines). For example, at a facility inspected by OSHA, an 86-percent reduction in respirable quartz exposure readings occurred after management installed an enclosed, automated sand transfer system (Document ID 1365, p. 3-26; 0161). Initially, a reading of 501 $\mu g/m^3$ had been obtained for a forming line operator who manually cut open and emptied 120 50-pound bags of silica sand into a hopper at an unventilated sand charging station. After the inspection, the facility installed an automated system with enclosed conveyors to transfer sand to the hopper from a storage silo. During a subsequent inspection, a reading of 70 $\mu g/m^3$ was obtained for an operator who monitored the automated transfer system (Document ID 1365, p. 3-26; 0161).The inspection report observed that sand leaked from the conveyor leading to the hopper because the conveyor was not the correct size. OSHA expects that with tightly sealed, correctly-sized components, exposures could be reduced further using this type of equipment.

Housekeeping

Housekeeping can either minimize silica exposure (when settled dust is effectively removed) or contribute to worker exposure by causing spilled or previously settled dust to become airborne (Document ID 1365, 3-4, 3-15, 3-25; 0235, p. 9). And therefore it is essential that housekeeping is done in a manner that minimizes silica re-entrainment into the air. As discussed previously in regard to additional controls for material handlers in this industry, considerable exposure reduction was associated with thorough cleaning in areas where raw materials were handled (Document ID 1365, p. 3-20; 0571). A facility observed by NIOSH reported that a regular schedule of afterhours cleaning using a walk behind sweeper, brooms and a HEPA vacuum, has reduced the accumulation of product materials in the brick production facility (Document ID 0239, p. 8). OSHA finds that thorough cleaning and rigorous housekeeping offer the same benefit (exposure reductions of 90 percent, in many cases to less than 50 μg/m^3) in other plant areas that have accumulated dust. Much of the dust is of similar origin, so it can be expected to behave similarly. Once emissions from grinding and conveying equipment have been reduced, eliminating this source of exposure is as effective in the grinding area as in other material handling areas.

Combination of Engineering Controls

As mentioned previously, the use of a combination of controls to reduce exposures was supported by representatives from the brick industry during the public hearings (Document ID 3577, Tr. 710-711, 746).

Pug mill operators and formers on the forming line are exposed to silica dust released as dry materials fall into the hopper and mill. Mixers with doors that seal well and enclosed, ventilated mixer hoppers can limit this dust release. For example, the installation of a mixer equipped with a ventilated enclosure, and improved water feed system was associated with a 79 percent reduction in respirable quartz exposure readings for a tile manufacturing facility (Document ID 0161, pp. 1048,1052). This exposure reduction was achieved after an initial reading of 1,028 μg/m^3 (the highest among the data available to OSHA for this industry) was obtained for a forming line operator who monitored a mixer equipped with poor LEV and a partial enclosure (Document ID 0161). The enclosure had several openings, and its doors did not seal properly, allowing dust to escape back into the work area. Later, the facility installed another mixer with an improved enclosure and a water-feed system to wet the materials during mixing. A reading of 214 μg/m^3 was obtained for an operator who primarily monitored the second mixer (Document ID 0161, p. 1048). Although this level still exceeds allowable limits, it represents a notable decrease in worker exposure level. If the facility had made ventilation improvements to the original pug mill still operating in the area, improved ventilation of the mixer hopper to the levels recommended by ACGIH, for example, it is likely the exposure would have been reduced even further.

4.21.4 Feasibility Findings

Based on the exposure profile in Table IV.4.21-B and other record evidence discussed above, OSHA finds that the standard is technologically feasible for the different categories of structural clay workers and additional controls previously discussed are used. Several commenters expressed concern that compliance with the PEL may not be achievable and that it is “difficult, if not impossible, in some of the locations” (Document ID 3577, Tr. 706, 742; 2378, p. 4; 3731, p. 1; 2085, p. 3; 2004, p. 2). However, others acknowledge that the difficulty in reducing exposures is dependent on the type of clay and shale being used and how easily it breaks into respirable sized particles (Document ID 3577, Tr. 706; 3586, Tr. 3356; 2085, pp. 2, 3).

In its written comments, however, Acme Brick acknowledges that compliance with the PEL of 50 μg/m^3 is technologically feasible (Document ID 2023, p. 6). During the public hearings, Garth Tayler and Tom Brown with Acme Brick stated that the majority of workers in their facility currently are exposed to silica levels below 50 μg/m^3 and that they have received samples back with results below the LOD, which they reported as 0.28 μg. When exposures above 50 μg/m^3 occur, respiratory protection is worn until engineering controls which lower the exposure to levels at or below 50 μg/m^3 are implemented. To ensure that exposure are reduced, Acme Brick continues to incorporate controls until three samples below 50 μg/m^3 are achieved (Document ID 3577, Tr. 725-726, 755-757, 760-761). These comments show that, with the right combination of controls to control all sources of silica exposure, achieving the PEL is technologically feasible.

Feasibility Finding for Material Handlers

Based on Table IV.4.21-B, OSHA concludes that more than 70 percent of material handlers already experience exposure levels of 50 μg/m^3 or less. The same level of 50 μg/m^3 or less can be achieved for the remaining 29 percent of workers in this job category most of the time by using a variety of situation-specific controls. Based on the information presented earlier in this section, OSHA has determined that the controls necessary for this job category include covering, ventilating, and modifying conveyors;

augmenting ventilation at transfer points; using well-maintained environmental cabs (for loader operators); installing push-pull ventilation (for workers performing manual transfers); using water sprays where practical (storage yards, roads, in areas where workers handle kiln-fired finished product); and performing thorough cleaning as needed.

Although most exposure control methods for material handlers are universally beneficial for all workers in this job category, some of the controls discussed previously are more appropriate for certain material handler subcategories than others. The following paragraphs summarize the control methods suitable for workers in the material handler subcategories. OSHA has also determined that some facilities may need to use a combination of engineering controls to reduce exposures to the PEL. Based on the information on additional controls presented in this section, describing in detail the effectiveness of each control, OSHA concludes that the control methods listed below will reduce the exposures of most material handlers to levels of 50 μg/m^3 or less most of the time

Loader Operators Subcategory: The primary controls for loader operators are LEV and suitable enclosures at receiving hoppers, conveyors (including conveyors designed to limit spillage), and transfer points to reduce exposure during the monitoring of material. Other controls include rigorous housekeeping to reduce the re-suspension of settled material and well-sealed enclosed cabs with air conditioning and air filtration systems.

Production Line Handlers Subcategory: Exposure control methods for this subcategory of material handlers include using low-silica stone (e.g., limestone) in place of high-silica gravel on kiln floors (where it can be crushed). Workers can also handle formed clay products in a slightly damp, rather than fully dried state, which is less dusty. These workers will also experience a reduction in exposure when housekeeping is improved and the exposure levels of other workers in the immediate area are better controlled (e.g., forming line operators and the associated sand application processes).

Post-Production Line Handlers Subcategory: Most material handlers in the post-production line already experience exposure less than the PEL. For those workers who experience exposure above 50 μg/m^3, additional controls for this group of workers include wet methods (water spray on fired product and in the yard), improved housekeeping and automation.

Based on the information presented in this subsection, OSHA concludes that the control methods listed above will reduce the exposures of most material handlers to levels of 50 μg/m^3 or less most of the time.

Feasibility Finding for Grinding Operators

Based on Table IV.4.21-B, OSHA concludes that exposure levels of 50 μg/m^3 or less have already been achieved for 29 percent of grinding operators. The silica exposures of most of the remaining 71 percent of grinding operators can be controlled to the PEL most of the time by using a combination of controls, including well-enclosed grinding equipment, conveyor enclosures, dust suppressants or water spray on raw materials, covered or troughed conveyors, tightly sealed storage units, and thorough cleaning.

This conclusion is supported by the study of a facility that used a combination of troughed conveyors, enclosed grinding machinery, covered conveyors, sealed bins, and raw materials with higher water content to achieve exposures of 67 μg/m^3 and 13 μg/m^3 for a grinding operator (Document ID 0232). OSHA has determined that exposures persisting above 50 μg/m^3 are usually associated with poor housekeeping practices like the use of compressed air or with poorly sealed equipment that leaks dust.

Based on the information on the effectiveness of additional controls discussed in detail above, OSHA finds that the exposure levels of most grinding operators can be controlled to 50 μg/m^3 or below most of the time with a combination of controls. These controls include a thorough initial cleaning if necessary to reduce accumulated dust levels and implementing a routine cleaning schedule to keep levels low. The controls also include the use of the following: enclosed, well-ventilated control rooms; enclosed grinding equipment; dust suppressants or water spray on raw materials; enclosed or troughed conveyors; and tightly-sealed storage units.

Elevated exposures can still occur during discrete activities such as opening the grinder housing doors. In cases where a grinder must inspect the area inside the sealed doors enclosing the grinder, the operator must deactivate the grinder and let the LEV evacuate dusty air before opening the doors. If this is not possible, the operator must wear respiratory protection to inspect the grinder. If the ventilation system is running and the grinder is turned off (but not evacuated), a respirator that provides an applied protection factor (APF) of 10 (e.g., a half-face piece respirator) should offer adequate protection under the PEL of 50 μg/m^3 [146] (Document ID 1720, pp. IV-366-377).

Based on the exposure profile in Table IV.4.21-B and other record evidence discussed above, OSHA finds that the PEL of 50 μg/m^3 is technologically feasible for grinders in the structural clay industry.

Feasibility Finding for Forming Line Operators

Based on the data shown in Table IV.4.21-B, OSHA concludes that 35 percent of forming line operators already experience results of 50 μg/m^3 or less. Employers of the remaining 65 percent of forming line operators can achieve exposure levels at or below 50 μg/m^3 for most of these workers by a combination of control measures. These controls include thorough, regular housekeeping, starting with thorough initial cleaning if needed; well-ventilated and enclosed mills, mixers, hoppers, and conveyors; tightly-sealed storage units; enclosed, automated sand transfer systems or bag dumping stations with LEV; exhaust-supply ventilation at workstations; and the elimination of compressed air for cleaning. Wet-clay formers will also experience reduced silica exposure when the silica exposures associated with adjacent activities (e.g., pug mill operators and sand coating activities) are reduced. Based on the information presented on additional controls and their effectiveness, OSHA concludes that with few exceptions (as discussed below for pug mill operators) forming line operators' exposures can be reduced to 50 μg/m^3 or less most of the time with the use of the controls listed below. Accordingly, OSHA finds that the PEL of 50 μg/m^3 is technologically feasible for forming line operators in the structural clay industry.

[146] If the grinder remains running, a higher level of respiratory protection will likely be required (e.g., a full-face piece respirator with an APF of 50).

Although most exposure-control methods for forming line operators are effective for all workers in this job category, some of the controls discussed above are particularly appropriate for certain subcategories. The following paragraphs summarize the control methods suitable for workers in the individual forming line operators' subcategories.

Pug Mill Operators Subcategory: The primary controls for this group of workers include improved enclosures for clay finishing equipment (mills, spray driers, conveyors), LEV fitted to the equipment enclosures, and water-feed systems that help reduce dust by wetting the dry clay. In work areas where dust has accumulated, improved housekeeping also helps reduce silica exposure levels.

Coatings Blenders Subcategory: For this subcategory, which prepares coatings mixtures for structural clay products, the primary control is LEV at sand transfer and dumping stations (particularly in the form of bag dumping stations, bag disposal equipment, and LEV for mixing equipment).

Formers Subcategory: Workers in this subcategory tend equipment that shapes bricks and applies sand coatings for tint or texture. Where the sand hopper is at the production line, these workers will also benefit from LEV in the form of a ventilated bag dumping station or batch-receiving hopper and bag disposal units. Where sand-based coatings are delivered from the coatings blending area by conveyor, enclosed and ventilated conveyors will be required. In both cases, formers will require coating sand application zones with LEV that enclose the coating process and capture silica dust before it spreads through the work area.

As mentioned in the additional controls section (IV-4.21.3), exposure levels may not be consistently reduced for some forming line operators, such as operators of pug mills and related clay finishing equipment, if they cannot spend at least 33 percent of the shift in a well-sealed control room. In order to keep these workers' exposures at or below the PEL of 50 $\mu g/m^3$, based on the exposure levels that can be expected for most of the shift (67 $\mu g/m^3$ or less), the supplemental use of respirator protection may be necessary.

Overall Feasibility Finding

Based on the information described in this section, OSHA concludes that the exposures of all material handlers and all forming line operators, except operators of pug mills and related clay finishing equipment, can be controlled to levels of 50 μg/m^3 or less most of the time. Exposures of most grinder operators and most production line handlers working with pug mills and related equipment also can be controlled to levels of 50 μg/m^3 or less most of the time, but these workers will likely require respiratory protection for certain activities, such as equipment inspections. OSHA therefore finds that the final PEL of 50 μg/m^3 is technologically feasible for the Structural Clay Industry.

4.22 HYDRAULIC FRACTURING

4.22.1 Description

Hydraulic fracturing is a process used to extract natural gas and oil deposits from shale and other tight geologic formations. While hydraulic fracturing has been in existence for around 60 years, innovative technology has emerged in the last 10 to 15 years that has made hydraulic fracturing a viable option for the extraction of gas or oil (Document ID 3589, Tr. 4086-87). Workers in the oil and gas industry pump fracturing fluid, composed of a base fluid (usually water with chemical additives) and a proppant (usually sand with a high crystalline silica content) into the well bore under extremely high pressures (e.g., 7,000 psi to 9,000 psi) to hold the fractures in the shale formation open after the pressure is released (Document ID 1538, pp. 1-2). The high pressures fracture the shale or rock formation, allowing the gas and oil trapped in the formation to flow into the well. Use of this process has increased significantly in recent years due to new horizontal drilling and multistage hydraulic fracturing technologies that improve access to natural gas and oil deposits (Document ID 1720, p. A-3). At the same time, there is increasing awareness of the hazards of this process, particularly that of exposure to RCS, which first came to widespread attention in 2010 as a result of a NIOSH report, Field Effort to Assess Chemical Exposures in Gas and Oil Workers (Document ID 1541)

Once well drilling is complete, the delivery of proppant to the wellhead used for hydraulic fracturing occurs in steps. Initially, sand truck drivers deliver sand to the site and pneumatically pump it from trucks into sand movers that store sand. Once the sand is placed in the sand movers, workers regulate the flow of sand out of the sand mover onto a series of associated conveyor belts, which carry the sand to a hopper from which the sand is metered into a blender. At the end of the process, the sand, water, and chemical additives are mixed together in the blender before the sand-laden fracturing fluid is pumped through a high-pressure manifold into the well (Document ID 1720, p. A-4).

Silica sand used as a proppant contains a high percentage of crystalline silica, typically ranging from 60 to 100 percent depending on the source (Document ID 1525, p. 1; 1529, p. 1). When silica sand is used as a proppant in hydraulic fracturing, high airborne concentrations of respirable silica dust can occur as workers deliver, convey, and mix large volumes of sand with fracturing fluid (Document ID 1720, p. A-3).

Hydraulic fracturing crews frequently spend several days performing active hydraulic fracturing at a site where a well has several zones, with additional days for equipment setup and removal on the days before and after hydraulic fracturing. The time spent in this process can be longer when multiple wells are located at the same site (Document ID 1538, p. 2). Once the job is complete, the crew moves to another site, where the process is repeated. During hydraulic fracturing several dozen workers can be on the site, but most work occurs outside the central sand-handling zone, which is only occupied by fracturing sand workers. The number of fracturing sand workers typically ranges from a half-dozen to two dozen, depending on the size of the project and whether multiple hydraulic fracturing crews are involved. A crew of 10 to 12 workers is typical (Document ID 3828, p. 348).

For the purpose of characterizing exposures to respirable crystalline silica, OSHA has organized activities at hydraulic fracturing sites into three main job categories: fracturing sand workers; ancillary support workers; and remote/intermittent support workers. Table IV.4.22-A provides information on these job categories and their sources of exposure. Fracturing sand workers have the highest potential for exposure and include approximately half of the crew, while ancillary support and remote/intermittent workers spend limited time in the immediate area where sand is being handled and thus have lower exposure levels (Document ID 1541; 1542; 1543; 1544; 1545; 1546).

Based on workplace observations and air monitoring surveys at 11 hydraulic fracturing sites, NIOSH researchers identified seven primary points of dust emissions from hydraulic fracturing equipment or operations. These included the following locations or equipment:

- Dust emitted from “thief” hatches (open ports on the top of the sand movers used to allow access into the bin);
- Dust ejected and pulsed through side fill ports on the sand movers during refilling operations;

- Dust released from the transfer belt under the sand movers;
- Dust released from operations of transfer belts between the sand mover and the blender;
- Dust released from the top of the dragon’s tail (end of the sand transfer belt) on sand movers;
- Dust created as sand drops into, or is agitated in, the blender hopper and on transfer belts;
- Dust generated by on-site vehicle traffic, including sand trucks and crew trucks, by the release of air brakes on sand trucks, and by winds.

(Document ID 3828, p. 355). Table IV.4.22-A shows how these seven primary and two other secondary sources of exposure relate to the three job categories. Dr. Gerhard Knutson, a ventilation consultant who testified on behalf of the U.S. Chamber of Commerce (Chamber), agreed with OSHA’s identification of exposure sources (Document ID 2264, p. 7-8; 3576, pp. 449-450).

;Table IV.4.22-A
Job Categories, Major Activities, and Sources of Exposure of Workers in the Industry Providing Support Activities for Oil and Gas Operations (NAICS 213112)

Job Category*	**Major Activities and Sources of Exposure**
Fracturing Sand Workers in the Central Area (e.g., sand mover operator, conveyor belt tender, blender tender, water operator, pump truck operator)	Operate and tend equipment in the central sand-handling area on hydraulic fracturing sites • Dust ejected from the thief hatches on the top of the sand movers (source #1 above). • Dust ejected from the side fill ports on the sand movers (source #2 above). • Dust released from the conveyor belt under the sand movers (source #3 above). • Dust released from conveyor belt operation between sand mover and blender (source #4 above). • Sand released at the top of the end of the sand belt on the sand movers (source #5 above) • Dust created as sand drops into or is agitated in the blender hopper (source #6 above).
Ancillary Support Workers (e.g., chemical truck operator, hydration unit operator)	Operate or tend equipment that is at a fixed location on the perimeter or slightly removed from the central sand-handling area, such as chemical trucks and hydration units. • Dust disbursed from processes operated by fracturing sand workers in the central sand-handling area. • Sand and aggregate on the ground, crushed by heavy equipment and disturbed by passing vehicles (source #7 above). • Accumulated dust in vehicle and equipment cabs occupied by drivers and operators.
Remote/Intermittent Support Workers (e.g., roving operator, ground guide, sand coordinator, mechanic, QA technician, fueler, wire-line crew)	Active over a wide area of the site, primarily outside the central sand handling area, but may include brief, occasional excursions into the central sand-handling area. These workers may spend time at a primary base location (truck, trailer) away from sand-handling. • Dust disbursed from processes operated by fracturing sand workers in the central sand-handling area. • Sand and aggregate on the ground, crushed by heavy equipment and disturbed by traffic on the site (source #7 above). • Dust released inside trailer while QA/QC technicians sieve sand to check sand quality. Normally only QC technicians are exposed in these instances because they are the only workers in the trailer while this work is performed.

*Job categories are intended to represent job functions; actual job titles may differ and responsibilities may be allocated differently, depending on the facility.
Sources: Document ID 1541; 1542; 1543; 1544; 1545; 1546.

4.22.2 Exposure Profile and Baseline Conditions

In the PEA, OSHA reviewed 83 8-hour time-weighted average (TWA) personal breathing zone (PBZ) respirable quartz results for workers at hydraulic fracturing sites. These samples were taken by NIOSH during a project conducted in collaboration with the oil and gas industry to investigate hazards at hydraulic fracturing sites. NIOSH conducted exposure monitoring at eleven hydraulic fracturing worksites in five states (seven sites in Colorado and individual sites in Arkansas, North Dakota, Pennsylvania, and Texas) as part of an industry-wide effort to identify and characterize exposures to vapors, gases, particulates and fumes among gas and oil field workers (Document ID 1541; 1542; 1543; 1544; 1545; 1546; 3828). The NIOSH report was one of the first comprehensive evaluations of respirable crystalline silica in hydraulic fracturing (Document ID 2177, Attachment B, p. 4).

In developing the final exposure profile, Table IV.4.22-B, OSHA added 31 recent exposure monitoring results obtained through OSHA's Information System (OIS) (Document ID 3958). These samples were taken during eleven compliance inspections conducted between 2011 and 2014 in Pennsylvania, Texas, Wisconsin and Colorado. These measurements were added to the exposure profile presented in the PEA, bringing the total number of exposure measurements to 114, from 22 different worksites.

The sampling data from the NIOSH site visits and the OIS database indicate that high exposures to respirable crystalline silica occurs at most hydraulic fracturing operations. The exposure profile in Table IV.4.22-B for respirable crystalline silica in the hydraulic fracturing (gas and oil extraction) industry includes 114 full-shift, PBZ samples. The median exposure is 111 μg/m^3, the mean is 272 μg/m^3, and the range is 6 (limit of detection (LOD))[147] to 2,570 μg/m^3. Of the 114 samples, 79 (69.3 percent) are above 50 μg/m^3, and 34 (29.8 percent) are above 250 μg/m^3.

[147] Results reported as "none detected" are assigned a value equal to the LOD. The LOD is determined individually for each sample based on the volume of air sampled and the method used to analyze the sample. Therefore, the limit of detection varies between samples. See Section IV-2–Methodology for additional information on LODs.

Respirable dust at these sites contained a relatively high percentage of silica. Among the 88 samples for which this information is available from all NIOSH site visits, more than half had greater than 41 percent silica in the sample with a range of 6 to 100 percent silica (Document ID 1541; 1542; 1543; 1544; 1545; 1546). Among the 34 OIS samples, the percent silica content averaged 33 percent with a range of 16 to 71 percent.

NIOSH site visits indicate that dust controls were either absent or that efforts to implement engineering controls were ineffective:

> NIOSH observed ineffective efforts to use engineering controls at some sites. Cotton (muslin) cloth sacks were attached to the ends of fill ports on sand movers, possibly to contain or capture dust ejected from the fill ports during bin filling. NIOSH determined the sacks to be ineffective; the bags were torn or degraded and visible dust was emitted during bin filling. Similarly, muslin bags atop thief hatch covers were not effective because dust was observed leaking from the bags during operation (Document ID 2177, Attachment B, p. 5).

Additionally, while some personal protective equipment (PPE) was being used at hydraulic fracturing locations, it was not always used properly:

> Workers at those sites used personal protective equipment (PPE) including filtering-face piece respirators, half-face elastomeric respirators, full face air-purifying respirators (APRs) with P-l00 cartridges, and combination acid gas/P-100 cartridges. However, NIOSH determined that PPE use was ineffective because most workers wearing respirators had visible facial hair that was in contact with the sealing surface of the respirator, did not understand how to properly wear or store the respirators, and did not participate in a formal respiratory protection program (Document ID 2177, Attachment B, p. 5).

The descriptions of working conditions from the NIOSH reports indicate that baseline operating conditions involve very high exposures with few engineering controls in place. From their field studies, Esswein et al. observed that dust controls for hydraulic fracturing operations are “only now emerging” given that the nature and severity of the hazard was just recently recognized by the industry (Document ID 3828, p. 355).

The American Petroleum Institute (API) asserted that OSHA's exposure profile does not adequately represent the wide range of conditions that can be encountered at hydraulic fracturing sites (Document ID 2301, pp. 3, 30-36). Similarly, the Marcellus Shale Coalition (MSC) commented (Document ID 2311, pp. 2-3) that the exposure profile provided in the PEA failed to reasonably characterize the hydraulic fracturing industry. Both API and MSC contended that other geological basins had as much or more widespread fracking than the ones sampled by NIOSH (Document ID 2310, p. 30; 2311, p. 3). However, they provided no explanation why geological basin would affect the exposure levels. API acknowledged that it does not have data to indicate that the topography differences of basins affect exposures (Document ID 3589, Tr. 4126). Additionally, Chamber of Commerce witness Dr. Knutson testified that he has seen industry exposure monitoring data from hydraulic fracturing sites other than the data in the record, and that he did not see a marked difference between this industry data and the data in OSHA's exposure profile (Document ID 3576, Tr. 500). Dr. Knutson testified that he was unable to submit this industry data to the record due to confidentiality agreements (Document ID 3576, Tr. 500).

The 114 samples of respirable crystalline silica in the final exposure profile (Table IV.4.22-B) were collected from 22 different worksites. NIOSH collected samples in diverse seasons and weather conditions, with temperatures ranging from 30º to 113º Fahrenheit (Document ID 3828, p. 350, Table 1). Elevations of the worksites ranged from 300 feet to over 5000 feet (Document ID 3828, p. 350).[148]

NIOSH visited single and multi-well site locations during single and multiple-stage well fracturing projects (Document ID 3828, p. 350). These sites included single stage "re-fracs" (rejuvenating old wells), multistage hydraulic fracturing, and "zipper-fracs" (multiple parallel wells) (Document ID 1578, p. 6).[149]

[148] The Site 5 report described "gusty wind" conditions on site, "between 5 and 7 mph" (Document ID 1545). Sites 1, 4, 5, and 6 were sampled during summer, Site 2 was sampled during winter, and Site 3 was sampled during spring (Document ID 1541; 1542; 1543; 1544; 1545; and 1546).

[149] Simultaneous or "zipper" hydraulic fracturing involves "two or more parallel wells [that] are drilled and then perforated in alternate intervals along the well bores and fractured at the perforations (Document ID 1528).

These varied environments represent a wide range of working conditions and, based on the available evidence, OSHA considers this range of exposures to be typical of the industry. Thus, OSHA has determined that the 114 samples in the exposure profile are the best available to characterize exposures in hydraulic fracturing. Most of the samples are from NIOSH reports. NIOSH stated that the sites sampled are typical of hydraulic fracturing sites across the industry (Document ID 3579, Tr. 226-28) and “included geographic, topographic, climatic, altitude, and environmental diversity” (Document ID 3828, p. 350).

API commented that OSHA improperly assumed that the NIOSH samples represented uncontrolled exposures, noting that wet methods were used on some sites due to rainfall, and enclosures were used at some sites (Document ID 2301, p. 41). OSHA does not consider natural rainfall to be an engineering control for the purpose of complying with the engineering controls provision of the standard. Additionally, NIOSH stated that rain was present only for short periods and it never interfered with sampling or completion of operations (Document ID 3828, p. 350). Regarding the use of enclosures, NIOSH stated that some fracturing sand workers operated machinery from closed and open cabs and these workers had elevated exposures even when these workers remained in cabs most of the day. Furthermore, NIOSH stated that blender trucks had enclosed cabs but none of these had High Efficiency Particulate Air (HEPA) filtration or positive pressurization (Document ID 3828, p. 354), making the cabs ineffective as silica controls.

API also criticized OSHA’s inclusion of samples from NIOSH site visit 6, which used ceramic proppant that contained less than 1 percent quartz. API argued that these samples are unrepresentative (Document ID 2301, pp. 30-31). An alternative proppant (e.g., ceramic media) is used occasionally at sites where conditions benefit from the proppant’s unique properties (e.g., strength, shape, size, uniformity) (Document ID 3828, pp. 348, 350). OSHA disagrees that including exposure results from this site is inappropriate. Eight of the 114 sample results (7 percent) came from NIOSH’s survey of this site; 93 percent of samples were collected at sites that used silica sand. According to API, silica sand accounts for 90 percent of the proppant used in the industry is silica sand

(Document ID 2301, p. 31). Therefore, OSHA does not believe that inclusion of the sample results from site 6 renders the exposure profile unrepresentative of the industry.

Halliburton commented that NIOSH did not measure exposures with accepted sampling devices, using a high-flow rate sampler that is "biased toward the collection of large, non-respirable dust particles," which would lead to exposures being overstated (Document ID 2302, p. 4). OSHA examined this issue, and in particular the BGI GK2.69 dust samplers used by NIOSH, and concludes, based on recent studies, that the sampler conformed to the international convention for particle-size selective samplers (i.e., ISO/CEN) with acceptable bias (see Section IV-3 – Feasibility of Measuring Respirable Crystalline Silica Exposures at the Final Rule's PEL and Action Level). Although this sampler is not listed among those included in NIOSH's Method 7500 for crystalline silica (Document ID 0901), NIOSH stated in its post-hearing submission that "the bias…against the ISO respirable convention…was not considered excessive" (Document ID 4233, p. 4). Therefore, OSHA concludes that the GK2.69 sampler has been adequately tested for performance against international convention, that NIOSH's use of the high-flow sampler for these field studies was appropriate, and therefore that the data generated by NIOSH should not be eliminated from the exposure profile.

API, through the National Service, Transmission, Exploration & Production Safety (STEPS) Network's Respirable Silica Focus Group, began collecting respirable silica exposure data associated with hydraulic fracturing in May 2013 (Document ID 3589, Tr. 4068-69, 4074-75; 4072, Attachments 32, 37). During the public hearings, OSHA requested additional data to reflect the industries assessment of current exposures in hydraulic fracturing, but no additional exposure monitoring data were submitted to the record (Document ID 3589, Tr. 4123-24).

Accordingly, OSHA is relying on the sampling data from NIOSH that was the basis of the preliminary exposure profile, supplemented by the more recent OIS data collected by OSHA and submitted to the record, for its final exposure profile. OSHA concludes that the exposure data available to determine baseline conditions represent a wide variety of locations and environmental conditions. OSHA considers this data to be the best available evidence to characterize exposures during hydraulic fracturing.

Exposure Profile and Baseline Conditions for Fracturing Sand Workers

Fracturing sand workers include sand mover operators, conveyor belt tenders, blender tenders, water operators, and pump truck operators (Document ID 3828, pp. 348-354). The exposure profile in Table IV.4.22-B for fracturing sand workers includes 70 samples; 51 of these samples are from the six NIOSH reports on hydraulic fracturing sites, and 19 exposure results are from the OSHA Information System (OIS) database (Document ID 1541, pp. 11-12; 1542, pp. 7-9; 1543, pp. 8-11; 1544, pp. 9-12; 1545, pp. 11-13; 1546, pp. 12-13; 3958). The median exposure is 159 μg/m^3, the mean is 373 μg/m^3, and the range is 10 μg/m^3 to 2,570 μg/m^3. Of the 70 samples, 58 (82.9 percent) exceed 50 μg/m^3, 48 (68.6 percent) exceed 100 μg/m^3, and 29 (41.4 percent) exceed 250 μg/m^3.

The worker with the highest full-shift sample result (2,570 μg/m^3) worked near sand movers while tending sand conveyor belts in hot, dry, breezy weather at a location where respirable dust samples contained 30 to 65 percent quartz (Document ID 1541, pp. 1, 4, 12). The next four highest exposures (2,000 μg/m^3, 1,950 μg/m^3, 1,100 μg/m^3, and 1,010 μg/m^3) occurred during sand moving operations (Document ID 1543, p. 8-9; 1545, p. 11). At these three sites where exposure levels exceeded 1,000 μg/m^3, the extremely high silica exposure levels were associated with worker positions immediately down-wind of points from which sand dust was released (e.g., thief hatches, conveyors, sand hoppers) (Document ID 1541, p. 5; 1543, p. 4; 1545, p. 2).

The baseline working conditions for fracturing sand workers presented in Table IV.4.22-B represent largely uncontrolled work processes using dry sands from various sources (Document ID 1541; 1542; 1543; 1544; 1545; 1546; 3958). The more recent exposure data from the OIS database provide no indication that exposure controls were used at the time these samples were collected (Document ID 3958).

Exposure Profile and Baseline Conditions for Ancillary Support Workers

Ancillary support workers operate or tend equipment, such as chemical trucks and hydration units that are at fixed locations on the perimeter or slightly removed from the central sand-handling area.[150] The exposure profile in Table IV.4.22-B for ancillary support workers includes 8 samples. Six of these samples are from the NIOSH site visits, and two are from the OIS database (Document ID 1542, p. 7 sample 2-05; 1543, pp. 8, 10, samples 3-10 and 3-21; 1544, pp. 9-10, 12, samples 4-08, 4-19, 4-26; 3958, Rows 180, 188). The median exposure is 64 μg/m^3, the mean is 195 μg/m^3, and the range is 9 μg/m^3 (LOD) to 820 μg/m^3. Of the 8 samples, 4 (50 percent) are above 50 μg/m^3, and 3 (37.5 percent) exceed 100 μg/m^3.

The highest exposure level for a worker in this job category (820 μg/m^3), obtained for a hydration worker, was more than three times the next highest level for a hydration worker (240 μg/m^3), obtained at the same worksite, but likely on a different day (Document ID 1543, pp. 8, 10). In contrast, hydration worker results were 9 μg/m^3, 26 μg/m^3, and 44 μg/m^3 at a second site where fracturing sand worker exposures reached 983 μg/m^3 (Document ID 1544, pp. 9-10, 12).

The elevated measurement suggests that the most highly exposed ancillary support worker spent more time in close contact with fracturing sand workers and their exposure sources than would normally be the case (Document ID 1543, pp. 8, 10). OSHA has concluded that unusual exposure patterns can result from workers temporarily assigned to another job duty (in this case fracturing sand worker), upset conditions, or from individual work practices, any of which could cause an ancillary support worker to spend more time than usual in the extremely dusty fracturing sand work area.[151]

Ancillary support workers typically work at fixed positions outside the central sand-handling area. Nonetheless, the primary sources of exposure for ancillary support

[150] Hydration workers employ hydration units to prepare fracking fluid.

[151] In its observations of a hydraulic fracturing site, NIOSH stated that these high exposures could be explained in part by weather conditions and equipment configurations and relative locations of workers (i.e., workers stationed in path of airborne dust) (Document ID 1543, p. 4). Additionally, NIOSH recommended limiting the number of workers, or time spent by these workers, in areas of high silica concentrations in order to reduce worker exposures (Document ID 1543, p. 6).

workers appear to be from proximity to the sand movers controlled by the fracturing sand workers (Document ID 1578, pp. 21-30). OSHA concludes that variable wind and weather conditions as reported in the NIOSH site visits (Document ID 3828, p. 350) carry airborne silica from the central work area where all of the largely uncontrolled primary sources of exposure are located. This migration of silica dust causes exposure for ancillary support workers, as demonstrated by Table IV.4.22-B (Document ID 1542, p. 4; 1543, p. 5; 1544, p. 4). Silica dust accumulated in the vehicle cabs and silica-containing sand on the ground disturbed by vehicle traffic can also contribute to ancillary support worker exposure (Document ID 1543, pp. 6-7; 1544, pp. 5-6; 3828, p. 354). The exposure profile represents ancillary support worker exposure on sites operating under poorly controlled conditions (Document ID 1542, p. 2; 1543, p. 2; 1544, p. 2).

Exposure Profile and Baseline Conditions for Remote/Intermittent Support Workers

Remote or intermittent support workers are active over a wide area of the site, primarily outside the central sand-handling area, but their work may include brief, occasional excursions into the central sand-handling area. Job descriptions include roving operator, ground guide, sand coordinator, mechanic, quality assurance (QA) technician, fueler, and wire-line crew.

The exposure profile in Table IV.4.22-B for remote/intermittent support workers includes 36 samples. Twenty-six of these samples are from six NIOSH reports (Document ID 1541, pp. 11-12; 1542, pp. 7-9; 1543, pp. 8-11; 1544, pp. 9-12; 1545, pp. 11-13; 1546, pp. 12-13), and an additional 10 samples are from the OIS database (Document ID 3958, Rows 191, 197, 877, 878, 879, 881, 901, 1080, 1081, 1082). The median exposure is 50 μg/m^3, the mean is 91 μg/m^3, and the range is 6 μg/m^3 (LOD) to 630 μg/m^3. Of the 36 samples, 17 (47.2 percent) are above 50 μg/m^3, and 8 (22.2 percent) exceed 100 μg/m^3.

The remote/intermittent support workers typically had substantially lower exposures compared to fracturing sand workers and ancillary support workers. Although these workers' exposures are intermittent, their duties take them near moving vehicles that disturb dust and into the central sand-handling area as they guide sand delivery trucks into positions near sand movers. The single sample for a QA technician was less than 25 μg/m^3, as was one of the three samples obtained for mechanics (the other two samples for mechanics were between 50 μg/m^3 and 100 μg/m^3) (Document ID 1543, pp. 8-9, 11; 1546, p. 12).[152]

This group of workers' exposure can occur due to emissions from the central sand-processing areas and also from aggregate crushed on the ground by passing heavy equipment (Document ID 3828, p. 354). Similar to the other job categories, remote/intermittent support workers mostly perform their activities without engineering controls.

Some remote/intermittent support workers, such as QA technicians who sieve sand as part of quality testing, handle silica-containing materials in a manner that could be a meaningful source of exposure if performed on a large scale. However, OSHA has no evidence suggesting that these workers experience significant exposure from the small-scale, short-term testing activities they perform at hydraulic fracturing sites.

[152] NIOSH did not document the QA technician's activities. However, it is reasonable to assume that sieving of small samples of sand was part of the worker's activities during sampling since it is one of the tasks involved with this job.

Table IV.4.22-B
Personal Respirable Crystalline Silica Exposure Range and Distribution of Results for Workers in the Gas and Oil Extraction (Hydraulic Fracturing) Industry (NAICS 211111, 211112, 213111, 213112)

	Exposure Summary			**Exposure Range**			**Exposure Profile**				
Gas and Oil Extraction (Hydraulic Fracturing) Industry	**N**	**Mean (μg/m^3)**	**Median (μg/m^3)**	**Min (μg/m^3)**	**Max (μg/m^3)**		**< 25 (μg/m^3)**	**≥ 25 and ≤ 50 (μg/m^3)**	**> 50 and ≤ 100 (μg/m^3)**	**> 100 and ≤ 250 (μg/m^3)**	**> 250 (μg/m^3)**
Fracturing Sand Workers	70	373	159	10	2,570		6 (8.6%)	6 (8.6%)	10 (14.3%)	19 (27.1%)	29 (41.4%)
Ancillary Support Workers	8	195	64	9	820		2 (25%)	2 (25%)	1 (12.5%)	1 (12.5%)	2 (25%)
Remote/Intermittent Workers	36	91	50	6	630		14 (38.9%)	5 (13.9%)	9 (25%)	5 (13.9%)	3 (8.3%)
Gas and Oil Extraction (Hydraulic Fracturing) Industry Total	**114**	**272**	**111**	**6**	**2,570**		**22 (19.3%)**	**13 (11.4%)**	**20 (17.5%)**	**25 (21.9%)**	**34 (29.8%)**

Notes: All samples summarized are personal breathing zone (PBZ) results representing 8-hour time-weighted average exposures.
Job categories are intended to represent job functions; actual job titles might differ, and responsibilities might be allocated differently, depending on the facility.
Percentages may not add to 100 percent due to rounding.

Sources: Document ID 1720; 3958; 1541; 1542; 1543; 1544; 1545; 1546.

4.22.3 Additional Controls

The exposure profile in Table IV.4.22-B shows that 69 percent (79 out of 114 samples) of workers sampled in the hydraulic fracturing industry have exposures above the final PEL of 50 μg/m^3. Therefore, OSHA finds that additional controls will be necessary to achieve the PEL for these overexposed workers. The workers with the highest baseline exposure are fracturing sand workers: Eighty-three percent (58 out of 70) of fracturing sand workers are currently exposed to 8-hour TWA levels above 50 μg/m^3, while 48 percent (21 out of 44) of the ancillary support workers and remote/intermittent workers are currently exposed at levels above 50 μg/m^3.

To limit workers' exposure to silica, emissions need to be eliminated or reduced from each source of dust emissions identified by NIOSH and described in Table IV.4.22-A. Fracturing sand workers will benefit the most from such a control strategy, because they operate in closer proximity to sources that are producing elevated exposures, especially exposures from thief hatches, blender hoppers, and conveyor and transfer belts. Addressing these sources will benefit all of the workers present at a site (Document ID 1541; 1542; 1543; 1544; 1545; 1546).

OSHA has determined that effective control methods include local exhaust ventilation (LEV) systems, enclosure and partial enclosure of material transfer points and conveyors, enhanced material transfer systems, use of dust suppressants, and use of control booths, along with improved work practices and administrative controls. In some situations, substitution of silica sand with ceramic proppant may also be feasible. Kenny Jordan of the Association of Energy Service Companies (AESC) testified that the controls he has observed include baghouses, augur movement of the sand in closed-loop systems, misting systems, and clean-up systems (Document ID 3589, Tr. 4101-4103). An individual site or company may need to choose one or more of the potential controls to adequately control all potential sources of exposure.

Local Exhaust Ventilation (LEV)

In general terms, LEV is highly effective when designed to capture dust at the release point and with sufficient suction (pressure and volume) to overcome competing forces, such as turbulence, leakage, other sources of air flow, and dust particles in motion. Captured air released in the work area needs to be treated with an appropriate air-cleaning device to prevent respirable particles from recirculating back into workers' breathing zones (Document ID 3883). LEV with a tight-fitting or partial enclosure is a control option for all the major sources of dust released from sand-handling equipment in hydraulic fracturing work zones (Document ID 1530, p. 3; 1537, pp. 9-10; 1570, pp. 8-10; 4072, Attachment 36, p. 9). Dr. Knutson of Knutson Ventilation, testifying on behalf of the Chamber, stated that he is currently exploring controls for clients in the hydraulic fracturing industry, including "looking at local exhaust ventilation as a major tool" in controlling respirable silica (Document ID 3576, Tr. 545).

As discussed below, the record contains several examples of effective dust control in hydraulic fracturing through ventilation systems. The record shows that adoption of this technology is already well underway in the industry, in large part because it is needed to come into compliance with the preceding PEL. In many cases its adoption will also result in compliance with the new PEL, but even where it does not, relatively minor adjustments or add-on controls will be needed to achieve that compliance.

KSW Environmental LEV Systems

This control is a powered LEV system built for the purpose of controlling dust emissions from the transfer of fracturing sand (Document ID 1570, p. 5). Specifically, the ventilation system controls airborne dust generated on top of the sand mover (thief hatches), transfer points between sand mover and t-belt (conveyor belt between sand mover and hopper), and transfer from the t-belt to the hopper (Document ID 1570, pp. 8-10). This control is commercially available now, and the manufacturer specifies that its LEV systems have been used at hundreds of worksites since 2009 (Document ID 1570, p. 5).[153]

[153] In the PEA, this control was cited as "FracSandDC, 2012". In 2012, KSW Environmental acquired the exclusive license to the Frac Sand Dust Control, LLC systems and technology, along with the business and name. Dupre Energy Services is the parent company of KSW Environmental (Document ID 1570, p. 6).

KSW Environmental has performed PBZ sampling for fracturing sand workers to evaluate the effectiveness of its LEV systems (Document ID 1530, p. 11).[154] Samples were collected on two days for workers operating the blender/hopper, t-belt, and dust control (located on top of the sand movers) (Document ID 1570, p. 14).

Although the record does not include the individual exposure results, the manufacturer reported that none of the six samples exceeded 50 μg/m^3 as an 8-hour TWA (Document ID 1570, p. 22). The manufacturer also shows images comparing the difference in dust generation when the controls were reportedly turned off and then on (Document ID 1570, p. 7). The images clearly show that visible airborne dust has been greatly reduced when the LEV system was used. In a June 19, 2014 presentation to STEPS, KSW Environmental reported that its LEV system reduced silica exposures, with all 12 samples below 50 μg/m^3 (Document ID 4204, Attachment 1, p. 35, Fn. 21; 4222, Attachment 2, p. 6).[155]

The KSW Environmental presentation also reported that four additional customer tests resulting in 76 PBZ samples showed that all worker exposures to silica were below 100 μg/m^3; these results were only reported as "yes" or "no" responses, and no individual PBZ values were reported. KSW Environmental reported that there were an additional 50 PBZ samples taken. Although the individual sample results were not provided to KSW Environmental, the manufacturer reported that, as a result of these tests, customers began selecting KSW Environmental as the preferred vendor for dust control. KSW Environmental explained that its technology now operates all around the United States including Pennsylvania, West Virginia, Ohio, Colorado, Wyoming, Oklahoma, and Texas. KSW Environmental stated that its goal is to reduce exposures to 25 μg/m^3 or less by enhancing the existing system, training customers and improving work practices, and

[154] These samples were collected using NIOSH method 7500 (Document ID 1570, p. 20).

[155] In their post-hearing briefs, both AFL-CIO and API referenced and provided the hyperlink to KSW Environmental's June 19, 2014 presentation to the Silica Focus Group: http://www.nationalstepsnetwork.org/docs_respirable_silica/june_19_2014/KSWE-STEPS-Meeting-6-19-14-REV-A.pdf (Document ID 4204, Attachment 1, p. 35, Fn. 21; 4222, Attachment 2, p. 6). OSHA therefore considers this publically-available presentation part of the record.

developing supplemental controls (Document ID 4204, p. 35, Fn. 21, pp. 3-4 of slide presentation).

The exhaust ventilation system manufactured by KSW Environmental is capable of achieving 45,000 cfm, with temporary or permanent shrouding at the blender/hopper (Document ID 4204, p. 35, Fn. 21; 4222, Attachment 2, p. 6, n. 21). KSW Environmental also addressed some work practices that may reduce exposures. Some of these included fixing damaged truck hoses (material transfer) and avoiding leaning over or standing in the hopper, leaning over the conveyor belt, leaning into hatches to view sand levels, and overfilling sand movers (Document ID 4204, p. 35, Fn. 21, pp. 11-15 of slide presentation).

OSHA received comments from industry questioning the effectiveness of the KSW Environmental ventilation system. API commented that there is limited air monitoring data demonstrating the effectiveness of the KSW Environmental system (Document ID 2301, p. 49; 4222, Attachment 2, pp. 6-7). API noted that at the June 19, 2014, STEPS Respirable Silica Focus Group meeting, KSW Environmental reported that 12 samples of respirable crystalline silica were below 25 $\mu g/m^3$, but that no information was provided regarding job category, sampling conditions, duration, sampling methods, or type of proppant used (Document ID 4222, Attachment 2, p. 7).

OSHA concludes that there is adequate information on the exposure samples taken by KSW Environmental to judge the results as credible. In a submission to the record, KSW Environmental reported that samples were collected for workers located near blender/hopper, t-belt, and thief hatches (referred to as “dust control operator,” “blender operator,” and “crow’s nest or T-belt operator”) (Document ID 1570, p. 14), which are among the major sources of dust emissions. KSW Environmental reported that sampling was conducted on two consecutive days with temperatures ranging from 37 to 74 degrees Fahrenheit, humidity ranging from 40 to 93 percent, and with variable wind directions and speed (Document ID 1570, p. 13). KSW Environmental also reported that these samples were collected using NIOSH method 7500 (Document ID 1570, p. 20). The samples were collected at a site in West Virginia located along a ridge extending into a valley, at an elevation of 1,180 feet (Document ID 1570, p. 11).

API commented that members that have used the KSW Environmental ventilation system have reported significant durability and workability concerns (Document ID 4222, Attachment 2, pp. 7-8). API listed three main concerns: the plastic sheeting is susceptible to damage and often must be removed purposely to view or access the emission points; the vacuum hoses that connect the emission points to the ventilation system must cross high traffic areas and areas accessed by sand delivery trucks, leading to hose damage that can adversely impact the efficacy of the control; and the presence of vacuum hoses and connections on top of the sand mover has resulted in more workers operating the equipment's ground level controls more frequently in a semi-enclosed environment, and this exposure has not been characterized (Document ID 4222, pp. 6-7).

API did not explain why the presence of vacuum hoses would cause workers to alter their work practices so that the workers have to operate controls for the sand movers on ground level (presumably as opposed to controls on top of the sand movers). API also did not explain why, when all sources of exposure are properly controlled, workers are overexposed at ground level more than when located on top of sand movers.

In contrast, KSW Environmental presented detailed photographs and illustrations of the ventilation system setup at a fracturing site in West Virginia (Document ID 1570, pp. 8-10, 15-19). OSHA's review of these photos and illustrations reveals none of the concerns expressed by API (Document ID 1570, pp. 8-10, 15-19). OSHA concludes that ventilation hoses can be attached to thief hatch openings such that they do not prevent workers from operating on top of the sand mover (Document ID 1570, pp. 8-10, 15-19). Additionally, OSHA believes that hoses can be placed such that they are not damaged by (nor do they interfere with) vehicular traffic (Document ID 1570, pp. 8-10, 15-19). API's concern about plastic sheeting can also be addressed by purchasing thicker or reinforced plastic that is more appropriate for the hydraulic fracturing environment. As this industry is a very technologically advanced sector, OSHA is confident that material design for partial enclosures and placement of vacuum hoses will improve and overcome these practical concerns.

API also questioned the availability of the KSW Environmental system. While noting that the system “has shown tremendous growth in the two years since it first presented it[s] services to [the] STEPS Respirable Silica Focus Group,” API stated that the system cannot currently service all of the hydraulic fracturing industry (Document ID 4222, Attachment 2, p. 8).

OSHA understands API’s comment regarding this particular manufacturer’s ability to service the hydraulic fracturing industry at this time to be a suggestion that the industry will need additional time to adopt this new technology. The Agency believes that, given time, the availability of this and other dust control systems will grow and present viable options for hydraulic fracturing companies. Consequently, the final rule provides an additional three years (five years total) for hydraulic fracturing operations to comply with the final rule’s PEL using engineering and work practice controls. As discussed elsewhere in this chapter, OSHA recognizes that most of this time will be needed for the industry to come into substantial compliance with the preceding PEL of 100 μg/m^3. However, once exposures are reduced to 100 μg/m^3, relatively minor additional steps will be needed to bring them to 50 μg/m^3 or below (e.g., Document ID 1570, p. 22).

After reviewing all of the information provided by the manufacturer and the industry and worker stakeholders and considering all of the arguments, OSHA has determined that this control, or a similar ventilation system, can substantially reduce exposures to respirable crystalline silica generated at thief hatches, hoppers, and t-belts. This conclusion is based on KSW Environmental PBZ sampling tests, which reported all 12 samples below 50 μg/m^3, and four customer reports of 76 samples below the previous PEL of 100 μg/m^3 (Document ID 1570, p. 14, 22; 4204, p. 35, Fn. 21; 4222, p. 7).

J&J Truck Bodies and Trailers Ventilation System

Another ventilation control documented in the record is a central dust collection manifold built into movers with filtration that controls dust from t-belt conveyors, trailer manways, and blenders (Document ID 4072, Attachment 36, p. 9; 1530, p. 3; 1537, p. 9). This system is similar to the KSW Environmental system described above and draws air from the sand mover to control dust released while sand trucks pneumatically fill the sand mover (Document ID 1530, pp. 3-5; 1537, p. 9). The manufacturer, J&J, specified that the system features a 45,000 cfm vacuum and filter system, dust collection manifold, and all necessary accessories (Document ID 1537, p. 9; 4072, Attachment 36, p. 9).

The manufacturer reports that 2011 test results on two prototypes suggest substantial reductions in airborne dust (Document ID 1530, p. 5). In these tests, the manufacturer reports that there was significantly less airborne dust during the loading of proppant onto the sand mover when the dust control system was used. This dust control system was used at 10 different hydraulic fracturing sites with reportedly good results (Document ID 1530, p. 5). No exposure data was submitted as part of this exhibit. Commercially available versions of these systems are described in the record (Document ID 4072, Attachment 36).

The manufacturer specifies that the cost of sand movers with integrated dust controls is comparable to other sanders available on the market. Additionally, the manufacturer specifies that the sand movers have the same functional capabilities with or without the control systems (Document ID 4072, Attachment 36, p. 10).

OSHA was not able to obtain additional information regarding exposure levels associated with this control. However, both commercially available systems (J&J and KSW Environmental) control generated airborne dust at the sand mover, t-belts, and hoppers using a 45,000 cfm ventilation capacity. These two systems control the same emission sources and have the same capacity and thus, OSHA expects the J&J system to be equally as effective as the KSW Environmental system in controlling dust from these sources.

DCS Quad Dust Collector

National Oilwell Varco (NOV) has developed a commercially available powered LEV system that can be installed as an add-on retrofit option for sand movers. The unit uses power from the sand mover and operates at a speed of 3,200 cfm (Document ID 1532; 1537, pp. 9-10). This system controls only the source(s) associated with the sand mover while the KSW and J&J Truck body systems uses 45,000 cfm to address other sources of exposure along the sand moving line to the blender hopper. NOV reports that the dust collection system minimizes dust during pneumatic filling of sand movers (Document ID 1537, pp. 9-10). No exposure data is available in the record regarding the effectiveness of this design, so OSHA cannot determine whether it would reduce exposure levels to at or below the PEL.

NIOSH Baghouse Technology

NIOSH has designed and tested a baghouse passive dust collection system that fits over individual thief hatches on sand movers and deposits collected sand back into the sand mover (Document ID 1537, p. 5; 1538, p. 2; 1546, p. 10).[156] NIOSH recommends that "baghouse material should be selected to control respirable particulates in the size range of 3-5 microns" (Document ID 1546, p. 10). NIOSH designed the bag-house to be self-cleaning, as the captured dust falls back onto the sand container as the bag-house collapses when positive air pressure is stopped after bins are full.

NIOSH reports that the design appears to be an effective point source control and will likely be commercially available in the future pending a patent (Document ID 1537, p. 5; 1538, p. 3).[157] NIOSH stated that the design has been evaluated for proof of concept and has also been evaluated in a field test with an industry partner (Document ID 3998, Attachment 1, pp. 3-4). NIOSH stated in its post-hearing submission to the record that it has made a presentation to the STEPS group regarding the development of the bag-house (Document ID 4233, p. 13).

[156] Baghouse dust collectors capture the particulate in an airstream by forcing the airflow through filter bags. A baghouse works by taking the inlet dustladendust-laden air and initially reducing the velocity to drop out larger particles, then filtering the remainder of the particles by passing the air through a fabric bag. Separation occurs by the particles colliding and attaching to the filter fabric and subsequently building upon themselves, creating a dust cake. Since the dust has been deposited on the outside of the bag, when the dust cake is removed from the bag or cleaned, it falls by gravity into the collection hopper located below the bag section. Collected dust is then removed from the collector through a hopper valve (Document ID 1540, p. 31). NIOSH has described the design considerations for baghouse dust collectors used in mining operations, a field that has dynamic working conditions and highly variable dust sources (much like hydraulic fracturing sites) (Document ID 1540, p. 31).

[157] NIOSH did not provide additional information regarding the exact timeline for commercial availability of this design (Document ID 3998, Attachment 1, p. 4)

API commended NIOSH for its research and development related to the baghouse technology, but questioned the availability and effectiveness of the NIOSH mini-baghouse (Document ID 4222, Attachment 2, p. 5). API commented that the NIOSH mini-baghouse does not support OSHA's conclusions of the technological feasibility of controlling access hatch emissions with LEV, pointing to an April 24, 2014, notice of license availability indicating that the NIOSH baghouse system remains a prototype that has not yet been fully tested and is not commercially available (Document ID 4222, Attachment 2, p. 5). Similarly, the Chamber and Dr. Knutson noted that there is no information on the effectiveness of the NIOSH baghouse technology or the time it will take to implement (Document ID 2264, pp. 29-30; 4224, Attachment 1, p. 10).

OSHA recognizes that this baghouse design is not yet commercially available and that the record does not include PBZ exposure data associated with this control. However, NIOSH has completed the essential steps of the design stage by considering the size distribution of particles (i.e., particles in the respirable dust range) captured by the baghouse and by performing proof-of-concept evaluations (Document ID 1537, p. 5; 1546, p. 10). Also, as NIOSH pointed out, the design should capture particles in the respirable range, ensuring effective control (Document ID 1546, p. 10). OSHA expects this design to capture these smallest particles in the respirable range, and believes that exposures from thief hatches can be almost completely eliminated with a properly-functioning, dust capturing device. Moreover, baghouse dust collection devices, such as the one designed by NIOSH for hydraulic fracturing, are already used in the mining industry to successfully control the high levels of silica dust generated due to dynamic working conditions (Document ID 1540, p. 31). These baghouses typically are able to contain almost all of the fugitive mine dust, including respirable dust, achieving air cleaning efficiencies of up to 99.97 percent (Document ID 1540, p. 31). Given these encouraging developments, OSHA expects that NIOSH and the hydraulic fracturing industry will continue working together to further develop and test this technology.

Dr. Knutson raised several issues associated with the NIOSH baghouse designed to collect fugitive dust from thief hatches (Document ID 2264, pp. 29-30). He argued that the baghouse had no cleaning mechanism to dislodge the dust from the contaminated side of the filter (i.e., the filter cake), and as a result the baghouse would need to be large. However, NIOSH designed the baghouse to be self-cleaning (Document ID 1537, p. 5; 1546, p. 10). Dr. Knutson argued that if new filter media is used, the efficiency of the baghouses would be low and exposures will be “similar to the current situation” until the media is “seasoned” (Document ID 2264, p. 30). OSHA recognizes that the bag filters become more efficient as dust is collected to form a cake on the inside of the bag, but this does not mean that new filter media will be ineffective given that the filter media selected is designed to capture particles in the low end of the respirable range. OSHA believes that, as NIOSH continues its testing, both new and seasoned media will be used, which will permit an assessment of the impact, if any, of using new filter media. Dr. Knutson also argued that covering thief hatches with the baghouses would increase pressure inside the sand movers and therefore increase emissions of silica dust through all other openings or cracks in the sand mover (Document ID 2264, p. 30). OSHA does not dispute that increased pressure within the sand mover could increase dust emissions through other openings, but concludes that such emissions can be addressed through work practices (e.g., ensuring that unused ports are capped and that equipment is diligently maintained).

Dr. Knutson further suggested that additional silica exposures would occur as a result of installing and removing the baghouses from the thief hatches (Document ID 2264, p. 30). In its design, NIOSH describes that the baghouses include a transition flange that is fitted over the thief hatch opening, and this flange then connects the hatch opening to the baghouse (Document ID 1537, p. 5). OSHA understands that this transition flange can serve to reduce or eliminate emissions when the baghouse is disconnected from the thief hatch as the flange would seal the bag opening once it is disconnected. Changing baghouse filters in any application is a maintenance task that typically requires the use of respiratory protection. Accordingly, OSHA disagrees that an additional hazard will be created by installing or removing the baghouse.

Finally, Dr. Knutson stated that the media on the sample ports must be removed to obtain the samples (Document ID 2264, p. 30). OSHA expects that work practices allow workers to take sand samples at times other than during the pneumatic or mechanical filling of sand movers since to do otherwise would clearly result in a high-exposure event.

Based on the information presented here (i.e., collection of silica particles in the respirable range, initial field tests, and success of design in other industries), OSHA concludes that the bag-house technology, or a similar dust collection device, will foreseeably prove effective in reducing exposures of workers to RCS resulting from dust emissions from thief hatches. The Agency acknowledges that further testing is necessary to evaluate the impact on worker exposures from this technology and believes that providing additional time to phase in the final rule's engineering requirement, as discussed further below, is appropriate to allow the technology to be further developed.

Material Transfer Systems

The record contains information on a containment system developed by SandBox Logistics, LLC that replaces the pneumatic loading process with a containerized process, eliminating most of the dust emission points that currently exist (Document ID 3589, Tr. 4140-4141; 3554).

The SandBox process begins when sand is loaded into the sandbox storage unit at the sand mine. The storage unit has dimensions of eight feet by ten feet and weighs approximately 53,250 pounds when filled with fracturing sand (Document ID 3589, Tr. 4141). From this point, the sand is kept totally contained throughout the rest of the supply chain. The storage unit is put on a chassis designed specifically for it and then transferred to the worksite. At the worksite, the storage unit is put on a conveying system (also known as a cradle) where the sand is gravity fed onto a conveyor belt, which feeds the sand directly into the blender hopper (Documents ID 3554, pp. 9-11).

According to the manufacturer (SandBox Logistics), most of the silica dust producing steps in the process have been eliminated (Document ID 3589, Tr. 4140-4142). The company states that the delivery system eliminates the need for sand movers and pneumatic deliveries, which are the primary sources of dust emissions (Document ID 3554, pp. 14-15). Because of this, exposures from fill ports and transfer belts under the sand mover would be eliminated (Document ID 3554, p. 15). The company states that the belt design on the cradle generates fewer airborne particles, reducing exposures from the top end of the transfer (or t-) belt and material transfer that would occur between the sand mover and blender hopper (Document ID 3554, p. 15). The company also states that the SandBox process reduces silica dust, avoids demurrage charges for idled rail and truck, and reduces proppant degradation (Document ID 3554, p. 17).

SandBox Logistics submitted a summary of an initial industrial hygiene study that collected PBZ and area samples during the delivery of proppant to the well-head using the company's delivery system (Document ID 4020). The study collected PBZ samples for transfer-belt workers (number not specified) and found a geometric mean exposure of 87 μg/m^3 (Documents ID 4020, Attachment 1, p. 4), compared to 327 μg/m^3 for conveyor belt operators (transfer-belt operators) as reported by Esswein (Document ID 3828, p. 351) from the NIOSH surveys of fracking operations. This represents a 73-percent reduction in geometric mean exposure when compared to NIOSH's data, and the company reported a 65-percent reduction in the number of samples that exceeded 100 μg/m^3 (Document ID 4020, Attachment 1, p. 4).

API and the Chamber argued that exposures under the Sandbox Logistics technology remained above 50 μg/m^3, which is the final PEL (Document ID 4222, Attachment 2, pp. 8-9; 4224, pp. 9-10), and API argued that the exposures of the t-belt operators at the sandbox facility were 327 μg/m^3 (Document ID 4222, Attachment 2, p. 9). However, OSHA believes API misread the reported data: SandBox Logistics' submission stated that the exposure of 327 μg/m^3 represented baseline, uncontrolled conditions as reported by Esswein et al. (2013) (Document ID 4020, Attachment 1, p. 4, Fn). As stated above, the controlled exposure using the SandBox system was a mean exposure of 87 μg/m^3 (Documents ID 4020, Attachment 1, p. 4).

Although the sampling data from SandBox Logistics showed a geometric mean exposure above 50 μg/m^3, the data still demonstrate a significant decrease in exposures for t-belt workers operating the system. Additionally, SandBox Logistics reported that its engineers expect exposures can be further reduced with just a few minor modifications (Document ID 4020). Moreover, this method reduces the number of exposure sources by eliminating the need for sand movers, which should make it an important, effective, and viable part of an overall exposure control strategy.

Enclosures

Process enclosure can reduce emissions of dust from the major sources of emissions under positive pressure (e.g., fill ports and unused thief hatches on sand movers) and areas of turbulence (e.g., conveyors and sand drop points from the ends of conveyors) (Document ID 1541, pp. 5-6). There are several types of enclosures that can effectively reduce exposures on hydraulic fracturing sites.

Caps on Fill Ports

NIOSH reported based on its field studies that the fill ports on the sides of the sand movers can be a primary source of silica exposure for all fracturing sand workers in the area during the periods when the sand movers are refilled by the sand delivery truck drivers (Document ID 1541, pp. 5-6). Sand delivery trucks connect pneumatic sand transport hoses to the ports to add sand to the sand movers. The ports are designed for filling the sand mover and not as relief valves for dusty air (that is generated during pneumatic sand transport from the delivery truck) to escape the sand mover. When left uncapped during filling, dusty air vents out through any unused fill ports (particularly those on the opposite side of the sand mover) (Document ID 1541, p. 5).

One component of silica risk management at hydraulic fracturing sites involves preventing silica release from those fill ports that are not in use. During its field surveys, NIOSH found that ports on the sides of sand movers were often left open (Document ID 1538, p. 3). Fill ports are not intended for pressure relief and should be closed with manufacturer-provided or replacement end caps, as recommended by NIOSH in its field studies (Document ID 1541, p. 6; 1543, pp. 6-7; 1544, p. 7-8; 1546, p. 11). OSHA expects that tight closure with a cap will prevent silica emissions from this source because little or no dusty air would exit through these ports, and would thus greatly reduce emissions from fill ports. In a post-hearing submission by API, the STEPS network identified capping unused fill ports as one of several “quick fix” suggestions to reduce silica exposures among hydraulic fracturing workers. Fugitive emissions from fill ports contribute to higher exposures to workers at the site, especially fracturing sand workers who are the closest to the sand movers (Document ID 3828, p. 355). Thus, OSHA expects that controlling emissions from this source will contribute to reducing exposure of fracturing sand workers and others who are affected by the fugitive dust released from uncapped fill ports.

Partial Enclosures on Conveyors and Transfer Points

Exposure reduction can be achieved by partially enclosing conveyors, particularly conveyor drop points. For the mining industry, NIOSH advocates reducing drop points (Document ID 1540, p. 144), and for hydraulic fracturing sites, NIOSH recommended shrouding or skirting along the sides of the sand mover and at the end of the sand belt to limit dust released as material falls from the belt (Document ID 1541, p. 6; 1542, p. 5; 1543, p. 5; 1544, p. 6; 1545, p. 9; 1546, p. 10). The STEPS network also recommended as a “quick fix” minimizing sand fall distances during transfer operations as a way to reduce respirable crystalline silica emissions (Document ID 4024, Attachment 2). Noting NIOSH’s recommendation, Dr. Knutson acknowledged that shrouding and skirting could be beneficial (Document ID 2264, p. 26). Additionally, as presented in the discussion for LEV, one company (KSW Environmental) already provides LEV with temporary or permanent shrouding at the hopper (a transfer point) (Document ID 4204, p. 35, Fn. 21). According to ACGIH, ventilated conveyors require extra ventilation when the fall distance is three feet or greater (Document ID 3883, pp. 13-80, 13-83).

Dr. Knutson commented that there are several difficulties in using enclosures in hydraulic fracturing operations. He argued that (1) sand equipment is mobile and there are weight and size restrictions on the equipment, (2) sand transfer operations require visual inspection to ensure that sand is being conveyed correctly, (3) enclosures restrict access for maintenance, and (4) enclosures complicate spill cleaning, which could increase exposures (Document ID 2264, pp. 25-26). As pointed out by API (Document ID 2301, p. 52), Eric Esswein of NIOSH agreed that conveyors cannot be completely closed (Document ID 1538, p. 3). However, he also reported that companies would consider enclosing the conveyor under the sand movers and that walls along the sides of the conveyor could be made deeper to effectively enclose the conveyor (Document ID 1538,

p. 3). The NIOSH field study reports also suggested that the conveyor under the sand mover be replaced with a screw auger to contain dust (Document ID 1543, p. 6; 1544, p. 7; 1545, p. 9; 1546, p. 10).

OSHA finds that using partial enclosures with LEV on conveyor, transfer, and drop points would reduce exposures to all workers, especially fracturing sand workers, who operate in proximity to these sources.

Operator Booths

Providing climate-controlled booths for fracturing sand workers is another practical option for protecting workers who must work in particularly harsh environments. Some of the most highly exposed workers will benefit from operator enclosures (clean air booths) placed at or near the sand mover and conveyor belt operator work stations where workers can observe operations while breathing filtered air.

NIOSH analyzed the elements of effective control booths and cabs, reporting that the level of dust protection depends on the adequacy of the following factors: enclosure integrity (well-sealed); filtration (sufficiently efficient to keep out respirable particles); pressurization (positive pressure inside to keep dusty outside air from leaking in); work practices to keep doors and windows closed; climate control (so doors and windows can be kept closed); housekeeping in the enclosure (remove any dust that gets inside); and maintenance (including changing outside air filters as necessary) (Document ID 1540, pp. 196, 225, 231, 235).

A table summarizing NIOSH studies on personnel enclosures (cabs) associated with mining equipment (routinely used with massive quantities of dusty, silica-containing mineral materials) shows that cabs can reduce respirable dust exposures from 50 to 99.9 percent; efficiencies less than 90 percent were attributed to insufficient pressurization of the cab (Document ID 1540, p. 227).

API commented that the evidence on which OSHA relied to claim in the PEA that control booths can be 90-percent effective in reducing exposures is deficient because the evidence was taken from other industries with less dusty operations and does not account for the opening and closing of control booths nor the dust brought into the booth by the worker's "grossly contaminated" clothes (Document ID 2301, p. 59). Specifically, OSHA pointed to the NIOSH mining handbook, which describes the use and effectiveness of control booths in a variety of mining dust concentrations and conditions, and an inspection at a structural clay facility where a booth was used (Document ID 1720, p. A-41). OSHA disagrees that its evidence base was inappropriate in the manner described by API because OSHA's evaluation of the potential effectiveness of filtered booths at fracking sites did not assume that there would be no other controls or that conditions on the site would continue to be extremely dusty. In fact, OSHA stated in the PEA that its estimate of effectiveness for filtered booths assumed that side ports would be closed and LEV applied to thief hatches (Document ID 1720, p. A-40), thus reducing silica concentrations outside the booth and increasing its effectiveness.

Dr. Knutson was also critical of OSHA's calculation of the effect on exposures of using filtered booths, citing what he believed to be a faulty premise that workers are exposed to a constant concentration of silica over a shift, when in fact their exposures fluctuate depending on what tasks are being performed. He argued by way of example that if one accounts for task-specific changes in exposure throughout the shift, the actual reduction in exposure achieved is less than estimated by OSHA (Document ID 2264, pp. 30-31). OSHA did not make its estimate based on a premise that exposure is constant over the shift, but instead relied on full-shift TWA exposure measurements. Detailed task-specific exposure data was not available in the record. Use of TWA data did not affect how OSHA views the effectiveness of filtered booths in reducing exposure, nor its preliminary feasibility findings. In the hypothetical example given by Dr. Knutson, he assumed that the silica concentration in areas away from the booth was higher than in the vicinity of the booth, while OSHA's approach, based on 8-hour TWA exposure data, would assume concentrations are equal in different areas., Dr. Knutson's approach yielded an exposure estimate for a worker using a booth for part of a shift that was 23 percent higher (62 $\mu g/m^3$ vs. 47.8 $\mu g/m^3$) than would be the case assuming constant exposure throughout the shift, a difference that OSHA believes would not have materially changed its preliminary feasibility findings.

API contends that workers cannot spend an entire shift in a control booth (Document ID 2301, p. 58), and OSHA agrees that some work outside the booth may be needed. However, the amount of time outside the control booth can be minimized by integrating control panels into to the booth that would reduce the need to exit the control booth to monitor equipment performance. API's members believe that workers who may benefit from control booths would be required to spend much of their shift outside the booth, although API did not provide a rationale for this statement other than the workers' responsibility to monitor and control equipment. While control booths may be able to integrate control panels for equipment, such that workers can monitor and operate equipment from inside the booth, API has said that placing controls inside enclosed booths would be difficult and costly (Document ID 2301, p. 58). OSHA does not believe that it is infeasible to do so, however, as such control booths already exist in other high-silica industries such as mining (Document ID 1540, p. 225).

API further questioned the feasibility of these operator control booths, stating that its member companies report that dust control booths cannot feasibly be added to retrofit hydraulic fracturing equipment, particularly sand movers and conveyor belts (Document ID 2301, p. 60). Additionally, API contended that adding control booths could push many sand mover transporters over weight thresholds established by equipment transportation suppliers (thus increasing the cost of moving the equipment from one site to another) , and therefore, the booths must be capable of being removed, shipped separately, and reinstalled between each hydraulic fracturing site (Document ID 2301, p. 60).

API did not submit any specific evidence or explanation showing why booths cannot be added to retrofit hydraulic fracturing equipment or that portable control booths are not a feasible option to reduce exposures to dust. Regarding weight limitations, OSHA notes that bulldozers, cranes, and other very large heavy equipment fitted with enclosed cabs are frequently moved. If earthmoving and mining equipment with enclosed cabs can be transported over the road, then so can sand movers.

OSHA has determined that there are several types of operator enclosures that could be used to reduce exposures on hydraulic fracturing worksites. Environmental cabs on trucks and heavy equipment represent one form of mobile control booth. Portable control booths positioned on pallets or a truck bed are also an option. Worker enclosures, including operator control booths and heavy equipment cabs, are used successfully in operations in other industries that deal with large quantities of silica-containing materials. These include the Mining Industry (Document ID 1540, pp. 225-238), Concrete Products Industry (Section IV-4.3), Foundries (Section IV-4.8), Structural Clay Industry (Section IV-4.21), and Rock-Crushing Machines Operators and Tenders (Section IV-5.10). OSHA notes that the STEPS network also recommended using enclosed cabs or booths as a "quick fix" to reduce silica exposures (Document ID 4024, Attachment 2).

OSHA concludes that similar operator booths can be practical and effective controls for the hydraulic fracturing industry. Recognizing that the exposure-reduction potential of an operator enclosure or booth is related to both the efficiency of the booth in excluding dust and the amount of time the worker spends in the booth, OSHA expects that these booths will significantly reduce exposures to the more highly exposed fracturing sand workers controlling material transfer and delivery (e.g., sand mover operator, conveyor belt tender, blender tender).

<u>*Dust Suppressants*</u>

In this section, OSHA reviews the capabilities of dust suppressants to reduce exposures from dust created due to transfer of the proppant and from dust re-suspended in the air from general traffic at the worksite.

Dust Suppressants for Proppants

The record contains information about treating proppants with liquid dust suppressants to reduce respirable crystalline silica levels. The American Refining Group (ARG), a company specializing in refining, reported to the STEPS Respirable Silica Focus Group about a laboratory study that demonstrated the advantages of using a liquid dust suppressant in hydraulic fracturing operations (Document ID 4072, Attachment 35, pp. 9-10). API explained that the dust suppressant tested was a hydrofinished waxy oil that consists primarily of saturated hydrocarbons that works by binding smaller particles that may otherwise be released during moving, loading, dumping, and agitating the proppant

(Document ID 4222, Attachment 2, pp. 5-6). ARG stated that the EPA approved this material as an inert ingredient for pesticide use, and according to API HPV Testing Group data, the dust suppressant presents no acute or chronic toxic effects to humans (Document ID 4072, Attachment 35, p. 5). ARG concluded that the dust suppressants:

- offer a 99.8-percent reduction in respirable silica;
- reduce exposures during material transfer;
- add lubricity to treated sand thereby reducing friction and shearing; and
- reduce the need for larger exhaust rates on ventilation systems.

ARG also stated that it was looking for partners to perform field trials by measuring short and long-term performance (Document ID 4072, p. 11).

API commented that while the laboratory study indicated that the dust suppressant may be effective in reducing exposures, field tests have not yet been conducted (Document ID 4222, Attachment 2, pp. 5-6). Additionally, API expressed concern that adding this dust suppressant to the mixture may compromise the integrity of the operation, stating that directly wetting or chemically amending proppant material prior to introduction to the blender can cause serious binding issues and cause a fracture to fail (Document ID 4222, Attachment 2, pp. 5-6). API contended that without evidence that the suppressant will not impact fracture performance, it cannot be considered a feasible control (Document ID 4222, Attachment 2, pp. 5-6).

OSHA recognizes that this particular agent is still in development and must be field tested to evaluate its effectiveness on reducing worker exposures and its effect, if any, on proppant performance. Nevertheless, it appears to be a promising technology that could serve to reduce silica-containing dust emissions.

Another approach to suppressing dust is use of water misting, which has been suggested by NIOSH to be effective if misting nozzles are placed in the proper location and fine-spray, atomizing nozzles are used (Document ID 1546, p. 10). As a general principle, atomized water sprays will not exceed a 0.1-percent moisture application rate, though over large areas the application rate may be as high as 1.5 percent (Document ID 1540, p.

61). Mr. Esswein commented that one company working with NIOSH “had some success” with misters that knocked dust out of the air without wetting the sand (Document ID 1538, p. 3). Kenny Jordan of AESC testified that misting systems are among the dust controls currently in use (Document ID 3589, Tr. 4102).

In a road milling study, investigators Van Rooij and Klaasse reported results of using aerosolized water without additives to control dust (see Section IV-5.8 – Millers Using Portable or Mobile Machines for more details). The system consists of 24 spray nozzles (located at the picks drum, collection conveyor, and loading conveyor), which spray aerosolized water onto the milled asphalt material (Document ID 1217, p. 4). Aerosolized water alone provided a substantial benefit, reducing the mean exposure for drivers and tenders combined by 86 percent compared with baseline operations (Document ID 1217, pp. 8-10).

Dr. Knutson commented that there are sand agglomeration and equipment clogging issues with wetting the process material, such as when introducing water in sand movers and conveyor belts (Document ID 2264, pp. 23-24). Similarly, API commented that “OSHA, ERG, and NIOSH, all recognized that directly wetting or chemically amending proppant material prior to introduction to the blender can cause serious binding issues and cause a fracture to fail” (Document ID 2301, p. 56).

The goal of a water misting system is to limit the dispersal of respirable dust after it has been released, in contrast to other water-based dust control systems that apply water to source material to prevent generation of airborne respirable dust. In the PEA, OSHA cited NIOSH experience in the mining industry to distinguish using water to prevent dust from becoming liberated by directly spraying the material from using it to limit the dispersion of dust by spraying the dust cloud, causing particles to fall from the air (Document ID 1720, p. A-36). In his testimony, Dr. Knutson also made this distinction (Document ID 3576, Tr. 458). As cited above, one employer has had some success with using misting systems to limit the dispersion of airborne dust without wetting the sand (Document ID 1538, p. 3), and Mr. Jordan testified that misting systems are used at some facilities (Document ID 3589, Tr. 4102). Therefore, OSHA finds that misting systems designed to remove airborne dust have utility to reduce dust emissions without unduly wetting the source material.

Based on the evidence in the record, OSHA expects that dust suppressants such as the one developed by ARG or NIOSH's misting recommendation have the potential to reduce exposures from conveyors and transfer points. Although more research must be done to evaluate the efficacy of dust suppressants like ARG’s, water misting technology has been used at some sites and, with proper design, can be used to prevent dispersion of released dust without excessive wetting of the proppant.

Dust Suppressants for General Work Areas

Wet dust suppression methods have proven effective for controlling silica dust in general work areas in which exposures result from re-suspended dust (Document ID 0516; 1539; 1540; 4073, Attachment 8e). Spraying water or amended water (including additives to extend the functional benefit of the water spray), is widely used to control dust in outdoor storage yards in general industry and in demolition and excavation operations in construction (Document ID 0239; 0516; see Section IV-5.3 – Heavy Equipment Operators and Ground Crew Laborers). NIOSH has recommended that water trucks be used on hydraulic fracturing sites to control dust in general work areas (Document ID 1543, p. 6; 1544, p. 7; 1545, p. 10; 1546, p. 11).

NIOSH described several test results of watering haul roads with control efficiency ranging from 40 percent to 95 percent. The control efficiency for water can be highly variable as it is dependent upon frequency of water application, road material type, traffic, and weather conditions (Document ID 1540, p. 252). In a report on the characteristics of fugitive dust generated from unpaved mine haulage roads (Organiscak and Reed), the authors found that “road wetting was very effective in suppressing the respirable dust generated by the haulage trucks” (Document ID 4073, Attachment 8e, p. 15). The most common method of haul road dust control is surface wetting with plain water, but water amended by adding hygroscopic salts, surfactants, soil cements, bitumens, and films (polymers) to the road surface is also widely used (Document ID 1539, p. 69). Road material used for unpaved mine haulage roads are similar to other unpaved haulage roads and areas where there is vehicular traffic. Dr. Knutson stated that applying wet methods to roads and production areas has proven effective. Although he identified some difficulties associated with its use (mud creating slip and fall hazards, freezing problems, and potential runoff issues), he nevertheless stated that "wetting roads is feasible and will do some good" (Document ID 2264, p. 23). Dust controls such as wet methods can therefore be applied similarly to minimize exposures to haulage road fugitive dust.

In addition, there are additives that can enhance the effectiveness of water for dust suppression. A study by Addo and Sanders offers additional support for the application of dust suppressants to work areas and storage yards (Document ID 0516). The study examined three chemical dust suppressants (lignosulfate, calcium chloride, and magnesium chloride) applied to an unpaved roadway for four and a half months and found that, compared to an untreated roadway, the suppressants reduced fugitive dust emissions by 50 to 70 percent (Document ID 0516, p. 106).

Work Practices and Administrative Controls

Based on available evidence of worksite conditions, OSHA finds that work practices can help reduce exposures. Such work practices and administrative controls, which provide workers with standard operating procedures that help control or avoid sources of dust exposure, include covering fill ports during sand mover filling and hydraulic fracturing processes, requiring workers to stand back from dust emission points as much as possible, minimizing hot-loading unless adequate controls are in place to protect workers,[158] and limiting personnel in the areas where greatest exposure tends to occur.

Paragraph (e) of the final rule requires that employers establish regulated areas where employee exposures are or can reasonably be foreseen as exceeding the PEL. Such areas must be demarcated, and entry is allowed only to authorized persons whose work duties require them to be in the restricted area. The purpose of this requirement is to prevent

[158] This term refers to the act of filling a sand mover, which is also operating to release fracturing sand to the blender hopper (Document ID 3828, p. 354). OSHA recognizes that the practice of hot-loading reduces otherwise unproductive time spent refilling the sand mover.

unnecessary exposure of workers. OSHA expects that restricting areas to authorized personnel will reduce exposures of workers at hydraulic fracturing sites by limiting the number of personnel in the vicinity of the sand moving operation. The STEPS network also recommended as a "quick fix" that access to potential exposure zones by non-essential workers be limited (Document ID 4024, Attachment 2).

Another work practice control option involves adjusting equipment to minimize the height from which fracturing sand falls from conveyor belts during transfers to other conveyors or to the blender hopper. Reducing the drop distance minimizes the influence of competing air currents and reduces the amount of dust that becomes airborne as fracturing sand transfers between conveyors or from conveyor to blender hopper. ACGIH recommends that drop distances for general conveyor belts be less than 3 feet (Document ID 3883, p. 13-83). For the mining industry, NIOSH recommends that fall heights for materials be minimized whenever possible to reduce dust emissions at conveyor transfer points (Document ID 1540, p. 144). OSHA concludes that this principle applies to hydraulic fracturing operations as well.

Substitution

Substitution of proppant material is another option for reducing silica exposures at hydraulic fracturing sites. Hydraulic fracturing requires a granular media proppant—typically sand. To function as a proppant, the sand must stand up to considerable pressure in the well, and the physical properties of quartz make this type of sand particularly useful. However, alternate media are available and used for this purpose under certain circumstances (Document ID 1538, p. 3).[159] NIOSH observed a hydraulic fracturing crew using ceramic sand containing less than 1 percent silica (Document ID 1546, pp. 7-8).[160] OSHA concludes that substituting such a proppant for silica sand would reduce silica

[159] An example is the use of a ceramic proppant (Black Cat) that has higher compressibility than sand. It is used at sites where there is very high formation pressure, and this alternative proppant allows for successful fracture of the underground geological formations such that gas can be extracted (Document ID 1538, p. 3).

[160] NIOSH reported that the proppant's material safety data sheet listed less than 1 percent quartz in the product. NIOSH analysis confirmed that the percentage was slightly lower than 1 percent (Document ID 1546).

exposure levels substantially (depending on the amount of silica in the alternative proppant) compared to using pure silica sand, but the Agency recognizes that use of low-silica-containing substitutes is a solution for specific circumstances and that future development may be necessary to increase the availability of substitute materials and broaden their application.

Low-silica alternate media can also be used in combination with (high-quartz) natural sand media. NIOSH obtained PBZ samples at a hydraulic fracturing site that used a mixture of natural sand and ceramic proppant (58 percent of the total proppant used that day was the low-silica ceramic proppant, while the remaining 42 percent was silica sand) (Document ID 1546, pp. 7-8). PBZ samples confirmed that the silica content of the samples was lower (3 to 25 percent silica) than at sites using only high-silica sands (typically between 50 and 100 percent silica) (Document ID 1546, p. 4). Although reducing the silica content of the proppant does reduce the silica in the airborne dust, worker exposures can still be significant; at this NIOSH site, nine of the 11 PBZ samples exceeded 50 $\mu g/m^3$, although none exceeded 100 $\mu g/m^3$ (Document ID 1546, p. 4).

OSHA acknowledges that these substitute materials are more costly than natural sands (Document ID 1712, p. 6-16). Due to their cost, alternate proppants tend to be reserved for special circumstances (particularly high-pressure wells) where the special characteristics (increased durability, uniformity, or roundness) are needed to help extend well life (Document ID 1538, p. 3).

Combination of Controls

Based on the best available evidence, OSHA concludes that the most effective control strategy is one that addresses all of the sources of exposure simultaneously. Such a strategy would ensure that all workers benefit from reductions in exposure. Table IV.4.22-C shows the primary and secondary exposure sources for each job category. This classification, presented in the PEA, is based on NIOSH information from six site visits (Document ID 1541; 1542; 1543; 1544; 1545; 1546; 1720, p. A-21).

Table IV.4.22-C Sources of Worker Exposure to RCS			
Source	**Hydraulic Fracturing Worker (Central Zone)**	**Ancillary Support Workers (Nearby)**	**Remote/Intermittent Support Workers**
Thief hatches –sand mover top	**	*	*
Conveyor belt under sand movers	**	*	*
Blender hopper	**	*	*
Conveyor belt operation	**	*	*
Transfer point from sand belts on sand movers	**	*	*
Sand Fill Ports	**	*	*
Sand sieve (QC laboratory only)	NA	NA	**
Dust in vehicle cabs	NA	**	*
Dust raised by traffic	*	**	*
Number of Primary Sources	6	2	1
** = Exposure is directly associated with the workers' activities and equipment. * = Exposure is primarily as bystander; silica dust originates with other workers' activities. Sources: Document ID 1541, 1542, 1543, 1544, 1545, and 1546.			

Sources of dust emissions are located in close proximity to each other and to the workers potentially exposed, and therefore the relative contribution of each source can only be assessed qualitatively. Esswein et al. reported significant visible emissions observations from each of the major sources identified in Table IV.4.22-C, and the most highly exposed workers were those closest to the sand moving operation (Document ID 3828, p. 354). They also reported that PBZ exposures can exceed 100 μg/m^3 even when workers are not in close proximity to the primary sources of dust generation (Document ID 3828, p. 354). Accordingly, meeting the final rule's PEL requires that all sources of dust be addressed.

According to Esswein et al., "controls to limit silica-containing dust generation during hydraulic fracturing are only now emerging due to the relatively recent understanding of the hazard and magnitude of the risk" (Document ID 3828, p. 355). Local exhaust ventilation (LEV) is the primary dust control strategy that has been and continues to be developed to reduce silica exposures of hydraulic fracturing workers. As discussed above, among the more promising are LEV systems that contain and collect airborne dust along the sand moving line. These include points at the thief hatches, conveyor under the sand mover and to the blender hopper, transfer points from sand belts on sand movers, and at the blender hopper. Two of these systems, from KSW Environmental Document ID 1570; 4204, Attachment 1, p. 35, Fn. 21) and J&J Bodies (Document ID 1530; 4072, Attachment 36) are designed to control each of these sources by venting thief hatches and partially enclosing and venting the conveyor and hopper. Summary data provided by KSW Environmental show promising results, reporting that all 12 exposure measurements were below 50 μ/m^3 and that four customer surveys reported 76 PBZ samples all below 100 μg/m^3. These exposure results represent a significant improvement in comparison to the 42 percent of fracturing sand workers currently exposed above 250 μg/m^3 (Table IV.4.22-B). Exposure data for the J&J system were not available, although prototypes have been tested at 10 fracturing jobs with “excellent results” reported (Document ID 1530, p. 5).

Two other systems provide dust capture on the sand mover. National Oilwell Varco (NOV) developed a dust collection system for retrofit on the sand mover that collects dust during the filling operation (Document ID 1532; 1537, p. 9). NIOSH has designed a baghouse to collect dust from thief hatches that will use filter material designed to collect respirable particulate. Both of these systems are self-cleaning and the NOV system is available now. The baghouse designed by NIOSH continues to undergo testing and will likely be commercially available in the future (Document ID 1538, pp. 2-3). OSHA notes that bag houses are commonly used to control crystalline silica and other dusts in many industry sectors and are not a novel approach. Although it is expected that the baghouse will capture nearly all of the dust emitted from thief hatches, no data are yet available that describe the impact of using the device on workers’ exposures. Even with the LEV systems described above, dust can be released from unused sand fill ports when the sand mover is being filled. These emissions can be prevented very simply by ensuring that unused ports are capped (Document ID 1541, p. 6; 3828, p. 355).

Another previously discussed system designed to address dust release from the sand mover is that from Sandbox Logistics, LLC. This system replaces the pneumatic loading process with a containerized process, eliminating most of the dust emission points that currently exist from the sand mover (Document ID 3554; 3589, Tr. 4140-4143). Because of this, exposures from fill ports and transfer belts under the sand mover would be eliminated (Document ID 3554, p. 15). SandBox Logistics submitted a summary of an initial industrial hygiene study that collected PBZ and area samples during the delivery of proppant to the well-head using the company's delivery system and found a geometric mean exposure of 87 μg/m^3 for t-belt operators (Documents ID 4020, Attachment 1, p. 4).

For those LEV systems that address dust emissions from the sand mover alone, partial enclosure and ventilation of conveyors and blender hoppers will still be needed to control those dust sources. Use of water misting systems can provide additional dust control and has been suggested by NIOSH to be effective if misting nozzles are placed in the proper location and fine-spray, atomizing nozzles are used (Document ID 1538, p. 3; 1546, p. 10). Water misting has been used at some hydraulic fracturing sites (Document ID 1538, p. 3; 3589, Tr. 4102). While exposure data describing the effectiveness of such systems at hydraulic fracturing sites are not available, an aerosolized water system used on road milling equipment reduced the mean exposure for drivers and tenders combined by 86 percent compared with baseline operations (Document ID 1217, pp. 8-10).

Traffic on hydraulic fracturing worksites is a primary source of exposure for ancillary/remote workers and a secondary source for fracturing sand workers (see Table IV.4.22-C). Evidence in the record demonstrates the capability of dust suppressants to reduce silica exposures due to re-suspension of dust from traffic (Document ID 0516, p. 106; 1539; 1540; 4073, Attachment 8e). This evidence shows that exposures at or below the PEL of 50 μg/m^3 have been achieved and that reductions in dust emissions range from 40 to 95 percent (Document ID 0516; 1540). Using the low end of the range, OSHA estimates that a 50-percent reduction in dust emissions from road dust raised by vehicle traffic is achievable.

Once all of the sources of exposure have been controlled by the methods described above, sealed and ventilated control booths would offer additional protection for fracturing sand workers that operate machinery in the sand moving area. As previously stated in this Additional Controls section, control booths can reduce exposure concentrations by up to 99 percent. OSHA expects a 90-percent efficiency to be achievable, as demonstrated by Cecala et al. (Document ID 1563, p. 1). Assuming that operators can spend about half their time in the booth, exposures can be reduced by almost half.

Further reductions in exposure can be achieved by using work practices such as reducing drop heights at transfer points and at the hopper, and establishing regulated areas where exposures may exceed the PEL (as is required by the final rule).

4.22.4 Feasibility Finding

Based on the exposure profile in Table IV.4.22-B and other information in the record, OSHA has determined that some engineering controls are already commercially available for the hydraulic fracturing industry, and other controls that have demonstrated promise are currently being developed. OSHA recognizes, however, that engineering controls have not been widely implemented at hydraulic fracturing sites, and no individual PBZ results associated with controls have been submitted to the record.

The available information indicates that controls for dust emissions occurring from the sand mover, conveyor, and blender hopper have been effective in reducing exposures. KSW Environmental reported that a commercially-available control technology reduced exposures in one test with all 12 samples below the NIOSH recommended exposure limit (REL) of 50 μg/m^3 (Document ID 4204, p. 35, Fn. 21). KSW Environmental also stated that four additional customer tests resulted in 76 PBZ samples, all below 100 μg/m^3 (Document ID 4204, p. 35, Fn. 21). Another manufacturer of a similar ventilation system (J&J Bodies) reported that there was significantly less airborne dust during the loading of proppant onto the sand mover when its dust control system was used. This dust control system was used at 10 different hydraulic fracturing sites with reportedly good results (Document ID 1530, p. 5).

These findings indicate that, with good control of the major dust emission sources at the sand mover and along the conveyor to the blender hopper, exposures can be reduced to at least 100 μg/m^3. Use of other dust controls, including controlling road dust (reducing dust emissions by 40 to 95 percent), applying water misting systems to knock down dust released from partially-enclosed conveyors and blender hoppers (reducing dust emissions by more than half), providing filtered booths for sand operators (reducing exposure to respirable dust by about half), reducing drop height at transfer points and hoppers, and establishing regulated areas, will further reduce exposures to 50 μg/m^3 or below. Additional opportunities for exposure reduction include use of substitute proppant, where appropriate, and development and testing of dust suppression agents for proppant, such as that developed by ARG (Document ID 4072, Attachment 35, pp. 9-10). OSHA anticipates that once employers come into compliance with the preceding PEL, the additional controls to be used in conjunction with those methodologies to achieve compliance with the PEL of 50 μg/m^3 will be more conventional and readily available.

Therefore, OSHA finds that the PEL of 50 μg/m^3 can be achieved for most operations in the hydraulic fracturing industry most of the time. As shown in Table IV.4.22-B, this level has already been achieved for almost one-third of all sampled workers (and nearly 1 in 5 sand fracturing workers, the highest exposed job category). OSHA expects that the growing availability of the controls needed to achieve the preceding PEL, along with further development of emerging technologies and better use and maintenance of existing controls will reduce exposures to at or below the PEL for the remaining operations.

API, MSC, and Halliburton questioned whether the analysis of engineering controls presented in the PEA was sufficient to demonstrate the technological feasibility of reducing exposures to RCS at hydraulic fracturing sites to levels at or below 50 μg/m^3, in part because the analysis did not include industry-specific studies on the effectiveness of dust controls but largely relied instead on research from other industries (Document ID 2301, Attachment 1, pp. 29, 60-61; 2302, p. 4-7; 2311, p. 2-3). These stakeholders argued that OSHA needed to do significantly more data collection and analysis to show that the PEL of 50 μg/m^3 is feasible for hydraulic fracturing operations.

OSHA sought additional information on current exposures and dust control practices. Throughout the NPRM and hearings, OSHA, as well as other stakeholders, requested additional information on exposures and engineering controls (Document ID 3589, Tr. 4068-4070, 4074-4078, 4123-4124; 3576, Tr. 500, 534). Submissions to the record indicate that significant efforts are currently being made to develop more effective dust controls specifically designed for hydraulic fracturing (Document ID 1530; 1532; 1537;

1538; 1570; 4072, Attachments 34, 35, 36; 4204, p. 35, Fn. 21). However, industry representatives provided no additional sampling data to evaluate the effectiveness of current efforts to control exposures. Thus, NIOSH and OSHA provided the only detailed air sampling information for this industry, and summary data were provided by a few rulemaking participants (Document ID 4204, Attachment 1, p. 35, Fn. 21; 4020, Attachment 1, p. 4).

When evaluating technological feasibility, OSHA can consider engineering controls that are under development. Under section 6(b)(5) of the OSH Act, 29 U.S.C 655(b), OSHA is not bound to the technological status quo and can impose a standard where only the most technologically advanced companies can achieve the PEL even if it is only some of the operations some of the time. *Lead I* (*United Steelworkers v. Marshall*, 647 F.2d 1189 (D.C. Cir. 1980)); *American Iron and Steel Institute v. OSHA*, 577 F.2d 825 (3rd Cir. 1978). Relying on these precedents, the D.C. Circuit reaffirmed that MSHA and OSHA standards may be "technology-forcing" in *Kennecott Greens Creek Min. Co. v. MSHA*, 476 F.3d 946, 957, 960 (D.C. Cir. 2007), and that "the agency is 'not obliged to provide detailed solutions to every engineering problem,' but only to 'identify the major steps for improvement and give plausible reasons for its belief that the industry will be able to solve those problems in the time remaining.'" *Id.* (finding that MSHA provided "more than enough evidence," including "identif[ying] several types of control technologies that are effective at reducing . . . exposure," to conclude that the industry could comply with the two-year implementation date of a technology-forcing standard) (citing *Nat'l Petrochemical & Refiners Ass'n v. EPA*, 287 F.3d 1130, 1136 (D.C. Cir. 2002)).

Above, OSHA has described technologies that have been developed and tested, and that have demonstrated that the PEL is obtainable. These technologies have been developed to reduce exposures to the preceding PEL, but some of them appear also to have the capability to reduce some exposures to the PEL of 50 $\mu g/m^3$. KSW Environmental has provided data that indicate exposures can be achieved at or below the PEL (Document ID 1570, p. 22; 4204, Attachment 1, p. 35, Fn 21; 4222, Attachment 2, p. 6), and NIOSH has presented concepts of "mini-bag houses" that can be retrofitted on existing equipment (Document ID 1537, p. 5; 1546, p. 10). SandBox Logistics, LLC, has developed a shipping container for bulk transport of sand specifically designed for hydraulic fracturing operations that eliminates the need for sand movers, a major source of exposure to silica at fracturing sites (Document ID 3589, Tr. 4148). OSHA views these and other advanced controls discussed above as on the “horizon,” but not currently widely available for operational use (*Am. Fed'n of Labor & Cong. of Indus. Organizations v. Brennan*, 530 F.2d 109, 121 (3d Cir. 1975). Once they are deployed, as noted above, more conventional adjustments and additional controls can be used with them to lower exposures to the new PEL or below.

Evidence in the record shows that widespread recognition of silica exposure hazards on hydraulic fracturing sites and industry’s efforts to address them through the STEPS network accelerated after 2010, when NIOSH first publicized the severity of hazardous silica exposures as part of its Field Effort to Assess Chemical Exposures in Gas and Oil Workers (Document ID 1541). Recognition of silica exposures in the industry well above the preceding PEL of 100 $\mu g/m^3$ prompted the development of engineering controls to reduce exposures to RCS. While some companies in the hydraulic fracturing industry are able to obtain and implement controls to comply with the preceding PEL (*See, e.g.*, Document ID 4204, Attachment 1, p. 35, Fn. 21), the technology is not currently widely available. Given the progress that has been made since 2010, OSHA concluded that these technologies will become more widely available and enable the industry to comply with the final PEL within five years. As noted by Kenny Jordan, the Executive Director of the Association of Energy Service Companies (AESC), his organization’s participation on the National Occupational Research Agenda (NORA) NIOSH Oil and Gas Extraction Council enabled members to be “at the forefront of building awareness of the silica at the well site issue, particularly among those working in fracking operations” (Document ID 3589, Tr. 4059). In the five years since that time, the substantial progress in controlling silica exposures at fracking sites described above has occurred.

In June 2012, the STEPS network, in which AESC and many other industry, educational and regulatory entities participate, launched a respirable silica focus group to spread awareness, better characterize on-site silica exposures, and facilitate and evaluate the development of engineering controls (Document ID 3589, Tr. 4059; 1537). This enabled several manufacturers of engineering controls, such as KSW Environmental (formerly Frac Sand Dust Control and Dupre) who had developed a working model in 2009 (Document ID 1520), to collaborate and share information on various engineering controls. As a consequence, the silica control field has grown significantly during this period, including the development, testing and, in some cases, deployment of new technologies, including those from KSW Environmental, J and J Truck Bodies, SandBox Logistics, and NIOSH's baghouse. For example, John Oren, the co-inventor of the SandBox Logistics technology, said it had taken his company only three years to develop the product and make it commercially available (Document ID 3589, Tr. 4148). OSHA concludes that an additional five years will be more than enough time for these and other firms to complete development and increase manufacturing and sales capacity, and, simultaneously, for hydraulic fracturing employers to test, adopt and adapt these emerging technologies to their workplaces. Indeed, in light of the progress that has already been made, it may be more accurate to call the standard "market-accelerating" than "technology-forcing."

During the rulemaking, API touted the efforts of this industry to develop technology to protect workers against the hazards of silica (Document ID 4222, Attachment 2, p. 9). OSHA agrees with API that these efforts have been noteworthy and that more time is warranted to allow for continued development, commercialization, and implementation of these innovative technologies. OSHA is confident that with the innovation displayed by this industry to date, the hydraulic fracturing industry can further reduce worker exposures to the PEL if sufficient time is provided. Therefore, OSHA is providing an extra 3 years from the effective date of the standard – for a total of 5 years – to implement engineering controls for the hydraulic fracturing industry. OSHA concludes that this is ample time for this highly technical and innovative industry to come into compliance with the final PEL. This is consistent with, but longer than, the time frame OSHA granted for implementation for engineering controls for hexavalent chromium, where OSHA provided four years to allow sufficient time for some industries to coordinate efforts with other regulatory compliance obligations as well as gain experience with new technology and learn more effective ways to control exposures (71

FR 10100, 10372, Feb. 28, 2006). Thus, with the extra time provided for this industry to come into compliance, OSHA finds that the final PEL of 50 μg/m^3 is feasible for the Hydraulic Fracturing industry.

In the two years leading up to the effective date, the hydraulic fracturing industry will continue to be subject to the preceding PEL in 29 CFR 1910.1000 (Table Z). In order to meet the preceding PEL of 100 μg/m^3 during this interim period, such compliance will include adoption of the new engineering controls discussed above as they become widely available for field use.[161] As a result, OSHA expects many exposures in hydraulic fracturing to be at or near the 50 μg/m^3 level ahead of the five-year compliance date due to the expected efficacy of this new technology.

[161] Compliance with Table Z requires implementing all feasible engineering and administrative controls to achieve the PEL before using protective equipment such as respirators. 29 CFR 1910.1000(e). OSHA acknowledges that the technologies to meet the PEL in Table Z are not currently widely available in the quantities needed for the entire industry to achieve compliance. Accordingly, as employers work toward implementing controls during the interim period, supplemental respiratory protection may be necessary to comply with the PEL of 100 μg/m^3. Likewise, during the additional three-year phase-in period, OSHA anticipates that many employers may need to use supplemental respiratory protection to comply with the PEL of 50 μg/m^3.

5. TECHNOLOGICAL FEASIBILITY FOR THE CONSTRUCTION INDUSTRY

5.1 ABRASIVE BLASTERS

5.1.1 Description

This section addresses abrasive blasting operations that occur in the construction industry. Abrasive blasting is commonly used in the construction industry to remove surface coatings, create architectural surface finishes, or clean the surfaces of structures and equipment (such as oil tanks, water tanks, gasoline tanks, bridges, and steel beams). Workers in this industry perform abrasive blasting as part of their jobs or assist in abrasive blasting operations by maintaining the abrasive blasting machine and components or by helping to maneuver the hoses. OSHA has identified abrasive blasting as a significant source of crystalline silica exposure when conducted at construction sites (Document ID 1720, p. IV-385).

OSHA has identified two job categories associated with abrasive blasting in the construction industry: abrasive blasting operator and abrasive blaster's helper. Table IV.5.1-A summarizes the major activities and primary sources of silica exposure for these abrasive blasting job categories in the construction industry.

Table IV.5.1-A Job Categories, Major Activities, and Sources of Exposure of Abrasive Blasters

Job Category*	Major Activities and Sources of Exposure
Abrasive Blasting Operator	Uses abrasive blasting equipment to clean a variety of surfaces. • Dust generated from the use of silica-containing abrasive blast media. • Dust generated from abrasive blasting on concrete substrates. • Dust raised by sweeping or shoveling spent abrasive material (housekeeping).
Abrasive Blaster's Helper (Pot Tender)	Tends blasting equipment. • Dust raised by filling abrasive blasting reservoir (e.g., emptying bags of silica-containing abrasive media). • Dust generated by abrasive blasting operations carried out by the Abrasive Blasting Operator. • Dust raised by sweeping or shoveling spent abrasive material (housekeeping).
*Job categories are intended to represent job functions; actual job titles may differ and responsibilities may be allocated differently, depending on the construction site.	

5.1) Abrasive Blasters

Source: Document ID 1720, p. IV-373.

Abrasive blasting workers are employed in a diverse range of manufacturing and service industries in general industry. Their work occurs mainly in the following application groups and is addressed in those sections of this technological feasibility analysis: IV-4.3 Concrete Products, IV-4.4 Cut Stone, IV-4.6 Dental Laboratories, IV-4.8 Foundries, IV-4.10 Jewelry, and IV-4.20 Shipyards (Maritime Industry).

Generally, abrasive blasting related to construction differs from industrial abrasive blasting in that construction workers perform these activities at temporary worksites using portable abrasive blasting equipment without the use of a fixed-position abrasive blasting room, booth, or cabinet fitted with dedicated exhaust ventilation. Abrasive blasting operations similar to those found on construction sites can occur on the premises of some manufacturing and nonmanufacturing general industry establishments, where the abrasive blasting operation is not a normal part of the establishments' main business (e.g., food manufacturing, retail stores). The baseline conditions, exposure profile, and additional controls presented here apply to this type of abrasive blasting work, regardless of whether the abrasive blasting is for the purpose of construction or maintenance.

OSHA has existing requirements for abrasive blasting under the Ventilation Standard for construction (29 CFR 1926.57). In certain situations, that standard requires abrasive blasting operators to wear abrasive blasting respirators approved by NIOSH for protection from dusts produced during abrasive blasting operations (29 CFR 1926.57(f)(5)(i) through (iii)). That standard also includes specifications for blast-cleaning enclosures (29 CFR 1926.57(f)(3)), exhaust ventilation systems (29 CFR 1926.57(f)(4)), air supply and air compressors (29 CFR 1926.57(f)(6)), and operational procedures (29 CFR 1926.57(f)(7)). OSHA also has similar requirements for abrasive blasting under the general industry Ventilation Standard (29 CFR 1910.94).

Construction workers who perform abrasive blasting at least occasionally are associated with numerous construction industry North American Industry Classification System (NAICS) codes, including: 236210, Industrial Building Construction; 236220, Commercial and Institutional Building Construction; 237110, Water and Sewer Line and

Related Structures Construction; 237120, Oil and Gas Pipeline and Related Structures Construction; 237130, Power and Communication Line and Related Structures Construction; 237310, Highway, Street, and Bridge Construction; 237320, Paint and Wall Covering Contractors; 237990, Other Heavy and Civil Engineering Construction; 238190, Other Foundation, Structure, and Building Exterior Contractors; and 238990, All Other Specialty Trade Contractors. This section presents information from these segments of the construction industry and is representative of most abrasive blasting operations and conditions in construction.

5.1.2 Exposure Profile and Baseline Conditions

The following paragraphs describe baseline conditions for the job categories of abrasive blasting operator and abrasive blaster's helper, based on OSHA Special Emphasis Program (SEP) inspection reports, NIOSH reports, New York Department of Transportation reports, and published articles. These reports present information on abrasive blasting (identified by construction industrial classification codes) performed for construction purposes at building sites, steel and concrete tanks (inside and outside), swimming pools, highways/bridges, and an oilfield construction site. Together, these sources provide the best available information on workers performing miscellaneous abrasive blasting operations in construction.

For the exposure profile, OSHA reviewed exposure data that was originally contained in the PEA (Document ID 1720, p. IV-375). OSHA derived that data from OSHA SEP reports, NIOSH studies (mainly from 1999 to 2009), New York Department of Transportation memoranda (Document ID 0925; 1255), and published articles. OSHA supplemented these data with more recent data from 12 samples identified in OSHA's Information System (OIS) (Document ID 3958). The exposure profile summarizes the results of 71 silica samples for abrasive blasting workers at 27 commercial, storage tank, and highway construction sites, including bridge locations.[162]

Table IV.5.1-B presents the exposure profile and summarizes the silica exposure data available to OSHA for the job categories of abrasive blasting operator and abrasive blaster's helper.

Baseline Conditions for Abrasive Blasting Operators

Based on descriptions of abrasive blasting operators' activities and equipment in the sources mentioned above, OSHA concludes that baseline conditions for this group of workers include the use of a portable abrasive blasting machine in the following three scenarios:

- using dry silica-containing abrasive blast media;
- using alternative media on silica-containing surfaces; and
- using wet methods with silica sand abrasive media.

These baseline conditions are represented in Table IV.5.1-B by the data summarized for workers performing "dry blasting, uncontrolled" and "wet methods used."

OSHA's existing Ventilation Standard for construction (29 CFR 1926.57) requires abrasive blasting operators to wear abrasive blasting respirators approved by NIOSH, in certain circumstances, for protection from dusts produced during abrasive blasting operations.

The exposure profile in Table IV.5.1-B includes 55 samples of respirable crystalline silica for abrasive blasting operators. Of the 55 results, 38 samples (69 percent) were obtained while workers performed dry abrasive blasting, with 8-hour time-weighted

[162] As noted in Section IV.2 – Methodology, all sample results included in the exposure profile are 8-hour time-weighted averages (8-hour TWAs) calculated assuming zero silica exposure during any unsampled portion of the shift. Unless explicitly stated otherwise, all sample results discussed in the additional controls section are also 8-hour TWAs calculated in the same manner. Assumptions made in calculating 8-hour TWAs are discussed in Section IV.2 – Methodology.

average (TWA) exposure levels ranging from below the limit of detection (LOD)[163] to 29,040 micrograms per cubic meter (μg/m^3). The median silica exposure for this job category is 251 μg/m^3, and the mean exposure is 3,160 μg/m^3. The remaining 17 silica sample results (31 percent of total samples) were from operators using wet blasting methods. Those results show 8-hour TWA silica exposures ranging from 36 μg/m^3 to 407 μg/m^3, with a median exposure of 125 μg/m^3 and a mean exposure of 161 μg/m^3.

Among operators, the highest silica exposure levels are found when workers are performing dry blasting using silica sand abrasive in unventilated enclosed spaces. For instance, a silica exposure of 29,040 μg/m^3 was obtained by OSHA for a worker blasting inside a city water tower (Document ID 0547, p. 324).[164] A NIOSH Health Hazard Evaluation also found high readings associated with dry blasting in a tank that was only naturally ventilated (Document ID 0885, p. 17). Workers conducting abrasive blasting operations using a silica sand abrasive[165] inside a steel plate water tank were exposed to silica at levels ranging from 15,000 to 27,000 μg/m^3 (Document ID 0885, p. 29). An OSHA inspection of a painting contractor in 2013 found respirable dust exposures of 32,000 μg/m^3 (12,983 μg/m^3 respirable silica) and 25,000 μg/m^3 (8,749 μg/m^3 respirable silica) during sampling of abrasive blasting operators, although the inspection

[163] Results reported as “none detected” are assigned a value equal to the LOD. The LOD is determined individually for each sample based on the volume of air sampled and the method used to analyze the sample; therefore, the limit of detection varies between samples. See Section IV.2 – Methodology for additional information on LODs.

[164] The prior silica PEL limited exposure to silica-containing respirable dust, and the limit on exposure to respirable dust decreased with increasing silica content. For this sample, OSHA reported the silica PEL as 0.31 mg/m^3 and a respirable dust level of 96.17 mg/m^3. Based on the respirable dust level, the silica PEL of 0.31 mg/m^3 corresponds to a silica content of 30.2 percent. To express the PBZ result in terms of the gravimetric measurement of silica, OSHA multiplied the silica concentration by the respirable dust value, and determined that the silica exposure was 29,040 μg/m^3.

[165] In this study, NIOSH collected half-shift (240 minute) samples to reduce the chance of filter overloading. According to NIOSH, workers typically spend the same proportion of their shifts performing abrasive blasting as they spend performing abrasive blasting during the 4-hour sampling period, so silica concentrations measured during the sampling period are also representative of the workers’ 8-hour exposures. NIOSH stated: “[A]t this operation, half-shift sample concentrations are reasonable approximations of full-shift concentrations (2 hours of sandblasting per 4-hour half-shift is similar to 4 hours of sandblasting per 8-hour full-shift). Therefore, half-shift, 4-hour time-weighted average (TWA) exposures are believed to be reasonable approximations of full-shift, 8-hour TWA exposures” (Document ID 0885, p. 14).

information does not state whether the abrasive blasting was performed in an enclosed area (Document ID 3958, Rows 591, 593).

The lowest exposures for dry blasting operators occurred when workers were using a non-silica containing abrasive blasting media. However, significant silica exposures can still occur during the use of non-silica abrasives, mainly when the work surface contains silica. NIOSH obtained a 90-minute short-term reading of 440 μg/m^3 (83 μg/m^3 as an 8-hour TWA) for a worker using abrasive containing less than 1-percent quartz to remove paint from the steel understructure of a bridge. The worker blasted inside a temporary enclosure; silica was believed to come from concrete adjacent to the steel being cleaned (Document ID 0910, p. 4).

Similarly, a result of 73 μg/m^3 was collected for an operator who used a non-silica abrasive to blast a swimming pool (Document ID 0505, p. 11). The specific source of the silica was not indicated; however, OSHA notes that swimming pools are typically lined with painted concrete and tile, both of which contain silica. Although these results are markedly lower than results for workers performing abrasive blasting using silica sand, it nonetheless indicates the potential for exposure from abrasive blasting on materials that contain silica, even when the worker uses a non-silica-containing blasting media. While these non-silica abrasive media can reduce silica exposure levels, they do not necessarily eliminate silica exposure under all conditions.

NIOSH evaluated a wet blasting operation in which abrasive blasting operators blasted the exterior concrete surfaces of a parking garage with a wet blasting system that projected a mixture of water and silica sand (Document ID 0230, p. 3). Sixteen silica exposure results, ranging from 36 μg/m^3 to 407 μg/m^3, were obtained during these abrasive blasting operations (Document ID 0230, p. 21). A separate OSHA SEP inspection of a wet abrasive blasting operation at a bridge painting site found a silica exposure level of 45 μg/m^3 for the abrasive blasting operator (Document ID 0497, p. 20). These data, when compared to the data obtained for dry abrasive blasting using silica sand, suggest that wet abrasive blasting is useful in preventing very high levels of silica dust levels during abrasive blasting operations, but that exposures to silica will still frequently exceed the revised PEL.

Baseline Conditions for Abrasive Blasters' Helpers

Baseline conditions for abrasive blasters' helpers are similar to those for abrasive blasting operators, with the key exception being the helper's greater distance from the actual abrasive blasting. Also, abrasive blasters' helpers typically use particulate-filtering half face piece respirators instead of the supplied-air abrasive blasting respirators used by the operator.

The baseline conditions for abrasive blasters' helpers are represented in Table IV.5.1-B by the data summarized for workers "assisting with dry blasting, uncontrolled" and "assisting with wet methods used." The exposure profile in Table IV.5.1-B includes 16 samples of respirable crystalline silica for abrasive blasters' helpers. Eight of these samples are associated with dry abrasive blasting, with a median silica exposure of 35 μg/m^3, a mean exposure of 811 μg/m^3, and exposures ranging from 10 μg/m^3 to 4,700 μg/m^3. The remaining eight samples, all from one concrete parking garage construction site described in a NIOSH study, represent exposures among abrasive blasters' helpers during the use of wet abrasive blasting using silica sand on a concrete surface (Document ID 0230, p. 3). Table IV.5.1-B shows that the median silica exposure for these samples was 68 μg/m^3, with a mean exposure of 60 μg/m^3 and exposures ranging from the limit of detection (12 μg/m^3) to 104 μg/m^3. As with abrasive blasting operators, exposure data on abrasive blasters' helpers indicate that wet abrasive blasting methods can prevent extremely high silica exposures among helpers.

Silica exposures for abrasive blasters' helpers can vary widely depending on the activities required of the helper (e.g., refilling media reservoirs, maintaining air compressors, maneuvering hoses), the helper's proximity to the location where abrasive blasting is performed, and the amount of time spent near the abrasive blasting (Document ID 1720, p. IV-377). As with abrasive blasting operators, some of the highest exposure levels for abrasive blasters' helpers were associated with dry blasting using silica sand in unventilated enclosed spaces. For instance, NIOSH reported a silica exposure of 4,700 μg/m^3 as an 8-hour TWA (actual exposure of 27,000 μg/m^3 over 84 minutes of sampling) for a helper involved in dry sandblasting operations on the interior of a 750,000-gallon steel-plate water tank (Document ID 0885, p. 15). The helper shoveled sand from an elevated ledge to the bottom of the inside of the tank. OSHA also obtained an exposure reading of 1,466 μg/m^3 for a helper involved in a sandblasting operation inside a city water tower, a job that lasted 8 hours (Document ID 0547, p. 325).[166] Additionally, NIOSH measured a 72-minute short-term silica reading of 1,470 μg/m^3 (221 μg/m^3 as an 8-hour TWA) for a helper involved in an operation that was removing paint from the steel understructure of a bridge using coal slag abrasive media. The abrasive blaster's helper spent the majority of the sampling period in the temporary enclosure, where silica concentrations were quite high (Document ID 0910, p. 4).

[166] As noted earlier, the prior silica PEL limited exposure to silica-containing respirable dust. For this sample, OSHA reported the silica PEL as 0.59 mg/m^3 and a respirable dust level of 9.84 mg/m^3. A silica PEL of 0.59 mg/m^3 corresponds to a silica content of 19 percent. To express the PBZ result in terms of respirable crystalline silica in μg/m^3, OSHA multiplied 9.84 mg/m^3 by 19 percent (the silica concentration of the respirable dust) and determined that the silica exposure was 1,866 μg/m^3.

Table IV.5.1-B
Personal Respirable Crystalline Silica Exposure Range and Distribution of Results for Construction Workers: Abrasive Blasters (NAICS 236210, 236220, 237110, 237120, 237130, 237310, 237320, 237990, 238190, 238990)

	Exposure Summary			**Exposure Range**		**Exposure Profile**				
Job Category	**N**	**Mean ($\mu g/m^3$)**	**Median ($\mu g/m^3$)**	**Min ($\mu g/m^3$)**	**Max ($\mu g/m^3$)**	**<25 ($\mu g/m^3$)**	**≥25 and ≤50 ($\mu g/m^3$)**	**>50 and ≤100 ($\mu g/m^3$)**	**>100 and ≤250 ($\mu g/m^3$)**	**>250 ($\mu g/m^3$)**
Abrasive Blasting Operator (Dry blasting, uncontrolled)	38	3,160	251	12	29,040	10 (26.3%)	1 (2.6%)	4 (10.5%)	4 (10.5%)	19 (50%)
Abrasive Blasting Operator (wet methods)	17	161	125	36	407	0 (0%)	3 (17.6%)	3 (17.6%)	7 (41.2%)	4 (23.5%)
Abrasive Blasting Operator Subtotal	55	2,233	189	12	29,040	10 (18.2%)	4 (7.3%)	7 (12.7%)	11 (20%)	23 (41.8%)
Abrasive Blaster's Helper (Assisting with dry blasting, uncontrolled)	8	811	35	10	4,700	3 (37.5%)	2 (25%)	0 (0%)	1 (12.5%)	2 (25%)
Abrasive Blaster's Helper (with wet methods)	8	60	68	12	104	2 (25%)	1 (12.5%)	4 (50%)	1 (12.5%)	0 (0%)
Abrasive Blaster's Helper Subtotal	16	436	53	10	4,700	5 (31.3%)	3 (18.8%)	4 (25%)	2 (12.5%)	2 (12.5%)
Total	**71**	**1,828**	**114**	**10**	**29,040**	**15 (21.1%)**	**7 (9.9%)**	**11 (15.5%)**	**13 (18.3%)**	**25 (35.2%)**

Notes: All samples are personal breathing zone (PBZ) results and represent 8-hour time-weighted average exposures.
Job categories are intended to represent job functions; actual job titles might differ, and responsibilities might be allocated differently, depending on the site.
Percentages may not add to 100 percent due to rounding.

Sources: Document ID 1720; 3958; 0230; 0495; 0496; 0497; 0499; 0500; 0502; 0503; 0504; 0505; 0508; 0509; 0510; 0547; 0784; 0885; 0910; 0925; 1255; 1426.

5.1.3 Additional Controls

The exposure profile in Table IV.5.1-B shows that approximately 68 percent (49 out of 71 samples) of abrasive blasting operators and helpers have exposures above the final PEL of 50 μg/m^3. Therefore, OSHA finds that additional controls will be necessary to achieve the PEL for these overexposed workers. Some abrasive blasting workers are potentially exposed to levels of silica hundreds of times higher than the PEL.

Additional Controls for Abrasive Blasting Operators

Traditional practice in industrial hygiene uses a hierarchy of controls to determine how to protect workers from hazardous exposures. At the top of the hierarchy is elimination, followed in order by substitution, engineering controls, administrative controls, and personal protective equipment. Respiratory protection falls into the bottom level of the hierarchy.

Exposure control options for abrasive blasting operators include:

- Substituting alternative abrasive blasting media for silica sand;
- Blasting with wet methods or other processes that reduce or eliminate dust generation;
- Local exhaust ventilation (LEV) of temporary containments or enclosed areas (with proper filtration to protect adjacent workers);
- Dust suppressant additives;
- Housekeeping; and
- Respiratory protection.

Given the high levels of hazardous dust generated during abrasive blasting, OSHA finds that respiratory protection will continue to be necessary, in many circumstances, to reduce silica exposures to acceptable levels, even with other controls in place. All pertinent comments and testimony supported the need for respiratory protection for workers performing abrasive blasting operations. In its written comments, the Construction Industry Safety Coalition (CISC) questioned OSHA's position requiring employers to implement technologically feasible engineering and work practice controls before placing employees in respirators (Document ID 2319, p. 37). However, 3M agreed with OSHA that effective engineering and work practice controls should be the primary means of reducing employee exposures to respirable crystalline silica (Document ID 2313, p. 6). Based on information submitted to the docket and summarized in this section, the Agency maintains its position that adherence to the hierarchy of controls is essential to help reduce the extremely high silica exposures experienced by abrasive blasting workers and adjacent workers at construction sites.

Use of Alternative Abrasive Media

To eliminate or reduce the hazards posed by using silica sand as the abrasive media, employers can select alternative blasting media that does not contain crystalline silica. Silica sand, which became popular as an abrasive blasting material because of its effectiveness and its low cost, can contain as much as 96 percent crystalline silica. However, in recent years the amount of silica sand used or sold for abrasive blasting has been declining, and, in many applications, other types of abrasive blasting media have replaced sand (Document ID 1720, p. IV-383). During OSHA's public hearings, Paul Mellon of Novetas Solutions testified that the annual tonnage of silica sand used for abrasive blasting operations decreased 67 percent from 1996 to 2007, primarily due to the use of alternative blasting media and high-pressure water-jet blasting techniques (Document ID 3545, p. 4).

Many types of alternative abrasive blasting media are available for use as a substitute for silica sand. Alternative abrasive media containing less than 1 percent silica include garnet, staurolite, aluminum oxide, and slags of copper, coal, or nickel (Document ID 3747, p. 14). In its written comments, the International Safety Equipment Association (ISEA) describes one blasting media alternative, steel shot, as an effective and economical substitute for silica sand (Document ID 2212, p. 4). ISEA also identified 23 states that have demonstrated the feasibility of using alternative abrasive blasting media in response to bans or restrictions on the use of silica sand for abrasive blasting (Document ID 2212, p. 3). Sarah Coyne, the Health and Safety Director of the International Union of Painters and Allied Trades, described coal slag (Black Beauty) as the most preferred alternative to sand; coal slag has a 0.01 percent silica content and results in low dust output. Ms. Coyne said that she isn't aware of any of the union's signatory contractors using silica sand for abrasive blasting, "and the reason for that is because it kills their workers" (Document ID 3581, Tr. 1644**)**.

A NIOSH-sponsored study evaluating several types of abrasive media found that the silica exposures of abrasive blasting operators can be reduced with the use of certain media (Document ID 0772; 0773; 0774). Phase I of the study involved collecting exposure monitoring data during test trials in which the abrasive blasting operator used different media to blast a steel surface inside a ventilated enclosure (Document ID 0772, pp. 5-20). Exposures ranging from 2,930 μg/m^3 to 22,030 μg/m^3 were obtained during trial runs in which silica sand media was used (Document ID 0774, Table 10, p. 19).[167] No respirable quartz was detected in samples collected during trial runs in which the operator used crushed glass, coal slag, nickel slag, olivine, specular hematite, copper slag, or steel grit (Document ID 0772, p. 82). The study also showed that blasting operations using some media with low silica content and non-siliceous substrates can still result in elevated airborne concentrations of silica (Document ID 0774, Table 10, p. 19). Exposure readings ranging from 240 μg/m^3 to 6,830 μg/m^3 were obtained during trial runs with garnet along with a sample result of 740 μg/m^3 during copper slag use (Document ID 0774, Table 10, p. 19). The study also indicated that the potential presence of other toxic substances requires that alternative blast media be selected carefully (Document ID 0772, p. 4).

In another study, the use of blasting media containing less than 1-percent quartz resulted in an area respirable quartz level of 1,580 μg/m^3 (369-minute sample duration) inside a ventilated containment structure erected around two steel tanks (Document ID 0212, p. 13). NIOSH concluded that the high levels of dust produced by the abrasive blasting overwhelmed the LEV (Document ID 0212, p. 15). A 2012 report from Alberta Human Services on worker exposure in the Alberta construction industry found that the use of vitreous smelter slag (0.28 percent quartz silica) and nickel slag (0.30 percent quartz

[167] The referenced report table cannot be viewed in the record, but it is publicly available from NIOSH's website at http://www.cdc.gov/niosh/topics/silica/pdfs/ab_p3tab.pdf.

silica) in abrasive blasting resulted in a maximum silica concentration of 270 µg/m^3 (Document ID 3747, p. 11).

In a study of exposures among painters using three alternative blasting abrasives during a New Jersey highway footbridge repainting project, Meeker et al. reported that steel grit, specular hematite, and coal slag all resulted in elevated silica exposures, ranging from 420 µg/m^3 to 90,100 µg/m^3, likely due to the very high silica content in the paint (Document ID 3855, p. 82). High variability in silica exposures during the two- to three-hour task-based sampling periods, however, made it difficult for researchers to detect statistical differences in exposures associated with the different abrasives. Sources of the high level of variability are unknown; however, they could be related to harsh environmental conditions during abrasive blasting as well as the small sample size. This study also found that workers could be exposed to other hazardous substances (such as beryllium, cadmium, chromium, manganese, and nickel) during the use of the alternative blasting abrasives (Document ID 3855, p. 83).

OSHA received a number of comments pertaining to the health hazards associated with using alternative abrasive media. The Precast/Prestressed Concrete Institute (PCI) cautioned that coal and copper slags, commonly used as a substitute for silica sand in abrasive blasting, contain hazardous substances (such as beryllium) that cause adverse health effects in workers (Document ID 2276, p. 9). The Meeker study, described above, found elevated levels of arsenic, beryllium, and other toxic metals among painters using the three alternative blasting abrasives (Document ID 3855, p. 82).

Additional literature suggests there may be more benign abrasive media substitutes. For example, based on a review of engineering control technology for abrasive blasting, Flynn and Susi report that dolomite (i.e., calcium magnesium carbonate) might be a good, nontoxic alternative to silica-containing abrasive blasting media (Document ID 1717, p. 682). The authors also commented on the apparent potential for good results with crushed glass (Document ID 1717, p. 682). However, OSHA received comments on some of the limitations of using alternative blasting media: for example, PCI commented on performance limitations and/or high costs associated with many types of alternative blasting media (Document ID 2276, p. 9).

OSHA received numerous comments calling for a ban on the use of silica sand in abrasive blasting. The Building and Construction Trades Department, AFL-CIO (BCTD) urged OSHA to prohibit abrasive blasting with silica sand, and identified Great Britain, Germany, Sweden, and Denmark as countries that currently ban the use of silica sand in abrasive blasting (Document ID 2371, Attachment 1, p. 31). Sally Greenberg of the National Consumers League testified that the U.S. Navy, Air Force, Coast Guard, and 23 state departments of transportation prohibit the use of silica sand in abrasive blasting (Document ID 3588, Tr. 3752). One commenter suggested a partial ban on silica sand abrasive blasting in areas such as confined spaces and shipyards where it is difficult to protect adjacent workers (Document ID 2163, Attachment 1, p. 18). Dr. Paul Schulte of NIOSH testified that NIOSH has called for a ban of silica sand in abrasive blasting since 1974 (Document ID 3579, Tr. 141-142). Diane Brown of the American Federation of State, County and Municipal Employees (AFSCME) reported that local unions in Maryland no longer use silica-based abrasive media and have switched to other materials, such as aluminum shot (Document ID 2106, p. 2). Additionally, the design standard developed by the American National Standards Institute (ANSI) on exhaust systems for abrasive blasting operations at fixed location enclosures prohibits the use of silica sand as an abrasive blasting agent in such operations (Document ID 0528, p. 1).

Other commenters argued against banning silica sand in abrasive blasting. James Toscas of PCI commented that the use of certain alternative abrasives, like steel grit, may cause particle embedment or discoloration on their architectural cladding products (Document ID 2276, p. 9). Mr. Toscas further described how other alternatives, like staurolite, olivine, baking soda, nut shells, glass beads, and dry ice, are not hard enough to provide the desired finish on their products, and stated that other alternatives, like aluminum oxide and stainless steel grit, were cost prohibitive (Document ID 2276, p. 9). The American College of Occupational and Environmental Medicine (ACOEM) supported the use of alternative abrasive media, but cautioned that substitutes must demonstrate safety in short- and long-term inhalation toxicology studies (Document ID 2080, p. 4).

CISC joined other commenters in warning about the other possible hazards associated with substitutes for silica sand (Document ID 2319, p. 37).

Many of the silica sand substitutes used in abrasive blasting can create hazardous levels of dust containing other hazardous substances. In a laboratory study of alternative materials for abrasive blasting which was funded by NIOSH, researchers focused on eleven health-related agents, including arsenic, beryllium, cadmium, chromium, and lead. In summary, nine of the eleven alternate abrasives had substantially higher levels of some other health-related agents, as compared to silica sand (Document ID 0772, pp. 1-3, 144). Other studies conducted by NIOSH on the toxicity of silica sand substitutes for abrasive blasting found that many alternatives, including coal slag, garnet, copper and nickel slags, olivine, and crushed glass, produced lung damage and inflammatory reactions in rodent lungs similar to the effects of silica sand, indicating that the use of such materials might not be effective in reducing lung disease risks to workers (Document ID 3857, pp. 139-142; 3859, pp. 1121-1122). While other alternatives, such as steel shot, dolomite, and walnut shells, are considered lower hazard materials, abrasive blasting on silica-containing surfaces and other hazardous surface materials (e.g., lead paint) can also produce high levels of airborne toxic dust. Although OSHA finds that substituting non-silica abrasive media for silica sand does reduce silica exposures, the limitations on selecting effective substitutes may leave silica sand as the only feasible choice in some applications. Wet abrasive blasting (discussed below) can be an effective control when silica sand cannot be replaced with a non-silica abrasive alternative. Regardless of the abrasive blast media used, abrasive blasting operations create high levels of potentially hazardous dust and workers will still need respiratory protection.

OSHA has considered the comments associated with the complex issues related to banning silica sand for use in abrasive blasting. Based on the information available, the Agency concludes that a ban on the use of silica sand is not warranted at this time. OSHA bases this decision on a number of factors already discussed in this section, including the potential hazards, and concerns about the effectiveness, of certain abrasive alternatives.

Under the existing OSHA Ventilation Standard (29 CFR 1926.57), abrasive blasting operators in construction must use abrasive blasting respirators, in certain circumstances, for protection from the high level of hazardous dust generated by this operation. The Ventilation Standard also contains requirements applicable to engineering controls used to control and reduce levels of hazardous dusts.

Wet Blasting and Other Alternative Methods to Dry Abrasive Blasting

Alternative techniques to dry abrasive blasting can be used to reduce the silica exposure levels of abrasive blasting workers and adjacent workers, although the effectiveness of these methods in reducing silica exposures has not been extensively documented. These techniques, summarized below in Table IV.5.1-C, include wet abrasive blasting, centrifugal wheel blasting, vacuum blasting, and blasting with dry ice pellets. Hydroblasting is a surface cleaning technique that does not use abrasive blast media and instead uses a high pressure water jet (along with additives). Other cleaning techniques that do not use abrasive blasting and are suitable for smaller jobs include thermal, chemical, and mechanical stripping methods (Document ID 1720, p. IV-339). Other removal techniques that could reduce or eliminate silica dust levels during surface preparation include blast cleaning with baking soda (sodium bicarbonate), reusable sponge abrasives, or plastic media blasting (PMB); cryogenic stripping (immersing small parts into liquid nitrogen, followed by gentle abrasion or PMB); and laser paint stripping (generates no waste and uses a pulsed carbon dioxide laser as the stripping agent) (Document ID 1720, p. IV-378).

Wet methods can be used to reduce the amount of dust generated during surface preparation. All wet blasting techniques produce substantially lower dust emissions compared with dry abrasive blasting. For example, after reviewing other published and unpublished work, Lahiri et al. estimated that silica exposure associated with sandblasting can be eliminated by using hydroblasting (which involves no abrasive media), even when the surface being hydroblasted contains silica (e.g., concrete) (Document ID 0776, p. 505). OSHA recognizes that although this method effectively cleans many surfaces with minimal silica release, it cannot replace abrasive media blasting under all circumstances. PCI explained that the industry needs to use abrasive blasting abrasives that are aggressive enough to provide the desired concrete finishes (Document ID 2276, p. 9); this may eliminate hydroblasting as a feasible method for some job specifications.

Table IV.5.1-C
Examples of Alternatives to Dry Abrasive Blasting

Name	Description/Comments
Wet Abrasive Blasting	Can be used in most instances where dry abrasive blasting is used. Includes: 1) compressed air blasting with the addition of water into the blast stream before the abrasive leaves the nozzle, and 2) water jetting with the addition of abrasive into the water stream at the nozzle. Additives and rust inhibitors may be used.
Hydroblasting	High Pressure Water Jetting: Uses pressure pump, large volume of water, and specialized lance and nozzle. Pressures range from 3,000 to 25,000 pounds per square inch (psi). Can remove loose paint and rust; will not efficiently remove tight paint, tight rust, or mill scale. Can be used in most instances where abrasive blasting is used. Primary application is for an older surface rusted in a saline environment (rather than for new steel). Rust inhibitors could be required to prevent flash rusting. Ultra High Pressure Water Jetting: Similar to high pressure water blasting. Uses pressurized water from 25,000 to 50,000 psi. Removes tight paint and rust, but not mill scale.
Centrifugal Wheel Blasting	Uses a rotating wheel assembly inside an enclosure equipped with a dust collector. Abrasive is propelled outward from the rotating wheel and removes rust, paint, and mill scale. Abrasives are recycled and include steel shot, steel grit, cut wire, and chilled iron grit. The operator has no contact with airborne dust or high velocity particles.
Vacuum Blasting	Uses standard blast nozzle inside a shroud (head) that forms a tight seal with the work surface. Vacuum is applied inside shroud during blasting to remove dust and debris. Abrasives are recycled and include aluminum oxide, garnet, steel shot, steel grit, and chilled iron grit. When used properly, cleans effectively with minimal dust.
Dry Ice Pellets	Dry ice blast cleaning with solid carbon dioxide. Waste is minimized and includes paint chips and rust. Storage and handling costs can be significant.
Thermal Stripping	Uses a flame or stream of superheated air to soften paint, allowing for easy removal. Generates one waste stream (i.e., waste paint). Effective for small parts; not suitable for heat-sensitive surfaces. Very labor intensive.
Chemical Stripping	Uses hazardous chemical strippers, such as methylene chloride-based or caustic solutions. Effective for small fiberglass, aluminum, and delicate steel parts. Requires adequate ventilation and other safety measures. Generates multiple waste streams (i.e., contaminated rinse water and waste strippers).
Mechanical Stripping	Involves chipping, grinding, sanding, or scraping the coating off small parts or surfaces through the use of needle guns, chipping hammers, sanders, and grinders. Generates paint waste and airborne dust. Some power tools are equipped with dust collection systems.

Source: Document ID 1720, p. IV-339.

5.1) Abrasive Blasters

A 2008 report from Germany's Institute for Occupational Safety and Health of the German Social Accident Insurance (BGIA) [168] indicates that silica exposures are reduced by wet methods, but that "dust emissions are influenced substantially by the type and quantity of the water feed." The German report indicates that, compared with dry abrasive blasting, modest amounts of water result in some exposure reduction, but can still result in extremely high silica levels. As an extreme example, during laboratory tests using quartz-free blasting media moistened with 10 percent water to abrasively blast concrete,[169] airborne quartz concentrations were still up to 6,000 μg/m^3 (Document ID 0553, p. 145).

The BGIA report also indicates that increasing the water content to form a slurry improves dust control. One example involved replacing the conventional pneumatic blast unit with an ultra-high-pressure slurry blasting unit (29,000 psi) to work on a concrete silo. Under these conditions, investigators measured an average quartz concentration of 500 μg/m^3. They considered it possible that average results could be lower still, but concluded that use of such equipment was unlikely to reduce concentrations below 150 μg/m^3 (Document ID 0553, p. 145).

Increasing water application rates may reduce respirable dust concentration by a factor of 2 – 2.5 for workers performing wet abrasive blasting (Document ID 0230, p. 10). As mentioned previously, NIOSH evaluated a wet blasting operation in which workers blasted the exterior concrete surfaces of a parking garage (Document ID 0230). Their system used a mixture of 80 percent silica sand and 20 percent water. NIOSH reported that this method appeared to reduce the silica exposures associated with abrasive blasting, but the extent of the reduction was not determined, and operators' exposures remained as high as 407 μg/m^3 (Document ID 0230, p. 21). The same study is published as Mazzuckelli et al. (Document ID 0795). NIOSH concluded that the exposure readings obtained for this evaluation were lower than readings obtained for other abrasive blasting

[168] At the time of the report, Germany's Institute for Occupational Safety and Health of the German Social Accident Insurance was known as BGIA, but this organization is now called by the German acronym IFA.

[169] The pneumatic abrasive blasting unit operated at a pressure of 102 to 116 psi (Document ID 0553).

operations. The data in the record support NIOSH's conclusion, showing many dry blasting exposures in the thousands of μg/m^3.

Heitbrink (Document ID 0733, p. 22) conducted a field study of a wet abrasive blasting technique and obtained significantly reduced silica exposures compared with data reported in the literature for use of dry silica sand. The tested device was a water induction nozzle described as a venturi nozzle in which water is added to the abrasive-air mixture to reduce dust during blasting. Workers' exposures were monitored while blasting outdoors in open areas on concrete panels using silica sand abrasive from which the fines had been removed.[170] In 10 samples, the geometric mean silica exposure was 60 μg/m^3, and the range was 20 μg/m^3 to 130 μg/m^3. The author found that when compared to other published data, wet blasting using abrasive sand with the fines removed was effective in reducing silica exposures (Document ID 0733, p. 22).

CISC commented that using wet methods and creating a slurry may lead to environmental problems and may not be a viable solution in many circumstances (Document ID 2319, p. 36). PCI stated that wet method abrasive blasting is not feasible for its industry because it creates a slurry that obscures the surface and prevents the abrasive blasting operator from achieving consistent results (Document ID 2276, p. 9). PCI also commented that using wet method abrasive blasting is problematic under freezing conditions because the ice can create a slipping hazard, and noted that there can be a slipping hazard from the slurry even in warmer weather (Document ID 2276, pp. 9-10). PCI also commented on the potential for mold problems when using water, and stated that water is not always available on construction sites (Document ID 2276, pp. 9-10). Heitbrink determined that excessive water application rates were not a problem at the site, but noted that such water application rates could present a problem at other work sites[171] (Document ID 0733, p. 22). These data were also reported in a study by Old and Heitbrink (Document ID 0928, p. D58). OSHA concludes from the NIOSH studies and

[170] The abrasive media had been screened through a 100-mesh sieve so that particles passing through the sieve comprised less than 3 percent of the media (Document ID 0928, p. D56).

[171] During Heitbrink's (2007) study, water was applied at rates ranging from 3.2 kilograms per minute (kg/min) to 8.6 kg/min (equal to 0.8 gallons/minute to 2.2 gallons/minute). The author noted that water puddles did occur at these water application rates.

the exposure profile that wet abrasive blasting is an effective method and feasible control for reducing airborne silica dust most of the time when using silica sand in abrasive blasting. However, the use of wet abrasive blasting may not be practicable in all situations involving abrasive blasting. In such cases, other engineering controls discussed in this section can be used to reduce silica dust exposures.

CISC noted that there have not been any studies demonstrating the most effective flow rate for wet blasting, and that different environments and conditions have not been analyzed to conclusively determine the effectiveness of wet methods (Document ID 2319, p. 36). The amount of water required for effective dust control during blasting depends on the device and the application, and on the relation between water flow rates and dust emissions has not been widely studied to date. In some cases, a volume of water is mixed directly with a volume of abrasive. For instance, Heitbrink provided an overview of wet blasting technology and described a wet abrasive blasting device that mixes water and abrasive in a pressurized tank, with a ratio of about 80 percent abrasive and 20 percent water (Document ID 0733, p. 4). In other devices, the water is supplied continuously at a given flow rate. The patent for a water induction nozzle tested by Heitbrink reported that visual dust was reduced as the water flow rate increased from 1 to 5 liters per minute (Document ID 0733, p. 2). Heitbrink pointed to the need for controlled laboratory testing to develop recommended water application rates for wet blasting. OSHA concludes that wet abrasive blasting is an effective method of controlling dust levels during abrasive blasting operations, despite questions about the optimal abrasive/water mix for dust control. Sample data from wet abrasive blasting in the NIOSH study (Document ID 0230) and an OSHA SEP inspection (Document ID 0497) show a marked decrease in dust levels when compared to uncontrolled, dry abrasive blasting. These data also demonstrate that wet method abrasive blasting equipment is available to companies for use at construction job sites and that it is, in fact, used by employers in some applications.

Although wet methods may not reduce exposures to at or below the new PEL of 50 $\mu g/m^3$ on a consistent basis, wet methods nonetheless can be used to reduce the amount of silica dust generated during abrasive blasting operations using silica sand or blasting on silica-containing surfaces. Table IV.5.1-B shows that average levels of silica dust are much higher during dry abrasive blasting. Wet methods are an important dust control where abrasive blasting operations are enclosed to prevent dust from entering the surrounding environment and exposing other workers at the construction site.

Enclosures and Local Exhaust Ventilation

Enclosures in which workers perform blasting keep silica contained, providing a measure of exposure control for other workers performing activities outside the enclosure. However, enclosures need to be properly ventilated to avoid concentrated levels of silica resulting in extremely high exposures to the person performing the abrasive blasting. For example, NIOSH found elevated short-term results of 820 $\mu g/m^3$, 1,730 $\mu g/m^3$, and 2,960 $\mu g/m^3$ (sample durations of 93, 96, and 93 minutes, respectively) for area samples collected inside an unventilated enclosure used to confine dust generated during the blasting process (Document ID 0910, p. 4). In order to control dust levels, the OSHA Ventilation Standard for abrasive blasting in construction (29 CFR 1926.57) already requires all blast-cleaning enclosures to be adequately ventilated, irrespective of whether silica or an alternative abrasive agent is used.

CISC commented that OSHA did not present any exposure monitoring results, studies, or data to show the extent to which enclosures or LEV systems reduce workers' silica exposures (Document ID 2319, p. 37). The record, however, contains support for OSHA's determination that enclosures and LEV reduce exposures. NIOSH researchers found that the high levels of dust produced by abrasive blasting in ventilated enclosures declined rapidly when blasting ceased, reducing overall exposures (Document ID 0212, p. 15). A World Health Organization document on airborne dust, submitted by the AFL-CIO, describes how enclosures are usually coupled with exhaust ventilation to remove contaminants from the workplace (Document ID 4072, Attachment 15, p. 97).

While the data in the record do not provide precise measurements of the extent to which silica exposures go down in ventilated enclosures, evidence in the record, coupled with basic ventilation principles, indicates that use of ventilated enclosures will result in reduced exposures among operators working within the enclosures. Basic ventilation engineering principles indicate that establishing air changes in an enclosed area by using LEV and filtration will likely result in lower dust levels in comparison to an unventilated enclosure.

LEV can also be used on the blasting equipment itself to capture dust generated during the blasting operation. Although not associated with the construction industry, the National Automobile Dealers Association testified on the subject of LEV-equipped blasting equipment, noting that it is not uncommon for autobody shops to use ventilated spot blasters for dust controls purposes, and that the use of ventilated blasters and ventilated sanders helps minimize exposure (Document ID 3587, Tr. 3722). Flynn et al. found that controls, such as vacuum blasting using a ventilated shroud around the nozzle to collect dust, can reduce exposures when used properly; the authors concede, however, that there is a lack of exposure data that would allow for definitive conclusions on the effectiveness of controls for abrasive blasting (Document ID 1717, pp. 685-86).

Portable blast-cleaning equipment and temporary containment structures must have sufficient exhaust ventilation to: 1) prevent a build-up of dust-laden air and reduce the concentrations of hazardous air contaminants; 2) prevent any leakage of dust to the outside; and 3) provide prompt clearance of dust-laden air from the enclosure when blasting ceases. Exhaust ventilation systems must be constructed, installed, inspected, and maintained according to 29 CFR 1926.57, the OSHA Ventilation Standard for construction. The exhaust air from blast-cleaning equipment must be discharged to the outside through an appropriate dust collector to protect the workplace, the environment, and the surrounding community from hazardous air contaminants. The dust collector should be set up so that the accumulated dust can be emptied and removed without contaminating work areas.

Thus, while LEV alone is not expected to control workers’ silica exposures to at or below the final rule’s PEL, OSHA nonetheless finds that LEV installed in accordance with 29 CFR 1926.57 is useful in reducing dust in enclosures.

Use of Dust Suppressant Additives

Dust suppressant additives provide a limited amount of dust control during blasting with silica sand. For instance, during a study evaluating several types of abrasive media, silica sand abrasive was used to blast the side of a coal barge (Document ID 0774, p. 3). Silica exposures ranged from 9,910 $\mu g/m^3$ to 50,522 $\mu g/m^3$, with a geometric mean of 27,959 $\mu g/m^3$. When a dust suppressant was used with the silica sand abrasive, silica levels in four readings had a geometric mean of 19,040 $\mu g/m^3$ (ranging from 9,180 $\mu g/m^3$ to 28,200 $\mu g/m^3$), about 68 percent of the mean for untreated silica sand (Document ID 0773, p. 45). Although these levels are still excessive, dust suppressant methods used in combination with other measures, such as ventilation and work practices, can help to reduce silica exposures when silica sand must be used as the blasting agent. Effective dust suppressant additives will also help reduce silica exposures when workers (e.g., abrasive blasters' helpers) handle abrasives before and after the actual abrasive blasting. OSHA did not receive comments or exposure information on dust suppressant additives, and continues to believe that they (in combination with other control measures) are useful in reducing workers' exposures to silica.

Housekeeping

Dry sweeping of spent abrasive blasting media and debris can be a sizeable source of silica exposure for workers. For example, a NIOSH study of abrasive blasting in a shipyard found exposure levels of 85 $\mu g/m^3$, 160 $\mu g/m^3$, and 280 $\mu g/m^3$ for workers who spent the entire sampling period dry sweeping material from surfaces, using a hand broom or a whiskbroom (Document ID 0852, p. 3). CISC noted that this study was not related to abrasive blasting in construction and involved workers who spent the entire sampling period with their faces close to the dust source (Document 2319, p. 37).

Although the study is not specific to the construction industry, it demonstrates that dry sweeping material will create higher airborne dust levels than other cleaning methods (such as vacuums, shovels, and scrapers). Using vacuums, shovels, and scrapers to clean surfaces introduces less dust into the air than dry sweeping – regardless of industry. Riala (1988) completed a study of Finnish construction site workers that compared silica exposures among workers dry sweeping with exposures among workers using alternate cleaning methods (Document ID 1163). When compared with dry sweeping, exposures were approximately three times lower when the workers used squeegees to scrape surfaces and approximately five times lower when workers used vacuums (Document ID 1163, p. 3). Additionally, when wet abrasive blasting is implemented as a control, moisture in the abrasive media will continue to suppress dust as long as workers dispose of or recover the abrasive before it dries.

Respiratory Protection

OSHA's Ventilation Standard for construction, at 29 CFR 1926.57(f)(5)(ii)(A-C), requires that employers provide abrasive blasting respirators for abrasive blasting operators to wear when they are working inside of blast-cleaning rooms, or when the nozzle and blast are not physically separated from the operator in an exhaust-ventilated enclosure and either the operator is using silica sand in manual blasting operations or the concentrations of toxic dust dispersed by the abrasive blasting might exceed the limits set in 29 CFR 1926.55 or other pertinent OSHA standards.[172]

Employers must also adhere to OSHA's Respiratory Protection standard (29 CFR 1910.134) when respiratory protection is required. Much of the testimony and comments on the subject of abrasive blasting in construction acknowledged that respiratory protection is necessary for abrasive blasting workers. In its post-hearing brief, the Laborers' Health and Safety Fund of North America acknowledged that abrasive blasting operations can be difficult to control and would require the use of respirators (Document ID 4207, p. 2).

Julie Tremblay of 3M's Personal Safety Division questioned the respirator requirements under the OSHA Ventilation Standard, stating that the standard specifies the type of respirator that is required based on the work being done rather than on the exposure level. OSHA's Ventilation Standard for construction requires that employers use only respirators approved by NIOSH under 42 CFR Part 84 to protect employees from dusts

[172] Similar requirements apply to general industry under the Ventilation Standard at 29 CFR 1910.94.

produced during abrasive-blasting operations. Ms. Tremblay noted that the specified respirator is available with two different levels of performance: assigned protection factors (APF) of either 25 or 1000 (Document ID 2313, p. 3). 3M requested that OSHA mandate the use of a respirator with an APF of 1000 or higher for abrasive blasting operators.

OSHA's Respiratory Protection Standard, at 29 CFR 1910.134(d), requires employers to evaluate respiratory hazards in the workplace, identify relevant workplace and user factors, and base respirator selection on these factors. This would dictate selecting the appropriate abrasive blasting respirator and the level of performance that would protect the abrasive blasting operator from the expected level of exposure. During dry blasting with silica sand inside unventilated enclosures or spaces (in an apparent violation of OSHA's Ventilation Standard), workers were exposed to extremely high levels of silica, as high as 29,040 μg/m^3 (or 580 times the new PEL) (Document ID 0547). In this case, under the new PEL, a supplied-air respirator with an APF of 1,000 would be necessary to protect a worker in these conditions. However, OSHA does not anticipate that a supplied-air respirator with an APF of 1,000 would be necessary in all circumstances.

To be effective, respirators must be selected, used, and maintained properly. And workers must be vigilant in following work practices to prevent contamination of their respirators. For example, one NIOSH study found silica readings of 85 μg/m^3 and 87 μg/m^3 in sampling conducted inside airline respirators (Document ID 0880, p. 10). The source of exposure was undetermined, but was assumed to be due to contamination of the airlines. These results highlight the importance of properly maintaining and cleaning respiratory protective equipment.

Moreover, respirators protect only the workers wearing them. Depending on their proximity to the blasting operation, abrasive blasters' helpers and adjacent construction site workers might have significant exposures and thus require respiratory protection. For example, OSHA obtained a respirable silica exposure of 1,466 μg/m^3 for a helper at a site that used silica sand to remove paint from inside a city water tower (Document ID 0547, p. 325). Because the exposure was 16.7 times the calculated PEL for silica, the particulate-filtering face piece with an APF of 10 worn by the worker was not sufficiently protective.

Despite the disadvantages of respirator use, OSHA concludes that, given the extremely high levels of silica that can be generated by abrasive blasting, respirators will usually be necessary to control the silica exposures of abrasive blasting workers. It is likely that respirators will be required even when individual controls or combinations of them (for example LEV and alternative blasting media) are in place.

Additional Controls for Abrasive Blasters' Helpers

Controls are essential not only to protect the abrasive blasting operator, but also the abrasive blaster's helper and any workers near the blasting operation. The exposure levels associated with abrasive blasters' helpers are routinely lower than abrasive blasting operator exposures, but, as shown in Table IV.5.1-B, half of the silica samples on helpers still exceed the new PEL of 50 μg/m^3. Control measures that reduce operator exposures will also reduce the silica concentrations to which helpers are exposed. Furthermore, some of the controls described as additional controls for abrasive blasting operators will directly affect specific job tasks performed by helpers. The use of wet media during blasting can reduce exposures to helpers during clean up if the helper sweeps or shovels spent media while the media is still wet. Likewise, the use of alternative abrasive blast media in place of silica sand will eliminate or reduce the helpers' silica exposures. Although not evaluated due to a lack of available information, OSHA expects that dust suppressants added to the media before abrasive blasting will also help reduce the silica exposure levels of helpers when they perform housekeeping activities and when they empty bags of abrasive media into the grit pot.

Abrasive blasters' helpers also rely on respiratory protection during abrasive blasting operations, but they are not required to use the abrasive blasting respirators specified for operators under OSHA's Ventilation Standard for construction. The Ventilation Standard permits the use of properly fitted particulate-filter respirators for short, intermittent, or occasional dust exposures, such as cleanup, dumping of dust collectors, and other activities when it is not feasible to control the dust by enclosure, exhaust ventilation, or other means (29 CFR 1926.57(f)(5)(iii)). These types of activities are usually carried out by abrasive blasters' helpers. Testimony from Sarah Coyne with the International Union of Painters and Allied Trades discussed the role of the abrasive blasters' helpers and noted that helpers often do not receive adequate respiratory protection and personal protective equipment (PPE) even though conditions at the worksite could result in considerable amounts of dust (Document ID 3581, Tr. 1616-17). Based on the available exposure data summarized in Table IV.5.1-B, OSHA anticipates that abrasive blasters' helpers would generally need to be equipped with properly fitted, half-face respirators with an APF of 10, and in some situations, would require a higher level of respiratory protection.

5.1.4 Feasibility Findings

Based on the available information, including submitted comments, testimony, and exposure data, OSHA concludes that for most abrasive blasting operators, and approximately half of abrasive blasting helpers, employers will not reliably achieve the new PEL of 50 $\mu g/m^3$, even with the use of engineering controls. Thus, OSHA cannot find that the new PEL is technologically feasible for these workers.

In the final rule, OSHA is requiring employers to implement feasible engineering and work practice controls, such as housekeeping, to reduce levels of silica to the extent feasible. Employers must already comply with 29 CFR 1926.57(f), which provides specifications for blast-cleaning enclosures, exhaust ventilation systems, air supply and air compressors, and operational procedures. The Ventilation Standard, which will continue to apply concurrently with this standard, requires abrasive blasting operators, in certain circumstances, to wear abrasive blasting respirators approved by NIOSH under 42 CFR Part 84 (29 CFR 1926.57(f)(5)(ii)). In some cases the Ventilation Standard permits dust-filter respirators to be used for short, intermittent or occasional dust exposures. The Ventilation Standard also requires operators to be equipped with other PPE (such as heavy canvas or leather gloves and aprons, protective footwear, and eye and face protection). In addition, all requirements of OSHA's Respiratory Protection Standard (29 CFR 1910.134) apply when respirators are use in the workplace.

5.1) Abrasive Blasters

OSHA did not include abrasive blasting in Table 1 of the final rule because employers have a variety of options for controlling exposures to respirable crystalline silica during blasting operations. These include: (1) use of abrasive media other than silica sand to reduce crystalline silica dust emissions; (2) use of wet blasting techniques; (3) use of dust suppressors; (4) use of LEV systems; and (5) use of hydroblasting technologies that avoid having to use abrasive media. Employers can choose among these dust control strategies to select control methods that best fit the needs of each job. OSHA believes that, for these operations, the employer is in the best position to decide, based on the specific circumstances of the job, what approach, or combination of approaches, will most effectively meet the requirements of the project while protecting workers engaged in blasting operations. The employer is required to implement feasible engineering controls to reduce silica dust to the PEL. If the employer cannot meet the PEL, it must supplement the controls with appropriate respiratory protection, as needed.

Feasibility Finding for Abrasive Blasting Operators

Based on the available information, OSHA concludes that the silica exposure levels of most abrasive blasting operators cannot be reduced to levels at or below the new PEL of 50 μg/m^3, even with the use of feasible engineering controls. OSHA notes that the best available information indicates that the use of engineering controls (such as wet abrasive blasting, substituting alternative non-silica abrasive blasting media, and local exhaust ventilation) can be used to reduce the extremely high silica dust levels generated by abrasive blasting operations. OSHA also concludes that appropriate respiratory protection will be required to protect employees from harmful silica exposure. All testimony and comments received by OSHA were in agreement with OSHA's preliminary finding that most abrasive blasting operators' silica exposures will be above 50 μg/m^3 even with the use of engineering controls. Therefore, there is nothing in the record supporting a change to this finding.

This conclusion is based, in part, on the median 8-hour TWA reading of 125 μg/m^3 for workers who used wet abrasive blasting. As indicated in Table IV.5.1-B, over 80 percent of workers had exposure levels that exceeded the final PEL of 50 μg/m^3 when employing wet abrasive blasting methods. Thus, the use of appropriate respiratory protection, especially within enclosures, where exposures are highest, will still be needed to protect workers from hazardous levels of contaminants that may be generated during abrasive blasting (from the abrasive, the substrate, or both). To ensure protection for abrasive blasting operators, employers conducting abrasive blasting operations must follow the requirements under both the Ventilation Standard and the Respiratory Protection Standard.

Feasibility Finding for Abrasive Blasters' Helpers

Based on the available information, including the exposure profile in Table IV.5.1-B, OSHA concludes that half of all abrasive blasters' helpers currently experience exposures that exceed the new PEL of 50 μg/m^3. Even when wet abrasive blasting is performed, more than half (62 percent) of the abrasive blasters' helpers were exposed above 50 μg/m^3. OSHA notes that the available information indicates that the use of engineering controls (such as wet abrasive blasting, substituting alternative non-silica abrasive blasting media, and local exhaust ventilation) will greatly reduce the extremely high silica dust levels generated by abrasive blasting operations using silica sand. OSHA anticipates that abrasive blasters' helpers will remain at risk of exposures above 50 μg/m^3, and these workers will require appropriate respiratory protection whenever they work in the vicinity of the abrasive blasting activity. To ensure protection for abrasive blasters' helpers, employers conducting abrasive blasting operations must follow the requirements under both the Ventilation Standard and the Respiratory Protection Standard.

5.2 DRYWALL FINISHERS

5.2.1 Description

After segments of drywall have been installed, drywall workers use a joint compound paste to seal the joints between segments and to cover divots from nails. Once the joint compound is dried, workers sand the surface by hand to create a smooth finish. The drywall installer might perform the finishing, or a specialized trade worker might perform this work. Sanding dried joint compound containing silica is believed to be the primary source of silica exposure in this job category. Mr. Zimbelman, a homebuilder representing the National Association of Homebuilders (NAHB), testified that during drywall sanding tasks, the workers performing the sanding are typically the only crew present on a home construction site (Document ID 3587, Tr. 3549-3550). Industries that engage in drywall work are classified in the North American Industry Classification System (NAICS) code, 238310 (Drywall and Insulation Contractors).

Silica-free joint compounds have become widely available in recent years; however, some joint compound products may continue to contain silica. NIOSH tested bulk samples of a commercially available joint compound and found up to 6 percent quartz, although silica was not listed on the material safety data sheet for the product (Document ID 0213, p. 5). In another study, NIOSH determined that three of six drywall compounds purchased at a retail store contain trace amounts of silica (Document ID 1335, p. iii). Epling et al. (1999) identified four personal air samples taken during the application and sanding of drywall joint compound that contained between 1.1 and 3.7 percent respirable crystalline silica (Document ID 0662, p. 11). Table IV.5.2-A summarizes the major activities and sources of exposure for drywall sanders.

Table IV.5.2-A
Job Category, Major Activities, and Sources of Exposures of Drywall Finishers

Job Category	Major Activities and Sources of Exposure
Drywall Finisher	Applying joint compound to sections of drywall and sanding dried joint compound to create a smooth finish. • Dust generated while sanding dried, silica-containing joint compound.
Source: Document ID 1431.	

5.2.2 Exposure Profile and Baseline Conditions

Fifteen sample results obtained by NIOSH form the basis of this exposure profile (Table IV.5.2-B) (Document ID 1335). NIOSH, in collaboration with the Center to Protect Workers' Rights, obtained these results from 10 drywall finishers working at two work sites: an office renovation job and a project renovating a low-income public housing apartment complex (Document ID 1335, p. 2). Workers in this study applied typical joint compounds -- silica-free joint compounds or compounds with very low silica content -- and performed sanding by hand or with a pole sander. Drywall finishing jobs monitored by NIOSH lasted from 1.5 hours to more than 12 hours per shift (Document ID 1335, pp. 13-15). No work practice controls were identified.

The exposure profile in Table IV.5.2-B for drywall finishers includes 15 full-shift, personal breathing zone samples of respirable crystalline silica. The median exposure is 12 $\mu g/m^3$, the mean is 17 $\mu g/m^3$, and the range is 8 $\mu g/m^3$ (limit of detection (LOD)) to 72 $\mu g/m^3$, which was the only reading above 50 $\mu g/m^3$. The 72 $\mu g/m^3$ sample was obtained for a worker performing overhead sanding directly above his breathing zone (Document ID 1335, p. 13). One other sample exceeded 25 $\mu g/m^3$ (Document ID 1335, p. 14).

Sample data from OSHA inspections between 1985 and 1996 indicate that drywall workers were at times exposed to levels of silica above the previous PEL (Document ID 1167, p. 2). These silica exposures may be the result of using joint compound with silica content or the result of a different silica exposure source at the worksite. The summary information presented in this OSHA Integrated Management Information System (IMIS) data review shows that 22 percent of the samples collected in Standard Industrial Classification (SIC) 1742 (plastering, drywall, insulation) exceeded the PEL. Because individual sample information such as job activities, sampling duration, and silica content were not provided in the review, these samples provided no basis to explain the elevated silica exposures and were not included in the exposure profile.

Baseline conditions for drywall finishers include using low-silica or silica-free joint compounds and manual sanding without specific work practices or other controls. All of the results in the exposure profile are associated with these baseline conditions.

Table IV.5.2-B Personal Respirable Crystalline Silica Exposure Range and Distribution of Results for Construction Workers: Drywall Finishers											
	Exposure Summary			**Exposure Range**			**Exposure Profile**				
Drywall Finishers	**N**	**Mean (μg/m³)**	**Median (μg/m³)**	**Min (μg/m³)**	**Max (μg/m³)**		**<25 (μg/m³)**	**≥25 and ≤50 (μg/m³)**	**>50 and ≤100 (μg/m³)**	**>100 and ≤250 (μg/m³)**	**>250 (μg/m³)**
Drywall Finisher	15	17	12	8	72		13 (87%)	1 (6.5%)	1 (6.5%)	0 (0%)	0 (0%)
Drywall Finishers Total	**15**	**17**	**12**	**8**	**72**		**13 (87%)**	**1 (6.5%)**	**1 (6.5%)**	**0 (0%)**	**0 (0%)**

Notes: All samples are personal breathing zone (PBZ) results and represent 8-hour time-weighted average exposures.
Job categories are intended to represent job functions; actual job titles might differ, and responsibilities might be allocated differently, depending on the site.
Percentages may not add to 100 percent due to rounding.

Sources: Document ID 1431; 1720; 1335.

5.2.3 Additional Controls

Based on the one sample in the exposure profile (Table IV.5.2-B) that showed one exposure over the final PEL of 50 μg/m^3, OSHA finds that additional controls will be necessary to achieve the PEL for some drywall finishers some of the time (e.g., when overhead work places the breathing zone close to the silica exposure source). Additional controls could include substitution, ventilated sanders, wet methods, and pole sanders.

Substitution

The primary source of exposure for drywall workers is the use of silica-containing joint compounds. In cases of elevated exposure, the best control mechanism is substitution: changing to a joint compound that does not contain silica. NIOSH has indicated that there are a number of commercially available compounds that do not contain silica; OSHA therefore has concluded that substitution in new construction is possible most of the time. A representative of the National Association of Home Builders (NAHB), Mr. Gerald Howard, agreed, stating that much of the drywall joint compound currently used in residential construction has very low silica content and members can resolve any concerns with respect to silica exposure by making sure to use low silica containing product (Document ID 2296, Attachment 1, p. 30).

However, some joint compounds that do not list silica as an ingredient might still contain small amounts of silica, and during remodeling projects drywall finishers might be exposed while refinishing existing drywall surfaces that had used silica-containing joint compound (Document ID 1335, p. iii). Representatives from the Leading Builders of America (LBA) and the Construction Industry Safety Coalition (CISC) expressed concern about the reliability of controlling exposures by substituting silica-free joint compound during home construction. They cited NIOSH HETA-74-0078-2660 (1997), in which one worker performing sanding on low-silica or silica-free joint compound experienced a silica exposure of 80 μg/m^3 (Document 1335, p. 14).

CISC critiqued OSHA's findings for drywall finishers, asserting that "silica-free" joint compound is effective in keeping exposures below the proposed PEL only if it is "truly silica free" (Document ID 2319, pp. 38-40). CISC claims there are "significant concerns that silica-free joint compound in fact contains more than just trace amounts of silica and thus could result in significant exposures to silica under some conditions of use." This argument assumes noncompliance with OSHA requirements for material safety data sheets, see 29 CFR 1926.59, Hazard Communication), and is largely contradicted by the NIOSH study of drywall finishers in which six different containers of joint compounds were tested for silica content. Three of these joint compounds did not contain silica and the other three compounds contained less than "minor quantities" (less than 0.5 percent) of silica (Document ID 1335, pp. 3-4, 7, 10). The researchers concluded that for the most part the results of each sample analysis agreed with the composition stated in the manufactures' material safety data sheets. The subsequent air sample results collected when applying and sanding these joint compounds with limited controls (pole sander) showed 13 of 15 samples below 25 μg/m^3 (this standard's action level) and only 1 sample above the final PEL of 50 μg/m^3 (Document ID 1335, pp. 13-15). The one sample above the new PEL was taken on an individual who was performing overhead sanding without engineering controls. Researchers noted that when workers were sanding ceilings more dust appeared to be present in the workers' breathing zone than when they were sanding flat surfaces below eye-level (Document 1335, p. 8).

The NIOSH study was conducted on drywall workers using unspecified joint compounds, and bulk sample analyses revealed that three out of six joint compounds used contained silica (Document ID 1335, p. 8). There was no specific information about the silica content of the joint compound used at the site where the excessive exposure occurred. The work that was conducted was described as 'remodeling' work, and there was no indication that existing drywall joint compound was disturbed, which may have affected the results. Significantly, the total dust exposure of this sample also exceeded the OSHA Particulates Not Otherwise Regulated (PNOR) PEL (15 mg/m^3), which demonstrates that the work performed was excessively dusty. NIOSH noted that "when workers were sanding ceiling, or in tight confines such as closets or in corners, more dust appeared to be present in the workers' breathing zone than when they were sanding flat surfaces below eye level…" (Document ID 1335, p. 8). NIOSH's recommendation was to use engineering controls, such as wet finishing techniques, and personal protective equipment to limit exposures to dusts created during drywall finishing operations (Document ID

1335, p. iv). Due to the excessive dust exposures incurred by this worker on which the 80 $\mu g/m^3$ silica sample was collected, an employer would be required under 29 CFR 1926.55 to implement controls to reduce the amount of dust in the worker's breathing zone due to the particulate alone, regardless of its silica content. Therefore, due to the potential for excessive dust when drywall finishing, dust controls are frequently required even when using silica-free joint compound.

OSHA expects that the construction industry will largely be able to control silica exposures during drywall finishing through substitution. In the construction industry in general, there is an expectation that drywall finishers usually sand only new joint compound, but might briefly encounter older joint compound occasionally while sanding areas where repairs are being made on a pre-existing joint. Additional controls may be necessary when manipulating old building materials, including existing drywall joint compound, which may or may not contain silica. When working with known or suspected silica-containing joint compound, ventilated (or vacuum) sanders, wet methods, and pole sanders are all effective methods for controlling exposure to respirable crystalline silica (Document ID 0800).

Ventilated Sanders

NIOSH tested the effectiveness of five off-the-shelf ventilated sanding systems during drywall finishing: three designed to control dust during pole sanding and two to control dust during hand sanding. Total dust area sample results revealed that all five systems successfully reduced airborne dust exposures by 80 to 97 percent (Document ID 0849, p. 820). The effectiveness of ventilated sanders was confirmed in a study by Young-Corbett and Nussbaum (2009a), which found that using a ventilated sander during drywall sanding reduced respirable dust in the PBZ by 88 percent compared with a block sander used with no controls (Document ID 1239, p. 388). Although ventilated sanders are the most effective control option after substitution and offer indirect benefits to workers and managers, there are many perceived barriers to their adoption in the workplace. Workers and managers are concerned about: 1) maneuverability in small spaces, 2) reliance on a nearby power source, 3) product cost, 4) delays in learning the new equipment, and 5) maintenance (Document ID 1240, pp. 320-323). Furthermore, some models of ventilated sanders require a water source for the unit's water filter (Document ID 0213, Appendix C).

CISC criticized OSHA's reliance on the Young-Corbett and Nussbaum study that evaluated various sanding systems during drywall finishing tasks. The criticism focused on the use of a laboratory setting, the use of students instead of construction workers, a sampling time of 5 minutes, and the lack of respirable sampling specific to crystalline silica (Document ID 2319, p. 39). While all laboratory studies have limitations, the information provided by these studies constitutes the best available data on existing engineering controls for sanding systems in drywall finishing operations. OSHA concludes that the Young-Corbett and Nussbaum laboratory study simulated actual drywall finishing operations in the construction industry. The participants in the study were provided with instruction on the proper use of each sanding tool (Document ID 1239, p. 388). The sampling time and non-silica dust sampling were appropriate because of the repeated measures comparing dust generation rates of the four drywall sanding tools (Document ID 1239, p. 386).

In discussing the NIOSH study of drywall finishers, CISC expressed concern that pole sanders or sanders equipped with dust collection systems cannot be used in tight spaces and may result in quality issues (Document ID 2319, pp. 113-114). OSHA has not received any information or evidence in the record indicating that pole sanders or ventilated sanders cannot be used in tight spaces. CISC also pointed out that the NIOSH researchers acknowledged that some commercially available ventilated sanders lacked sanding head flexibility (Document 2319, p. 39; 0213, p. iv). The NIOSH researchers specified in their report that this was a subjective comment obtained from a questionnaire and that an additional control device, not incorporated into the experimental design, was tested and was able to overcome most of the flexibility problems (Document ID 0213, p. iv).

Certain defined types of experimental data are not intended to exactly replicate workplace conditions, but OSHA finds these data are useful in evaluating the effectiveness of controls. Studies may be intentionally designed to eliminate extraneous factors that would interfere with a correct interpretation of a control method's capacity to reduce silica emissions and associated exposure levels. Far from being a drawback, these studies typically are designed by the investigators to answer specific questions regarding the effectiveness of dust controls. The resulting data may be obtained under isolated conditions that ensure no additional sources of exposure are present. This exposure information can objectively show how well a control method works in an environment where other sources of silica are also controlled (e.g., as might occur on a well-controlled work site, or a site where only one source of silica exposure is active at a time). Sample results from the controlled condition are also routinely compared by investigators to the sample results for the uncontrolled condition. The resulting ratio shows the exposure reduction efficiency for the control method, independent of work rate variability, variations in construction materials, or other factors that do not relate to the individual control's functional performance. When available, this type of information is invaluable for ranking the benefits of one control method compared to another. As stated earlier in this section, the preferred control for drywall finishers is the use of commercially available joint compounds that do not contain silica. In the event that a company uses a silica-containing joint compound, or a worker comes into contact with existing silica-containing joint compounds, the use of ventilated sanders is a viable and feasible option for controlling dust as demonstrated by these studies (Document ID 0213; 1239). OSHA concludes that ventilated sanders provide a feasible and effective control for silica dust if silica-containing joint compound is used.

Wet Methods

The Young-Corbett and Nussbaum study (2009a) found that a wet sponge sander reduces respirable breathing zone dust concentrations generated from simulated drywall finishing tasks by 60 percent compared with a block sander used with no controls (Document ID 1239, p. 385). A wet sponge sander, which is a sponge with an abrasive surface, is one type of wet method. Other wet methods include wiping a clean, damp sponge over the still damp joint compound to smooth the seam and rinsing the sponge in a bucket of water as it becomes loaded with compound, or wetting dried joint compound with a spray bottle and sanding with sandpaper (Document ID 0213, App. C; 1240, p. 316). Although wet methods are technologically simple and can be used wherever a water source is available, a telephone interview of 264 drywall finishing companies found that less than 10 percent of these firms reported using them regularly (Document ID 1240, p. 318). Workers and managers have concerns about the finished texture, increased work time, mess, and adding moisture to the product, which could harm the product and delays painting (Document ID 0678; 0848; 0213; 1218; 1240). LBA and CISC noted that the Young-Corbett and Nussbaum (2009a) study did not recommend wet methods because the wet sponge performed poorly in terms of ease of use and perceived productivity (Document ID 2269, p. 16; 2319, p. 40). Although the study did note some difficulties using wet methods, OSHA continues to consider it a viable option for reducing exposures, given that it was found to reduce respirable dust by 60 percent (Document ID 1239, p. 385), and OSHA suggests that the use of a heat gun can expedite the drying process if necessary.

CISC objected to sanding with wet methods because it could result in an inferior end quality texture (Document ID 2319, p. 40). The companies who “rarely” or “never” used wet methods to control dust when drywall sanding cited quality and productivity concerns (Document ID 1240, p. 320). The major reasons were that it was hard to achieve the desired texture, it reintroduced moisture into the board, it took too much time, it was not cost effective, it was easier and faster to sand dry compound, and it was more difficult to sand wetted compound (Document ID 1240, p. 320). However, a survey of 264 drywall finishing firms, employing a total of 25,782 workers, revealed that in 2009 roughly half of these companies were using wet methods “always,” “often” or “sometimes” (Document ID 1240, pp. 318-19). This self-reported data indicates that the technology currently exists that makes the use of wet methods feasible for use in the field.

The LBA questioned the validity of OSHA demonstrating technological feasibility from the exposure reduction levels found in a study (Document ID 2269, pp. 16-17) using a laboratory setting versus a real world test. As OSHA explained in earlier in this subsection on additional controls (see discussion under the heading Ventilated Sanders), OSHA believes that the data from controlled environments is useful in assessing the effectiveness of controls.

Pole Sanders

A pole sander is a drywall finishing tool that incorporates a handle of various lengths with a base to hold the abrasive material for sanding. The pole sander creates distance between the worker and the point at which dust is generated reducing dust levels in the breathing zone (Document ID 0849, p. 821). Data from the Young-Corbett study found that a pole sander is almost as effective as a wet sponge sander, reducing respirable breathing zone dust concentrations generated from simulated drywall finishing tasks by 58 percent compared with a block sander with no controls (Document ID 1239, p. 388).

In the event that a joint compound containing silica is used, OSHA concludes that the use of pole sanders is a feasible control for reducing exposure to silica dust during sanding operations in the drywall finishing industry.

5.2.4 Feasibility Finding

The exposure profile in Table IV.5.2-B shows that 93 percent of silica exposures are at or below the 50 μg/m^3 PEL and 87 percent are below the action level of 25 μg/m^3. Therefore, OSHA concludes that most drywall finishers are currently at or below the PEL.

The preferred control for drywall finishers is the use of commercially available joint compounds that do not contain silica and therefore result in zero exposure. In the event that substitution is not practical, or during renovation work where silica-containing joint compound may be present, other available control options include ventilated sanders, wet methods, and pole sanders. Based on studies quantifying reductions in total dust levels when using ventilated sanders, OSHA estimates that the silica exposure of all drywall finishers can be reduced to levels at or below 50 μg/m^3 (Document ID 0800, p. 820; 1239, pp. 388-389). OSHA determined this estimate by reducing the highest drywall finisher reading summarized in Table IV.5.2-B (72 μg/m^3) by 80 percent, the minimum amount by which ventilated sanding equipment reduced respirable dust in the NIOSH study of drywall sanding techniques (Document ID 0213, p. iv). OSHA also concludes that the use of pole sanders and wet methods can reduce the silica exposure drywall finishers to levels at or below 50 µg/m^3 under circumstances when they offer a more convenient form of dust control. OSHA reached this conclusion by reducing the highest drywall finisher reading (72 µg/m^3) by 58 and 60 percent, the amounts by which pole sanding and wet methods, respectively, reduced total respirable dust (Document ID 1239, p. 388).

Accordingly, OSHA has determined that on the rare occasions when silica-containing joint compound might be encountered, exposures of less than 50 µg/m^3 can be achieved for most drywall finishers most of the time by using ventilated sanding equipment. Therefore, the standard is technologically feasible for the task of drywall finishing.

Removal of Drywall Finishers from Table 1

The entry on Table 1 for drywall finishers included in the proposed rule was removed in the final rule because drywall finishers can use drywall compound that does not contain silica, in which case, drywall finishing with silica-free substitutes would not be covered by the final rule. Sanding silica-free joint compound can potentially generate high levels of respirable nuisance dust that does not contain silica and for which respiratory protection may be needed in some situations. Therefore, OSHA removed the entry indicating that respiratory protection is not required when sanding drywall compound.

In the event that the use of silica-free joint compound is not possible, or during renovation work where silica-containing joint compound might be present, ventilated sanders, pole sanders, and wet sanding methods provide other available control options. Based on studies quantifying reductions in respirable dust levels when using ventilated sanders, OSHA concludes that the silica exposure of all drywall finishers can be effectively reduced to levels at or below the PEL (Document ID 0800; 0213; 1239) and therefore finds that the standard is technologically feasible for construction workers engaged in drywall finishing.

5.3 HEAVY EQUIPMENT OPERATORS AND GROUND CREW LABORERS

5.3.1 Description

Workers in this job category operate a variety of wheeled or tracked vehicles ranging in size from large heavy construction equipment (such as bulldozers, scrapers, loaders, cranes and road graders) to smaller and medium sized utility vehicles (such as tractors, bobcats and backhoes) with attached tools that are used to move, fracture, or abrade rock, soil, and demolition debris. Attachments can include augers, backhoes, buckets, hammers, hoe-rams, blades, draglines, rippers, scrapers, shovels, and trenchers (Document ID 1431, p. 3-34). In this section, OSHA analyzes both heavy equipment operators and the laborers who assist them; for both groups, exposures to respirable dust and respirable silica are expected to be fairly low. Operators generally spend most of their working time seated at some distance from the point of tool action. While larger heavy equipment has the potential to generate greater amounts of respirable dust, the operators of such equipment are typically positioned farther from the source of dust (at the point of tool action) than operators of smaller equipment. Dust control methods, primarily the use of water suppression, are similar across all types and sizes of equipment.

Table IV.5.3-A provides an overview of the tasks performed by heavy equipment operators, which include loading and dumping rock and soil, as well as demolition debris from concrete or masonry structures. When these materials contain crystalline silica, dust generated during these activities is a primary source of exposure for the equipment operators and for laborers working in the vicinity (see Exposure Profile, Table IV.5.3-B). Workers who operate heavy equipment typically spend most of their working time in an operator’s seat. In contrast, ground crew laborers may on occasion work in closer proximity to the point of tool action (Document ID 3589, Tr. 4185). Equipment and operations reviewed here do not include rock or concrete drilling rigs, rock crushers, asphalt or concrete milling machines, drivable saws, or tunnel boring machines; these types of equipment and operations are reviewed in other sections of the feasibility analysis.

5.3) Heavy Equipment Operators and Ground Crew Laborers

Table IV.5.3-A
Job Categories, Major Activities, and Sources of Exposure of Heavy Equipment Operators and Ground Crew Laborers

Job Category*	Major Activities and Sources of Exposure
Heavy Equipment Operator	From an operator's seat, manipulating tractor or vehicle-based implements (e.g., backhoe, crane, power shovel, excavator, hammer, dump truck) to perform activities such as excavation, loading, and dumping of rock, concrete, soil, and other construction materials and debris during earthmoving and demolition. • Dust from demolition activities, the breakdown of construction materials, and the transport of construction debris. • Dust from abrading or fracturing during rock and earthmoving activities (rock ripping, hoe-ramming) or from load transfer of silica-containing materials. • Fugitive dust from the movement of heavy equipment on silica-containing material (e.g., haul roads, work sites).
Ground Crew Laborer Assisting Heavy Equipment Operator	Working near heavy equipment supporting the heavy equipment operator (applying dust suppressant, spotting, clearing debris). • Dust from demolition activities, the breakdown of construction materials, and the transport of construction debris. • Dust from abrading or fracturing during rock and earthmoving activities (rock ripping, hoe-ramming). • Fugitive dust from the movement of heavy equipment on silica-containing material (e.g., haul roads, work sites).

*Job categories are intended to represent job functions; actual job titles might differ, and responsibilities might be allocated differently, depending on the site.
Sources: Document ID 1431, pp. 3-34--3-37; 1720, Table IV.C-53, p. IV-395; 3583, Tr. 2388, 2440; 3589, Tr. 4185.

In the PEA, OSHA did not distinguish between different kinds of work involving the use of heavy equipment. OSHA included all earthmoving work, as well as demolition work, within the category of "Heavy Equipment Operators." Furthermore, Table 1 of the proposed rule described these operations as "Use of Heavy Equipment During Earthmoving." Several commenters requested clarification on what uses of heavy equipment OSHA intended to cover by the entry on Table 1 in the proposed rule. The

International Union of Operating Engineers (IUOE) did not believe that earthmoving should be the focus, stating:

> [T]his activity does not fracture or abrade silica-containing materials, and thus, does not expose heavy equipment operators to high concentrations of respirable silica….There are earthmoving activities, such as "rock ripping," which fracture or abrade silica-containing materials (Document ID 2262, p. 6).

The IUOE's position was supported by Martin Turek, Assistant Coordinator and Safety Administrator for IUOE Local 150, who testified that "it is unlikely that moving soil or clay will generate respirable silica in concentrations … above the [proposed] PEL" (Document ID 3583, Tr. 2358). Brad Sant, Senior Vice President of Safety and Education at the American Road and Transportation Builders Association (ARTBA) also felt OSHA should differentiate between typical earth moving and moving concrete debris. He stated:

> So if you're doing blasting or something where you know you're breaking up the material, that's a high hazard area and that's someplace where you really need to pay attention. If you're moving dirt that's clay, that's not likely to have a lot of silica, that's something we could just set aside. And so you're really going to focus on the hazardous areas that are known hazards and deal with it in a little more thoughtful way (Document ID 3583, Tr. 2258-2259).

The IUOE recommended that the "standard make clear that earthmoving and demolition are not the same construction activity" (Document ID 2262, p. 15). They suggested that standard earthmoving activities, such as site clearance and road preparation, should be analyzed separately from demolition activity. They also recommended that OSHA target the standard to address heavy equipment operations that can rip or abrade soil or rock in such a way as to cause exposure to respirable silica dust. Examples of operations IUOE identified as potential sources of exposure to respirable silica dust include using a hoe-ram attachment on a backhoe to break up boulders into smaller rock, and ripping soil and rock when "a shank is attached to the back of a bulldozer and pulled through the ground." (Document ID 4234, IUOE Post Hearing Brief Part 1, pp. 10-11).

In their post hearing brief, IUOE recommended that OSHA adopt the following definition of earthmoving: "Earthmoving as used on Table 1 means an activity that fractures or abrades silica-containing materials in such a manner as to generate airborne concentrations of respirable silica at or above the action levels. Earthmoving does not include demolition or underground construction" (Document ID 4234, pp. 9-10). The director of Occupational Safety and Health for the Laborer's Health and Safety Fund of North America agreed with IUOE. He testified that the Agency should reconsider how demolition is treated in Table 1, stating that "Demolition, by its nature, involves the crushing of construction materials which contain silica" (Document ID 3589, Tr. 4185). ARTBA also agreed with IUOE that the material being moved can be a more important consideration than the operation itself:

> You can be moving huge amounts of material in an earthmoving operation where there is very little silica content and have very little exposures. Where on the opposite end, you could be moving crushed granite or something like that that has a very high [silica] content …where exposures can be high (Document ID 3583, Tr. 2256).

In response to these comments and testimony, OSHA agrees that it is appropriate to separate demolition and other activities that abrade or fracture silica-containing material from other earthmoving tasks, such as site preparation and road development, which involve, but do not abrade or fracture, silica-containing material. OSHA has restructured its exposure profile and technological feasibility analysis accordingly.

5.3.2 Exposure Profile and Baseline Conditions

The exposure profile presented in the PEA included 24 full-shift time-weighted average (TWA) personal breathing zone (PBZ) respirable quartz readings. These sampling results were obtained from four NIOSH reports, five OSHA Special Emphasis Program (SEP) inspection reports, and one journal article (Document ID 1431, p. 3-34). In response to comments, the exposure profile in the FEA was reorganized and updated with four samples obtained from the OSHA Information System (OIS) (Document ID 3958) and eleven samples from three studies submitted by a commenter (Document ID 4073, Attachments 9a, 10a, and 10c). After close review of the samples used in PEA exposure profile, four samples were removed: one sample for a loader operator loading earth into trucks underground since it was taken during tunnel development; one sample for a crane operator lifting and placing new construction materials in support of the drilling rig since it did not involve handling materials containing silica; and two samples for water truck drivers supporting a walk-behind masonry saw because they did involve the operation of heavy equipment. (Document ID 0192; 0226; 1431).

The final exposure profile in Table IV.5.3-B includes 35 samples of respirable crystalline silica for heavy equipment operators. The median is 12 μg/m^3, the mean is 26 μg/m^3, and the range is 4 μg/m^3 to 170 μg/m^3. Of the 35 samples, 3 of the samples (8.6 percent) are above 50 μg/m^3.

The new data from the OIS include exposure measurements taken on three different demolition sites. All three demolition sites used wet methods. A backhoe operator who was demolishing concrete inside a large garage had a TWA exposure of 43 μg/m^3, and the laborer assisting the backhoe operator had no detectable silica exposure. A sample for an operator of a hoe-ram, which was being used to break-up concrete slabs, showed a TWA exposure of 49 μg/m^3. No detectable silica exposures were found for an operator using a skid steer to move demolition debris and an excavator to load the debris in a truck (Document ID 3958). These four sample results were added to the exposure profile.

Four personal air samples added to the exposure profile were collected during an evaluation of employees' exposures to respirable silica dust during the demolition and processing of a concrete foundation (Document ID 4073, Attachment 10a, p. 7). Two heavy equipment operators (one using an excavator to demolish a concrete foundation and load the debris into a truck and another who fed the transported material to a mobile crusher using a loader) were assessed over two days. Only one of the four personal air samples measured a respirable crystalline silica concentration above the limit of detection (15.0 μg/m^3) (Document ID 4073, Attachment 10a, pp. 9-12). The evaluation report did not mention dust control methods other than the appropriate use of respirators.

Another two personal air samples added to the exposure profile were collected during a separate evaluation of employees' exposures to respirable silica dust at the same site

(Document ID 4073, Attachment 10c, p. 7). One sample was collected for a loader operator loading concrete debris into a pulverizing machine. The loader was equipped with a sealed cabin with filtered air. No respirable crystalline silica was detected. The other sample was collected for a bobcat operator who pushed and layered pulverized concrete by dragging a steel beam across the area until the material was level. Water was applied to the pulverized material to limit dust emission. Respirable crystalline silica was detected in the Bobcat operator's sample, but it was below 12.0 μg/m^3.

Three personal air samples added to the exposure profile were collected during a study to characterize workers' exposures to respirable silica during demolition, as well as to evaluate the efficacy of dust suppression methods for reducing dust exposures at two demolition sites (Document ID 4073, Attachment 9a, p. 3). Two laborers applied water, using hoses near the excavators, to suppress dust. Another held a hose on a fire truck. Water atomizing spraying systems designed to suppress dust after it becomes airborne were used on site. Results showed two of the laborers exposed below 12.0 μg/m^3. For the third laborer, the study reported a respirable crystalline silica exposure of 31.0 μg/m^3.

Two additional personal air samples were added to the exposure profile for employees engaged in work directly related to heavy equipment operation during demolition tasks. Two of the samples are from a survey report on the demolition of plaster ceilings. One laborer assisted a skid-steer loader operator by spraying water on the debris (including plaster ceiling) with water. The other laborer assisted a track-hoe operator by spraying water on the ceiling and debris as the plaster ceiling was pulled down. Their estimated 8-hour TWA exposures were 37 and 49 μg/m^3, respectively (Document ID 0858, pp. iv, 7). This group of employees (engaged in work directly related to heavy equipment) is supplemented by a personal air sample already mentioned above in the description of OIS data added to the exposure profile. This laborer experienced no detectable silica exposure while spraying water on debris as an assistant to a backhoe operator demolishing concrete inside a large garage (Document ID 3958).

As previously discussed, the exposure profile divides the tasks performed by heavy equipment operators and their laborers/assistants into two types: 1) demolition and activities that fracture or abrade crystalline silica-containing material; and 2) non-abrading or non-fracturing earthwork, such as excavation and load transfer of silica-containing materials. OSHA considers employees to be engaged in a given type of task if they are either operating the equipment to perform the task or assisting the heavy equipment operator who is performing the task. Assisting includes, but is not limited to, applying wet dust controls, spotting, and maintaining a safe work space.

Based on the exposure profile presented in Table IV.5.3-B, OSHA estimates that 91 percent of heavy equipment operators and the laborers who assist them have respirable crystalline silica exposures at or below the PEL of 50 μg/m^3. Heavy equipment operators spend most of their working time seated at some distance from the dust source, and their work is usually done outdoors in open spaces under various weather conditions. Heavy equipment operators are typically seated 2-3 meters above the point of dust generation (Document ID 3998, Attachment 5b 5, p. 120). The exposure profile shows that 92 percent of equipment operators performing demolition or fracturing or abrading of silica-containing materials are exposed at or below 50 μg/m^3, and 88 percent of heavy equipment operators not involved with the demolition or fracturing or abrading of silica-containing materials are exposed at or below 50 μg/m^3. Also, according to the exposure profile, laborers who assist heavy equipment operators during demolition all have exposures at or below 50 μg/m^3. The exposure profile contains no information specific to ground crew laborers assisting heavy equipment operators performing non-abrading or non-fracturing earthwork (excavating, grading, load transferring). Heavy equipment operators performing these tasks usually do not need direct assistance from laborers. Occasionally, these heavy equipment operators will need assistance, such as spotting or grubbing. Workers who are not operating the heavy equipment, and workers who are performing jobs nearby, may be called on to help and may be exposed to fugitive dust in the process (Document ID 3998, Attachment 13q 13, p. 1; 2116, p. 17). It is likely that these laborers spend most of their shifts performing activities that are covered by other sections of OSHA's technological feasibility analysis (e.g., jackhammering).

Demolition and rock and earthwork activities that fracture or abrade crystalline silica-containing material involve machines equipped with augers, backhoes, buckets, hammers, hoe-rams, blades, draglines, rippers, and trenchers (Document ID 1431, p. 3-34). Demolition occurs mostly outdoors; however, in some cases, smaller to medium-size heavy equipment (such as track-hoes or bobcats) can be operated inside buildings or other structures. Restricted air movement in an enclosed area can result in the accumulation of airborne dust and an increased potential for high exposures in poorly ventilated spaces. The exposure profile contains several measurements associated with demolition conducted inside buildings. The demolition of roads and building infrastructure involves the breaking, chipping, and crushing of silica-containing material; these are inherently dusty operations that are typically conducted outdoors.

Much non-silica-abrading and non-silica-fracturing earthmoving involves machine excavation and fill or backfill. Typical earthmoving activities in this category involve roads, causeways, dams, levees, canals, and berms. Tasks include land grading to reconfigure the topography of a site or to stabilize slopes; roadway excavation; and stripping or clearing excess earth for site preparation. Significant atmospheric dust arises from the mechanical disturbance of granular material. Dust generated from these open sources is termed "fugitive" because it is not discharged to the atmosphere in a confined flow stream. Common sources of fugitive dust include unpaved roads, aggregate storage piles, and heavy construction operations. For these sources of fugitive dust, the dust is generated by two basic physical phenomena: 1) pulverization and abrasion of surface materials by application of mechanical force through implements (tracks, blades, etc.); and 2) entrainment of dust particles by the action of turbulent air currents, such as wind erosion of an exposed surface. Emissions will vary depending on: the characteristics of the material being disturbed (such as moisture content, particle sizes, and weight); the nature of the loading and removal activity; dust control procedures; and wind (Document ID 3637, pp. 3-10, 3-11).

A representative of Fann Contracting, Inc., a company that performs highway construction projects primarily in northern and eastern Arizona, stated:

> Exposure to potential silica containing dust from construction in Arizona is much greater than potential exposure to silica containing dust in Missouri or Oregon or Alaska due to soil characteristics and

> environmental conditions, along with the proposed rule lumping maritime and general industry indoor industries with outdoor construction activities, yet OSHA is trying to draft a nationwide rule that one size fits all but there are too many weather and environmental variables across the entire United States to take into account (Document ID 2116, p. 3).

While there is regional variation in climate and the silica content of the soil, the commenter provided no evidence that would allow OSHA to assess the potential effects of regional differences on silica exposures among heavy equipment operators and laborers. OSHA recognizes that environmental conditions may impact the amount of water required to suppress dust in a given situation and expects employers to account for variation by adjusting the amount of water used or the frequency of water applications. Water used as a dust suppressant has little residual effect on some types of soil, roads, or work sites and may need to be re-applied at the dust source. Applying a mixture of water and surfactants or salts provides better fugitive dust control for some locations (Document ID 0548, pp. 1, 2; 1540, pp. 253, 254; 0933, pp. 56, 57).

Table IV.5.3-B shows that approximately 7.7 percent of operators, and no laborers, involved in demolition, abrading or fracturing activities have exposures exceeding 50 $\mu g/m^3$ (N=19). Roughly 12 percent of operators involved in non-abrading and non-fracturing earthwork have exposures above that level (N=16). Although the median (12 $\mu g/m^3$) and mean (26 and 25 $\mu g/m^3$, respectively) exposures are similar for demolition, abrading and fracturing operators and for operators performing non-abrading and non-fracturing earthwork, the latter have a wider range of exposures (maximum result of 170 $\mu g/m^3$).

OSHA notes that the air sampling data in the profile reflect low exposures associated with the use of wet methods or the extensive use of calcium chloride. The data for demolition, abrading, and fracturing operators and laborers includes nineteen samples taken at ten sites. Two sites did not use wet methods to suppress dust, while eight sites used wet methods (and one of those eight sites used a sealed cab in addition to wet methods) (Document ID 3958, Rows 5, 16; 0228, pp. 5, 9; 0858, pp. 6-7; 0226, p. 11; 0170, p. 12; 4073, Attachment 10a, p. 7).

The data for non-abrading and non-fracturing earthmoving tasks includes sixteen samples taken at eight sites; nine of those samples (56 percent) were taken when water or calcium chloride were used for dust suppression. One heavy equipment operator used a sealed cab at a site without water suppression (Document ID 3958, Row 954; 0226, p. 11; 0228, p. 9; 0133, p. 17; 0716, p. 16; 4073, Attachment 10c, p. 7).

Authors drawing on data from a variety of sources have reported slightly higher exposure levels for heavy equipment operators than what is reported in the exposure profile; however, their data sets included operators of particularly dusty equipment that OSHA addresses in other sections of this technological feasibility analysis (see Sections IV-5.8 – Millers Using Portable or Mobile Machines, IV-5.9 – Rock and Concrete Drillers, and IV-5.10 – Mobile Rock-Crushing Machine Operators and Tenders) (Document ID 3998, Attachment 5b 5, pp. 112, 117).

Working with a large set of construction data, Flanagan et al. (2006) reported a geometric mean silica exposure of 50 μg/m^3 for 102 workers operating many types of heavy equipment (Document ID 0677, p. 147; 0677, Attachment 2). For the 45 measurements that were associated with the specific task of demolition, the geometric mean was lower, at 30 μg/m^3. Thirty measurements taken for workers specifically operating backhoes, excavators, bulldozers and bobcats for demolition, road work, tunnel, and other industrial operations tended to be even lower, with a geometric mean of 10 μg/m^3; this was the lowest result reported among the various construction tool or equipment categories evaluated. As noted by CISC, the authors did not provide detailed information about controls or sample durations (Document ID 2319, pp. 41-42). However, the authors did report that the median sample time for the entire construction database was 219 minutes. These results, which were not expressed as 8-hour TWA values, confirm that many heavy equipment operators already experience silica exposure levels of 50 μg/m^3 or below (Document ID 0677, pp. 146-147). As compared to workers performing many other types of construction activities, heavy equipment operators are more often engaged in tasks lasting more than four hours. Of the 23 samples in the exposure profile for which the sample duration was available, 19 (83 percent) exceeded 240 minutes;, the median sample duration was 469 minutes (Document ID 0133, pp. 9, 11, 12, 14, 15, 17; 0170, pp.

11, 12, 13; 0226, p. 11; 0228, pp. 9, 15; 0716, pp. 16, 56; 0858, p. 7; 1431, pp. 3-34, 3-37; 3958, Rows 5, 16, 237; 4073, Attachment 9a, p. 3; 4073, Attachment 10a, p. 7; 4073, Attachment 10c, p. 5, 7).

OSHA reviewed several studies received during the comment period indicating that demolition conducted by heavy equipment operators typically results in TWA exposures at or below 50 μg/m^3. Bello and Woskie (2014) measured exposures for an excavator operator during demolition; the operator's exposures ranged from 9 to 13 μg/m^3 (Document ID 4073, Attachment 9a, p. 3). A study of silica exposures among Canadian construction workers reported average exposures of 30 μg/m^3 for heavy equipment operators during demolition (Document ID 3747, p. 8). The same authors reported that eight 12-hour TWA silica exposures on operators of heavy equipment during "earthmoving" operations ranged from less than 7 to 29 μg/m^3 (Document ID 3747, p. 79).

Baseline operating conditions for heavy equipment operators engaged in demolition or fracturing or abrading silica-containing materials are operating heavy equipment without a sealed cab using water as a dust suppressant. The majority (92 percent) of silica exposures for these workers in OSHA's exposure profile are less than or equal to 50 μg/m^3 (Document ID 0133, pp. 9, 11, 12, 14, 15, 17; 0170, pp. 11, 12, 13; 0226, p. 11; 0228, pp. 9, 15; 0716, pp. 16, 56; 0858, p. 7; 1431, pp. 3-34, 3-37; 3958, Rows 5, 16, 237; 4073, Attachment 9a, p. 3; 4073, Attachment 10a, p. 7; 4073, Attachment 10c, pp. 5, 7). One of the three samples in the profile involving heavy equipment operators using only water as a dust suppressant during demolition activities shows exposures above 50 μg/m^3 (see Table 26-OL).

Baseline operating conditions for laborers engaged in demolition or tasks involving abrading or fracturing silica-containing material involve using water and/or calcium chloride as a dust suppressant. For the samples included in the exposure profile, the use of a dust suppressant was indicated for all laborers engaged in tasks using heavy equipment (Document ID 3958, Row 5; 0858, p. 7; 4073, Attachment 9a, p. 3). Exposures for these employees were at or below 50 μg/m^3.

5.3) Heavy Equipment Operators and Ground Crew Laborers

Baseline operating conditions for heavy equipment operators not abrading or fracturing silica-containing material are operating heavy equipment with a cab with the windows or doors open. Use of dust suppressants (water or calcium chloride) to minimize dust was indicated for just over half of the samples (9 out of 16). The majority (88 percent) of silica exposures for these workers in OSHA's exposure profile are less than or equal to 50 μg/m^3. The use of dust suppressants appears to provide protection, as the majority of heavy equipment operators performing these tasks had exposures below 25 μg/m^3 (Document ID 1431, pp. 3-34, 3-37; 3958, Row 237; 0133, pp. 9, 11, 12, 14, 15, 17; 0226, p. 11; 0228, p. 9; 0716, pp. 16, 56; 4073, Attachment 10c, pp. 5, 7).

OSHA found (above in this subsection) that ground crew laborers or workers assisting heavy equipment operators excavating, grading, or load transferring have little potential for direct exposure to silica. Water is frequently applied to work sites for dust suppression and to aid in soil compaction decreasing the risk to employees not assigned to specific tasks (Document ID 3747, p. 126; 1533, p. 57; 2116, p. 31). Where the application of dust suppressants is not sufficient, laborers could be exposed to large amounts of respirable dust (e.g., while surveying, performing maintenance, or flagging). At an earthworks work site in Alberta, Canada, large dust plumes were observed generated by heavy equipment where workers were nearby (Document ID 3747, pp. 61, 82-84).

Phillip Rice from Fann Contractors, Inc., stated that EPA (or in Arizona the Arizona Department of Environmental Quality or ADEQ) rules and regulations requires the use of water spray systems to be installed and operated continuously on all material transfer point locations, using water spray or equivalent on haul roads, and where mobile equipment operate around a crusher to keep dust down. He noted that the water does help keep the dust down if used as required (Document ID 2116, p. 31). OSHA believes that when dust is controlled at the source, such as applying water during earthmoving activities and on haul roads, laborers and bystanders are not exposed above 50 μg/m^3.

Table IV.5.3-B
Personal Respirable Crystalline Silica Exposure Range and Distribution of Results for Construction Workers: Heavy Equipment Operators and Ground Crew Laborers

	Exposure Summary			Exposure Range			Exposure Profile				
Heavy Equipment Tasks	**N**	**Mean (μg/m³)**	**Median (μg/m³)**	**Min (μg/m³)**	**Max (μg/m³)**		**< 25 (μg/m³)**	**≥ 25 and ≤ 50 (μg/m³)**	**> 50 and ≤ 100 (μg/m³)**	**> 100 and ≤ 250 (μg/m³)**	**> 250 (μg/m³)**
Demolition/Abrading/Fracturing Equipment Operator	13	26	12	11	87		9 (69.2%)	3 (23.1%)	1 (7.7%)	0 (0%)	0 (0%)
Demolition Laborer	6	25	22	8	49		3 (50%)	3 (50%)	0 (0%)	0 (0%)	0 (0%)
Excavating/Grading/Load Transfer Equipment Operator	16	25	12	4	170		14 (87.5%)	0 (0%)	1 (6.2%)	1 (6.2%)	0 (0%)
Heavy Equipment Operators Total	**35**	**26**	**12**	**4**	**170**		**26 (74.3%)**	**6 (17.1%)**	**2 (5.7%)**	**1 (2.9%)**	**0 (0%)**

Notes: All samples are personal breathing zone (PBZ) results and represent 8-hour time-weighted average exposures.
Job categories are intended to represent job functions; actual job titles might differ, and responsibilities might be allocated differently, depending on the site.
Percentages may not add to 100 percent due to rounding.

Sources: Document ID 0133, pp. 9, 11, 12, 14, 15, 17; 0170, pp. 11, 12, 13; 0226, p. 11; 0228, pp. 9, 15; 0716, pp. 16, 56; 0858, p. 7; 1431, pp. 3-34, 3-37; 3958, Rows 5, 16, 237; 4073, Attachment 9a, p. 3; 4073, Attachment 10a, p. 7; 4073, Attachment 10c, p. 5, 7.

Table IV.5.3-C compares silica exposures among heavy equipment operators with the silica exposures of laborers engaged in the same task. This data is a subset of the exposure profile (Table IV.5.3-B). In each instance listed, the laborer provided water for dust control during demolition activities. The heavy equipment operators' exposures are higher than the laborers' exposures except when the operator is in a sealed cab.

Table IV.5.3-C
Comparison of Exposures Between Heavy Equipment Operators and Assisting Laborers

	8-Hour TWA RCS, µg/m³				
Heavy Equipment	**Operator**	**Laborer**	**Laborer Task**	**Controls**	**Silica Containing Material**
Backhoe	43.3	12.0	Spraying water on debris.	Water	Concrete
Excavator	87.0	49.0	Spraying water on debris	Water	Plaster
Bobcat	49.0	37.0	Spraying water on debris	Water	Plaster
Excavator	Less than 9	31.0	Holding hose	Water/Sealed Cab-Operator	Brick Building
Excavator	Less than 9	12.0	Holding hose	Water/Sealed Cab-Operator	Brick Building
Excavator	Less than 9	8.0	Holding hose	Water/Sealed Cab-Operator	Brick Building
Sources: Document ID 3958, Row 5; 0858, p. 7; 4073, Attachment 9a, p. 3.					

5.3.3 Additional Controls

The exposure profile in Table IV.5.3-B shows that approximately 9 percent (3 out of 35 samples) of heavy equipment operators have exposures above the final PEL of 50 µg/m^3. Therefore, OSHA finds that the additional controls described below will be necessary to achieve the PEL for these overexposed workers.

Enclosed Cabs

In situations where heavy equipment operators have elevated exposures to respirable crystalline silica during the demolition and fracturing or abrading of silica-containing materials, a properly ventilated enclosed cab under positive pressure with filtered air can be used to reduce exposures. Rappaport et al. (2003) reported an 85 percent reduction in exposures among heavy equipment operators performing highway construction activities in enclosed cabs as compared to operators in open cabs (10 μg/m^3 versus 65 μg/m^3) (Document ID 3998, Attachment 5b 5, pp. 119-120). Maintaining cabs in good operating condition is a part of reducing operator exposures to respirable dust. NIOSH has reported that studies show properly maintained cabs can attain dust reductions of between 44 and 100 percent for dozers (Document ID 1540, p. 258).

Pannell and Grogin (2000) reported that pressurized, enclosed cabs without high-efficiency filtration can provide a high degree of protection for operators performing excavation work where the silica content of the soil is unusually high (Document ID 0952, pp. 14, 16). For 44 samples obtained for workers operating a water wagon or a scraper with pressurized, enclosed cabs not equipped with high-efficiency filtration, the investigators reported mean respirable dust results of 72 μg/m^3 for each group (over sampling periods of 4- to 5-hours) (Document ID 0952, p. 15). These respirable dust values were roughly 80 to 90 percent lower than the results obtained for operators of open-cab equipment, who had mean respirable dust exposures of 426 μg/m^3 (four results for grader operators), 672 μg/m^3 (40 results for dozer operators), and 837 μg/m^3 (10 results for workers operating a second dozer) (Document ID 0952, p. 15). Respirable dust samples collected inside and outside a scraper showed that the pressurized, enclosed cab reduced the operator’s exposure by nearly 90 percent (Document ID 0952, p. 16). The project in this study involved constructing a solid low-level radioactive waste disposal facility, which was unusual in that the 64,000 cubic meters of soil that was excavated contained up to 65 percent silica in a semi-arid environment, creating unusually high respirable silica exposures. The authors recommended the following actions, among others, to minimize exposures: (1) use equipment furnished with environmentally controlled pressurized cabs; (2) use water spays for dust suppression; and (3) regularly clean cab interiors to prevent re-suspension of tracked-in dust (Document ID 0952, p. 17).

NIOSH has recommended several design and operational features for cabs in order to minimize operators' exposures to respirable dust during construction activities (Document ID 0839, pp. 2-3). The NIOSH recommendations are as follows:

- Cabs should be equipped with a recirculation filter that continuously filters the air circulating within the cab to eliminate dust that has entered the cab (e.g., on shoes, or through an open door);
- The inlet for intake air should be strategically located so that it avoids, as much as possible, the equipment's major dust sources. Typically, this means high above ground level;
- Cabs should avoid the use of floor heaters or any discharge of clean air low in the cab, which entrains dust from the floor and dirty work clothes before entering the worker's breathing zone. Ideally, air flow would circulate from the top of the cab to the bottom, and recirculation pick-up would occur low in the cab; and
- Cabs must be well maintained and kept clean. Filters must be changed regularly so that they do not become overloaded with dust, and seals must be maintained to preserve pressurization inside the cab. A gritless, natural base sweeping compound should be applied to the floor of the cab to bind dirt and dust tracked in during normal work activities. The compound should also be used for regular housekeeping activities (Document ID 0839, pp. 2-3; 1540, p. 233).

CISC commented that OSHA's reliance on two samples for enclosed cabs and 17 samples for unenclosed cabs in the PEA was insufficient to assess the exposures of heavy equipment operators who work all across the country in widely varying environments. In addition, CISC noted that the study by Pannel and Grogin, described above, did not analyze pressurized cabs with high-efficiency filtration (Document ID 2319, pp. 41-42). In addition to the data in OSHA's exposure profile, the research shows that enclosed cabs are effective in greatly reducing silica exposures among heavy equipment operators (Document ID 3998, Attachment 5b 5, pp. 119-120; 0952, pp. 14, 16). Table IV.5.3-C also shows that heavy equipment operators' exposures exceeded the exposures of their assisting laborers except for when the operators were in enclosed cabs. In response to CISC's comment about the lack of literature on high-efficiency filtration, OSHA has removed the requirement for high-efficiency filtration from the regulatory text and now only requires 95 percent efficiency.

In its post-hearing submission, IUOE identified several companies that retrofit enclosed cabs or manufacture equipment used for air filtration and pressurization, including Sy-Klone, Clean Air Filters Company, Red Dot Corporation, Polar Mobility Research Ltd., and MI Air Systems (Document ID 4025, p. 11).

Use of Wet Methods or other Dust Suppressants

The application of water has been shown to be effective in controlling dust containing respirable crystalline silica (Document ID 4073, Attachment 8e, pp. 14-15; 0839, p. 2; 1540, p. 61; 1533, pp. 56-60). Tank trucks equipped with hoses and nozzles can provide water or other dust suppressants during earthmoving tasks that cover large areas, haul roads, and job sites in general. In addition, in many instances, laborers assist heavy equipment operators by applying water or other types of dust suppressants to material being demolished, abraded, or fractured.

In one instance, a heavy equipment operator with an exposure concentration of 87 $\mu g/m^3$ was using a track-hoe without an enclosed cab, indoors on the ninth floor of a building, pulling down plaster ceiling. The laborer assisting the operator sprayed the ceiling with water as it was pulled down. This laborer's exposure was below 50 $\mu g/m^3$ (Document ID 0858, p. 7).

Use of water or other dust suppressants during the operation of heavy equipment can address exposures among bystanders, such as employees who do not operate the heavy equipment or who are performing jobs nearby at the site (Document ID 3998, Attachment 13q 13, p. 1).

Water mist can be delivered to points where silica-containing material is being disturbed by water truck and manual spraying, or by large atomized misting devices (e.g., by Dust Boss or Buffalo Turbine) that permit water mist to be delivered from farther distances (Document ID 4234, Attachment 4, p. 2; 4073, Attachment 4a). In some cases, dust suppressants have been applied using spray equipment attached directly to the tool on a large excavator (Document ID 1217, pp. 6, 11, 12). A study by Addo and Sanders (1995) offers support for the effectiveness of dust suppressants. The study examined three chemical dust suppressants (lignosulfate, calcium chloride, and magnesium chloride) applied to an unpaved roadway for four and a half months and found that, compared to an untreated roadway, the suppressants reduced fugitive dust emissions by 50 to 70 percent (Document ID 1533, p. 63).

NIOSH described several test results of watering haul roads with control efficiency ranging from 40 percent to 95 percent. The control efficiency for water can be highly variable as it is dependent upon the frequency of the water application, the type of road material in question, traffic, and weather conditions (Document ID 1540, p. 252). In a report on the characteristics of fugitive dust generated from unpaved mine haulage roads (Organiscak and Reed), the authors found that “road wetting was very effective in suppressing the respirable dust generated by the haulage trucks” (Document ID 4073, Attachment 8e, p. 15). The most common method of haul road dust control is surface wetting with plain water, but other methods include adding hygroscopic salts, surfactants, soil cements, bitumens, and films (polymers) to the road surface (Document ID: 1539, p. 69). Road material used for unpaved mine haulage roads are similar to unpaved haulage or construction roads. Dust controls such as wet methods can therefore be applied similarly to minimize exposures to haulage road fugitive dust.

Several hearing participants addressed the effectiveness of wet methods and other dust suppressants. In most situations where dust is present, utility excavators are already requiring the use of wet methods, and in some situations respirators, to control dust exposures, and these control methods appear to be working (Document 3583, Tr. 2241). A representative of the National Rural Electric Cooperative Association (NRECA) stated that use of wet boring methods plus enclosed-cab excavators results in no detectable respirable crystalline silica exposures for employees performing excavation work (Document ID 3583, Tr. 2277). Kyle Zimmer, a representative of IUOE Local 478, testified that calcium chloride is regularly used as a dust suppressant during site work in cold weather because chloride compounds lower the freezing point of water (Document ID 3583, Tr. 2342). He also testified that the variables that affect silica concentrations are often highly predictable and that a competent person can adjust controls to adapt to changing conditions (Document ID 3583, Tr. 2351).

As demonstrated by OSHA's exposure profile data and the other evidence in the record, dust suppression methods (such as wet methods) are a commonly used and effective means for reducing exposures among heavy equipment operators and laborers to 50 μg/m^3 or below.

5.3.4 Feasibility Finding

Table 1 of the final rule for construction requires employers to use specified engineering controls with heavy equipment unless the employer assesses and limits exposures in accordance with paragraph (d). With respect to heavy equipment used in demolition or the abrading or fracturing of silica-containing material, Table 1 provides that when only one employee is engaged in the task, the operator must be in an enclosed cab or when other employees are engaged in the task, the operator must be in an enclosed cab and the employer must ensure that water and/or dust suppressants are applied as necessary to minimize dust emissions. For heavy equipment used for earthmoving tasks involving silica-containing material that do not involve demolition or abrading or fracturing (including excavating, grading, and load transfer), Table 1 provides that when only one employee is engaged in the task, the operator must be in an enclosed cab or the employer must ensure water or dust suppressants are applied as necessary to minimize dust emission or when other employees are engaged in the task, the employer must ensure that water and/or dust suppressants are applied as necessary to minimize dust emissions, in which case there is no requirement for an enclosed cab. The evidence presented in this section shows that use of the specified dust control systems result in greatly reduced worker exposures to respirable crystalline silica. As discussed above, water use for dust control is widely practiced where heavy equipment is used for demolition and other earthmoving operations, and environmentally controlled cabs are readily available on new equipment and can be retrofitted on existing equipment.

Feasibility Finding for Demolition and Abrading or Fracturing Silica-containing Materials

Enclosed cabs and the application of dust suppressants have been demonstrated to be effective means for reducing exposures in heavy equipment operators during demolition or tasks involving the abrading or fracturing of silica-containing materials.

OSHA finds that the use of an enclosed cab can effectively keep exposures to 50 μg/m^3 or below for heavy equipment operators. When laborers are present, the use of wet methods or other dust suppressants will keep exposures at or below 50 μg/m^3 most of the time.

OSHA concludes that most heavy equipment operators and laborers engaged in the demolition, abrading, or fracturing of silica-containing materials are currently exposed to silica levels at or below 50 μg/m^3. (12 of 13 samples in the exposure profile for heavy equipment operators, and all 6 samples for laborers doing demolition activities, were 50 μg/m^3 or below.) For workers who are currently exposed above 50 μg/m^3, the controls described in this section can be implemented to reduce silica exposure levels to 50 μg/m^3 or below in most operations, most of the time. Therefore, OSHA finds that the standard is technologically feasible for workers doing this work.

Feasibility for Earthmoving Activities Involving Silica-containing Materials other than Demolition or Fracturing or Abrading

OSHA concludes that most heavy equipment operators doing earthmoving work involving silica-containing material (other than demolition, fracturing, or abrading), are currently exposed to silica levels below 50 μg/m^3. (For heavy equipment operators involved in earthmoving tasks such as excavation, grading, and site preparation, 14 of the 16 sample results in the exposure profile are below 25 μg/m^3.) For workers who are currently exposed above 50 μg/m^3, the controls described in this section can be implemented to reduce silica exposure levels to 50 μg/m^3 or below in most operations, most of the time. Therefore, OSHA finds that the standard is technologically feasible for workers doing this work.

5.4 HOLE DRILLERS USING HANDHELD OR STAND-MOUNTED DRILLS

5.4.1 Description

This section covers workers in the construction industry who use handheld drills to create clearly defined holes for attachments (e.g., anchors, bolts, hangers) or for small openings for utility pass-throughs in concrete and other silica-containing construction materials. Workers use common electric drills, pneumatic drills, handheld core drills, stand-mounted drills, rotary drills, rotary hammers, percussion hammer drills, or other impact drills to drill holes.[173] The portability and light weight of handheld drills allow workers to operate them at any angle. For practical reasons, drillers often must remove the dust and debris that build up in the bottom of the hole. Occasionally, hole drillers use compressed air to blow dust from holes (Document ID 1391, pp. 24, 33). Workers also often dry sweep the work area. A worker operating a common drill and a rotary bit may employ a technique known as pecking, in which the operator removes the drill briefly from the hole and continues to run the drill to allow the accumulated chips and dust to fly off the rotating bit (Document ID 1431, p. 3-39). At least one gas-powered drill includes a self-cleaning design to clear the hole of dust by continuously forcing air through the chuck and drill shank (Document ID 1253, p. 1). Drilling may be performed only briefly or intermittently or might be done continuously during the work shift (Document ID 1431, p. 3-39). Handheld drills can be mounted on stands or rigs, for example when drilling overhead, to improve precision and/or to allow the operator to use the drill without having to support its weight (Document ID 4073, Attachment 7b, p. 1).

[173] As proposed, Table 1 had separate entries for “Rotary Hammers or Drills” and “Jackhammers and Other Impact Drillers.” OSHA received comments from Thethe Power Tool Institute suggesting that impact drills be covered by the entry for “Rotary Hammers or Drills,” rather than by the “Jackhammers and Other Impact Tools” entry (Document ID 1973, Attachment 1, p. 4). NIOSH also commented on the potential for confusion, noting that a rotary hammer or drill is technically an impact driller (Document ID 2177, Attachment B, pp. 32-33). Therefore, the entry for handheld or stand-mounted drills in final Table 1 covers activities related to the use of impact and rotary hammer drills. Chipping and breaking activities, which are associated with more intense silica exposures, are covered by the entry for jackhammers and handheld power chipping tools.

This section does not address impact tools used to perform chipping or breaking activities, which are addressed in Section IV-5.5 – Jackhammers and Other Powered Handheld Chipping Tools. In regards to core drills, only small, handheld core drills with bits up to a few inches in diameter are covered by this section. This section does not address the use of portable and mobile hole saws used to produce large holes or openings. That equipment is discussed in Section IV-5.6 – Masonry and Concrete Cutters Using Portable Saws.

Table IV.5.4-A summarizes the job categories, major activities, and primary sources of silica exposure for workers in this industry.

Table IV.5.4-A
Job Categories, Major Activities, and Sources of Exposure of Hole Drillers Using Handheld or Stand-Mounted Drills

Job Category*	Major Activities and Sources of Exposure
Hole Driller	Create pilot holes; drill holes for attachments (e.g., anchors, bolts, hangers) or for openings to assist in lifting slabs; drill small diameter holes for access through walls and other structures. • Dust from action of drill bit. • Dust raised by sweeping, brushing, and/or using compressed air to clear holes (including housekeeping).

*Job categories are intended to represent job functions; actual job titles might differ, and responsibilities might be allocated differently, depending on the site.
Sources: Document ID 1431, pp. 3-39-3-40; 1253, p. 1.

5.4.2 Exposure Profile and Baseline Conditions

In the PEA, OSHA reviewed 14 sample results associated with handheld hole drilling activities. These samples were collected in settings that included work in multilevel structures, on a bridge, and during outdoor rock drilling operations. These sample results were extracted from three NIOSH reports, one OSHA Special Emphasis Program (SEP) inspection report, and two published articles (Document ID 0229, pp. 9, 12; 1253, p. 7; 0847, pp. 5-6; 0155, pp. 74-76, 88-89; 1423, p. 833; 0798, p. 77).

Three samples presented in the preliminary exposure profile for “jackhammers and impact drillers” have been moved from that section to the final exposure profile for hole drillers because they are associated with drilling that more closely aligns with the task description for hole drillers. Two of those 3 samples were taken when workers were drilling holes in a concrete bridge pier with a drill hammer. The results of those 2 samples were both below the limit of detection (LOD) (Document ID 0138, pp. 10-19). The third sample, with a result of 118 μg/m^3, involved air drilling holes into concrete to install rebar (Document ID 0019, pp. 50-52).

OSHA has supplemented the samples from the PEA with 4 sample results submitted to the rulemaking record from OSHA's Information System (OIS) database. Three of the 4 OIS samples had results below the LOD of 12 μg/m^3 (Document ID 3958, Rows 806, 825, 828). Work activities in these three OIS inspections were described as a worker drilling holes on an interstate median; a sheet metal worker (employed by a plumbing or HVAC contractor) drilling to hang units (OSHA assumes the worker was hanging units indoors) with no exposure controls used; and a carpenter drilling a concrete structure outdoors to install concrete forms, with no controls indicated. The fourth OIS hole driller sample was for a worker described as air drilling on an interstate median, with an exposure result of 128 μg/m^3 (Document ID 3958, Row 808).

OSHA's final exposure profile in Table IV.5.4-B includes 21 samples of respirable crystalline silica for hole drilling using handheld equipment. The median is 48 μg/m^3, the mean is 64 μg/m^3, and the range is 12 μg/m^3 to 286 μg/m^3. Of the 21 samples, 10 (roughly 48 percent) are above 50 μg/m^3, and five (approximately 24 percent) exceed 100 μg/m^3.

Of the 21 8-hour TWA PBZ respirable silica results summarized in the exposure profile, 8 samples represent hole drilling indoors on concrete with no use of engineering controls or dust-suppressing work practices (Document ID 1423, p. 833; 1431, p. 3-40; 0155, pp. 74-76, 88-89; 0798, p. 77; 1720, pp. IV-402-403; 3958, Row 825). Both ordinary drills and, more routinely, percussion or rotary drills were used for drilling holes into concrete and other substrates containing silica. Dry sweeping, brushing, the use of compressed air, and pecking[174] are also baseline practices that can contribute to dust exposures.

As summarized in Table IV.5.4-B, hole drillers working indoors on concrete with no controls had a median respirable silica exposure of 59 μg/m^3 and a mean exposure of 80 μg/m^3, with overall exposures ranging from 12 μg/m^3 to 286 μg/m^3. The highest indoor sample result (286 μg/m^3) was recorded in Lofgren (1993) for a worker performing dry drilling on a wall on the lower level of a concrete parking garage where air circulation was poor (Document ID 1423, p. 833).[175] This study also reported 2 other sample results for workers performing the same tasks at the same worksite; those workers had exposures of 260 μg/m^3 (for 110 minutes) and 110 μg/m^3 (for 177 minutes), which were converted to 8-hour TWAs of 41 μg/m^3 and 60 μg/m^3, respectively. These other 2 sample results were also included in the exposure profile.

The Construction Industry Safety Coalition (CISC) questioned OSHA's use of the Lofgren data, suggesting that OSHA had "cherry-picked" the data by excluding the 260 μg/m^3 and 110 μg/m^3 results (Document ID 2319, pp. 43-44). Although not explicitly stated in the PEA, OSHA did include those 2 sample results in the preliminary exposure profile, and they are also included in the final exposure profile. In accordance with the procedures in Section IV-2 – Methodology, OSHA adjusted the sample results (with sample durations of 110 and 177 minutes) to 8-hour TWA values using the assumption that no additional silica exposures occurred during the un-sampled portion of the shift (Document ID 1423, p. 833).

CISC also noted that sample results in Hallin (1983) (Document ID 1391) contain exposure results of 1740 μg/m^3 and 720 μg/m^3 for workers using a percussion drill and hammer drill, and questioned why those sample results were not included in the exposure profile (Document ID 2319, p. 45). The data in Hallin were samples taken in Sweden in the 1980s (Document ID 1391). As explained in Section IV-2 –

[174] A drilling operation that periodically retracts the drill bit to clear chips.

[175] The Lofgren (1993) study reported the sample as 300 μg/m^3 collected for 457 minutes. This is equivalent to an 8-hour TWA exposure of 286 μg/m^3 assuming no exposure for the remainder of the shift.

Methodology, the data in the exposure profiles only include samples obtained in the U.S.; moreover, data obtained prior to 1990 is not included in the exposure profiles.

McKernan et al. (2002) contained a sample result of 60 μg/m^3 (58 μg/m^3 as an 8-hour TWA) for a worker drilling concrete and brick without controls to install rebar at an indoor construction site (Document ID 0798, p. 77). This sample is also included in the profile.

The exposure profile includes 3 samples from an OSHA SEP report of workers drilling a concrete floor indoors with pneumatic drills to make holes to help lift out floor sections. Two of the 3 sample results were reported as "below LOD," with adjusted 8-hour TWA values of 67 μg/m^3 and 69 μg/m^3, while the third sample had an 8-hour TWA value of 48 μg/m^3 (Document ID 0155, pp. 74-76, 88-89).

The Agency obtained the remaining sample for indoor operations from the most recent OIS data, (Document ID 3958, Row 825). The work activities described for this sample result involved a sheet metal worker employed by a plumbing or HVAC contractor drilling to hang units. No engineering controls were used, and the sample result was below the limit of detection (12 μg/m^3).

The exposure profile shows 13 sample results for outdoor operations (or other mixed controls, including when the work location and work practices were not specified). Seven of these samples were obtained from three NIOSH studies; 3 samples, previously included in the PEA profile for jackhammer operators and impact drillers, were from two SEP reports; and 3 samples were obtained from the OIS database (Document ID 0847, pp. 5-6; 0229, pp. 9 and 12; 1253, pp. 3 and 7; 0138, pp. 10-19; 0019, pp. 50-55; 3958, Rows 806, 808, 828). Among hole drillers working outdoors (or in mixed or unspecified conditions), the median exposure was 30 μg/m^3 and the mean exposure was 54 μg/m^3, with overall exposures ranging from 12 μg/m^3 to 130 μg/m^3.

Eight of the 13 sample results for this exposure category were at or below 50 μg/m^3. Two of these 8 sample results are from the OIS database (Document ID 3958, Rows

806, 828). Two other sample results below 50 µg/m^3 are from an SEP inspection report for workers drilling holes in a concrete bridge pier with a drill hammer (both sample results below the LOD) (Document ID 0138, pp. 10-19). Two other sample results below 50 µg/m^3 were obtained from a NIOSH study in which two workers spent an entire 8-hour shift alternately drilling 2-inch holes through brick and steel and installing masonry anchors in exterior and courtyard walls. These workers had exposure values of 14 µg/m^3 and below the LOD of 12 µg/m^3 (Document ID 0229, pp. 9, 12). Additionally, 2 sample results below 50 µg/m^3 were obtained from another NIOSH study that reported exposures as less than or equal to the LOD of 30 µg/m^3 (Document ID 1253, p. 7).

In the same study, NIOSH also obtained 2 samples reported as 120 µg/m^3 and 130 µg/m^3 (Document ID 1253, pp. 3, 7). NIOSH investigated outdoor rock drilling operations where workers operated 75-pound or 30-pound gas-powered drills by hand.[176] The larger drill was designed to generate compressed air (20 to 30 pounds per square inch [psi]) that it forced through the shank to clear the hole. This drill was considerably faster and resulted in higher 8-hour time-weighted average (TWA) exposures (120 µg/m^3 and 130 µg/m^3) than did the use of the smaller, slower drill that did not include a forced air feature. As previously noted, two 8-hour TWA sample results associated with the smaller drill were both less than or equal to the limit of detection (30 µg/m^3). NIOSH noted that the workers rarely operated either size drill more than 3 hours a day because they are heavy and difficult to control; therefore, the 8-hour TWAs that OSHA uses in the exposure profile assume that the workers did not drill beyond the sampling period and had no additional silica exposure for the remainder of the day (Document ID 1253, pp. 1, 3, 7).

CISC asserted that because this NIOSH study involved drilling in the Rocky Mountains, it can “hardly be representative of hole drilling using handheld drills for

[176] Although NIOSH investigators collected five PBZ samples, only four were included in the exposure profile. The sample that was excluded was a 20-minute sample that did not collect any dust (total or respirable) (Document ID 1253, p. 7). Since there was no respirable mass detected in the filter, and the period sampled was short, OSHA could not use this sample to characterize the nature of exposures during this drilling activity.

all of construction” (Document ID 2319, p. 45). CISC did not elaborate on the reason that it is not representative. The type of rock the workers drilled contained quartz concentrations between 15-23 percent (Document ID 1253, p. 4). OSHA believes that the sampling results from this study are among the best evidence available to OSHA to characterize exposures of workers performing hole drilling with handheld drills.

Three other hole driller sample results for “other mixed conditions” were above 50 $\mu g/m^3$. One was for a worker described as air drilling on an interstate median, with an exposure of 128 $\mu g/m^3$ (Document ID 3958, Row 808). Another elevated sample result (118 $\mu g/m^3$), for a worker air drilling holes to install rebar, was obtained from an SEP report (Document ID 0019, pp. 50-55). The remaining sample was obtained from a worker performing outdoor and uncontrolled handheld drilling as part of bridge demolition; the reported exposure concentration was 780 $\mu g/m^3$ (73 $\mu g/m^3$ as an 8-hour TWA) (Document ID 0847, pp. 5-6). Area sample results as high as 2,150 $\mu g/m^3$ (sample duration not specified) from this operation indicate that a considerable amount of respirable dust was generated in the absence of exposure controls. The area samples and presence of another worker on the bridge performing silica-generating tasks (concrete sawing) suggest that silica emissions from other nearby workers may have contributed to the exposures of the outdoor handheld drill operator (Document ID 0847, pp. 5-6).[177]

The sample results presented in the exposure profile represent the best data available to OSHA for estimating the exposures of workers drilling holes with handheld equipment. Although somewhat limited, these data indicate that outdoor drilling most often results in worker exposure levels at or below 50 $\mu g/m^3$, and that exposures do not generally exceed 50 $\mu g/m^3$ unless contributing factors (such as the use of forced air combined with large, aggressive drill size, or emissions from other nearby silica

[177] As discussed in IV.2 – Methodology, OSHA assumes that the sampling period encompasses the duration of the silica-generating task, and that the worker was not exposed to silica during the unsampled portion of the shift. Section IV.2 discusses the impact of secondary exposures and the importance of controlling all silica-generating activities at the source.

generating activities) make the job particularly dusty. No other exposure data for hole drillers was submitted to the rulemaking record.

Table IV.5.4-B
Personal Respirable Crystalline Silica Exposure Range and Distribution of Results for Construction Workers: Hole Drillers Using Handheld or Stand-Mounted Drills

	Exposure Summary			Exposure Range		Exposure Profile				
Hole Drillers Using Handheld or Stand-Mounted Drills	**N**	**Mean (µg/m^3)**	**Median (µg/m^3)**	**Min (µg/m^3)**	**Max (µg/m^3)**	**< 25 (µg/m^3)**	**≥ 25 and ≤ 50 (µg/m^3)**	**> 50 and ≤ 100 (µg/m^3)**	**> 100 and ≤ 250 (µg/m^3)**	**> 250 (µg/m^3)**
Indoors, concrete substrate, no controls	8	80	59	12	286	1 (12.5%)	2 (25%)	4 (50%)	0 (0%)	1 (12.5%)
Other mixed conditions	13	54	30	12	130	6 (46.2%)	2 (15.4%)	1 (7.7%)	4 (30.8%)	0 (0%)
Hole Drillers Using Handheld Drills Total	**21**	**64**	**48**	**12**	**286**	**7 (33.3%)**	**4 (19%)**	**5 (23.8%)**	**4 (19%)**	**1 (4.8%)**

Notes: All samples are personal breathing zone (PBZ) results and represent 8-hour time-weighted average exposures.
Job categories are intended to represent job functions; actual job titles might differ, and responsibilities might be allocated differently, depending on the site.
Percentages may not add to 100 percent due to rounding.

Sources: Document ID 1720; 3958; 0019; 0138; 0155; 0229; 0798; 0847; 1253; 1423.

5.4.3 Additional Controls

The exposure profile in Table IV.5.4-B shows that approximately 48 percent (10 out of 21 samples) of hole drillers have exposures above the final PEL of 50 μg/m³. Therefore, OSHA finds that additional controls will be necessary to achieve the PEL for these overexposed workers. The median exposure for hole drillers is 59 μg/m³ when dry drilling indoors on concrete without controls, but just 30 μg/m³ for other conditions (generally outdoors). Although the data used by OSHA for the exposure profile indicates that drilling outdoors will generally yield lower exposures than drilling indoors, the data also shows that exposures in excess of 50 μg/m³ can occur, particularly when workers are using larger drills. Local exhaust ventilation (LEV) is the primary option available for reducing exposure levels among hole drillers both indoors and outdoors.

Local Exhaust Ventilation

Shepherd et al. (2009) found that, compared with uncontrolled drilling, using dust collection cowls connected to portable vacuums reduced silica exposures by 91 to 98 percent (Document ID 1142, p. 49). The researchers tested four combinations of two cowls and two vacuums (all commercially available, including a bellows-style cowl and a telescoping ring cowl) in multiple 1-hour trials. For each trial, the worker-subjects used a 6.9 amp hammer drill with a 3/8 inch bit to continuously drill a series of 3-inch holes between shoulder and waist height in a vertical concrete wall. For half of the randomized trials, the test wall was located indoors in a large enclosed space (100 feet by 60 feet by 30 feet, similar to a warehouse), with several operators each using the four combinations of equipment. The wall was moved outdoors for the other half of the trials. In this case, the investigators found no statistical difference between indoor and outdoor trials for the various equipment combinations. Average respirable quartz levels varied among the different cowl/vacuum combinations, but all combinations resulted in personal breathing zone (PBZ) exposures of 28 μg/m³ or less during these periods of constant drilling. In contrast, periods of uncontrolled drilling resulted in a geometric mean exposure level of 308 μg/m³ (Document ID 1142, p. 42). Although the investigators note that exposure levels may vary for different drill types and drill bit sizes, OSHA estimates that even moderately effective ventilated dust collection cowls would still result in silica exposure levels that are 50 μg/m^3 or less during periods of intense drilling and that 8-hour TWA values would be even lower.

CISC raised several issues with the use of the Shepherd et al. study. CISC stated that the study consisted of only 1-hour drilling in controlled conditions in a laboratory setting; the LEV systems did not reduce *inhalable* exposures to 50 μg/m^3; and the vacuums would require frequent filter changes to maintain effectiveness. Additionally, CISC stated that the Shepherd study mentioned that hood designs for portable handheld hammer drills needed to be examined and that technical improvements were needed to capture particles more efficiently (Document ID 2319, pp. 45-46).

Although the Shepherd study contains short-term laboratory data, OSHA still finds it relevant to evaluating the effectiveness of using LEV as a control for handheld and stand-mounted drills. Experimental studies under controlled conditions, like the Shepherd study, can objectively show how well a control method works in an environment where other sources of silica are also controlled (e.g., as might occur on a well-controlled work site, or at a site where only one source of silica exposure is active at a time). Sample results from the controlled condition are also routinely compared by investigators to sample results obtained for uncontrolled conditions. The resulting ratio shows the exposure reduction efficiency for the control method, independent of work rate variability, variations in construction materials, or other factors that do not relate to the individual control's functional performance. OSHA acknowledges that there are limitations to experimental data, but believes that the Shepherd study provides useful information about the effectiveness of LEV.

The Shepherd study evaluated the effectiveness of LEV in reducing three size fractions of dust particles (respirable, thoracic, and inhalable). Respirable sized particles are those capable of entering the gas-exchange (alveolar) regions of the lung, and, as explained in the PEA, have a 50-percent cut-point of 4.0 μm (Document ID 1455, p. xvi; 1720, p. IV-20). Thoracic-sized particles have a 50 percent cut-point of 10 μm. And inhalable-sized particles may deposit anywhere in the respiratory tract and have a 50 percent cut-point of 100 µm (Document ID 1834, p. 13; 1540, p. 280). The mass concentration of silica collected in the inhalable fraction was nearly ten times higher than it was in the respirable fraction for all LEV configurations tested (Document ID 1142, p. 46).

Contrary to CISC's assertion, the Shepherd study demonstrates that it is possible to reduce respirable silica levels to 50 µg/m^3 or less (Document ID 1142, p. 49). The respirable silica sample results reported in Table 1 of the Shepherd study show that all four LEV systems tested reduced exposures below 50 µg/m^3, and two of the LEV configurations reduced silica exposures below 25 µg/m^3, during the sampled period (Document ID 1142, pp. 46-47). While Shepherd does recommend further study of hood design for portable hammer drills, this is to reliably achieve exposures below 25 µg/m^3, improve capture of larger, non-respirable particles, and improve ease of use and acceptance in the field (Document ID 1142, pp. 48, 50).

Additionally, although the study pointed out that vacuums would require frequent filter changes, filter changes are a common work practice for effective dust collection systems, and OSHA does not consider the need to change a filter evidence of infeasibility. As a general matter, controls need to be frequently evaluated to ensure proper and effective operation; examination of controls is consistent with good industrial hygiene practices. Additionally, technology is available to prevent clogging of the final filter and thus maintain sufficient vacuum airflow rates. Vacuum filters with cyclonic pre-cleaners or filters with an automatic backflush system can be used, with several such self-cleaning vacuum dust collection systems commercially available (Document ID 3791, p. v; 3998, Attachment 10, pp. 20, 29-30, 38). Employers opting to follow Table 1 must use dust collectors with a filter cleaning mechanism in order to maintain airflows sufficient to achieve effective capture at the hood.

Proposed Table 1 did not specify the amount of air flow required for the dust collection system. 77 FR at 56495. CISC questioned why the Table 1 specifications in the proposed rule did not set parameters for the functioning of the dust collection system for hole drillers (Document ID 2319, p. 107). In the final rule, OSHA has revised Table 1 to specify that the dust collection system for handheld and stand-mounted drills must provide the airflow recommended by the tool manufacturer or greater.

In an earlier study of vacuum suction dust control devices conducted in Sweden, Hallin (1983) evaluated rotary and percussion hammers equipped with various LEV systems and various drill bit sizes (Document ID 1391). During the study, the tools were operated indoors, usually in a test room designed to mimic a small enclosed construction area with poor air circulation (one air change per hour). Under these conditions, the study showed that the use of LEV resulted in a 57-percent reduction in the median respirable quartz exposure level for workers drilling 50-millimeter-deep holes in concrete with 6-millimeter drill bits (from a median of 140 $\mu g/m^3$ without LEV to a median of 60 $\mu g/m^3$ with LEV-equipped tools). Hallin found an 85-percent reduction in the median respirable quartz exposure level for workers drilling 80-millimeter-deep holes in concrete with 10-millimeter drill bits (295 $\mu g/m^3$ without LEV compared with 45 $\mu g/m^3$ with LEV). In this study, each LEV system consisted of a suction-type connection and a dust extractor. Hallin's test readings are concentration values (rather than calculated 8-hour TWAs) and were based on short sample durations (ranging from 60 to 180 minutes of intensive drilling). The workers did not use compressed air to clean the holes during these tests, which took place in a room approximately 15 feet by 18 feet by 8 feet (Document ID 1391, pp. 11, 13, 24).

CISC commented that the use of the Hallin study is an example of OSHA's inadequate analysis of the effectiveness of controls, given that the Hallin study was performed indoors under test room conditions. Additionally, silica levels were estimated from a composite of respirable dust samples, and individual PBZ samples were not collected (Document ID 2319, p. 46). OSHA believes that as a controlled study, the Hallin study is instructive; it can objectively show how well a control method works in an environment where other sources of silica are also controlled. Additionally, OSHA believes that the conditions of the study – small and enclosed areas with poor circulation – resemble drilling in real-world conditions. The study shows that the levels of respirable quartz were reduced by 57 and 85 percent in two different trials.

The Hallin study also indicated a greater potential for overexposure during overhead drilling performed indoors. Drilling without controls for 120 minutes in a concrete ceiling with a percussion drill resulted in respirable quartz concentration exposures of 1,740 μg/m^3 (435 μg/m^3 as an 8-hour TWA) (Document ID 1391, p. 15). When the same model of percussion drill was fitted with a dust collector, the respirable quartz reading for a 180-minute sample was 80 μg/m^3 (an 8-hour TWA of 30 μg/m^3) (Document ID 1391, pp. 15, 22). Another uncontrolled overhead drilling trial using a hammer drill for 120 minutes produced a respirable quartz concentration exposure of 720 μg/m^3 (180 μg/m^3 as an 8-hour TWA) (Document ID 1391, p. 16).

Based on the Hallin study, OSHA stated in the proposal that it was unable to confirm that using a cowl and dust collector would sufficiently protect workers, and proposed to exclude overhead drilling from the tasks and controls on Table 1. 78 FR 56274, 56460. Additionally, OSHA agreed with the recommendations made by the Hallin study that overhead drilling is ergonomically stressful and should not be performed consistently throughout a full shift. 78 FR at 56460.

OSHA received a number of comments related to overhead drilling. The Sheet Metal and Air Conditioning Contractors National Association commented that overhead drilling should be included on Table 1, noting that it can be done as safely as other work postures if it was done as directed on Table 1 (i.e., no visible dust) (Document ID 2226, Attachment 1, p. 2). The Power Tool Institute recommended a new entry for overhead drilling with carbide bits, stating that drilling with carbide bits limits the amount of material removed (Document ID 1973, p. 6). The Power Tool Institute also recommended that, when used with a hood or cowl and HEPA-filtered dust collection system, no respiratory protection be required for up to four hours of drilling, and that a half-mask respirator with an APF of 10 be permitted when drilling for greater than four hours (Document ID 1973, p. 6). OSHA believes that, due to the ergonomically stressful nature of overhead drilling, it is unlikely that overhead drilling would be performed consistently throughout a full shift. Ms. Chris Trahan, reading a statement from Laurie Shadrick on behalf of the United Association of Journeymen and Apprentices of the Plumbing and Pipefitting Industry of the United States, Canada and Australia, noted that drilling may only take up 3-5 percent of work time for a worker installing hangars (Document ID 3581, Tr. 1584).

CISC questioned whether, in light of the Hallin study result, exposures during overhead drilling could be controlled to 50 μg/m^3 (Document ID 2319, p. 45). OSHA finds that the Hallin study shows that, when effective controls are implemented, exposures can be reduced to 50 μg/m^3 or less, most of the time, when performing overhead drilling. The Hallin study reports two sample results during controlled overhead drilling, with adjusted 8-hour TWAs of 30 μg/m^3 (based on a sample result of 80 μg/m^3 in a 180-minute sample) and 17 μg/m^3 (based on a sample result of 68 μg/m^3 in a 120-minute sample) (Document ID 1391, p. 22).

Additionally, evidence in the record shows that technology has developed since the Hallin study was published in 1983. Ms. Trahan, reading a statement on behalf of the United Association of Journeymen and Apprentices of the Plumbing and Pipe Fitting Industry of the United States, Canada and Australia, noted that “the industry is seeing an increase in the use of local exhaust ventilation for overhead drilling, including [integrated] dust collectors and add-on controls” (Document ID 3581, Tr. 1584). OSHA received testimony that an overhead drill stand (referred to as an overhead drill press by the commenter), was developed with a vacuum attachment that addresses both ergonomic and silica hazards (Document ID 3581, Tr. 1673, 1705). OSHA encourages the use of such drill stands, as they reduce ergonomic stressors and allow the driller to stand at a greater distance from the point of contaminant generation. Use of a stand-mounted drill is expected to reduce silica exposures, both by increasing the distance to the worker’s breathing zone and through the local exhaust ventilation that is integrated into the stand.

Upon review of the evidence in the record, OSHA has determined that it is appropriate to cover overhead drilling in the Table 1 entry for handheld and stand-mounted drills.

There are commercially available controls that can reduce exposures. As the Hallin (1983) study shows for controlled overhead drilling, 8-hour TWA exposures can be reduced to levels to or below 50 $\mu g/m^3$.

OSHA finds that exposures from drilling (including overhead drilling) will be lower when performed using effective LEV in areas supplied with general (or natural) ventilation. NIOSH studies of exposure controls for lead-based paint removal showed that adding dilution ventilation to enclosed work areas reduced airborne lead fume concentrations by nearly half (45 percent, from 22 $\mu g/m^3$ to 12 $\mu g/m^3$ of lead) during lead paint removal by the heat gun method (Document ID 1274, p. 3).[178] Accordingly, paragraph (c)(2) of the final rule requires general exhaust ventilation as needed to minimize the accumulation of visible airborne dust for tasks performed indoors or in enclosed areas.

CISC commented that many hoods or cowls are not designed for dust collection (Document ID 2319, p. 108). The National Utility Contractors Association (NUCA) stated that no drills are currently manufactured with a bag/HEPA filter (Document ID 2171, p. 10). However, OSHA received evidence of commercially available engineering controls (Document ID 4073, Attachment 4a). Ms. Eileen Betit, testifying on behalf of the Building and Construction Trades Department (BCTD) of the AFL-CIO, discussed the increasing variety of commercially available ventilated drills, noting that one drill manufacturer introduced a hollow drill bit that suctions the dust as the hole is being drilled (Document ID 3581, Tr. 1673). Additionally, Charles Austin, an industrial hygienist representing the International Association of Sheet Metal, Air, Rail and Transportation (SMART), testified that there are commercially available hammer drills with built-in dust collection systems, as well as dust collection systems that can be attached to HEPA vacuums, that can be used when drilling holes in concrete and masonry for installation of duct work (Document ID 3581, Tr. 1588-1589). Based on the evidence in the record, OSHA has determined that several

[178] Fumes are very small particles, the largest of which (1 micrometer) are in the lower end of the respirable size range (DiNardi, 2003 – Document ID 0623, p. 1268). Like silica particles, fumes remain airborne rather than settling out of the air during a work shift.

manufacturers produce LEV dust removal systems for a variety of tool types, including most models of drills (Document ID 0566; 0629, p. 1; 1671; 0736; 3998, Attachment 10, pp. 20-21, 27, 33, 39, 42; 4073, Attachment 4b, Slides 12 - 18).

When the LEV cowl is supplied with its own dust collection bag, both Hallin and Shepherd suggest that better dust capture is achieved by removing the bag and attaching a vacuum hose in its place, using a commercially available adaptor and vacuum source (Document ID 1391, p. 23; 1142, p. 43). OSHA expects that, for most tools, a dust control system using an appropriate vacuum will provide the most reliable dust capture.[179]

Local exhaust ventilation can also be used to effectively control exposures during the use of small, handheld core drills. These drills can be fitted with vacuum attachments consisting of a cowl with a vacuum port that fits around the annular coring bit and draws dust from the cutting area, or a suction feature that pulls air from the already-hollow center of the coring bit (Document ID 3998, p. 19). LEV systems are commercially available for core drills up to 3.25 inches in diameter (Document ID 3501, p. 6; 3998, p. 22). In hearing testimony, Mr. Joel Guth of iQ Power Tools described effective local exhaust controls for core drills (Document ID 3585, Tr. 3000). Sampling data submitted to the record by iQ Power Tools reported a sample result of 28 $\mu g/m^3$ during the use of a handheld core drill equipped with local exhaust ventilation. This study assessed full-shift personal breathing zone exposures for a worker performing 200 cuts with a handheld core drill using a 3” diameter bit. This study noted a typical frequency of 25 – 200 cuts per day and assessed maximum exposure conditions for this tool type (Document ID 3501, pp. 6-7).

Based on the evidence in the record, OSHA has determined that there are effective controls for hole drilling using handheld and stand-mounted drills that can reduce

[179] The Precast/Prestressed Concrete Institute (PCI) asserted that requiring rotary hammers to be equipped with a hood or cowl with HEPA vacuum systems could turn a one-person operation into a two-person operation. PCI stated that an additional worker may be needed to hold and move the equipment as the work progresses (Document ID 4029, p. 3). OSHA does not believe this will be necessary, as the hole driller can simply push the wheeled vacuum system to new work locations as the work progresses. Wheeled vacuum systems vary in size; some are quite compact and easy to move (Document ID 3998, Attachment 10, pp. 20-22, 29-30, 37-38).

exposures to 50 μg/m^3 or below. These controls include using handheld drills equipped with commercially available shroud or cowling with a dust collection system that has sufficient airflow as recommended by the tool manufacturer, a filter with 99 percent or greater efficiency, and a filter cleaning mechanism.

Dust Capture Devices

Peter Chaney, Director of Safety and Health for the Mechanical Contractors Association, noted that Table 1's specifications for handheld hole drillers did not include other types of effective silica dust control devices and equipment, such as dust collection cups on drill bits (Document ID 2143, p. 3). OSHA acknowledges that a simple, non-ventilated dust barrier that captures dust at the point of generation may be effective for an "employee who drills only an occasional small hole in the course of a day" (Document ID 1533, pp. 40-41). For example, WorkSafe BC, the workers' compensation control board for British Columbia, Canada, notes that dust caps and dust bubbles fit between the drill and the working surface (on the end of the drill) and are useful for overhead ceiling and wall drilling (Document ID 4072, Attachment 19, p. 2).

WorkSafe BC recommends use of a dust cap as an alternative to vacuum dust collection when only a few (i.e., 12 or fewer) holes will be drilled in a wall or ceiling (Document ID 4072, Attachment 19, pp. 3-4; Attachment 14, p. 17). These may be useful for existing drills for which commercially available local exhaust attachments are not available. However, WorkSafe BC recommends that in addition, half-face, HEPA-filtered respirators be used (Document ID 4072, Attachment 14, pp. 5, 17). No WorkSafe BC or other exposure data was submitted to the record addressing the effectiveness of these devices, but OSHA notes that the WorkSafe BC occupational exposure limit is 0.025 mg/m^3 (25 μg/m^3).

The Hallin study describes a 120 minute overhead drilling trial using a percussion drill with a Hilti rubber cup as the dust collection device that resulted in an exposure of 680 μg/m^3 (170 μg/m^3 as an 8-hour TWA) (Document ID 1391, p. 22).

Based on the available data and the lack of sufficient evidence to show the extent to which this type of control can reduce exposures, OSHA has decided not to include dust capture devices as an option on Table 1.

Work Practices

As noted in Table IV.5.4-A, dust raised by sweeping, brushing, and/or using compressed air to clean holes can be a significant source of silica exposures for hole drillers. Implementation of work practice controls is an important component of reducing exposure from this source. Careful work practices are necessary to prevent settled dust from being re-suspended and entering the worker's breathing zone. When vacuum cleaners are used, OSHA recommends that that they be equipped with HEPA-filters.

The use of ventilated tools can eliminate some housekeeping needs. When a tool equipped with integrated local exhaust (vacuum dust collection) is used, there will be less accumulated dust that will need to be removed from surfaces, thereby minimizing worker exposures and reducing the amount of housekeeping needed. In hearing testimony, Deven Johnson, Director of Training, Health and Safety for the Operative Plasterers and Cement Masons International Association, explained that when the dust is collected as it is generated and passes through a HEPA-filtered container, "you don't need anybody else to clean it up. It's already contained." (Document ID 3581, Tr. 1594). Moreover, BCTD submitted Return on Investment (ROI) calculations showing that workers spend less time performing housekeeping and clean-up activities when handheld drills with integrated dust collection systems are used (Document ID 4073, Attachments 7a and 7b).

Work preplanning can also be an effective strategy for reducing silica exposures associated with the use of handheld and stand-mounted drills. WorkSafe BC recommends, in its silica exposure control plan guidance, that project planning be used to reduce silica exposures. For example, by planning formwork to reduce the need for drilling, or by scheduling drilling when the concrete is still wet, project work will pose less of an exposure concern (Document ID 4072, Attachment 14, p. 7).

Proper maintenance of exposure controls is essential to ensure their effectiveness. BCTD recommended that OSHA require employers to inspect and ensure proper function of tool LEV controls before each use of a rotary hammer or drill (Document ID 4223, Appendix 1, pp. 8-9). Similarly, a U.K. Health and Safety Executive document titled “Controlling construction dust with on-tool extraction” recommends that employers check controls for proper function before each use, conduct weekly maintenance checks of the hood or ducting, airflow, and filter cleaning mechanisms, and replace filters when needed. This document also recommends servicing and systematic testing at least every 14 months (Document ID 3756, Attachment 4, p. 3). Although OSHA agrees that the regular inspection of controls is essential to ensuring proper function, the interval of inspection that is necessary may vary by tool. As such, OSHA believes that tool manufacturers are in the best position to determine an appropriate inspection interval; employers must follow manufacturers’ instructions.

Compressed Air Cleaning

The practice of sweeping or brushing debris from the hole appears to contribute to exposures among workers drilling in concrete. The use of compressed air to clean the holes also increases exposures, regardless of whether the air is blown by the drill (a design feature of some drills) or by a worker using a compressed air nozzle.

Although OSHA recognizes that the complete elimination of compressed air cleaning or dry brushing or sweeping may not be possible in every situation, OSHA believes that improved cleaning techniques, e.g., using a high-efficiency particulate air (HEPA)-filtered vacuum, can often be used instead of, or as a supplement to, cleaning with compressed air. These alternative cleaning methods can reduce silica exposures. Hallin reported that airborne respirable quartz readings were 55 percent lower when holes were cleaned with a suction probe before being blown clean with compressed air (Document ID 1391, pp. 32 - 33).

OSHA received a number of comments related to the use of compressed air. BCTD recommended that OSHA require employers to use HEPA-filtered vacuuming or wet methods to clean accumulations of silica and prohibit the use of compressed air, dry sweeping, and dry brushing to clean contaminated clothing or surfaces (Document ID 2371, Attachment 1, pp. 32-33). PCI, on the other hand, expressed concern regarding a prohibition on dry sweeping, brushing, and compressed air cleaning, stating that in many cases, they are the only feasible cleaning methods (Document ID 2276, p. 10). PCI noted that anchor holes must be blown clean to obtain adequate adhesion, and recommended that the use of compressed air and dry sweeping be allowed unless exposures will exceed 50 µg/m^3 (Document ID 2276, pp. 10-11).

OSHA has determined that there are a number of feasible alternatives to using compressed air. At least one tool manufacturer offers an anchor system with "no hole cleaning requirement whatsoever," due to the use of a drill with a ventilated drill bit (Document ID 4073, Attachment 4b, Slide 12). Another manufacturer offers a "hole cleaning kit" for large hammer hole drilling, which consists of a doughnut-shaped dust collection head that attaches directly to a vacuum cleaner hose. The head is placed against the surface to be drilled and captures dust generated as the hole is drilled (Document ID 4073, Attachment 4b, Slide 17). This hole cleaning kit also includes two sizes of hole cleaning tubes. Such a control could be used with existing as well as new drills (e.g., Document ID 3998, Attachment 10, p. 42).

CISC, noting that the larger drill described in the NIOSH study (Document ID 1253, p. iv) forced compressed air through the drill shank, asked whether OSHA would permit the use of heavy equipment that incorporates compressed air in the drilling action (Document ID 2319, p. 45 n. 8). Compressed air, when used with effective ventilation control as a part of a design feature for optimal drill performance would not violate the rule's restrictions on use of compressed air for cleaning.

The exposures reported by NIOSH when a 75-pound rock drill with a forced air feature was used exceeded 50 µg/m^3 (exposures of 120 µg/m^3 and 130 µg/m^3) (Document ID 1253, pp. 1, 7). However, this drill did not have LEV integrated into the design of the tool. In some cases, both compressed air and LEV are an integral part of a tool, and are designed to work in concert. For example, RR926, a research report by the UK Health and Safety Executive titled "On-tool controls to reduce exposure to respirable dusts in the construction industry" describes a study by Potts and Reed that studied the effectiveness of compressed air jets "to further improve containment of dust-contaminated air" inside a ventilated shroud on a surface drill. This study found that this system reduced the dust concentration outside the enclosure by approximately 50 percent (Document ID 3791, p. 11). Similarly, Hallin reported that airborne quartz readings were 40 percent lower when "blowing through a suction disc" as compared to blowing holes clear with compressed air with no exhaust capture (Document ID 1391, pp. 32-33). OSHA acknowledges that such specially designed systems may be effective in controlling respirable silica exposures, and expects that such systems would employ compensating LEV with an exhaust air flow rate greater than the flow rate of the forced air feature.

Data suggest that decreasing workers' reliance on blowing or dry sweeping drilling debris can reduce exposures by approximately 50 percent (see, e.g., Document ID 1391, pp. 32 - 33). Holes can be cleaned using portable HEPA-filtered vacuums with extension wands, or commercially available hole cleaning kits connected to HEPA-filtered vacuum dust collection systems (Document ID 3998, Attachment 10, p. 42). This 50-percent reduction would bring exposure levels to 50 μg/m^3 or below for all the drill operators who are currently exposed to silica at levels between 50 μg/m^3 and 100 μg/m^3. OSHA believes that reducing reliance on unventilated drills that blow air down the hole will provide the same degree of exposure control as reducing the use of other forms of compressed air to clean holes.

5.4.4 Feasibility Finding

Paragraph (c) of the construction standard gives employers the option of following Table 1, which includes specified engineering and work practice controls for workers operating handheld and stand-mounted drills; alternatively, the employer must assess and limit exposures in accordance with the more traditional regulatory approach of compliance with the PEL contained in paragraph (d). When drilling holes using handheld or stand-mounted tools, such as small core drills, rotary hammers, hammer drills, or other handheld impact drills, Table 1 requires employers to ensure use of a drill equipped with a commercially-available shroud or cowling with a dust collection system. The dust collector must provide at least the minimum air flow recommended by the manufacturer, have a filter with 99 percent or greater filter efficiency, and include a filter cleaning mechanism. The tool must be operated and maintained in accordance with the manufacturer's specifications to minimize dust emissions. A HEPA-filtered vacuum must be used when cleaning drilling debris from holes. OSHA finds that when dust controls on handheld or stand-mounted drills are fully and properly implemented, TWA exposure levels will remain at or below 50 µg/m^3; therefore, Table 1 does not require the use of respiratory protection.

Several drilling equipment manufacturers sell dust extractors or dust collectors with filtration systems to minimize dust escaping into the work area. Some of these include Bosch, DeWalt, Hilti, Metabo, and iQ Power Tools (Document ID 3998, Attachment 10; 4073, Attachment 4a; 3501, pp. 6-7). OSHA has determined that it is feasible for employers to obtain controls for handheld drills that meet the specifications in Table 1.

Based on the data in the record, OSHA concludes that roughly half of workers using handheld drills are currently exposed to silica levels below 50 µg/m^3. For workers who are currently exposed above 50 µg/m^3, the controls described in this section can be implemented to reduce silica exposure levels to 50 µg/m^3 or below in most operations, most of the time. Additional controls, such as fitting an LEV cowl and vacuum suction to a drill (as described by Shepherd et al. (Document ID 1142, p. 49)), can reduce exposures to 50 µg/m^3 or below for even the most highly-exposed workers operating handheld drills (i.e., the 24 percent that OSHA estimates, based on Table IV.5.4-B, are exposed to silica levels greater than 100 µg/m^3). As discussed in the additional controls section, the use of a stand-mounted drill is expected to reduce silica exposures, both by increasing the distance to the worker's breathing zone and through the local exhaust ventilation that is integrated into the stand. Research presented in Shepherd et al. (2009), shows the exposure reduction achieved by commercially available test equipment. The study reported that uncontrolled drilling produced mean exposures of 308 µg/m^3 during continuous drilling. In contrast, several combinations of drill cowls and portable vacuums reportedly reduced silica exposures among drillers by at least 90 percent (to levels of 28 µg/m^3 or less) (Document ID 1142, p. 46). This study demonstrates that commercially available controls can reduce even the highest sample values in the exposure profile to levels at or below 50 μg/m^3. Therefore, OSHA finds that the standard is technologically feasible for workers using handheld and stand-mounted drills.

5.5 JACKHAMMERS AND OTHER POWERED HANDHELD CHIPPING TOOLS

5.5.1 Description

Hand-operated breaking and chipping power tools and equipment, commonly known as jackhammers, pavement breakers, breaker hammers, percussion or chipping hammers, needle guns, and related tools (collectively, "jackhammers, percussion/chipping hammers, and other powered handheld impact tools") are used at construction sites for fracturing silica-containing material (Document ID 1431, p. 3-44; 2177, Attachment B, p. 32). These tools deliver rapid repetitive blows to fracture rock, concrete, asphalt, or masonry during demolition, repair and renovation, or excavation. Workers typically use these types of tools with the point of impact within one to five feet of the breathing zone, and they can hold the equipment at any angle, including overhead, depending on the weight of the tool (a limitation in some cases) and the configuration of the structure being chipped (Document ID 1431, p. 3-44). Construction workers who use rotary or impact drills for drilling holes in concrete are covered in Section IV-5.4 – Hole Drillers Using Handheld or Stand-Mounted Drills.

During the hearings, George Kennedy of the National Utility Contractors Association (NUCA) stated that jackhammering is one of the construction activities most likely to expose employees to silica (Document ID 3583, Tr. 2255). Workers can use chipping breaking and impact drilling equipment for short periods of time of two or three hours or for as long as seven hours based on a review of selected OSHA inspection reports (Document ID 1431, p. 3-44). With regard to estimating the typical duration of use, Flanagan et al. (2006) recorded worker activities, in addition to worker exposures, during a wide range of construction activities, including "demolition with handheld power tools." Of the 41 samples for which the duration of the task was recorded, the median task time was 231 minutes (range 30 to 473 minutes) (Document ID 0677, p. 147 and Attachment 2).

At some job sites where a large volume of concrete must be removed (e.g., bridge deck renovation), several jackhammer operators might perform pavement breaking simultaneously in the same general area, increasing the dust concentration in the area.

Handheld chipping operations frequently use dry sweeping to clear larger chipping debris from the work area and use handheld blowers or compressed air to remove fine dust from the chipped surface (Document ID 1431, p. 3-44), which can result in higher worker exposures. High exposures can also occur when demolition of silica-containing materials by heavier jackhammers and smaller chipping or percussion hammers takes place indoors where dust emissions can build up if mechanical ventilation is not available.

Table IV.5.5-A summarizes the major activities and the primary sources of silica exposure for workers using jackhammers, percussion/chipping hammers, and other powered handheld impact tools.

Table IV.5.5-A
Major Activities, and Sources of Exposure of Workers Using Jackhammers and Other Powered Handheld Chipping Tools

Application Group	Major Activities and Sources of Exposure
Jackhammer, percussion/chipping hammers, and other powered handheld impact tools	Chipping and breaking concrete, stone, and masonry during demolition, renovation, and excavation. • Dust from chipping or breaking action of the tool. • Dust raised by sweeping, brushing, and/or using compressed air to clear the work surface (housekeeping).

*Job categories are intended to represent job functions; actual job titles might differ, and responsibilities might be allocated differently, depending on the site.
Source: Document ID 1431.

5.5.2 Exposure Profile and Baseline Conditions

The PEA exposure profile included respirable quartz samples for jackhammering and chipping hammers at multiple commercial and highway construction sites, including a bridge, from NIOSH reports, numerous OSHA Special Emphasis Program (SEP) inspection reports, data from CJ Shields of the OSHA North Aurora Area Office, a published article, and a New Jersey state construction partnership report by ERG for the 2008 Technological Feasibility Study of Regulatory Alternatives for a Proposed Crystalline Silica Standard for Construction (Document ID 1431, p. 3-45; 1720, pp. IV-410 – IV-411).

Table IV.5.5-B presents the exposure profile updated from the PEA based on the data available in the record. The updated profile includes 37 additional samples from the OSHA OIS database for respirable crystalline silica exposure conducted between 2011 and 2014 (Document ID 3958). The updated exposure profile excludes seven samples previously included in the PEA based on sampling dates prior to 1990. Also, three samples on impact drillers were removed from the exposure profile on jackhammers and added to the profile on hole drillers, since the use of impact drills is now discussed in Section IV-5.4 – Hole Drillers Using Handheld or Stand-Mounted Drills.

The exposure profile in Table IV.5.5-B includes 134 samples of respirable crystalline silica for workers using jackhammers and other handheld power chipping tools. The median is 126 μg/m^3, the mean is 250 μg/m^3, and the range is 12 μg/m^3 to 2,350 μg/m^3. Of the 134 samples, 93 (almost 70 percent) are above 50 μg/m^3, and 72 (approximately 54 percent) exceed 100 μg/m^3.

Compared to the PEA, the FEA shows a decrease in overall median exposures from 140 to 126 μg/m^3, an increase in the percent of samples at or below 50 μg/m^3 from 26.6 to 30.6 percent, and a slight decrease from 33.0 to 31.3 in the percent of samples over 250 μg/m^3.

Of the 134 respirable quartz readings summarized in the exposure profile, 66 sample results (49 percent) represent jackhammering outdoors under uncontrolled conditions. These results range from less than or equal to the limit of detection (LOD) to 624 μg/m^3 and have a median of 148 μg/m^3 and a mean of 194 μg/m^3. This category included 23 results that exceeded 250 μg/m^3; thirteen of these were from bridge deck job sites (Document ID 0912, pp. 2-3). The elevated results may have resulted from having multiple jackhammers working side by side, using compressed air as a cleaning technique, and cross exposure from other highway equipment (Document ID 1431, p. 3-45).

Five of the results in the exposure profile (4 percent) represent jackhammering outdoors while attempting wet dust control methods. Under these conditions, exposures ranged from 12 μg/m^3 to 639 μg/m^3, with a median of 140 μg/m^3 and a mean of 226 μg/m^3. There is not enough information available to determine how the water suppression was applied for four of these five samples. Although sample durations and silica concentrations in the raw material in these four trials are comparable to outdoor trials with no engineering controls, the resulting exposures were somewhat higher than for uncontrolled operations. One possible reason for this result is that the water dust suppression control was not applied optimally.

Thirty-two of the results in the exposure profile represent the use of jackhammers, percussion/chipping hammers, and other powered handheld impact tools indoors under uncontrolled conditions. These results range from less than or equal to 12 μg/m^3 to 2,350 μg/m^3 and have a median of 111 μg/m^3 and a mean of 404 μg/m^3.

Eleven of the results in the exposure profile represent the use of powered handheld impact tools (chipping hammers, impact drills) indoors while attempting wet dust control methods. Under these conditions, exposures range from 12 μg/m^3 to 880 μg/m^3, with a median of 260 μg/m^3 and a mean of 328 μg/m^3.

The twenty remaining results (15 percent) were collected during chipping and breaking activities performed under a variety of “other conditions” (e.g., a complex mixture of tasks, use of a variety of tools, unknown locations (indoors or outdoors), and/or use of a constructed enclosure around the activity). These exposures ranged from 12 μg/m^3 to 1,144 μg/m^3, with a median of 13 μg/m^3 and mean of 152 μg/m^3.

OSHA also evaluated other sampling results not available for inclusion in the profile. In a review of exposure monitoring data from a variety of published and private sources, Flanagan et al. (2006) reviewed 178 respirable quartz samples associated with the use of jackhammers or chipping guns in construction and found a geometric mean of 150 μg/m^3 for those samples (Document ID 0677, Attachment 2). This mean is consistent with the exposure profile provided in Table IV.5.5-B, where the median outdoor and indoor baseline levels are 130 and 111 μg/m^3 respectively, with more than half of all workers using chipping and breaking equipment exposed above 100 μg/m^3. OSHA’s and Flanagan’s data sources likely overlap because they draw from much of the same published literature and some of the same unpublished sources. The overlap is explained in Section IV-2 – Methodology.

A report addressing silica exposures during underground tunnel construction summarized respirable quartz concentrations for workers using chipping equipment in the tunnel. Over the periods monitored, the geometric mean exposure level for 10 workers operating chipping guns was 70 μg/m^3, with a range of 9 μg/m^3 to 1,640 μg/m^3 (Document ID 0562, p. 637). These samples contained a mean quartz content of 11.9 percent with a range of 2.3 to 23.6 percent. The exposures of the tunnel chipping gun operators are lower, although similar, to the median indoor baseline samples of the profile (111 μg/m^3).

OSHA also takes note of an international study conducted by Nij et al. (2004) that collected samples from construction workers in the Netherlands (i.e., concrete drillers, tuckpointers, and demolition workers) whose tasks involved the use of jackhammers and other dust-generating tools (Document ID 0836, p. 192). The authors reported silica results for 14 samples from eight workers who were drilling concrete with jackhammers and hammer drills. Results ranged from 36 μg/m^3 to 4700 μg/m^3, with a mean exposure of 1090 μg/m^3 and geometric mean exposure of 420 μg/m^3. Silica results for 21 samples from 10 demolition workers ranged from 38 μg/m^3 to 1,300 μg/m^3, with a mean exposure of 250 μg/m^3 and geometric mean of 140 μg/m^3. These results provide some support for those documented in the exposure profile Table IV.5.5-B, however it is important to note that, in addition to jackhammering, the demolition workers performed activities such as using drills, excavators equipped with breakers, welding, sawing, and clearing of rubble, and the drilling operators also performed recess milling and sawing on concrete or lime sandstone. So, it is not known how much time or to what extent the silica exposures were attributable to jackhammering alone.

As reflected on the exposure information in Table IV.5.5-B, most construction workers who use jackhammers, chipping/ percussion hammers, or powered handheld impact tools work outdoors without engineering controls or dust-suppressing work practices. When comparing exposures from indoor and outdoor work, exposure results obtained indoors with and without use of wet suppression have higher maximum and mean values than results obtained from outdoor work. For example, the mean indoor-baseline (water controls not indicated) exposure level is 404 µg/m^3 compared to 194 µg/m^3 for outdoors-baseline (water controls not indicated), with 78 percent of samples above 50 µg/m^3 for indoors, compared to 73 percent for outdoors. The exposure profile contains 16 samples for which the description of the control methods indicated that wet methods were used for dust suppression; 11 samples taken indoors with a median of 260 µg/m^3 and 5 samples taken outdoors with median of 140 µg/m^3 (Document ID 3958, Rows 8, 522-523, 723-725, 1064-1066; 1143, Rows 63, 183-184; 0019, p. 67; 0079, p. 31). When wet methods were used, then median sample result was almost twice as high indoors compared with outdoors.

Because visible dust levels can build up when working indoors due to decreased air circulation, it is more likely that methods of dust control will be attempted when working indoors (i.e., 25.6 percent of indoor samples applied water, compared to 6.7 percent of outdoor samples).

For the samples taken outdoors, the median value for samples taken when wet methods were used (140 µg/^{3}) was only slightly lower than the median value when control methods were not used (148 µg/m^3). For samples taken indoors, the median value when wet methods were used (260 µg/3) was substantially higher than the median value when no control methods were used (111 µg/m^3). The higher median dust level for samples in which wet methods were used during jackhammering indoors runs counter to the concept of dust suppression using wet methods. A closer examination of these sample data provides several possible explanations. Three of the 4 highest samples in the indoor/water applied category (all three > 600 µg/m^3) were obtained during an OSHA inspection that describes three individuals jackhammering a concrete ramp in a large pool area (Document ID 3958, Rows 1064, 1065, 1066). The high silica exposures may have been the result of multiple, concurrent jackhammering operations in an enclosed area. The control description of water suppression lacked sufficient detail to determine the type of wet method used, and how it was applied, in this operation. Another possible explanation is that wet methods in this case were used due to the presence of higher than expected levels of respirable dust during this project, so that without the use of wet methods, silica exposures levels would have been even higher. Removing these 3 samples from the 11 samples on indoor jackhammering with wet methods would result in a median level of 104 $\mu g/m^3$, slightly lower than indoor jackhammering with no controls used. This result is similar to the comparison of jackhammering outdoors with wet methods used and jackhammering outdoors with no controls used.

The final exposure profile below compiles the best available exposure monitoring data of workers using jackhammers, percussion/chipping hammers, and other powered handheld impact tools. This exposure monitoring data, as described in more detail above, was obtained under a range of conditions. Therefore, the monitoring data distribution results reflected in the final exposure profile in Table IV.5.5-B represent the best available evidence of these workers’ existing exposure levels.

Table IV.5.5-B
Personal Respirable Crystalline Silica Exposure Range and Distribution of Results for Construction Workers: Demolition Workers Using Jackhammers and Other Powered Handheld Chipping Tools

	Exposure Summary			Exposure Range		Exposure Profile				
Demolition Workers Using Jackhammers and Handheld Power Chipping Tools	**N**	**Mean (μg/m³)**	**Median (μg/m³)**	**Min (μg/m³)**	**Max (μg/m³)**	**< 25 (μg/m³)**	**≥ 25 and ≤ 50 (μg/m³)**	**> 50 and ≤ 100 (μg/m³)**	**> 100 and ≤ 250 (μg/m³)**	**> 250 (μg/m³)**
Outdoor - baseline	66	194	148	12	624	11 (16.7%)	7 (10.6%)	10 (15.2%)	15 (22.7%)	23 (34.8%)
Outdoor with water applied	5	226	140	12	639	1 (20%)	0 (0%)	0 (0%)	3 (60%)	1 (20%)
Indoor - baseline	32	404	111	12	2,350	7 (21.9%)	0 (0%)	8 (25%)	8 (25%)	9 (28.1%)
Indoor with water applied	11	328	260	12	880	3 (27.3%)	0 (0%)	1 (9.1%)	1 (9.1%)	6 (54.5%)
Other	20	152	13	12	1,144	11 (55%)	1 (5%)	2 (10%)	3 (15%)	3 (15%)
Demolition Workers Using Jackhammers and Handheld Power Chipping Tools Total	**134**	**250**	**126**	**12**	**2,350**	**33 (24.6%)**	**8 (6%)**	**21 (15.7%)**	**30 (22.4%)**	**42 (31.3%)**

Notes: All samples are personal breathing zone (PBZ) results and represent 8-hour time-weighted average exposures.
Job categories are intended to represent job functions; actual job titles might differ, and responsibilities might be allocated differently, depending on the site.
Percentages may not add to 100 percent due to rounding.

Sources: Document ID 1720; 3958; 0016; 0019; 0021; 0029; 0044; 0045; 0079; 0088; 0101; 0109; 0177; 0179; 0183; 0197; 0219; 0226; 0027; 0798; 0846; 0850; 0857; 0874; 0911; 0912; 1143.

5.5.3 Additional Controls

The exposure profile in Table IV.5.5-B shows that almost 70 percent (93 out of 134 samples) of workers using jackhammers and other handheld powered chipping tools have exposures above the final PEL of 50 μg/m^3. Therefore, OSHA finds that additional controls will be necessary to achieve the PEL for these overexposed workers.

Seventy-three percent of workers using jackhammers, chipping hammers or other powered handheld impact tools when working outdoors without any controls, were exposed to silica at levels above 50 μg/m^3. Seventy-eight percent of the workers using these tools indoors without any controls (baseline conditions) were exposed to silica at levels above 50 μg/m^3. As a result, controls will be required to reduce these operators' exposures. Additional, properly-implemented controls may need to be used by some workers already using some form of control. Control options include LEV and wet suppression methods, which, as Table IV.5.5-B indicates and studies discussed below show, will reduce respirable silica exposures significantly. OSHA judges that these methods are technologically feasible and if properly implemented will reduce exposures to the lowest feasible level.

Wet Methods

Various studies have demonstrated that properly used wet methods can substantially reduce respirable silica levels by 90 percent and higher (Document ID 0865; 0867; 0838; 0914; 1267, pp. 493-494; 2177, Attachment D, p. 19). NIOSH studies that examined water spray devices designed to optimize dust suppression (directed mist or solid cone nozzle) have found that dust and/or silica is reduced from 72 to 90 percent at a flow rate of approximately 350 milliliters per minute (ml/min) for jackhammers operated outdoors (Document ID 0865; 0867; 1267, pp. 493-494).

In a study by NIOSH, two workers were sampled to investigate reductions achieved through the use of a water spray attachment on jackhammers (Document ID 0867). The RCS sample results for the trials conducted for dry jackhammering ranged from 380 μg/m^3 to 2800 μg/m^3. The RCS sample results for trials conducted when using the water spray attachment ranged from 50 μg/m^3 to 320 μg/m^3, after excluding a trial during which the water spray nozzle was clogged. The water spray attachment used by worker 1 delivered approximately 250 ml of water per minute and reduced exposures to RCS by 39 percent compared to no control. The water spray attachment used by worker 2 delivered approximately 300 ml of water per minute and reduced exposures to RCS by 77 percent compared to no control. The authors observed that water applied at these flow rates did not add a substantial amount of water to the work surface (Document ID 0867, p. 17).

Information submitted to the docket by NIOSH includes a presentation from the Hazards Control Department of the University of California Lawrence Livermore National Laboratory, showing that wet suppression reduced respirable dust by 81 percent for outside work and 95 percent for inside work and reduced silica concentrations by 86 percent for outside work and 98 percent for inside work. The reductions resulted in mean exposure levels of 48 μg/m^3 for inside work and 65 μg/m^3 for outside work (Document ID 2177, Attachment D, p. 19).[180]

Although not commercially available at this time, the record shows a number of examples of water suppression systems that have been developed and tested and are ready for commercial introduction (Document ID 0741; 0838; 0914; 2177, Attachment D, pp. 4-7; 3732, Attachment 3, p. 10). During the hearings, Ken Hoffner of the joint labor management New Jersey Laborers' Health and Safety Fund described the system it has developed and tested. The system demonstrates “that the application of wet controls and respiratory protection for the jackhammer and impact drilling activities listed in Table 1 will achieve compliance with the recommended PEL” (Document ID 3589, Tr. 4213). Mr. Hoffner estimated that the water suppression system the Fund developed costs about $350, could supply up to six jackhammers at the same time, and has run without repair for eight years (Document ID 3589, Tr. 4234-4237).

During the hearings, some commenters argued that water may not be available on site, that in cold climates it may be an unworkable control, and that it may introduce slip

[180] This experimental study was a simulation conducted in a fabricated enclosure, so was not included in the exposure profile since it did not represent field data. There were four samples collected of dry inside jackhammer work, with exposures ranging from 860 μg/m^3-1600 μg/m^3 of respirable crystalline silica. There were four samples collected using wet suppression while jackhammering inside, with exposures ranging from <30 μg/m^3 -100 μg/m^3).

hazards or runoff issues (Document ID 2319, p. 110; 2171, p. 4; 3589, Tr. 4229-4230, 4296). However, comments and hearing testimony described current contractor practices to make water available on worksites and to adapt to harsh winter conditions in construction (Document ID 4207, p. 2; 3585, Tr. 2932, 3059, 3062, 3094; 3583, Tr. 2341; 3589, Tr. 4229-4230, 4296). OSHA understands the concerns about possible slip hazards from the use of water, however, NIOSH investigators noted that the relatively low water flow rates (300 ml/min) used to suppress dust during jackhammering did not result in a substantial accumulation of water on work surfaces. Proper implementation of wet methods will include training operators to avoid using more water than necessary and taking measures to contain any runoff to prevent the accumulation of water on walking and working surfaces.

The information reviewed by OSHA indicates that water spray controls, when properly designed and used, can reduce typical breathing zone concentrations outdoors by 72 to 98 percent (midpoint of 85 percent) (Document ID 0838; 0865; 0867; 1267, pp. 493-494; 2177, Attachment D, p. 19; 0914). Applying a reduction of 72 percent to the sample results from the exposure profile, OSHA estimates that water spray controls could reduce the median silica exposure level for workers using jackhammers, chipping hammers, and other powered handheld impact tools outdoors from a median of 148 μg/m^3 to 41 μg/m^3 TWA. Applying a 72 percent reduction to outdoor baseline condition samples, OSHA estimates that 43 percent of exposures will exceed 50 μg/m^3. Field trials of water controls (described above) show that water spray systems mounted on jackhammers have reduced silica exposures to at or below 100 μg/m^3. For the water suppression to be effective, it must: 1) provide sufficient water mist (flow rate optimized); 2) provide a suitable droplet size and pattern (the correct nozzle); and 3) be appropriately directed at the point of impact (Document ID 0548).

Local Exhaust Ventilation

LEV systems present an additional control option for reducing the respirable quartz exposures of impact drillers. The available information on LEV dust control systems for chipping and breaking equipment suggests that some local exhaust ventilation systems might be nearly as effective as certain wet methods. NIOSH tested two tool-mounted

LEV shrouds: one custom built, the other a commercially available model during work with chipping hammers. Comparing multiple short–term samples, NIOSH found that use of the shrouds resulted in respirable dust levels between 0.6 and 1.38 mg/m^3, a reduction of 48 to 59 percent from uncontrolled conditions (Document ID 1267, 0865). In a separate evaluation, NIOSH evaluated workers using 25- or 30-pound jackhammers to chip concrete from inside concrete mixer truck drums. During 90- to 120-minute periods of active chipping, mean silica levels decreased 69 percent (from 970 µg/m^3 to 300 µg/m^3) when the workers used a tool-mounted LEV shroud in these enclosed spaces (Document ID 0862, pp. 10-11). When they used a combination of LEV and general exhaust ventilation for additional dust control, there was an improvement to a 78 percent reduction in the silica level (Document 0862, p. 12).

During a separate manufacturer-sponsored test at an indoor demolition site, a LEV shroud mounted on a breaker hammer with a bag-style vacuum fitted with a high-efficiency particulate air (HEPA) filter reduced the number of 5-micron-sized (respirable) particles by 27 percent (Document ID 0667, p. 2). A company representative noted that this result could have been improved if the trial had involved the optimal airflow rate recommended for shrouds (120 cubic feet per minute [cfm]) by use of another type of vacuum (Document ID 0651).

Several powered impact tool manufacturers currently offer LEV options (Document ID 1288, p. 2; 1700). Other companies specialize in manufacturing after-market cowls or exhaust ventilation systems for various handheld tools such as jackhammers and chipping equipment (Document ID 0566; 1264, pp. 4-9; 1266, pp. 9-28; 1671; 1366; 1399; 3806, pp. 272-273, 276).

As with grinding and tuckpointing operations, it is likely that many of the recommendations about vacuum design that would aid in maintaining adequate air flow would apply to the use of LEV for jackhammers, chipping/percussion hammers, and other powered handheld impact tools including use of cyclonic pre-separators, vacuums with two vacuum cleaner motors in parallel combined with a large filter area and a gauge indicating filter pressure to assist workers in determining when it is time to run a filter cleaning cycle (Document ID 0600, pp. 884-886; 0731, pp. 382-384; 0863, pp. 9-10).

Work Practices

OSHA believes that if jackhammer, chipping/percussion hammer, and other powered handheld impact tool operators were provided vacuums rather than using compressed air to clean work surfaces, additional exposure reductions would be possible, especially in indoor environments (Document ID 0933, p. 49; 3799, p. 2). Although there are no individual studies that show the cumulative benefit of using vacuuming in combination with wet methods or LEV systems, the prevention of dust accumulation and re-suspension of settled dust will contribute to the overall exposure reduction achieved by tool-based control systems.

5.5.4 Feasibility Finding

Paragraph (c) of the construction standard gives employers the option of following Table 1, which includes specified engineering and work practice controls for workers operating jackhammers and other powered handheld chipping tools; alternatively, the employer must assess and limit exposures in accordance with the more traditional regulatory approach of compliance with the PEL contained in paragraph (d). For workers operating jackhammers and other powered handheld chipping tools, Table 1 requires employers to use either a tool with a water delivery system that supplies a continuous stream or spray of water at the point of impact or a tool equipped with a commercially available shroud and dust collection system. If an employer uses the dust collection option, it must ensure that the tool is operated and maintained in accordance with the manufacturer's instructions to minimize dust emissions and that the dust collector provides at least the air flow recommended by the manufacturer, has a filter with 99 percent or greater efficiency and has a filter cleaning mechanism. For both the wet methods and dust collection options, Table 1 requires the use of a respirator having an assigned protection factor (APF) of 10 whenever an employee is expected to operate a jackhammer or other powered handheld chipping tool indoors or in an enclosed area regardless of duration or outdoors for more than four hours per shift. When multiple jackhammers are used simultaneously in close proximity, specified exposure control methods (Table 1) on each of the jackhammers will be required so that an operator of one jackhammer with controls is not exposed to dust created by another jackhammer used without controls.

Based on data summarized in Table IV.5.5-B, OSHA concludes that most (almost 70 percent) of operators of jackhammers, chipping hammers, or other powered handheld impact tools currently experience exposures above 50 μg/m^3. Evidence in the record demonstrates that water spray suppression systems reduce respirable crystalline silica exposures substantially, where the system is well designed and properly implemented and maintained. Two published studies (Document ID 0867, 0914), as well as OSHA's analysis of the exposure reduction achieved from the baseline profile, indicate that TWA exposures can be reduced to 50 μg/m^3 or less most of the time by using water to suppress dust when jackhammering outdoors for less than four hours per work shift. While tested designs for water spray on jackhammers exist, OSHA has not identified any integrated water spray systems for jackhammers that are commercially available at this time. However, these spray systems can be assembled from readily available hardware and materials using instructions from NIOSH and the New Jersey Laborers' Health and Safety Fund (Document ID 0741; 3589, Tr. 4234-4237). Therefore, OSHA finds that the Table 1 option of using wet systems when operating these tools is technologically feasible and effective.

OSHA's exposure profile contained no exposure data on the use of shrouds and local exhaust systems. However, studies have shown that LEV systems can reduce exposures from 26 to 60 percent for jackhammers breaking concrete (Document ID 1267; 0865; 0651; 0667). The reductions, however, are substantially less than those reported with the use of water suppression (72 to 98 percent) (Document ID 0867, p. 3; 2177, Attachment D, p. 19). One study of LEV controls for jackhammers found respirable dust concentrations in the breathing zone ranging from 0.6 to 1.38 mg/m^3. The corresponding respirable quartz exposures would range from about 180 to 410 μg/m^3 (assuming a quartz content of 30 percent, which is on the high side of what is usually seen in concrete and other silica-containing construction materials) (Document ID 1267, p. 493). Another study of a jackhammer equipped with LEV used in a confined space (concrete truck drum) found a silica exposure reduction of about 69 percent (Document ID 0862, pp. 3, 10-11). These reductions, while still substantial, would result in exposures substantially above 50 μg/m^3 in indoor or enclosed conditions, where there can be visible dust accumulation (Document ID 4073, Attachment 15j), or outdoors where work patterns require operation beyond the median task time (231 minutes) (Document ID 0677). OSHA finds that the Table 1 option of using tools equipped with LEV systems is technologically feasible in that commercially available integrated systems have demonstrated the ability to significantly reduce respirable silica exposures. Several manufacturers currently offer LEV options (Document ID 0542; 1700; 1288). Other companies specialize in manufacturing after-market ventilation systems for various handheld tools, such as jackhammers and chipping equipment (Document ID 1264; 1266; 1366).

OSHA concludes that approximately 70 percent of workers using jackhammers and other handheld powered chipping tools are currently exposed to silica levels above 50 μg/m^3. For workers who are currently exposed above 50 μg/m^3, the controls described in this section can be implemented to reduce silica exposure levels to 50 μg/m^3 or below in most operations, most of the time, when performed outdoors for fewer than four hours per shift. As indicated by the exposure profile (Table IV.5.5-B), jackhammering is most often conducted outdoors. And, based on the median task duration of 231 minutes (as well the physical exertion required while jackhammering), most jackhammering tasks are performed for fewer than four hours per shift. Therefore, OSHA finds that the standard is technologically feasible for workers using jackhammers and other handheld powered chipping tools. OSHA also finds that existing controls cannot reliably reduce TWA exposures to 50 μg/m^3 or below when operating jackhammers and chipping guns indoors or in enclosed areas, or when operating jackhammers or chipping guns outdoors for more than four hours in a shift. Supplemental respirator use is required in those situations.

5.6 MASONRY AND CONCRETE CUTTERS USING PORTABLE SAWS

5.6.1 Description

Portable and handheld power masonry and concrete saws are commonly found on construction sites where they are used to perform a wide variety of cutting activities, including cutting and resizing bricks, roofing tiles and concrete blocks and stone; cutting segments, including cores, out of existing pavement or masonry structures; cutting to straighten an edge or to weaken a structure in preparation for demolition; cutting grooves for utility installations; and cutting fiber-cement board. Exposures to respirable dust containing silica at levels above the previous PEL can occur when workers are using portable saws without effective dust controls.

For the purpose of describing control methods, OSHA has grouped portable masonry and concrete saws into five categories based on size and available controls: 1) handheld power saws; 2) specialty handheld power saws for cutting fiber-cement board; 3) rig-mounted core saws or cutting machines; 4) walk-behind saws; and 5) drivable saws.[181]

Two of these groups, specialty saws for cutting fiber-cement board and core cutting machines, have been added since the Preliminary Economic Analysis (PEA). OSHA added these groups in response to comments from the fiber-cement board industry, which provided substantial data on control technology (a specially-configured saw) for controlling silica exposures when saw operators cut fiber-cement board (Document ID 2322, Attachment B-F, Attachment H, pp. 1-7), and the Construction Industry Safety Coalition (CISC), which identified additional hole drilling processes and types of work related to installing fiber-cement board (Document ID 2319, pp. 19-21; 3580, Tr. 1279).

The following paragraphs describe the five groups of portable masonry saws:

Handheld power saws: Handheld power saws (also referred to as cut-off, chop, quickie, or handheld masonry saws) are normally fitted with 9 to 14 inch diameter blades and powered by small capacity combustion engines, electricity, or compressed air. These

[181] The unifying feature of all these saws is a blade that cuts a full or partial depth channel in the material, usually for the purpose of cutting away a portion of the material. Masonry and concrete saws typically produce a straight cut, but the cut is circular in the case of concrete coring machines.

saws can be used to cut concrete, masonry, and stone. Circular saws fitted with smaller blades ranging from 5 to 8 inches in diameter can also be used for smaller cuts in concrete and masonry (Document ID 0615, pp. 2, 24-28).[182] Two types of blades are commonly used: diamond tip and resin composite abrasive, with specialty variations also available. The diamond blades can be used either wet or dry (Document ID 0607; 0615, pp. 24-28).

When using a handheld saw, the operator holds the saw with both hands and leans over the work, which is typically between ground level and waist height. The cutter's breathing zone is often within arm's length of the point of dust generation (Document ID 0615, pp. 24-28). The worker's close proximity to the source creates the potential for high concentrations of respirable crystalline silica in the worker's breathing zone, resulting in elevated silica exposure values (summarized in Table IV.5.6-B, the exposure profile for this group of workers).

Handheld power saws cutting fiber-cement board: These specialized saw configurations consist of blades (typically 8 inches in diameter or less, with four to eight teeth) specifically designed for cutting fiber-cement board (Document ID 2322, Attachments A-I, p. 9, Attachment B, p. 8). The blades are fitted to a circular saw (or occasionally to other saws) with dust reduction designs (Document ID 2322, Attachments A-I, p. 9, Attachment B, p. 8). Although a form of handheld saw, this saw configuration (for fiber-cement board) is addressed separately in the FEA because it has been specifically designed and extensively tested by a member of the fiber-cement siding industry and by NIOSH for controlling the silica exposures of installers who perform cutting in that industry, and the saw is intended specifically for use on fiber cement board (Document ID 2322, Attachments A-I, pp. 5, 9, Attachment B, pp. v, 8). Fiber-cement board, produced with silica sand containing up to 45 percent silica, is used as siding and fascia applied to the exterior of buildings, so cement fiber boards are normally cut

[182] Although blades are usually 14 inches or smaller, larger blades are available for some equipment (Document ID 0615, p. 28).

outdoors (Document ID 2322, p. 11, 39, see also photos in Attachments B-F; 4139 [4139 is a duplicate/final copy of 2322, Attachment B]).

Rig-mounted core saws or drills: Saw operators use core saws to perform core cutting (also called core drilling, boring, or concrete coring) to create round holes for pipes, ducts and conduits to pass through walls, ceilings and floor slabs made of concrete, masonry or other materials that may contain silica. Core cutting machines (also called core drills) use a thin continuous round cutting surface on the round end of a cylindrical coring tool (“bit”) (see photographs in Document ID 0679, pp. 18-20). The annular bit’s cutting surface rotates around a central arbor (spindle) that runs through the center of the otherwise hollow cylindrical bit and attaches to an electric, hydraulic, or pneumatic power drive (Document ID 0615, p. 32). The machine is typically attached to the surface being drilled (bolted on via a rig for stability) (Document ID 3998, Attachment 13e, pp. 4, 9-photographs of core drill bolted to wall with rig), but for small or shallow holes the core drilling equipment can be handheld (Document ID 0675, p. 1098; 0679, pp. 18-21; 3501, p. 6). When the rotating diamond core cutting bit is applied to solid material, the bit cuts away a thin circle of material. The cut separates the central “core” of material, within the circumference of the bit, from its surroundings, leaving the core generally intact as it is removed from the hole (Document ID 3501, p. 6).[183] The cylindrical bit can be large; for example, NIOSH described a coring operation used to produce holes 2 to 31 inches in diameter in large sections of concrete conduit (Document ID 0898, p. 6).[184]

[183] In contrast to rig-mounted coring equipment, which allows workers to remove most of the material from the hole intact as a solid block by using a cylindrical cutting tool bolted to the surface being cut, the more familiar solid-tip drill bits (which tend to be smaller than most rig-mounted core drill bits) pulverize the material in their path, so the entire volume of solid material from the resulting round hole is turned to dust. Handheld drills using bits of this type or using small coring bits (up to a few inches in diameter) are covered in Section IV.5.4 – Hole Drillers Using Handheld or Stand Mounted Tools, while the large rig-based drills (usually mounted on vehicles or trailers) are addressed in Section IV.5.9 – Rock and Concrete Drillers.

[184] The coring operation occurred at a manufacturing plant producing construction materials (in a covered bay with only general dilution ventilation) where concrete conduit (large pipe), such as is used for water mains, was custom cored to allow fittings (i.e., junctions with other pipes) to be installed (Document ID 0898).

Coring cutting is typically a wet process. Water cools the blade, which is easily damaged if it becomes hot, and dust control is an added benefit (Document ID 3580, Tr. 1415; 3581, Tr. 1584; 3585, Tr. 2902).

Walk-behind saws: Walk-behind saws, also known as slab or green saws, are used to cut expansion joints or slabs out of existing pavement. Workers operate the equipment from behind using a control bar or handle(s) so that their breathing zone is typically five or more feet from the cutting blade. As walk-behind saws are used to cut pavement, they are most commonly used outdoors; however, they can also be used indoors (Document ID 1431, p. 3-63).

Drivable saws: A drivable saw operator typically sits in an open cab about 15 feet away from the pavement cut point, guiding the saw to make long cuts. This type of work is common for utility installations along roadways. The blade housed by this vehicle can be large (e.g., 8 feet in diameter and 2 inches thick) and is typically equipped with a water-fed system for cooling the blade. Because of their size, drivable saws are typically used outdoors (Document ID 1431, pp. 3-63 – 3-64).

Table IV.5.6-A summarizes the major activities and sources of silica exposure for workers using different types of portable and handheld masonry saws.

Table IV.5.6-A
Activities and Sources of Exposure of Masonry and Concrete Cutters Using Portable and Rig Mounted Power Saws

Task/Tool	Major Activities and Sources of Exposure
Handheld (Cut-off/Chop/Circular) Power Saw Operator	Using handheld power saw to cut bricks, concrete blocks, tiles (i.e., wall, floor, roofing), and small sections of concrete structures (e.g., pavement, curbs, walls). • Dust generated by cutting action of the abrasive blade in concrete or masonry.
Handheld Power Saw Operator cutting fiber-cement board (blade 8-inch or less)	Using handheld power saw to cut fiber-cement board. • Dust generated by cutting action of the abrasive blade in fiber-cement board.
Rig-mounted Core Saw Operator (wet process)	Using low speed rig-mounted, water-fed equipment to cut cores (i.e., remove cylindrical segments) from materials containing silica, such as concrete, stone or masonry (e.g., walls, floor slabs, ceilings). • Dust generated by cutting action of the abrasive blade.

Table IV.5.6-A Activities and Sources of Exposure of Masonry and Concrete Cutters Using Portable and Rig Mounted Power Saws	
Walk-Behind Saw (Slab Saw) Operator	Manipulating wheeled saw using handles. Cutting existing pavement, typically to form expansion joints or to cut slabs (or margins) of pavement sections to be removed by other tools. • Dust generated by cutting action of the abrasive blade in concrete or asphalt.
Drivable Saw Operator	Controlling saw from an open cab to make long cuts in existing pavement (e.g., to install underground utilities). • Dust generated by cutting action of the abrasive blade in concrete or asphalt.
*Job categories are intended to represent job functions; actual job titles might differ, and responsibilities might be allocated differently, depending on the site. Source: Document ID 1431.	

5.6.2 Exposure Profile and Baseline Conditions

In the PEA, OSHA reviewed 91 time-weighted average (TWA) personal breathing zone (PBZ) respirable quartz results for workers using portable saws to cut concrete, masonry and related materials on construction sites. The updated exposure profile adds 12 samples from OSHA compliance inspections available through OSHA's Information System (OIS), two samples from a study published by Flanagan et al. in 2001, two samples from a NIOSH study published in 2000, and additional samples provided during the comment period by the James Hardie Building company (96 samples) and the National Roofing Contractors Association (3 samples) (Document ID 3958; 0675; 0898; 2322; 4022). The added data included 14 samples for workers dry cutting with portable handheld power saws outdoors, one sample for a worker dry cutting with a portable handheld power saw indoors, four samples for core drillers using wet methods, 21 samples for workers using saws (with specialty blades of less than 8 inches) for cutting fiber-cement board without other controls, and 75 samples for workers using specially configured circular saws (with specialty blades of less than 8 inches) for cutting fiber-cement board with local exhaust ventilation.

In the FEA, OSHA has made several adjustments to the subcategories into which handheld power saws are grouped to make the groupings more specific. These adjustments include renaming the subgroups previously affiliated with data labeled as "Indoors or location unspecified" to produce subgroups that more clearly indicate that the cutting took place either indoors or outdoors, using either wet methods or dry cutting. OSHA evaluated all handheld saw samples and organized them into the revised subgroups based on working conditions and sampling location, and on whether water was used during cutting (regardless of whether the water was used effectively or not). A total of 16 samples from the PEA were realigned in the process, including four samples where wet methods were used indoors.[185]

The final exposure profile in Table IV.5.6-B for construction workers using portable saws to cut concrete, masonry and related materials includes 83 samples with a median value of 110 μg/m^3, a mean of 288 μg/m^3, a range of 6 to 10,318 μg/m^3. For outdoors, the profile contains 65 samples taken when cutting dry with a median of 130 μg/m^3, and 5 samples with a median of 19 μg/m^3 when cutting wet. For indoors, 3 samples taken when cutting dry had a median exposure of 1490 μg/m^3 compared to a median of 50 μg/m^3 for the 10 samples taken when cutting wet.

Baseline Conditions for Handheld Power Saw Operators

Baseline conditions for construction workers using handheld saws typically involve outdoor cutting on concrete or masonry with no engineering or work practice controls in place (78 percent of samples). When used without dust controls, handheld masonry saws can generate very high levels of respirable dust. The exposure profile presented in Table IV.5.6-B shows that the median 8-hour TWA respirable silica exposure level for masonry cutters working outdoors without controls is 130 μg/m^3, with approximately 72.3 percent of samples over 50 μg/m^3 and 15 percent over 250 μg/m^3 and a maximum exposure of 1,472 μg/m^3. By comparison, for five samples obtained for workers using handheld saws

[185] Samples that previously had been grouped as “indoors or location unspecified” were evaluated and reassigned (indoors or outdoors) based on information in the record. In some cases, location is inferred from the task description. For example, sawing on “floor” or “ceiling” was judged to have taken place indoors, as those terms are rarely associated with an outdoor environment, while sawing activities on “pavement” were placed in an outdoor group, as the term “pavement” is widely used for outdoor surfacing. In some cases, descriptions of other samples collected at the same construction site were consulted to obtain additional insight into the nature and location of the worksite. The previous group of samples “indoors or location unspecified” (eight samples) or “indoors or location unspecified-wet methods” (four samples) were divided into the current four groupings: 1) “outdoors, dry cutting”; 2) “outdoors, wet cutting” 3) “indoors, dry cutting”; and 4) “indoors, wet cutting”. Additionally, four samples previously grouped with “outdoor, wet methods” were moved to the category for “indoors, wet cutting.”

outdoors with wet methods to control dust, the median exposure value is 19 μg/m^3 and the maximum value is 154 μg/m^3.

Median exposure levels tended to be higher for workers using power saws indoors compared to similar work performed outdoors, regardless of whether controls were used. As shown in the exposure profile (Table IV.5.6-B), the median exposure of 50 μg/m^3 for wet cutting indoors is roughly 2.5 times higher than the median exposure of 19 μg/m^3 for wet cutting outdoors. And the median exposure for dry cutting indoors is more than 11 times higher than the median exposure for dry cutting outdoors (1,490 compared to 130 μg/m^3). Location also affects the portion of workers with exposures exceeding 50 μg/m^3. When saw operators performed cutting indoors with water, 50 percent of samples (5 of 10) were over 50 μg/m^3, compared with only 20 percent (1 of 5) over 50 μg/m^3 when sawing was performed outdoors with water. The three indoor dry cutting samples are greatly influenced by a single high value based on a 350-minute sample with a 14,150 μg/m^3 silica concentration (10,318 μg/m^3 as an 8-hour TWA), which was reported for a plumber who used a handheld saw to dry-cut slabs out of concrete bathroom floors indoors on each level of a 16-story building. A floor-stand fan aimed at an open window was the only attempt at dust control (Document ID 0846, p. 6).

The National Roofing Contractors Association submitted data from monitoring three roofers installing clay tiles on a residential roof using a dry 14-inch tile cutting saw (Document ID 4022, Attachments 1, 2). The samples were taken for 197, 198, and 202 minutes (Document ID 4022, Attachment 2, Appendix D). For these samples, the investigator indicated that the unsampled periods of the shifts were expected to have the same exposure concentration as was measured during the portion of the shift that was monitored (Document ID 4022, Attachment 1, pp. 2, 7, Appendix D). The two roofers who performed the majority of the tile cutting had quartz concentration exposures of 160 and 300 μg/m^3. However, the supervisor who did not do as much tile cutting had a quartz exposure of 33 μg/m^3 (Document ID 4022, Attachment 1, Appendix D). OSHA has converted these exposure concentrations to 8-hour TWAs (assuming exposures continued at the same levels during the unsampled periods), and has included these exposure results in the exposure profile.

The Concrete Sawing and Drilling Association (CSDA) submitted "Best Practices - Silica Data Analysis Chart," which compiles silica exposure data for workers using various construction tools, including various handheld and wall- (rig-) mounted power saws (Document ID 3497). Patrick O'Brien (representing CSDA) explained that the chart is based on all sawing and drilling data CSDA has collected over the last decade (Document ID 3585, Tr. 2900, 2907). The chart's introduction states that it contains exposure results collected by association member jobsites and from NIOSH (Document ID 3497, p. 1). It is unclear whether the results in CSDA's Best Practice document are individual PBZ samples. Some results are presented as a range of exposures, suggesting that the result represents multiple samples. Other results appear to be area samples, rather than PBZ samples. For example, OSHA matched several area samples in a NIOSH study (Linch, 2002) to results provided in CSDA's document (Document ID 0784, pp. 216-217). Further, although the chart reports the sample duration and the result, it is unclear whether the result is a concentration value or an 8-hour TWA. Finally, as CSDA stated that some of the results are from NIOSH, there appears to be some overlap between the results in the chart and NIOSH data that are already part of the exposure profile. Accordingly, although OSHA has insufficient information to include the data in the exposure profile (see IV-2 – Methodology), OSHA has considered this data and found it useful in evaluating the effectiveness of controls

In addition to the documents that contributed individual results to the exposure profile, OSHA reviewed a study by Flanagan et al. (2006) that summarized 65 results for workers using handheld saws (part of a larger set of construction silica exposure data compiled by the authors) (Document ID 0677, p. 147-Table II). The authors reported an overall geometric mean quartz concentration of 130 $\mu g/m^3$ for the sawyers using handheld saws, but provided no other information specific to this group (Document ID 0677, p. 147). The geometric mean reported by Flanagan et al. (2006) is in the same range as the information OSHA has summarized for this job category in Table IV.5.6-B, which shows a median of 110 $\mu g/m^3$ for the general category of handheld saw operators. OSHA also reviewed another construction silica dataset, compiled by Flanagan (2009), and determined that it is substantially similar to that summarized in the 2006 paper (Document ID 0677; 0677, Attachment 2). OSHA did not incorporate the individual exposure data reported by

Flanagan into the exposure profile because it overlaps with several sources of data that OSHA has already included in the exposure profile. While not used in the profile, these supplemental sources of exposure data provide additional information on expected exposure levels for workers using portable saws.

Another report from Flanagan et al. (2001) provides summary exposure information for workers using rig-mounted (but hand-guided) wall saws indoors. This equipment was used with a water feed and was associated with a median concentration value of 130 $\mu g/m^3$ (range 60 to 220 $\mu g/m^3$) for three samples (with a mean sampling time of 294 minutes) (Document ID 0675, p. 1098-Table I). The authors attributed at least one of the elevated exposures to work practices common among inexperienced workers who closely watch the progress of the blade, putting "their breathing zone . . . in the particle spray zone" (Document ID 0675, p. 1098). More experienced workers tended to stand back out of the spray (particularly when cutting walls with hand-guided saws on tracks) (Document ID 0675, p. 1098). The authors also indicated that to represent "worst case" conditions, they elected to monitor indoor work sites where jobs with long task durations were scheduled (Document ID 0675, p. 1097).[186]

Operators typically use handheld saws for brief, intermittent periods; however, the process might be repeated numerous times over the course of a shift (Document ID 1431, p. 3-63). During the rulemaking, OSHA received additional information indicating that most workers use handheld saws for less than two hours a day. Rashod Johnson of the Mason Contractors Association of America (MCAA) and Chairman of the ASTM E34 subcommittee on silica in construction from 2003-2013 stated: "90 minutes is actually a really long time to be cutting something. The vast majority of [cuts] are under 15 minutes in any given day" (Document ID 3581, Tr. 2911). Mr. Johnson explained that when more

[186] This strategy of selecting only work sites with long-duration ("full-shift") sawing jobs both allowed the investigators to evaluate "worst-case" conditions and also helped ensure that silica exposure results were above the limit of detection (LOD). The authors note that "many jobs do not involve such extensive periods of cutting, with workers often working at two or three job sites per day. Time spent commuting between sites and cleanup for each job provided periods of minimal or no exposure" (Document ID 0675, p. 1100).

cutting is necessary, the sawyer uses a cutting station that has a different set of engineering controls (Document ID 3581, Tr. 2911).

Dan Smith, Director of Training at the Bay Area Roofers and Waterproofers Training Center, stated that less than fifty percent of their commercial work involves cutting concrete tile and that this percentage is far lower in residential roofing (Document ID 3581, Tr. 1597). When cutting is performed, it is usually half an hour to 45 minutes a day (Document ID 3581, Tr. 1598). Middaugh et al. (2012) explained that concrete cutting in roadway construction is frequently performed with a handheld saw, noting that "typical curb cutting is performed for less than 2 hours per day" (Document ID 3610, pp. 157, 162). Additionally, a database of silica exposures in construction tasks shows similar times, as the median sample time for workers cutting brick, concrete and stone with a handheld portable saw was 101 minutes (range 9-447 minutes) (Document ID 0677, Attachment 2). At a construction site visited by OSHA, a worker using a water-fed handheld saw spent 40 percent (160 minutes, or 2 hours and 40 minutes) of a 401-minute monitoring period cutting a concrete floor (Document ID 0169, pp. 5-7).[187] Based on the information in the record, OSHA concludes that, most of the time, handheld power saw operators use the saw for two hours or less per shift.

Baseline Conditions for Handheld Power Saw Operators Cutting Fiber-Cement Board

Baseline conditions for construction workers using handheld power saws to cut fiber cement board are based on exposure data from five reports (two reports by NIOSH and three reports from a member of the fiber-cement board industry) that were provided to OSHA during the rulemaking (Document ID 4139; 2322, Attachments B-F). OSHA notes that the two NIOSH reports (Document ID 2322, Attachments B and C) were also entered in the record individually (as Document ID 4139 and 3998, Attachment 4a). The saws used in these reports were fitted with commercially-available, specially designed blades intended for cutting fiber-cement board (an exterior siding and underlayment

[187] OSHA calculated a respirable silica measurement less than or equal to 21 μg/m^3 (the LOD) for the period of this sample (12 μg/m^3 as an 8-hour TWA μg/m^3), and the concrete being cut contained 9 percent silica (Document ID 0169, pp. 5-7).

product) (Document ID 2322, Attachments A-I, pp. 6). Operators using these saws work outdoors cutting fiber-cement board products (siding, fascia) that are placed on the exterior of buildings (Document ID 2322, Attachments A-I, p. 6, Attachment D, pp. 11-13 [photographs]; 3998, Attachment 4c, p. 5-Figure 2; 4138, pp. v, 2, 5-Figure 2).[188]

The five reports from which data for the exposure profile is drawn conducted breathing zone sampling for workers using several types of saws with and without various forms of dust reduction measures, representing conditions and practices currently in use by the industry. These five reports contributed a substantial number of data points to the exposure profile. One earlier (EPBH 358-11a) and two later (EPHB 358-14a and -15a) NIOSH reports in the record evaluated prototype saws that were still under development (by a member of the fiber-cement board industry and a saw manufacturer) and are not commercially available. As such, exposure results for trials with these saws are not representative of exposures of workers in the U.S. and are not included in OSHA's exposure profile (Table IV.5.6-B).

The exposure profile for the cutters operating a variety of saws configured for fiber-cement board is presented in Table IV.5.6-B. The profile shows a mean 8-hour TWA exposure of 63 μg/m^3 and a median exposure of 21 μg/m^3 for 21 saw operators using various saws fitted with the specialty blade, but no controls. The highest 8-hour TWA exposure for this group, 605 μg/m^3, was obtained over a sampling period of 290 minutes for a siding cutter at a siding installation site. The cutter's primary activity was to use an uncontrolled circular saw to cut boards to lengths as the installer (another worker) requested them (Document ID 2322, Attachment D, p. 6). Although it was a typical fiber-cement siding installation, sampling notes indicate that this saw operator brushed accumulated dust off his clothing during the sampling period. The notes mention that the dust from the worker's clothing might have influenced the worker's exposure for the day (Document ID 2322, Attachment D, p. 6).

[188] The data sources are: Document ID 2322, Attachments B-F; 4139 (4139 is a duplicate/final copy of 2322, Attachment B).

The exposure profile also summarizes the exposure results for 75 operators using saws fitted with special cutting blades designed for fiber-cement board and some form of "dust collector" (but not always of a design with vacuum suction). These workers had a mean 8-hour TWA exposure of 11 μg/m^3 and a median exposure of 7 μg/m^3, although elevated exposures (maximum exposure of 76 μg/m^3) occurred with some saw/control configurations that proved less reliable (for example, saws attached to a dust receptacle, without the benefit of a vacuum dust collection device) (Document ID 2322, Attachments A-I, pp. 19-20). The fiber-cement board products being cut contained 15 to 50 percent silica, however, the respirable dust collected in the samples was 0 percent to 12 percent silica and percentages in the lower half of that range were most typical (Document ID 2322, Attachment D, pp. 5-10, Attachment E, pp. 5-9, Attachment F, pp. 5-10). OSHA also notes that the exposure results for the sawyers who were using dust controls might be lower than typical exposures for operators of the same equipment for cutting fiber-cement board on other worksites because these sawyers did not empty the dust from their dust collectors; other (unsampled) workers performed this task (Document ID 2322, Attachment D, p. 3, Attachment E, p. 3, Attachment F, p. 3).

In summary, saw operators cutting fiber-cement board use a variety of commercially available saws configured for this purpose with a specifically designed blade; some of these saws are equipped with LEV. Using portable saws without engineering controls can result in elevated exposures, although using LEV on dust collection saws with specially designed blades 8 inches or less reduces exposures to less than 50 μg/m^3 most of the time (in Section IV-5.6.3 under the heading Additional Controls for Handheld Power Saws Cutting Fiber-Cement Board).

<u>*Baseline Conditions for Rig-Mounted Core Saw or Drill Operators*</u>

In developing the PEA, OSHA reviewed information on core saws (core drills) and determined that operators generally experienced little or no silica exposure during this low-speed process, which is already performed using water-fed equipment as a standard practice (Document ID 0675; 0898). Accordingly, OSHA's preliminary exposure profile did not include any sample results for core cutters. During the rulemaking hearing, Holes, Inc., a company that performs concrete cutting, wall sawing, slab sawing, core drilling, concrete breaking, and demolition tasks, provided additional information regarding task process, scheduling, bits, tools, and wet methods used during concrete core drilling (Document ID 3580, Tr. 1435, 1447, 1484, 1534-1535). Holes, Inc. also agreed with CISC that OSHA considered too narrow a list of construction tasks in the proposal (Document ID 3580, Tr. 1363). OSHA has therefore evaluated rig-mounted core saws in the final exposure profile.

The record contains few exposure results for workers using core cutting machines (core drills). The final exposure profile in Table IV.5.6-B for core saws includes four sample results, all of which are below 50 μg/m^3. These four samples were obtained indoors and range from 11 to 29 μg/m^3 (median 12 μg/m^3, mean 16 μg/m^3). Two of the samples were taken for an operator who was coring 6-inch holes in an 8-inch thick wall over two days. These samples were reported in summary form as ranging from 20 to 20 μg/m^3 over an average sampling time of 261 minutes, which encompassed the operator's entire exposure (Document ID 0675, pp. 1097, 1098-Table 1). Because the summary results presented could be individualized (both results were 20 μg/m^3), OSHA calculated 8-hour TWAs of 11 μg/m^3 from the reported results.[189] These sample results were obtained at a construction site where other wet sawing techniques were also used, sometimes resulting in exposures to other (non-coring) saw operators, exceeding 50 μg/m^3; however, the diamond blade exposure levels associated with core sawing remained low (Document ID 0675, pp. 1097, 1098). Although most results from this study are presented in summary form, these two values are some of the only samples available for core saws. Additionally, OSHA finds there is little risk of these two samples misrepresenting the actual 8-hour TWAs, which for neither sample could exceed 20 μg/m^3 (in the worst case, if the worker performed the task for 480 minutes in one day, the 8-hour TWA would still be no higher than 20 μg/m^3).

Two additional samples from a worker using core sawing or cutting equipment with wet methods were obtained on two dates at a site visited by NIOSH (Document ID 0898, p.

[189] Flanagan et al. (2001) reports silica sample results in mg/m^3 as the concentration during the monitoring period; OSHA multiplied the samples by 1,000 to obtain values in μg/m^3 and determined the 8-hour TWA using the equation for an 8-hour TWA (Concentration1*Time1/480 minutes) from 29 CFR1910CFR 1910.1000(d)(1)(i).

3). Although technically a general industry site, the core sawing operation was performed on conduit (concrete pipe used in utilities construction, such as installing water mains) and could have been performed at the construction site (where exposures might be somewhat lower than in an indoor environment) instead of at the manufacturing site (in a 7,000 square-foot open bay with only general ventilation fans). This operator cut approximately 20 holes, 2-to 31-inches in diameter, and experienced 8-hour TWA exposures of 12 and 29 μg/m^3 on the two days sampled (Document ID 0898, p. 15).

CSDA submitted five sample results for workers using water-fed core cutting machines (tool listed as “Core Drill” or “two-speed coring rig”) indoors and outdoors. All of the results were below 50 μg/m^3 (range 10 to 40 μg/m^3) (Document ID 3497, p. 1). CSDA also provided four exposure results for the task of “wire sawing & core drilling” (Document ID 3497, p. 8). The controls for these results are listed as “water, away from sawing operation, remote control,” and the reported concentration values ranged from below the limit of detection (not further described) to 50 μg/m^3 (Document ID 3497, p. 8). As noted above, the results submitted by CSDA include area samples, and some of the results overlap with data already in OSHA’s exposure profile. Therefore, OSHA did not incorporate exposure results from the CSDA chart in the exposure profile for core cutters (Table IV.5.6-B).

Based on evidence in the record, OSHA has determined that baseline conditions for core sawing operators involve using wet methods (Document ID 0675, p. 1097; 0898, p. 6; 3580, Tr. 1415, 1435; 3581, Tr. 1584; 3585, Tr. 2902). Most core sawing machines include, and are intended to be used with, a water feed (Document ID 0679, pp. 18-21; 3580, Tr. 1415; 3581, Tr. 1584; 3585, Tr. 2902). The core sawing machines that can be used dry are not intended for use on concrete; nevertheless, a water-feed attachment is typically available either as standard or supplemental equipment (Document ID 0679, pp. 18-21). For all but the smallest holes, core sawing machines are bolted in position on the concrete surface to be cored and, compared to other cutting equipment, operate at low to moderate speeds to facilitate precision cuts. For example, a bolt-on water-fed core sawing machine capable of producing a wide range of hole sizes operates at 250 rotations per minute (rpm) when producing 5 to 14 inch holes, with a top speed of 1,000 rpm for small holes 1 to 3 inches in diameter (Document ID 0679, p. 21).[190] The data in the exposure profile reflects the best evidence available to OSHA regarding exposures among core saw operators.

Baseline Conditions for Walk-Behind Saw Operators

OSHA reviewed 20 silica sample results for workers operating walk-behind saws and found that 60 percent were at or below 50 µg/m^3. Twelve of the 20 sample results were collected when the sawing was conducted outdoors with sufficient wet methods. For these 12 samples, the median is 12 µg/m^3 and the mean is 18 µg/m^3; all 12 results were under 50 µg/m^3.[191]

The 12 walk-behind saw operators who used wet methods outdoors worked on various road construction sites (five sites total, including highway construction and interstate repair jobs), usually using water provided by a water truck (Document ID 0784, p. 216, 217-Table V; 1143, Rows 74, 75, 207, 208). Sample times ranged from 53 to 545 minutes. Four of the samples were from a site where the saws were used to cut "green" concrete (recently poured and not fully cured, rather than old or fully cured concrete) (Document ID 0784, p. 216-217).

Eight of the 20 samples for walk-behind saw operators were collected under conditions other than wet cutting outdoors (such as indoor cutting or cutting without wet methods, referred to as "other conditions" in the exposure profile), and all eight show exposure results over 50 µg/m^3. The median value of 236 µg/m^3 is almost 20 times higher than the median of 12 µg/m^3 for workers using wet methods outdoors. Four of the results for operators in "other conditions" (ranging from 65 µg/m^3 to 350 µg/m^3) were obtained by Flanagan et al. (2001) over 4 to 7 hours of indoor work involving wet sawing. In that

[190] Other drilling, cutting, and grinding equipment operates at rpm several times greater. For example, at a site where concrete coring was conducted, the coring equipment ran at 350 rpm, while a rig-mounted concrete saw used to cut a wall of the same structure operated at 2500 rpm (Document ID 0222, p. 4). A tuckpointing grinder blade operates in the range of 10,000 rpm (unloaded) (Document ID 0679, p. 25).

[191] One sample result included in the PEA originally reported as less than the limit of quantification of 61 µg/m^3 was found to be an error. The correct value (as reported by Linch (2002)) for a worker cutting with water supplied by a 4 horse power pump to the saw tip during the 231-minute sampling period is less than or equal to 20 µg/m^3 (the LOQ) (Document ID 0784, pp. 216-217-Table V).

case, a helper used a wet shop-vac to vacuum up slurry (Document ID 0675, pp. 1098-1099, Tables I and II).[192] These samples were collected at construction sites that were selected for evaluation because the sites were anticipated to represent worst-case conditions (longer than typical periods of cutting in enclosed indoor spaces). The saws were operated wet "primarily to limit wear on the expensive diamond blade" (Document ID 0675, p. 1097).

The "other conditions" category includes the highest sample result for walk-behind saw operators. The exposure result (calculated as an 8-hour TWA) of 461 μg/m^3 is associated with a sawyer cutting repair boundaries on a bridge deck under dry working conditions at a site where all seven silica samples (for the operators of a road milling machine, various saws, and jackhammers) exceeded the previous (calculated) PEL by up to 12 times (Document ID 0912, pp. 1, 5).

Two of the "other conditions" samples, with 8-hour TWA results of 172 and 298 μg/m^3, were obtained over 4 to 6 hours while the saw operators cut expansion joints in a roadway at a construction site visited by OSHA. No control measures were associated with these samples (Document ID 0111, pp. 17, 19, 22-24, 27, 28).[193] Nor were controls associated with the other exposure result (an 8-hour TWA of 140 μg/m^3, based on a 314-minute sample), obtained at a second road construction site that OSHA visited where a worker cut expansions joints (Document ID 0815, p. 2).

CSDA's Best Practices document includes 26 entries for water-fed walk-behind saws ("slab sawing") outdoors (Document ID 3497, pp. 2-4). Twenty-five of the 26 reported results were at or below 50 μg/m^3. The chart from CSDA contains a mixture of exposure results collected by association members and from NIOSH. Many of the NIOSH

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[192] Flanagan et al. (2001) present three individual results for inside slab sawing in Table II, and OSHA was able to calculate the 8-hour TWA for the fourth sample (for "Slab saw/walk-behind (inside)"). For the fourth value, the sample duration was 241 minutes (calculated from mean duration and the three given durations) and the concentration was 130 μg/m^3 (presented as the low value in the range, and not among the other three values). The 8-hrhour TWA for this concentration is 65 μg/m^3 (130*241/480) (Document ID 0675, pp. 1098-1099, Tables I and II).

[193] Silica 8-hour TWAs calculated from respirable dust concentration, sample volume, and percent silica in the sample.

exposure data points are likely already incorporated in OSHA's exposure profile (Document ID 3497, p. 1). The exposure results in the CSDA chart are not attributed to specific sources; however, a limited comparison of 13 results in the CSDA chart were matched with results from two other studies already in the record (Document ID 0675; 0784). OSHA found that some PBZ data from the CSDA chart were already included in OSHA's exposure profile, and also found that the CSDA chart included area samples intermixed with PBZ samples (though the area samples were not identified as such). Furthermore, individual results on CSDA's chart do not necessarily represent a single worker's exposure; at least one row summarized results for four workers. For these reasons (summarized samples, area samples, and overlap with data already in the exposure profile), OSHA did not incorporate the exposure results from the CSDA chart in the final exposure profile (Table IV.5.6-B).

Based on data collected from at least six construction sites visited by OSHA and NIOSH and other published reports, OSHA has determined that walk-behind saws are commonly used with wet cutting methods (Document ID 0784, pp. 216-217; 0846, p. 8; 1143-Companies BB and OOOO). At three sites, workers sprayed water at the point where the saw blade cut pavement. At a fourth site, water was sprayed as workers cut into "fresh" concrete that had not set completely (Document ID 0784, pp. 216-217-Table V). The sampling results presented in Table IV.5.6-B indicate that wet cutting is effective in maintaining worker silica exposures at or below 50 μg/m^3; the median exposure value for work done outdoors with sufficient wet methods is 12 μg/m^3, nine of the 12 sample results for this type of work (75 percent are below 25 μg/m^3, and none of the sample results exceed 50 μg/m^3. OSHA concludes that baseline conditions for walk-behind saws include wet cutting methods.

Additional evidence in the record shows the extent to which wet methods are already used with walk-behind saws indoors. Flanagan (2009) provides some information on workplace conditions associated with walk-behind saw operator exposure samples. Of 37 samples for operators using walk-behind saws, 30 (81 percent) were associated with water as a control measure, two (5 percent) were listed as using LEV as a control, and no control status was reported for the remaining five records (Document ID 0677, Attachment 2). That 81 percent of walk-behind saw operators in the Flanagan dataset used a water dust control supports OSHA's finding that wet methods are frequently used and can be considered the baseline condition for walk-behind saws.

A database of silica exposures in construction tasks shows that the median sample time for workers using walk-behind saws was 163 minutes (range 27 to 450 minutes) (Document ID 0677, Attachment 2). Exposure monitoring is typically either task-based (for the period during which a specific task is performed) or full-shift (sampling the entire work shift). For this reason, OSHA believes that the sample duration of less-than-full-shift samples reflects the amount of time that a worker spends performing tasks associated with silica exposure.

Baseline Conditions for Drivable Saw Operators

As summarized in Table IV.5.6-B, OSHA reviewed three sample results for workers operating water-fed drivable saws. The median exposure is 33 μg/m^3. Two out of the three results (66 percent) were below 50 μg/m^3 and one was 88 μg/m^3. One of the results was less than or equal to 12 μg/m^3 (limit of detection [LOD])[194] because of low respirable dust loading on the filter during the 70-minute sample period (Document ID 1143, Company A). The result of 33 μg/m^3 was based on a 125-minute sample that recorded a respirable quartz concentration of 128 μg/m^3. The highest result of 88 μg/m^3 was based on a respirable quartz concentration of 530 μg/m^3 measured over an 80-minute sampling period during which the water discharge on the saw was clogged (Document ID 1143, Company R).

These sample results were obtained over relatively short sampling periods (70 to 125 minutes), but are presented as 8-hour TWAs based on the assumption that the workers had no additional exposures during the unsampled portion of their shifts. CISC criticized OSHA for relying on three short-term samples and argued that OSHA should not assume zero exposure during the unsampled portion of the workers' shifts (Document ID 2319,

[194] Results reported as "none detected" are assigned a value equal to the LOD. The LOD is determined individually for each sample based on the volume of air sampled and the method used to analyze the sample. See Section IV-2 – Methodology for additional information on LODs.

pp. 51-52). CISC noted that ERG’s Report found that drivable saw operators often operate the saw for 1 to 2 hours and then move to other job sites (Document ID 2319, pp. 51-52). While this situation might occur at times, there is no evidence that this was the case for these three drivable saw samples, which are from OSHA enforcement data. OSHA inspectors are instructed to sample for the entire duration of silica exposure, and OSHA believes that the samples in the exposure profile captured all of the workers’ exposures for the day they were sampled. While the samples in the exposure profile may potentially underestimate exposures for drivable saw operators, OSHA does not have information to suggest that that any additional exposures actually occurred.

Table IV.5.6-B
Personal Respirable Crystalline Silica Exposure Range and Distribution of Results for Construction Workers: Masonry Cutters Using Portable Saws

	Exposure Summary			Exposure Range		Exposure Profile				
Masonry Cutters Using Portable Saws	**N**	**Mean (μg/m³)**	**Median (μg/m³)**	**Min (μg/m³)**	**Max (μg/m³)**	**< 25 (μg/m³)**	**≥ 25 and ≤ 50 (μg/m³)**	**> 50 and ≤ 100 (μg/m³)**	**> 100 and ≤ 250 (μg/m³)**	**> 250 (μg/m³)**
Handheld Saw Operator (Outdoors, dry cutting)	65	173	130	6	1,472	10 (15.4%)	8 (12.3%)	9 (13.8%)	28 (43.1%)	10 (15.4%)
Handheld Saw Operator (Outdoors, wet cutting)	5	44	19	12	154	4 (80%)	0 (0%)	0 (0%)	1 (20%)	0 (0%)
Handheld Saw Operator (Indoors, dry cutting)	3	3,940	1,490	12	10,318	1 (33.3%)	0 (0%)	0 (0%)	0 (0%)	2 (66.7%)
Handheld Saw Operator (Indoors, wet cutting)	10	60	50	12	136	3 (30%)	2 (20%)	2 (20%)	3 (30%)	0 (0%)
Handheld Saw Operator Subtotal	*83*	*288*	*110*	*6*	*10,318*	*18 (21.7%)*	*10 (12%)*	*11 (13.3%)*	*32 (38.6%)*	*12 (14.5%)*
Handheld Power Saw Operator Cutting Fiber-Cement Board (< 8-inch blade, no controls)	21	63	21	4	605	12 (57.1%)	5 (23.8%)	1 (4.8%)	2 (9.5%)	1 (4.8%)
Handheld Power Saw Operator Cutting Fiber-Cement Board (< 8-inch blade, dust collection tools)	75	11	7	2	76	69 (92%)	5 (6.7%)	1 (1.3%)	0 (0%)	0 (0%)
Handheld Power Saw Operator Cutting Fiber-Cement Board (<8 inch blade) Subtotal	*96*	*22*	*8*	*2*	*605*	*81 (84.4%)*	*10 (10.4%)*	*2 (2.1%)*	*2 (2.1%)*	*1 (1%)*
Rig-mounted Core Sawing or Core Drilling Operator (wet process)	*4*	*16*	*12*	*11*	*29*	*3 (75%)*	*1 (25%)*	*0 (0%)*	*0 (0%)*	*0 (0%)*
Walk-Behind Saw Operator (Sawing concrete outdoors, sufficient wet methods)	12	18	12	11	41	9 (75%)	3 (25%)	0 (0%)	0 (0%)	0 (0%)
Walk-Behind Saw Operator (Other conditions)	8	237	236	65	461	0 (0%)	0 (0%)	1 (12.5%)	3 (37.5%)	4 (50%)
Walk-Behind Saw Operator Subtotal	*20*	*106*	*32*	*11*	*461*	*9 (45%)*	*3 (15%)*	*1 (5%)*	*3 (15%)*	*4 (20%)*
Drivable (Vehicular) Saw Operator (Outdoors, sufficient wet methods)	2	23	23	12	33	1 (50%)	1 (50%)	0 (0%)	0 (0%)	0 (0%)
Drivable (Vehicular) Saw Operator (Other conditions)	1	88	88	88	88	0 (0%)	0 (0%)	1 (100%)	0 (0%)	0 (0%)

Table IV.5.6-B
Personal Respirable Crystalline Silica Exposure Range and Distribution of Results for Construction Workers: Masonry Cutters Using Portable Saws

	Exposure Summary			Exposure Range			Exposure Profile				
Masonry Cutters Using Portable Saws	**N**	**Mean (µg/m³)**	**Median (µg/m³)**	**Min (µg/m³)**	**Max (µg/m³)**		**< 25 (µg/m³)**	**≥ 25 and ≤ 50 (µg/m³)**	**> 50 and ≤ 100 (µg/m³)**	**> 100 and ≤ 250 (µg/m³)**	**> 250 (µg/m³)**
Drivable (Vehicular) Saw Operator Subtotal	*3*	*45*	*33*	*12*	*88*		*1 (33.3%)*	*1 (33.3%)*	*1 (33.3%)*	*0 (0%)*	*0 (0%)*
Masonry Cutters Using Portable Saws Total	**206**	**138**	**20**	**2**	**10,318**		**112 (54.4%)**	**25 (12.1%)**	**15 (7.3%)**	**37 (18%)**	**17 (8.3%)**

Notes: All samples are personal breathing zone (PBZ) results and represent 8-hour time-weighted average exposures.
Job categories are intended to represent job functions; actual job titles might differ, and responsibilities might be allocated differently, depending on the site.
Percentages may not add to 100 percent due to rounding.
Sources: Document ID 0657; 0898; 1720; 2322; 3958; 4022, Attachment 1; 0064; 0065; 0111; 0148; 0169; 0177; 0222; 0224; 0027; 0231; 0675; 0815; 0846; 0847; 0875; 0876; 0877; 0898; 0910; 0912; 1143; 1423.

5.6.3 Additional Controls

The exposure profile in Table IV.5.6-B shows that approximately 33 percent (69 out of 206 samples) of masonry and concrete cutters using portable saws have silica exposures above the final PEL of 50 μg/m^3. Therefore, OSHA finds that additional controls will be necessary to achieve the PEL for these overexposed workers. OSHA has determined that wet methods are a feasible and effective means of reducing worker exposures to respirable crystalline silica when using handheld masonry saws, core sawing and cutting machines, walk-behind saws, and drivable saws. Additionally, dust extraction systems are an effective control for some types of handheld saws.

Additional Controls for Handheld Power Saw Operators

Wet Methods

Wet Methods - Outdoor Cutting

Wet cutting methods are an effective dust control method for handheld power masonry saws. Table IV.5.6-B summarizes PBZ samples for masonry and concrete cutters using handheld saws and shows that the median exposure level is 19 μg/m^3 (maximum value 154 μg/m^3) when using wet methods outdoors. In contrast, the median exposure level is 130 μg/m^3 (maximum 8-hour TWA of 1,472 μg/m^3) when using handheld power saws outdoors without controls.

These exposure results show that using wet methods effectively reduces median and maximum silica exposures and can reduce worker exposures to 50 μg/m^3 or below most of the time. Sixty percent of handheld saw operator exposures in Table IV.5.6-B (nine out of 15) were 50 μg/m^3 or below when wet methods were used, and 80 percent of exposures (four out of five) were 50 μg/m^3 or below when wet methods were used outdoors.

CSDA submitted exposure data demonstrating the effectiveness of wet methods as a silica control measure for handheld (and similar hand-guided/wall) saws used outdoors. The data on the CSDA chart shows that “open air” (as opposed to “indoors” or “enclosed area”) handheld or hand-guided sawing performed without controls produced exposure concentrations of 10 to 150 µg/m^3; exposure concentrations were lower, ranging from 10 µg/m^3 to 29 µg/m^3, when operators used wet methods (Document ID 3497, pp. 1, 5, 6).

In addition to workplace samples, OSHA evaluated studies that used controlled short-term tests to examine the influence of wet methods on saw emissions and operator exposures to respirable dust and silica. Several investigators have evaluated the effectiveness of water-based dust control options for handheld saws in controlled settings and reported exposure level reductions ranging from 90 to 96 percent with various water application methods and cutting conditions. In a laboratory study, Thorpe et al. (1999) evaluated the effectiveness of two types of water supplies commonly used with handheld saws: 1) a pressurized portable water supply; and 2) a constant water supply (Document ID 1181, pp. 443, 445-447). During this evaluation, 15-minute PBZ samples were collected during uncontrolled and controlled (i.e., water-fed) cutting of concrete slabs containing 20 percent to 40 percent silica (i.e., worst-case conditions) (Document ID 1181, p. 447). The study protocol involved short sampling durations because handheld saws are typically used intermittently to make short cuts. The uncontrolled mean silica concentration during multiple 15-minute trials of intensive cutting ranged from 1,700 µg/m^3 to 4,800 µg/m^3 (reported as 1.7 to 4.8 mg/m^3) (Document ID 1181, p. 448-Table 2).

Reductions in exposure to respirable silica dust when cutting concrete slabs using wet methods compared with no controls were for 75% for diamond blades, and 94% for resin blades when using water supplied by mains, and 75% for diamond blades and 77% for resin blades when using water supplied by a portable tank. Both sources of water were effective at reducing respirable dust, however, the portable tank needed to be periodically re-pressurized to maintain the necessary flow rate, while the water supplied from the mains provided a more constant flow rate. Both types of systems used to supply water to an integrated water delivery system would be acceptable under the table.
NIOSH found that wet methods can significantly reduce exposures to respirable dust and quartz during block cutting with handheld tools (Document ID 0868, p. 13). NIOSH evaluated the performance of a commercially available water backpack and spray attachment, pre-set by the attachment manufacturer to provide 1.4 liters per minute water

consumption (0.36 gallons per minute), for handheld saws during concrete-block cutting (Document ID 0868, pp. 8, 11). The handheld electric abrasive cutter was used outdoors to make cuts through concrete blocks laid lengthwise on a plank 17 inches above the ground. During the 5- to 10-minute trials with water-fed saws, the water-spray attachment reduced quartz exposures by an average of 90 percent from uncontrolled levels (Document ID 0868, p. 10). This study demonstrates the effectiveness of wet methods to reduce silica exposures for workers using handheld saws.

Middaugh et al. conducted a workplace field study to evaluate the effectiveness of dust controls on cut-off saws (Document ID 3610, p. 158). Air sampling was conducted for ten days at five job sites on four experienced operators using gas-powered cutoff saws with 14-inch (35.6 mm) diameter blades to cut concrete curbs (Document ID 3610, p. 159). Air sampling was conducted both with and without wet methods; sampling ranged from 4 to 16 minutes and covered the entire duration of the task (Document ID 3610, pp. 159-161). The authors reported that the dust suppression system consisted of a two-nozzle spray and a 13.3-L hand-pressurized water supply system with an optimum mean flow rate of 0.83 L/min (0.2 gal/min) (Document ID 3610, p. 159). Without controls, the average respirable silica dust concentration during the 17 sampling periods was 0.96 mg/m^3, while with wet suppression the concentration levels were reduced to an average of 0.21 mg/m^3, a 78 percent reduction (Document ID 3610, p. 162). Middaugh stated: “Although some applications may require cutting for an entire 8-hr workday, typical cutting is performed for less than 2 hours per day” (Document ID 3610, p. 162). Middaugh et al. suggests that most handheld power saw operators will have TWA exposures of 50 μg/m^3 or below when using a water spray system during typical cutting activities.

Another study in the record, Shepherd and Woskie (2013), also demonstrates that wet methods can effectively reduce 8-hour TWA exposures to 50 μg/m^3 or less when handheld saw operators cut outdoors under typical cutting conditions (Document ID 3777). Shepherd and Woskie reported silica exposures generated during a controlled workplace field study where reinforced concrete pipe was cut outdoors, using both dry and wet methods, by apprentice and journeyman construction workers (Document ID

3777, p. 65). Sampling times were less than 12 minutes. The operators used a gas-powered cutoff saw with 14-inch diameter blades to make a series of 8-foot cuts, suggesting that cutting was nearly continuous during the sampling period (Document ID 3777, pp. 65-66). The authors estimated that if this level of intensive cutting were performed outdoors with wet methods for two hours, and no other exposure occurred for the remainder of the day, 83 percent (88 out of 106) of the saw operators' 8-hour TWA exposures would be 50 µg/m^3 or below (Document ID 4073, Attachment 8a, p. 1). The authors also estimated that if operators used the water-fed saws outdoors at this same level of intensity for six hours, 61 percent of operators would have 8-hour TWA exposures of 50 µg/m^3 or below (Document ID 4073, Attachment 8a, p. 1). The authors noted that the water flow rate testing before and after certain trials indicated that the "water supply was variable" (not stable) (Document ID 3777, p. 65). Dust suppression would likely have been improved with a more consistent water supply.

CISC questioned the probative value of data from these controlled studies (Document ID 2319, pp. 49-50). OSHA has relied on both the exposure data summarized in Table IV.5.6-B and controlled studies in determining the effectiveness of using wet methods to control silica exposures when operating handheld power saws. OSHA believes that controlled studies and short-term sampling are useful in evaluating the effectiveness of the control methods. The aforementioned studies evaluate the effectiveness of wet methods to control silica exposures during the use of handheld power saws and provide useful information obtained under both experimental conditions and at construction worksites. Laboratory studies are useful for confirming the extent to which water can suppress dust. Worksite studies involving short-term samples provide information that is useful in evaluating the overall potential for worker exposures (with control methods in place) during a typical shift that involves periods of intermittent sawing interspersed between breaks in sawing (for example, to deliver or obtain more bricks, adjust the saw, or complete other phases of the job). OSHA believes these studies are useful and further demonstrate the effectiveness of wet methods.

Some commenters, while acknowledging the availability of handheld saws with integrated water delivery systems, noted that dust suppression is not the actual purpose of the water-fed saws. Mr. Rashod Johnson of Mason Contractors Association of America (MCAA) testified that:

> the vast majority of masonry saws provide water on the blade itself. Water on the blade. This is solely for the purpose of cooling off the blade. The side effect just happens to be that the dust is sometimes suppressed. Now, manufacturers of these saws are starting to explicitly state that the water used in this blade – in this system is used for cooling the blade only and should not be used to suppress dust (Document ID 3585, Tr. 2885).

NIOSH, however, pointed out that some manufacturers' manuals include recommended water flow rates specifically for dust suppression (Document ID 4233, Attachment 1, p. 5). NIOSH pointed to Stihl's manual for the model 410 and 420 cut-off machines (handheld masonry saws), which specifically recommends a water flow rate for dust suppression (Document ID 3998, Attachment 12a, pp. 9, 15, 16). This manual states: "A water attachment kit is provided with your cut-off machine and should be used to reduce dust whenever wet cutting is feasible. For dust suppression purposes, the flow rate should be at least 0.6 liters (20 fl. oz.) of water per minute" (Document ID 3998, Attachment 12a, p. 9).

NIOSH also noted that Husqvarna's product literature for the K 3000 wet states:

> [T]he Husqvarna K 3000 Wet is a power cutter… for wet applications. The machine is equipped with the dust extinguisher system DEX, where an integrated water regulator controls the water volume, ensuring an amount that is just enough to bind the dust. This gives the user the possibility of wet cutting with a minimal amount of water and slurry, both indoors and outdoors (Document ID 3998, Attachment 12f, p. 1).

Product literature from other manufacturers states that water systems are necessary for reducing dust generation (Document ID 3998, Attachments 12a, p. 4, 15-16; 12e, p. 3; 13e, p. 9 of pdf-Flushing with Water). There is ample evidence in the record that water-fed handheld saws are commercially available from a variety of sources (CS Unitec, Document ID 0615; Hilti, Document ID 0737 and 3998, Attachment 12e; Stihl, Document ID 3998, Attachment 12a; Husqvarna, Document ID 3998, Attachment 12f;

Makita, Document ID 3998, Attachment 12g; Wacker Group, Document ID 3998, Attachment 12h). In some cases the operator simply connects a hose to a factory-installed port (pre-mounted) (Document ID 3998, Attachment 12a, pp. 6, 16-see Water kit-premounted). In other cases an adaptor kit is required and is pre-packaged with certain models of the saw (Document ID 3998, Attachment 12g, p. 3-Index: Install water system). Therefore, OSHA has determined that water-fed handheld saws are commercially available, and many include recommended flow rates for dust suppression.

There are several studies and saw manufacturers that discuss optimal water flow rates for handheld power saws. In addition to Stihl's recommendation for 0.6 liters per minute, mentioned previously (Document ID 3998, Attachment 12a, p. 16), Thorpe et al. (1999) showed in laboratory tests that a water application rate of 0.5 liters per minute (0.13 gallons per minute) provided optimal dust control for the amount of water applied (96.7 percent dust reduction), while doubling the water application rate (to 1 liter per minute) improved dust control by an additional 1.2 percent (to 97.9 percent) (Document ID 0846, p. 450-Table 4). Additionally, the Wacker Group, in operating instructions for its PowerCut model BTS-11 handheld saw, recommends wet cutting and specifies a water consumption rate of 40 liters per hour, equal to 0.67 liters per minute (0.18 gallons per minute) (Document ID 3998, Attachment 12h, pp. 8, 13).

Additionally, it is possible to replace the use of handheld saws with stationary saws equipped with wet dust control systems. Mr. Hoffer, Assistant Director of the New Jersey Laborers' Health and Safety Fund, stated that after 2004, when New Jersey passed a law prohibiting the dry cutting of brick, block or other silica-containing building materials, "one of the changes I saw was …people went ahead and bought table saws, masonry table saws" (Document ID 3589, Tr. 4237). Similarly, Mr. Johnson of MCAA explained that when extensive cutting is performed, sawyers use cutting stations (with a different set of engineering controls) instead of handheld saws (Document ID 3581, Tr. 2911). Based on the evidence in the record, OSHA concludes that, in situations where handheld saws are being used to cut silica-containing materials for extensive periods of time, the use of a stationary saw with a water delivery system is an effective solution to reduce exposures to dust and silica.

Some commenters stated that using wet methods at elevated heights could create a fall hazard (Document ID 2319, pp. 111-12; 3587, Tr. 3595). Rick Olson of the Tile Roofing Institute asserted that use of wet or vacuum controls would create additional fall hazards when cutting roofing tiles and pavers on a roof. He also stated that in California and Arizona, rooftop operations with roofing tiles or pavers are given an exemption from the requirement to use a dust reduction system when using power tools for cutting, grinding or drilling those masonry materials (Document ID 3587, Tr. 3595).

However, other testimony indicates that wet dust control systems can effectively be used to reduce exposures to silica during cutting of roofing tiles and pavers. Dan Smith, Director of training for the Bay Area Roofers and Waterproofers Training Center in Livermore, California, noted that everyone on a roof is already using fall protection and that the controls are no different than an air hose or an electrical cord that would be on the job site (Document ID 3581, Tr. 1603). Mr. Smith also questioned how the use of controls could pose more of a trip or fall hazard than the "near zero visibility that is created by cutting roofing tiles dry" (Document ID 3581, Tr. 1603-1604).

Mr. Smith testified that the roofing industry in California is starting to voluntarily cut roofing tiles and pavers wet (Document ID 3581, Tr. 1600-1601, 1638). He also explained that dry cutting of roofing tiles is prohibited in the U.K., and that the National Federation of Roofing Contractors "provides guidance and training. They use wet saws on scaffolding at the roof level…they use a [water] mister on the tile saw. They use a system like the hytile… which is a tile breaking tool" (Document ID 3581, Tr. 1600-1601). Based on the evidence in the record, OSHA believes that there are alternative solutions (e.g., cutting on the ground, project planning, cutting from scaffolds rather than a roof) to address any hazards posed by the use of wet methods in the roofing industry. Additionally, testimony from the Bay Area Roofers and Waterproofers Training Center indicates that use of controls may actually increase visibility, thereby reducing potential fall hazards during roofing work (Document ID 3581, Tr. 1603-1604).

Wet Methods - Indoor Cutting

Table IV.5.6-B shows that using wet methods indoors substantially reduces operator exposures compared to uncontrolled dry cutting indoors (median of 50 µg/m^3 for 10 samples using wet methods compared to median of 1,490 µg/m^3 for three dry cutting samples) (Document ID 0177, p. 77, 79, 80; 0846, pp. 4-5).[195] Although clearly beneficial, wet methods do not always reduce indoor exposures to the same levels observed for wet cutting outdoors (in Table IV.5.6-B, the median exposure is lower (19 µg/m^3) for outdoor wet cutting samples). Furthermore, 50 percent of the ten indoor wet sawing samples were 50 µg/m^3 or below, while a higher portion, 80 percent (four out of five), of the outdoor wet sawing samples were 50 µg/m^3 or below. The exposure levels of saw operators working indoors are affected when decreased air circulation limits the rate at which airborne dust disperses. As a result, modest releases of airborne silica dust that would dissipate outdoors can build up indoors, causing exposures to be higher (Document ID 3883, pp. 4-2 – 4-3, Sec. 4.1 and 4.3.1). Based on these findings, OSHA concludes that increased general or exhaust ventilation (fans, exhaust trucks, or fresh air ducts) may be necessary to prevent the accumulation of airborne dust in the work area and consistently control silica exposures indoor. Using a HEPA vacuum to clean up dried slurry can further reduce exposures indoors.

CSDA's Best Practices chart supports OSHA's conclusion that wet methods are effective indoors, but that overexposure can still occur. In the CSDA chart, the reported indoor handheld and hand-guided (wall) sawing concentration results ranged from 40 to 260 µg/m^3 (during various sampling times) when wet methods were used (Document ID 3497, pp. 1, 5). Similarly, Ms. Kellie Vazquez of Holes Inc. anecdotally reported that to reliably achieve exposures of 50 µg/m^3, saw operators performing indoor sawing (which includes hand-guided/rig wall sawing) using wet methods would need to wear respiratory protection (Document ID 3589, Tr. 1535).

Shepherd and Woskie (2013) evaluated sawyer exposure levels during the while use of dry and water-fed handheld saws indoors (in a large garage, with large doors opened and

[195] Indoor wet cutting data sources are Document ID 0065, pp. 16, 17, 22; 0169, pp. 6-7; 0222, p. 7; and 1423, p. 2.

closed beyond the control of the researchers), as part of the same controlled field study described previously (where apprentice and journeymen cut reinforced concrete pipe) (Document ID 3777, pp. 65, 69). The study design was the same for the indoor work as for the outdoor trials. Overall (considering both wet and dry saws), during brief periods of intensive cutting, the geometric mean silica concentration was 672 μg/m^3 (reported as 0.672 mg/m^3) outdoors, but more than twice as high indoors (1,503 μg/m^3, reported as 1.503 mg/m^3) (Document ID 3777, p. 67-Table I). The authors also documented the geometric mean silica exposure concentration measured during intensive sawing when operators used a water-fed handheld saw (419 μg/m^3), and found that this was less than 10 percent of the geometric mean silica concentration measured during dry cutting (4,384 μg/m^3), demonstrating the enormous benefit that wet cutting has on silica dust emissions (Document ID 3777, p. 67). Shepherd and Woskie also reported an 85 percent reduction in exposure between worker-paired control conditions (samples for dry cutting versus wet cutting performed by individual saw operators) (Document ID 4073, Attachment 8a, p. 1).

OSHA believes that these estimations are reflective of worst-case conditions. The silica content of the respirable dust samples taken when workers were cutting reinforced concrete pipe in this study ranged from 3 to 91 percent, with a median of 21.7 percent (Document ID 3777, p. 69). Most of the samples analyzed (134 out of 137) contained less than 39 percent silica, however, three samples contained between 63 and 91 percent silica. By comparison, 71 percent of the respirable dust samples taken on handheld saw operators reported by Flanagan contained less than 15 percent silica content (Document ID 0677, p. 149). Among 12 samples for handheld saw operators included in the OIS data in the docket, the highest silica content was only 11 percent (Document ID 3958, Rows 25, 26, 259, 260, 358, 360, 488, 489, 729, 730, 791, 840). Therefore, OSHA concludes that the short-term samples in the Shepherd and Woskie study taken indoors when cutting concrete pipe with a relatively high silica content represent the upper end of exposures typically experienced when using handheld power saws.

Another study also showed that wet methods reduce exposure levels for workers using various types of water-fed saws under worst-case conditions. Flanagan et al. (2001)

reported respirable quartz levels of 240 μg/m^3 and 260 μg/m^3 for the period of tool use for an average of 130 minutes per shift, with corresponding 8-hour TWA values of 65 μg/m^3 and to 70 μg/m^3) for handheld slab saw operators who used wet methods at indoor sites (Document ID 0675, p. 1098-Table I).[196] Factors contributing to worst-case conditions included longer than normal periods of sawing, enclosed spaces, numerous concurrent operations in one space, and the use of a wet (inadequately filtered) shop vacuum – rather than a HEPA vacuum – for cleanup (Document ID 0675, p. 1097). Although exposures during wet sawing were elevated, the authors described several ways to reduce exposures. A lack of ventilation in the indoor environment might have accounted for a substantial portion of the exposures experienced by all workers in the immediate area (including helpers). The authors stated: "Since area and helper exposures are similar to the operator's exposure, the primary exposure might be due to a buildup of respirable aerosol within the enclosed space, rather than direct exposure to slurry spray. Judicious use of dilution ventilation with box fans and open doors and windows may reduce the exposure" (Document ID 0675, p. 1099). In addition, inadequately filtered vacuums can produce airborne dust through re-entrainment of already collected particles. Flanagan et al. (2001) recommended that a commercially available vacuum attachment to collect slurry be evaluated to determine its effectiveness for controlling aerosol in the respirable size range (Document ID 0675, p. 1100). Further, the operator's position – staying out of the spray plume – could reduce exposure (Document ID 0675, p. 1098).

Another factor possibly contributing to worst-case conditions in the Flanagan et al. (2001) study was the amount of time workers spent sawing. Flanagan et al. (2001) stated that the saw operators in the study spent more than the typical amount of time sawing during their shifts. "Many jobs do not involve such extensive periods of cutting, with workers often working at two or three job sites per day. Time spent commuting between sites and setup/cleanup time for each job provide periods of minimal or no exposure" (Document ID 0675, p. 1100).

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[196] Although the authors did not report individual sampling results for most jobs, the exposure summary for operators using "Slab saw/handheld (inside)" includes only two values, so the range (high and low) provides the actual sample values.

Considering the examples of how exposures can occur during wet sawing, OSHA concludes that consistent dust control requires attention to the rate and application position of water used for wet dust suppression. Carefully managing slurry (for example, by capturing slurry before it dries, using work practices that limit the amount of slurry spray coming off the saw blade, and using a HEPA vacuum to cleanup dried slurry) can further reduce exposure levels.

Dust Extraction (Vacuum Suction, Local Exhaust Ventilation)

The exposure profile for handheld power saw operators (Table IV.5.6-B) contains one sample result for a handheld saw operated with LEV (grouped in the "indoor, dry cutting" category). This sample was obtained as a mason cut concrete block out of a wall to make room for a window, while a second worker (not monitored) held a HEPA vacuum nearby to capture dust (Document ID 3958, Row 791). The operator experienced an 8-hour TWA exposure of less than 12 $\mu g/m^3$ (the limit of detection), based on a sample in which the respirable dust exposure was also low (0.099 mg/m^3, equal to 99 $\mu g/m^3$). While this sample result showed that dust was effectively managed, an integrated dust collection system would be more reliable (since it would be attached to the tool and in the proper position at all times). Dust extraction systems are an increasingly effective form of silica dust control and evidence submitted to the record indicates that they continue to improve.

IQ Power Tools submitted evidence of the effectiveness of an integrated LEV system for a handheld gas power saw with a 12-inch blade. The saw included an integrated vacuum/filter and dust containment system. In a single 121-minute demonstration of outdoor concrete cutting, an operator used the saw to cut through both faces of 100 concrete blocks, standing in an upright position (blocks positioned at hip level in front of the operator; the operator stood more upright than the position in which a handheld saw is typically used) (CS-Unitec Catalog, 2009, Document ID 0615, pp. 24-28; 3501, p. 4). During this 2-hour period of active cutting, the operator experienced a personal exposure of 45 $\mu g/m^3$, with 17 percent silica measured in the sample (Document ID 3501, p. 4). Under tightly controlled conditions during a single 2-hour demonstration, this saw configuration shows great promise for maintaining operators' exposures at 50 $\mu g/m^3$ or below. However, OSHA finds that additional worksite testing is needed (e.g., including in the more typical cutting position) before it can confidently conclude that this saw configuration can control exposures to or below 50 μg/m^3.

The CSDA Best Practice chart includes two results of open-air hand sawing using a saw equipped with LEV. The chart shows silica exposure levels for both saw operators below an 8-hour TWA of 50 μg/m^3; however, no other information was provided about the size or design of the saw (Document ID 3497, p. 6).

Other studies show that the use of LEV reduces exposures to respirable silica, but not to the extent that exposures could be consistently maintained at or below an 8-hour TWA of 50 μg/m^3. Thorpe et al (1999) reported that an LEV system on a handheld saw with a 9-inch blade reduced mean respirable dust concentrations by over 90 percent (from 8,000 μg/m^3 to 700 μg/m^3) during periods of active concrete cutting (Document ID 1181, p. 448-Table 3).

NIOSH (EPHB 282-13) evaluated the performance of a commercially-available LEV system for handheld saws during brief trials of concrete-block cutting (Document ID 0868). The "electric abrasive cutter" was equipped with a 12-inch blade and an LEV shroud connected to a wet/dry high-efficiency particulate air (HEPA) filter vacuum cleaner with filter "pulse clean" capability[197] (Document ID 0868, p. 8). With new bags installed, this vacuum cleaner pulled 56 cubic feet per minute (cfm) through the shroud while the abrasive cutting saw was operating (Document ID 0868, p. 11). This relatively modest air flow rate reduced both silica and respirable dust exposures by 95 percent—slightly better results than obtained using a the water-spray attachment (90 percent reduction) (Document ID 0868, p. 10). Despite this substantial exposure reduction, respirable silica concentrations in the worker's breathing zone remained elevated at levels of 790 μg/m^3 to 1,100 μg/m^3 during five 10-minute trials of intensive cutting (Document ID 0868, p. 11). As explained in Section IV.5.11 – Tuckpointers and Grinders, the choice of vacuum suction device has a dramatic effect on dust control efficiency. Although not

[197] The vacuum was attached to the shroud via 3 meters of 35-millimeter (mm) (1.4-inch) diameter hose. "Pulse clean" is a self-cleaning feature involving a reverse air pulse that knocks dust from the filter.

tested by NIOSH, based on work by Collingwood and Heitbrink (2007), OSHA believes that it is reasonable to expect improved dust capture with a dust collection device that consistently offers greater air flow than the one tested by NIOSH (Document ID 0600, pp. 884-885).

A study by Meeker et al. (2009) evaluated a commercially-available LEV system used with a handheld electric abrasive saw with a 12-inch blade while cutting block or brick (Document ID 0803). Breathing zone measurements collected over brief periods (5 to 25 minutes) of controlled and uncontrolled outdoor sawing showed a 91-96 percent reduction in quartz concentrations (for example, a mean of 110 μg/m^3 when cutting block using LEV versus 2,830 μg/m^3 when using no controls) (Document ID 0803, p. 108). For three of the four combinations of saws, controls, and materials tested, the measured silica concentration ranged from less than 50 μg/m^3 to highs between 140 and 170 μg/m^3. The concentration was higher (610 μg/m^3) for one wet saw used without LEV (Document ID 0803, p. 108-Table 2). Since most workers cut intermittently even during times of active cutting (e.g., 10 or 20 seconds using the saw followed by a longer period–up to several minutes–of measuring and moving materials or equipment), 8-hour TWA values are likely to be considerably lower (Document ID 1238, p. 148).[198] Based on the highest result obtained by Meeker et al. during concentrated cutting with LEV (170 μg/m^3), OSHA estimates that a worker who cuts outdoors for 20 percent of the shift (about one-and-a-half hours) would experience an 8-hour TWA of 34 μg/m^3. Extended periods of intensive cutting and cutting indoors were not evaluated in the Meeker et al. study (Document ID 0803). Substantially higher 8-hour TWA exposures might result in enclosed areas with limited ventilation where airborne dust cannot easily dissipate. In those cases, supplemental exhaust ventilation could maintain sufficient air circulation and

[198] Sawyers make a cut (or a few sequential cuts) and then need time before the next cut to move to a new location or to reposition materials. Studying stationary saws, Yareb (2003) presented information from a real-time dust analyzer that showed bursts of 20 seconds of sawing, followed by similar or longer period (up to a minute) of repositioning. During the repositioning period, dust concentrations were reduced to nearly zero (Document ID 1238, p. 148). Yareb (2003) involved stationary saws. The repositioning period would be longer for handheld saws because the operator needs to put the saw down in order to have both hands free to reposition the material being cut.

reduce the rate at which airborne dust accumulates (Document ID 3883, pp. 4-2 – 4-3, Sec. 4.1 and 4.3.1).

Middaugh et al. (2012) evaluated a spring loaded guard/cowl with a centrifugal fan blowing into an 18.9 L canvas collection bag (not HEPA) during concrete curb cutting with a 14-inch (35.6 cm) blade (Document ID 3610, p. 156). The silica exposure concentration level measured was 33 $\mu g/m^3$ (Document ID 3610, p. 162). Middaugh stated that “Although some applications may require cutting for an entire 8-hr workday, typical cutting is performed for less than 2 hours per day” (Document ID 3610, p. 162). Assuming two hours of exposure at the measured silica level, OSHA has determined that this concentration would result in a TWA exposure of 82.5 $\mu g/m^3$. OSHA notes that the canvas dust collection bag does not offer the same level of protection as a particle air filter that is rated as 99 percent efficient for respirable size particles. The authors did not evaluate collection bag efficiency, but the bag may have permitted particles to pass, and exposure results might have been lower with a more efficient filter in place.

Croteau et al. (2002) conducted experiments on a handheld saw equipped with an LEV system exhausted at 75 cfm (Document ID 0611, pp. 458, 460, 466). This LEV set-up did not reduce respirable dust exposures compared to uncontrolled cutting (Document ID 0611, p. 458). The authors concluded that the shape of the dust collection shroud opening allowed the rotating blade to push dust away from the shroud (i.e., the blade rotated in the opposite direction than that for which the shroud was designed). The direction of the blade action is an important consideration in designing or selecting a saw shroud (Document ID 0611, p. 466).

A NIOSH HETA (2008) study evaluated an LEV-equipped handheld gas-powered saw to assess its potential for reducing respirable silica exposures at two residential building construction sites during a 2005 health hazard evaluation (Document ID 0876, p. 1). NIOSH determined that using the LEV-equipped saw did not have a significant benefit compared with the non-LEV equipped saw, LEV did not reduce exposures to acceptable levels (Document ID 0876, pp. 11, 13). However, the authors noted that the limited amount of data precluded a complete assessment of this type of control (Document ID 0876, p. 11).

CISC argued that LEV is unreliable for masonry saws (Document ID 2319, p. 50), basing this statement on OSHA's preliminary conclusion in the PEA that "the available data are not adequate to determine whether all workers using such saws can reliably and consistently achieve the proposed PEL of 50 μg/m^3" (Document ID 1720, pp. IV-438, 440). CISC offered no evidence that saw ventilation systems are unreliable. OSHA finds that LEV systems for handheld power saws are still undergoing development. The data was not adequate at the time of the PEA to determine whether saw operators' exposure levels could reliably be reduced to 50 μg/m^3 or below when using LEV. With few exceptions (Document ID 2322, Attachments A-F), the current data suggest that the saw-LEV configuration has not yet reached its full potential for managing silica exposures, particularly indoors. Nonetheless, the preceding discussion of LEV for handheld saws, as well as the next section on specialty saws for fiber-cement board siding, do show that saw manufacturers are making rapid and continuous improvement in developing LEV systems for saws.

A member of the National Utility Contractors Association (NUCA) stated that handheld saws are not manufactured with LEV dust collection systems (Document ID 2171, Attachment 1, p. 10). The Building and Construction Trades Department (BCTD), AFL-CIO and NIOSH disputed the assertion that tools with integrated dust controls are not commercially available (Document ID 2171, Attachment 1, p. 10; 3998, Attachment 10, p. 54-55, Attachment 12f; 4219, p. 5) and provided examples of such equipment from manufactures Diamond and Husqvarna (Document ID 4073, Attachment 4a). IQ Power Tools also provided evidence of its handheld saw with integrated LEV (Document ID 3501, p. 4). From the evidence in the record, OSHA concludes that handheld saws with integrated ventilation systems are readily available from commercial sources.

Operators usually use handheld saws for only a limited period of time (typically less than 2 hours) (Document ID 0677, Attachment 2; 3501, p. 4; 3581, Tr. 1597, 1598, 2911; 3610, pp. 157, 162). OSHA finds that when saw operators fully and properly implement

LEV controls for handheld saws, most of them will experience 8-hour TWA exposures of 50 μg/m^3 or below when they cut outdoors for up to four hours a day (Document ID 0803). However, when cutting with portable saws equipped with dust controls indoors, TWA exposures can be expected to exceed 50 μg/m^3 in less than four hours.

Additional Controls for Handheld Power Saws Operators Cutting Fiber-Cement Board

Local Exhaust Ventilation

Table IV.5.6-B includes 96 PBZ samples for workers cutting fiber-cement board using specialty handheld power saws to install fiber-cement siding on houses. Twenty-one operators using uncontrolled saws experienced mean silica exposures of 63 μg/m^3 (median 21 μg/m^3) with a high of 605 μg/m^3. When the saw operators used equipment with a feature (of any type) intended to capture or contain dust, the mean exposure for 75 sawyers was 11 μg/m^3 (median 7 μg/m^3) and the high was 76 μg/m^3.

LEV systems for a special configuration of handheld power saw fitted with purpose-designed polycrystalline diamond blades of less than 8 inches have proven particularly effective in controlling silica during outdoor cutting of fiber-cement board. OSHA received data from NIOSH and James Hardie Building Products, a manufacturer of fiber-cement board siding, providing information on a cooperative effort between NIOSH and a fiber-cement board industry member to evaluate controls for various saws that are either used in this industry or that are under development for the industry and to produce additional data on the effectiveness of saw/LEV configurations for cutting this this type of siding (Document ID 2322, Attachments B and C; 3579, Tr. 231-232; 3959, pp. 25-36). One type of saw performed more reliably than the others and at this time appears to be the best available technology for minimizing silica exposures while cutting fiber-cement board. OSHA has focused this technological feasibility analysis on that saw design (a handheld, dust collecting model, fitted with a special purpose blade (8 inches or less) and a dust collection device rated to draw 200 cfm.

Several NIOSH studies at fiber-cement siding installation sites demonstrate the effectiveness of the handheld dust-collecting saw, with special purpose blade, and vacuum dust collection system having a rated airflow capacity of 200 cfm when cutting fiber-cement siding (one form of fiber-cement board). These studies include NIOSH study numbers:

- EPHB 358-11a (Document ID 4138);
- EPHB 358-12a (Document ID 2322, Attachment B) (also in the record as Document ID 4139);
- EPHB 358-13a (Document ID 2322, Attachment C) (also in the record as Document ID 3998, Attachment 4a);
- EPHB 358-14a (Document ID 3998, Attachment 4b); and
- EPHB 358-15a (Document ID 3998, Attachment 4c).

Exposure data from the two NIOSH reports submitted by James Hardie under Document ID 2322 (i.e., EPHB 358-12a and EPHB 358-13a), and from three other reports from a consultant (also submitted as part of Document ID 2322, Attachments D-F) are included in the exposure profile (Table IV.5.6-B). These five reports evaluated several types of saws with and without various forms of dust reduction measures, representing the wide range of equipment currently in use by the industry.

During these five NIOSH studies, siding cutters on construction sites cut a variety of fiber-cement board siding products containing up to 50 percent silica (Document ID 4139, p. 11; 3998, Attachment 4c). NIOSH sampled a total of 21 worker-days at four different construction sites when operators primarily used handheld dust-collecting saws, with special purpose blades (slightly less than 8 inches in diameter), for cutting fiber-cement board, and vacuum dust collection systems rated at 200 cfm. All 8-hour TWA sample results associated with use of this equipment were 50 μg/m^3 or below (the highest 8-hour TWA exposure level was 41 μg/m^3, and 95 percent of the 8-hour TWAs (20 of 21 sample results) were below 25 μg/m^3 (Document ID 4138; 2322, Attachment B [also 3998, Attachment 4a]; 3998, Attachment 4b; 3998, Attachment 4c). Table IV.5.6-C tabulates these results.

Table IV.5.6-C Personal Breathing Zone Respirable Crystalline Silica Exposures for Workers Cutting Fiber-Cement Board (NIOSH In-Depth Survey Reports)

Work Conditions	**Sample duration**	**Silica 8-hour TWA**	**Cutters-days sampled (% quartz [A])**	**Document ID**
Standard circular saw (68% of the cuts) and miter saw (32% of the cuts); no controls other than new specialty saw blade [B]	One sample 72 minutes, three samples 434 to 575 minutes	21, 45, 64 and 127 µg/m^3 (four samples)	Cutter #1, on four days (quartz average: 6.9%)	4138, pp. 4, 10, 12-Table 3 (EPHB 358-11a)
Dust collection circular saw, new specialty saw blade [B], and vacuum dust collector, with 6-second delay before turning off	219 to 413 minutes	3 to 18 µg/m^3’ (six samples)	Cutters #1 and #2, on three days (quartz average: 10.4%)	4139, pp. 10, 18, 19-20-Table 4, 22, (EPHB 358-12a)
	220 to 487 minutes	2 to 16 µg/m^3 (six samples)	Cutters #2 and #3, on three days (quartz average: 9.1%)	3998, Attachment 4a, p. 22-23-Table 4 (EPHB 358-13a)
	403 to 440 minutes	16, 23, and 41 µg/m^3 (three samples)	Cutter #1, on three days (quartz average: 13.3%)	3998, Attachment 4b, p. 15, 16-Table 4 (EPHB 358-14a)
	422 to 513 minutes	7 to 12 µg/m^3 (six samples)	Cutters #1 and #2, on three days (quartz average: 13.1%)	3998, Attachment 4c, pp. v, 5, 13, 14-Table 4 (EPHB 358-15a)

Notes:
[A] % quartz is the average measured in all personal samples collected at the site on sampling days.
[B] Specialty blade: Polycrystalline diamond-tipped blade with 4 to 8 teeth specifically designed to cut fiber-cement siding and minimize dust generation (Document ID 4138, p. 3).

The specially-configured circular saw consists of a “dust collecting” saw designed to guide the dust from the blade into a built-in hood covering about 69 percent of the saw blade. The saw is fitted with a new-each-day special-purpose 7.25-inch polycrystalline diamond blade with four to eight teeth, and is specifically designed for cutting fiber-cement board. The saw hood is connected to a dust collection system (a 12-gallon shop-vac or equivalent, in this case rated at 200 cfm air flow and with a 6-second delay in turning off the shop vacuum when the saw was turned off, so the vacuum removed dust following the cutting of the board) with dual filtration. The actual air flow when the saw was in use was estimated to be between 70 to 90 cfm. (Document ID 3998, Attachment 4c, p. 5; 4139, pp. 9-10, 16, 17).

OSHA received comments from James Hardie Building Products requesting that OSHA add an entry on Table 1 for cutting fiber cement board with a circular saw with a polycrystalline diamond-tipped blade equipped with a shroud and dust collection system (Document ID 2177, Attachments A-I, pp. 3-4, Attachment B, pp. 17-18; 2322). OSHA finds that the information presented in the NIOSH reports (as summarized in Table IV.5.6-C) demonstrates that silica exposures can be reduced to 50 μg/m^3 or less when sawyers cut fiber-cement board using a dust control-style circular saw connected to a vacuum dust collector and fitted with a specialty blade designed for cutting fiber-cement board. In the final rule, OSHA has added an entry to Table 1 for handheld power saws cutting fiber-cement board.

Table IV.5.6-B shows that 75 operators using any type of dust control for saws with special cutting blades designed for fiber-cement board had a mean 8-hour TWA exposure of 11 μg/m^3 (median 7 μg/m^3), although elevated exposures (high of 76 μg/m^3) still occurred with some saw/control configurations that proved less reliable (for example, miter saws and saws attached to a dust receptacle without the benefit of a vacuum dust collection device). By contrast, the sample results summarized in Table IV.5.6-B for 21 operators using uncontrolled saws (circular and miter) had a mean 8-hour TWA exposure of 63 μg/m^3 (median 21 μg/m^3), with the highest exposure reaching 605 μg/m^3. The industrial hygiene consultant that performed the industry air monitoring reported that “dust collection” circular saws “equipped with dust collection systems (HEPA vacuums) appear to generate the least amount of airborne particulate,” while other combinations of saws and less effective dust control methods did generate visible airborne particulates (Document ID 2322, Attachment F, pp. 13-14, caption Photos 12 and 19). Most of these workers cut siding for approximately half of their shifts (Document ID 2322, Attachment B-F; 4139 [a duplicate/final copy of 2322, Attachment B]). The variability associated with other configurations of saws and controls used to cut fiber-cement board leads OSHA to conclude that the combination of small diameter (less than 8 inches) blades designed for cutting fiber-cement board with an LEV dust collection system operating at the air flow recommended by the tool manufacturer or greater can reduce worker exposures to 50 μg/m^3 or below most of the time during cutting of fiber-cement board. Specifying the minimum rate airflow capacity of the dust collector as the rate recommended by the tool manufacturer will permit employers to use dust collectors that have been matched to the tool and will provide optimal dust control when using saws with blades smaller than the 7.25-inch blades used in the NIOSH investigations.

Availability of Other Cutting Methods for Cutting Fiber-Cement Board

Other cutting methods are also available for fiber-cement board with minimal dust. NIOSH briefly describes a scoring (with a knife) and snapping process, which "should be relatively dust-free"; however, this method is not applicable to siding (Document ID 2322, Attachment B, p. 7). NIOSH also mentions that commercially available handheld and foot-powered shears are also "relatively dust free"; however, a power saw cuts faster and is more precise than the shears (which can slow production rates) (Document ID 2322, Attachment B, p. 7).

Additional Controls for Rig-Mounted Core Saw or Drill Operators

As indicated in the discussion of baseline conditions and the exposure profile for these workers, most operators of core sawing machines (or core drills) already use wet methods. The four exposures summarized in the Table IV.5.6-B are for workers using rig-mounted, water-fed core saws, and all experienced exposure levels of 50 $\mu g/m^3$ or below. Additional controls are not required for core sawing or cutting machines already used with a water feed, in part because the slow speed of the core sawing operations, paired with water application, limits aerosol production. Flanagan et al. (2001), explained the utility of wet methods and the benefit of the low bit rotation speed for dust control during core cutting activities:

> Water appears to be effective for reducing concrete core drilling emissions. When the core bit is sunk into the concrete, dust particle velocity is slowed and [the particles are] mixed with water before exiting the borehole, emitting slurry with little velocity to produce an airborne aerosol (Document ID 0675, p. 1100).

Core sawing machines operate at lower speeds than many types of equipment more typically associated with silica dust emission. A typical core sawing machine producing 6- to 8- inch holes operates at speeds in the range of 250 to 350 rpm (Document ID 0679,

p. 21; 0222, p. 4). In contrast, other drilling, cutting, and grinding equipment operates at rpm several times greater. For example, a rig-mounted concrete wall saw evaluated by Flanagan et al. (2001) operated at 2,500 rpm; a circular saw and a miter saw evaluated by NIOSH with a tachometer (device to measure rotation speed) operated at 5,765 and 5,920 rpm; and a tuckpointing grinder blade operated in the range of 10,000 rpm (unloaded) (Document ID 0222, p. 4; 4138, p. 4; 0679, p. 25). As indicated by Flanagan et al. (2001), lower blade speeds make dust control less challenging because particles and slurry are released from the slower blade at a lower velocity, producing less airborne aerosol (Document ID 0675, p. 1100).

Cleaning up silica-containing slurry promptly can further reduce exposures. Flanagan et al. (2001) studied work practices for a wet process at a construction site that assigned a helper to each operator who used a water-fed tool (core boring machines, handheld saws, hand-guided rig-mounted wall saws and walk-behind slab saws). The helper's job was to vacuum water and slurry released from the water-fed tools, keeping it from spreading more than a few feet from the point of operation (Document ID 0675, p. 1098). The operator performing core drilling, however, performed his own water control (without a helper), suggesting that the core boring equipment required less attention or produced less wet slurry (or both) than the water-fed saws used at the same site, so a second person (helper) was not necessary.

If cleaning up slurry from water-fed core sawing equipment proves inconvenient in some locations, a tool with an integrated water collection ring (to capture water after it is provided to the coring blade) is commercially available to construction contractors (Document ID 0679, p. 19).

<u>*Additional Controls for Walk-Behind Saw Operators*</u>

Wet Methods

Wet methods are the primary dust control option for walk-behind saws, and most manufacturers offer water-fed models.[199] The available data for construction workers

[199] Water-fed walk-behind saws (manual and self-propelled) are widely available from many manufacturers and construction tool distributors (Document ID 0715; 1676; 1185; 0643; and 0615).

using walk-behind saws, summarized in Table IV.5.6-B, provide evidence that workers using wet methods experience lower silica exposure levels.

OSHA finds that wet methods are at least as effective for walk-behind saws as they are for handheld saws. The saw blade functions in the same manner, and some factors that can make it difficult to use a water-fed saw are less problematic for walk behind saws (e.g., the cutting direction of a walk-behind saw is down into the pavement, so water flow is more predictable – following gravity). Handheld and walk-behind saws are so similar that at least one model of commercially available water-fed saw (Hilti model DSH 700/900) is designed to be used as either a handheld saw or a walk-behind saw; the operator can convert a handheld saw to a walk-behind saw by attaching the saw body to a wheeled base, which is commercially available as a saw accessory (Document ID 3998, Attachment 12e, pp. 3, 7). Due to the functional similarities between handheld and walk-behind saws, the laboratory and field studies providing evidence that water fed to the saw blade reduces dust emissions apply equally to both walk-behind and handheld saws.

Table IV.5.6-B shows that none of the 12 respirable silica results associated with wet cutting concrete outdoors using walk-behind saws exceeds 50 $\mu g/m^3$. Furthermore, eight of the results obtained for this group of walk-behind saw operators were reported as less than or equal to the LOD of 12 $\mu g/m^3$ (Document ID 0784, pp. 216-217-Table V). These eight samples, tabulated by Linch (2002), were collected at outdoor road construction sites. On one site, water was provided to walk-behind saws via a hose from a water truck while expansion joints were being sawed in fresh concrete. No silica was detected in the saw operators' breathing zones at this site (Document ID 0784, pp. 216-217). At the other site, during demolition of an interstate highway (involving sawing through and lifting out blocks of concrete), water for the saws was provided by 725-gallon tanks mounted on trucks. The sample results at this site ranged from below the limit of detection to 20 $\mu g/m^3$ (Document ID 0784, pp. 216-217). These results suggest that, in the manner most typically used (i.e., outdoors), water-fed walk-behind saws are generally associated with 8-hour TWA silica exposures of 50 $\mu g/m^3$ or below.

These results were obtained using the saw's normal water feed system intended for cooling the blade. CISC inquired whether an additional water feed is needed for these saws. Based on the information presented by Linch (2002), OSHA concludes that the existing water feed system is sufficient to reduce exposures to 50 μg/m^3 or below during outdoor cutting, although the water feed system should be regularly inspected and adjusted to maximize dust suppression. CISC also questioned the feasibility of using wet methods in situations where there is no established water main on site (Document ID 2319, p. 112). OSHA recognizes that a municipal water hookup may not be available on all construction sites and that the availability of such a hookup may be out of the construction contractors' control; however, OSHA believes that water tanks, which were used to provide water to the walk-behind saws in Linch (2002), are already commonly available on many construction sites and can provide water for a walk-behind saw (Document ID 0784, pp. 216-217).

Although the data are limited, water-fed walk-behind saws used indoors may result in exposures that are considerably higher than those measured outdoors. Flanagan et al. (2001) reported higher 8-hour TWA respirable silica levels for operators and assistants who used water-fed walk-behind saws indoors for most of their shifts when compared with samples taken outdoors. The samples, obtained under what the authors described as worst-case work conditions, resulted in four 8-hour TWA values between 65 and 350 μg/m^3 (calculated from the reported silica concentrations of 130 to 710 μg/m^3 for the sampling period) (Document ID 0675, pp. 1097, 1098-1099-Tables I and II). As noted in the previous discussion of this study with respect to handheld saws, Flanagan et al. (2001) recommended evaluation of a commercially available vacuum attachment to collect slurry "to determine its effectiveness for controlling aerosol in the respirable size range. The test could also include an assessment of the vacuum exhaust air as it is emitted into the room" (Document ID 0675, p. 1100). Based on the similarity between silica concentrations measured for indoor slab saw operators, helpers, and general area samples, Flanagan et al. suggested that "the primary exposure may be due to a buildup of respirable aerosol within the enclosed space, rather than direct exposure to slurry spray" (Document ID 0675, p. 1099 and Figure 5). These authors mention that exposures may be reduced by checking vacuum filtration and taking steps to improve general (dilution) ventilation during indoor work (Document ID 0675, p. 1099). Based on the observations and recommendations from Flanagan et al., OSHA observes that the results for indoor sawing can be influenced by factors such as dust emitted from inefficient vacuum filters and dust that builds up in spaces where general dilution ventilation is poor.

The CSDA report submitted to the docket shows that all entries for outdoor slab sawing using a saw equipped with a water supply produced silica exposure levels at or below a TWA of 50 μg/m^3 (Document ID 3497, pp. 2-4). However, an indoor slab sawing result listed in the chart exceeded 50 μg/m^3, despite the use of equipment with a water supply (Document ID 3497, p. 2).

Flanagan et al. also demonstrated the importance of water flow rates in dust suppression (Document ID 0675). These investigators reported respirable quartz levels as high as 710 μg/m^3 for a worker and assistant who spent four hours cutting concrete in an enclosed space using a water-fed walk-behind saw and wet shop vacuum (to collect the slurry) at an indoor construction site (8-hour TWA of 350 μg/m^3) (Document ID 0675, pp. 1098-1099). Water was supplied to the cutting blade at 0.5 gallons per minute. When similar work was performed with a water-feed rate of 2 gallons per minute, the exposures dropped to 200 μg/m^3 (8-hour TWA of 110 μg/m^3), about one-third of the original value[200] (Document ID 0675, p. 1099).

Both the Masonry & Concrete Saw Manufacturers Institute and the MCAA (represented by Mr. Johnson) commented that most water-fed systems are designed to keep the blade cool, rather than to suppress dust, and that this topic has not been sufficiently researched (Document ID 2316, p. 3; 3585, Tr. 2885). As discussed previously, considerable evidence shows that water application reduces dust emissions and that several saw manufacturers do state that using wet cutting will suppress dust. Furthermore, the water delivery system described in Linch (2002) was for the purpose of cooling or protecting the blade, but was effective in suppressing respirable silica levels (Document ID 0784, p. 216). Although no specific information is available in CSDA's Silica Data Analysis

[200] The manufacturer of a walk-behind saw with an original-equipment water port also recommends connecting a hose providing 2 gallons per minute (Document ID 1676).

Chart, the concentrations listed for slab sawing may be associated with saws "equipped with water supply" for the purpose of cooling. These data includes 26 samples for outdoor work, 21 of which (80 percent) are less than 25 μg/m^3, and only one sample (65 μg/m^3) exceeds 50 μg/m^3 (Document ID 3497, pp. 2-4). OSHA concludes that water used as coolant can also control silica exposures.

OSHA concludes that an integrated water delivery system effectively reduces silica exposures to 50 μg/m^3 or below when work with walk-behind saws is performed outdoors. NIOSH noted the potential for elevated exposures when work is performed indoors (Document ID 4233, p. 10). Both effective wet dust suppression and minimizing the accumulation of airborne particulate near workers' breathing zones (e.g., when sawing indoors or within enclosed areas with limited ventilation) can reduce worker exposures to respirable dust and silica, and available data demonstrate that exposures to respirable crystalline silica typically exceed 50 μg/m^3 when walk-behind saws equipped with water delivery systems are used indoors or in enclosed areas (Document ID 0675, pp. 1097, 1098-1099; 3497, p. 2).

Dust Extraction (Vacuum Suction, Local Exhaust Ventilation)

Although some manufacturers offer an LEV option for walk-behind saws,[201] OSHA could not obtain exposure monitoring data on the effectiveness of LEV under either actual working conditions or experimental conditions (Document ID 1431, p. 3-71). These saws do exist, however, and are available as an alternative for reducing construction workers' silica exposure levels if a condition arises in which wet sawing is not possible. For example, a power tool manufacturer offers a walk-behind saw described as providing a "dust-less cutting environment" (Document ID 3998, Attachment 10, p. 57). This saw connects via a vacuum hose to a two-part 300 cfm dust collection system on a wheeled cart. This gas-powered dust collection system includes a primary cyclonic dust separator and secondary fine filter rated to remove 99.9 percent of dust 0.5 micron or

[201] Examples of walk-behind saws that have an LEV option are described in the following: CS-Unitec-CSR-150 (Document ID 0616), EDCO-accessories-walk-behind-saw (Document ID 0639), EDCO-E-C10-I-0209 (Document ID 0640), and EDCO-E-MPS-I-1007 (Document ID 1676). In some cases the saw is factory equipped with vacuum ports; in other cases the manufacturer offers an optional vacuum-compatible blade guard.

larger (which includes respirable size dust, defined as falling in the 1 to 10 micron size range) (Document ID 3998, Attachment 10, p. 57).

Based on the information OSHA has for handheld and drivable saws, OSHA believes that LEV systems should perform equally well for walk-behind saws, provided that a shroud or blade housing fits close to the pavement being cut and sufficient vacuum suction is provided. For most walk-behind saws, OSHA expects that adequate performance will require a relatively large vacuum cleaner. For example, the instruction manual for one relatively small walk-behind saw indicates that the vacuum hood over the blade is intended to be used with a high-volume vacuum that provides more than 200 cfm of suction (Document ID 0640, p. 5).[202] Larger walk-behind saws are likely to require even larger vacuums. Such vacuums (for example 500 cfm) are used with walk-behind milling machines (Document ID 0636, p. 7). Considering that the thin cutting area of a saw is smaller and removes (pulverizes) less volume of material than a milling machine blade or drum, the dust released by a saw blade will be easier to control than the dust from the milling machine. Therefore, OSHA anticipates that an LEV system with a powerful vacuum will work at least as well for a walk-behind saw as for a walk-behind milling machine. OIS contains records indicating that exposure levels were below the limit of detection (12 µg/m^3) for an operator using a walk-behind grinder and scarifier (types of walk-behind milling machines) while a helper vacuumed grinding debris left behind the equipment (Document ID 3958).

Although the extent of the reduction in silica exposures has not been confirmed, based on the evidence in the record, OSHA believes that LEV and a suitably sized dust collection system can reduce operator exposures to 50 µg/m^3 or below during the use of walk-behind saws outdoors. However, because there is more evidence available on the effectiveness of wet methods to reduce exposures when operating walk-behind saws, wet methods are the only control option specified on Table 1 (as discussed more fully later in this section).

[202] This walk-behind saw is a “crack-chaser” style for use with 7- to 10-inch blades and a blade housing (hood) that encloses the blade nearly to ground level, which provides more complete enclosure than the guards used on many walk-behind saws.

Additional Controls for Drivable Saw Operators

Wet Methods

Drivable saws are typically factory equipped with water-fed systems that apply water directly to the cutting blade. Two of the three samples in the exposure profile were collected for saw operators with low to moderate respirable silica exposures (suggesting dust suppression was occurring). One 8-hour TWA result was reported as less than or equal to the LOD of 12 μg/m^3 (actual sample duration 70 minutes, during which the respirable dust concentration was too low to collect a sufficient amount of dust to measure silica) (Document ID 1143, Company A), and the other 8-hour TWA result was reported as 33 μg/m^3 (Document ID 1143, Company R). These levels could potentially be reduced further by adjusting the water spray to optimize dust capture.

The highest result in the drivable saw group was obtained for a saw operator who cut pavement while the water nozzle at the saw blade was likely clogged (given the high respirable dust concentration of 9,630 μg/m^3 associated with this sample – a level more typical of uncontrolled releases) (Document ID 1143, Company R). The 8-hour TWA measurement of 88 μg/m^3 for this sample was based on an 80-minute sample with an actual respirable quartz reading of 530 μg/m^3 during the period monitored. This result demonstrates the importance of using sufficient amounts of water to reduce silica exposures and ensuring that water-fed equipment works properly. Based on the data in the record, OSHA concludes that, with respect to drivable saws, water-spray optimized for dust suppression can control worker silica exposures to 50 μg/m^3 or below provided that the system is regularly inspected to ensure proper functioning.

The Masonry & Concrete Saw Manufacturers Institute (SMI) commented that current saws use water to cool the cutting tool, rather than as a dust control (Document ID 2316, p. 3). As noted previously, however, water provided for cooling has a marked impact on dust release and optimizing the water application for dust suppression offers further benefit for silica control. This is as true for drivable saws as it is for other types of saws and construction equipment. The function and purpose of drivable saws (to produce a thin cut through partial or full depth of pavement) are similar in function and purpose to the blades of other portable pavement saws. As discussed with respect to handheld and walk-behind saws, considerable research has confirmed that water application to saw blades provides marked reduction of dust, including silica dust (Document ID 0846; 0868; 1181; 3610). The types of materials (concrete and asphalt pavement) cut by drivable saws is similar, if perhaps somewhat more limited in range, than the types of materials typically cut with handheld or walk-behind saws.

5.6.4 Feasibility Finding

Feasibility Finding—Handheld Power Saw Operators

Paragraph (c) of the construction standard gives employers the option of following Table 1, which includes specified engineering and work practice controls when operating handheld power saws (also referred to as cut-off, chop, or quickie saws); alternatively, the employer must assess and limit exposures in accordance with the more traditional regulatory approach contained in paragraph (d). When using handheld power saws to cut silica-containing materials, Table 1 requires employers to use an integrated water delivery system that continuously feeds water to the blade, and to operate and maintain the system in accordance with the manufacturer’s instructions to minimize dust emissions.

The exposure results summarized in Table IV.5.6-B and the studies described above demonstrate that water spray systems reduce respirable crystalline silica exposures substantially when the system is well designed, and properly implemented and maintained. Water-fed handheld saws are commercially available from a variety of sources (CS Unitec, Document ID 0615; Hilti, Document ID 0737 and 3998, Attachment 12e; Stihl, Document ID 3998, Attachment 12a; Husqvarna, Document ID 3998, Attachment 12f; Makita, Document ID 3998, Attachment 12g; Wacker group, Document ID 3998, Attachment 12h).

Use of an integrated water delivery system on cut-off, chop, quickie or masonry saws has been shown to produce exposure reductions of 78-96 percent (Document ID 3610, p. 162; 3777, p. 67; 0868, p. 10; 1181, pp. 443, 447-Table 2, 450-Table 4; 4073, Attachment 8a, p. 1). When used outdoors, this results in 8-hour TWA exposures of 50 $\mu g/m^3$ or below for 80 percent (four out of five) of the samples in the profile (Table IV.5.6-B). In addition, the CSDA data compiled from member jobsites and NIOSH showed that all outdoor hand sawing using a saw equipped with a water supply (seven samples) produced exposure levels below an 8-hour TWA of 50 µg/m^3 (Document ID 3497, p. 6). OSHA finds that Table 1's requirement to use integrated wet systems when operating these tools is effective and technologically feasible.

Workers typically use handheld power saws for brief, intermittent periods. The median duration for using handheld portable saws in the Flanagan database of silica exposures in construction tasks was 101 minutes, although the range of cutting times reported in studies is 9-447 minutes (Document ID 0677, Attachment 2; 3581, Tr. 1598; 3610, pp. 157, 162). Using data obtained during periods of outdoor intensive cutting (8-feet at a time) using handheld water-fed saws, Shepherd and Woskie (2013) determined that among workers who cut at this intensity level for 2 hours, 83 percent would have 8-hour TWAs of 50 µg/m^3 or below. They also concluded, however, that if the workers continued cutting (still at the same constant intensity, outdoors using wet methods) for 6 hours in the shift, only 61 percent of those saw operators would have 8-hour TWAs of 50 µg/m^3 or below. Based on these data, OSHA concludes that outdoor wet cutting for more than four hours (the midpoint between the two and six hours of continuous intensive sawing considered by Shepherd and Woskie in 2013) could result in exposures over 50 µg/m^3. Therefore, Table 1 requires respirators for periods of cutting outdoors that extend beyond four hours in a day.

The vast majority of samples for handheld saws summarized in Table IV.5.6-B involve work outdoors. However, workers may occasionally use handheld saws indoors. OSHA's exposure profile (Table IV.5.6.B) shows that TWA exposures to silica exceed 50 µg/m^3 half of the time when wet cutting with handheld saws indoors, and Flanagan et al. (2001) reported 8-hour TWA exposures of 65 µg/m^3 and 70 µg/m^3 for handheld slab saw operators who used wet methods at indoor sites (Document ID 0675, p. 1098-Table I). Thus, when an employee uses a water-based system indoors or within enclosed areas, exposures are likely to exceed 50 µg/m^3. For that reason, Table 1 requires the use of respiratory protection with an APF of 10 for this work. This finding is based on data summarized in Table IV.5.6-B, which shows that half of the exposure samples associated with using handheld saws indoors exceed 50 μg/m^3, even with wet methods. Also, CSDA's data show indoor handheld sawing results in exposure above an 8-hour TWA of 50 μg/m^3 (presented as a range of 240-260 μg/m^3 for 130-minute samples) using wet methods (Document ID 3497, p. 5). And Shepherd and Woskie's (2013) evaluation shows that 52 percent (89 out of 171) of the (largely indoors) saw operator 8-hour TWA exposures would exceed 50 μg/m^3 (Document ID 4073, Attachment 8a, p. 1). OSHA concludes that the use of a water-fed saw substantially reduces exposure levels during indoor cutting, such that a respirator with an APF of 10 will be adequate.

Additionally, based on testimony from the New Jersey Laborers' Health and Safety Fund, MCAA, and the International Union of Bricklayers and Allied Craftsworkers, OSHA finds that it is feasible to use stationary masonry saws equipped with wet methods instead of handheld saws, This may be particularly useful when cutting will last more than two hours (Document ID 3589, Tr. 4237; 3581, Tr. 2911; 3585, Tr. 3064). Using stationary masonry saws offers the benefits of wet sawing while simultaneously reducing the challenges of controlling slurry in the work area and addressing other safety concerns associated with handheld portable saws (e.g., cuts, increased risk of amputations, ergonomic stressors) (Document ID 0803, p. 109). As described more fully in Section IV-5.7 – Masonry Cutters Using Stationary Saws, masonry cutters using stationary saws can achieve exposures of 50 μg/m^3 or below most of the time by using a water-fed saw and work practice controls when used either indoors or outdoors.

In sum, OSHA concludes that 34 percent of workers using handheld power saws are currently exposed to silica levels below 50 μg/m^3. For the remaining 66 percent of workers who are currently exposed above 50 μg/m^3, the controls described in this section can be implemented to reduce silica exposure levels to 50 μg/m^3 or below in most operations, most of the time, with exceptions in some cases for workers cutting outdoors for extended periods of time or workers cutting indoors. Therefore, OSHA finds that the standard is technologically feasible for workers using handheld saws. To achieve the PEL, however, supplemental respirator use may be necessary for workers cutting outdoors for extended periods of time and workers cutting indoors.

Feasibility Finding—Handheld Power Saw Operators Cutting Fiber-Cement Board

Paragraph (c) of the construction standard gives employers the option of following Table 1, which includes specified engineering and work practice controls when operating handheld power saws for cutting fiber-cement board (with blade diameter or 8 inches or less); alternatively, the employer must assess and limit exposures in accordance with the more traditional regulatory approach contained in paragraph (d). Table 1 requires the saw to be used outdoors and with a dust collection system operated and maintained in accordance with manufacturer's instructions to minimize dust emissions. The dust collector must provide the air flow rate recommended by the tool manufacturer, and the filter must have 99 percent or greater efficiency.

OSHA finds that the controls specified in Table 1 are technologically feasible, and that currently-available systems have demonstrated the ability of these controls to keep worker exposures to respirable silica at or below 50 μg/m^3 when used outdoors. This finding is based in part on the 21 sample results summarized in Table IV.5.6-C for operators using dust collecting circular saws with vacuum dust collectors on fiber-cement siding at siding installation sites evaluated by NIOSH. These samples show a maximum exposure of 41 μg/m^3, with 20 of the 21 sample results falling below 25 μg/m^3 (Document ID 4138; 2322, Attachment B [also 3998, Attachment 4a]; 3998, Attachment 4b; 3998, Attachment 4c). LEV systems for saws with larger blades are available, but evidence suggests this method is inconsistent when it comes to controlling silica exposures. OSHA has not included a requirement in Table 1 for larger handheld saws equipped with LEV systems.

OSHA concludes that most workers using handheld power saws to cut fiber-cement board outdoors are currently exposed to silica levels at or below 50 μg/m^3. For workers who are currently exposed above 50 μg/m^3, the controls described in this section can be implemented to reduce silica exposure levels to 50 μg/m^3 or below in most operations, most of the time. Therefore, OSHA finds that the standard is technologically feasible for these workers.

Feasibility Finding—Rig Mounted Core Saw or Drill Operators

Paragraph (c) of the construction standard gives employers the option of following Table 1, which includes specified engineering and work practice controls when operating rig-mounted core cutting machines; alternatively, the employer must assess and limit exposures in accordance with the more traditional regulatory approach contained in paragraph (d). For rig-mounted core cutting machines, Table 1 requires employers to use an integrated water delivery system that supplies water to the cutting surface and to operate and maintain the system in accordance with the manufacturer's instructions to minimize dust emissions.

Core saws already use wet methods extensively, resulting in worker exposure levels of 50 $\mu g/m^3$ or below. Three of the four exposure results for core saws in Table IV.5.6-B are below 25 $\mu g/m^3$ and the fourth sample result is 29 $\mu g/m^3$ (Document ID 0675, pp. 1097, 1098-Table 1; 0898, p. 15). Therefore, additional controls are not required for rig-mounted core saws or core cutting machines used with a water feed, and the standard is technologically feasible for workers using rig mounted core saws or drills.

Feasibility Finding—Walk-Behind Saw Operators

Paragraph (c) of the construction standard gives employers the option of following Table 1, which includes specified engineering and work practice controls for operating walk-behind saws; alternatively, the employer must assess and limit exposures in accordance with the more traditional regulatory approach contained in paragraph (d). For walk-behind saws, Table 1 requires employers to use saws with integrated water delivery systems that continuously feed water to the blade and to operate and maintain those systems in accordance with the manufacturer's instructions to minimize dust emissions.

Water-fed walk-behind saws (manual and self-propelled) are widely available from many manufacturers and construction tool distributors (Grainger-cat-Husqvarna-concrete saw Document ID 0715; EDCO-E-MPS-I-1007, Document ID 1676; Toolfetch-MK-diamond-walk behind-saw, Document ID 1185; EDCO-self-propelled-saws, Document ID 0643; CS-Unitec-catalog, Document ID 0615). OSHA finds Table 1's requirement for walk-behind saws to be technologically feasible.

Although walk-behind saws are most commonly used outside, they are occasionally used indoors. When workers use walk-behind saws indoors, they can experience higher respirable silica concentrations. Flanagan et al. presented four results for water-fed walk-behind saws used indoors (ranging from 65 µg/m^3 to 350 µg/m^3) over 4 to 7 hours of indoor work (Document ID 0675, pp. 1098-1099). Both Flanagan et al. and CSDA suggest that respiratory protection may be needed under these circumstances (Document ID 0675, p. 1098-1099; 3497, p. 2). Therefore, Table 1 requires the use of respiratory protection with a minimum APF of 10 when walk-behind saws are used indoors or in enclosed areas. Because of the lack of data evaluating worker exposures to respirable crystalline silica when using walk-behind saws equipped with LEV systems, OSHA has not included a specification for such systems in Table 1 of the final rule.

As reflected in the exposure profile (Table IV.5.6-B), the silica exposures of all walk-behind saw operators who work outdoors using water-fed machines are already controlled to levels at or below 50 µg/m^3. Additionally, most silica sample results (25 of 26 rows) reported by CSDA for water-fed walk-behind (slab) saws used outdoors were at or below 50 µg/m^3 (Document ID 3497, pp. 2-4). OSHA believes that the small percentage of walk-behind saw operators who are exposed at levels above 50 µg/m^3 can reduce their exposures through proper maintenance of water-fed systems (e.g., ensuring nozzles are cleaned or replaced as often as necessary to keep them functioning as intended) and sufficient use of water (i.e., according to the saw manufacturer's directions). OSHA concludes that most workers using walk-behind saws are currently exposed to silica levels at or below 50 µg/m^3. For workers who are currently exposed above 50 µg/m^3, the controls described in this section can be implemented to reduce silica exposure levels to 50 µg/m^3 or below in most operations, most of the time, with exceptions in some cases for workers using walk-behind saws indoors. Therefore, OSHA finds that the standard is technologically feasible for workers using walk-behind saws.

Feasibility Finding—Drivable Saw Operators

Paragraph (c) of the construction standard gives employers the option of following Table 1, which includes specified engineering and work practice controls for operating drivable saws; alternatively, the employer must assess and limit exposures in accordance with the more traditional regulatory approach contained in paragraph (d). When using drivable or ride-on saws to cut silica-containing materials, Table 1 requires that the saw be equipped with an integrated water delivery system that continuously feeds water to the cutting surface, and that the system be operated and maintained in accordance with the manufacturer's instructions to minimize dust emissions. Due to their size, these saws these saws are used on roadways and parking lots, and OSHA's information covers their use in outdoor environments, thus Table 1 applies only to drivable saws used outdoors.

Based on the data summarized in the exposure profile (Table IV.5.6-B), OSHA finds exposure levels of 50 $\mu g/m^3$ or below have already been achieved for 67 percent of drivable saw operators. Drivable saws are typically equipped with water delivery systems (Document ID 4073, Attachment 4a), and OSHA finds that Table 1's requirements for drivable saws are technologically feasible.

OSHA concludes that most workers using drivable saws are currently exposed to silica levels below 50 $\mu g/m^3$. For workers who are currently exposed above 50 $\mu g/m^3$, the controls described in this section can be implemented to reduce silica exposure levels to 50 $\mu g/m^3$ or below in most operations, most of the time. Therefore, OSHA finds that the standard is technologically feasible for these workers.

5.7 MASONRY CUTTERS USING STATIONARY SAWS

5.7.1 Description

Workers in the construction industry use stationary saws to cut silica-containing masonry materials, such as bricks, concrete blocks, stone, and tile. These table-top or stand-mounted saws include a flat platform where the work piece (e.g., a brick) sits. To form a cut, the worker brings a rotating circular abrasive blade into contact with the work piece, either by pressing a swing arm-mounted blade down onto the piece, or by moving the piece on a sliding platform into contact with a fixed-position blade (depending on the saw design). In either configuration, the saw's orientation is fixed. The cutting surface is generally about waist-high and arm's length from the worker's breathing zone.

Stationary saws similar to those found on construction sites can be used to cut silica-containing material at manufacturing and nonmanufacturing general industry establishments. For these establishments, stationary saws may be used as part of a temporary construction activity or as part of the establishment's main business (e.g., granite countertop fabrication shops). At these locations, the baseline conditions, exposure profile, and additional controls presented here apply equally to construction as well as maintenance work.

5.7.2 Exposure Profile and Baseline Conditions

Record evidence indicates that most stationary masonry saws are designed for use with an integrated water application system that controls dust and improves blade longevity. However, comments and testimony received by OSHA suggest that workers often cut brick and block dry, particularly when working outdoors.

The Mason Contractors Association of America (MCAA) testified that most stationary masonry saws are equipped for wet cutting (Document ID 3585, Tr. 2885; 2286, p. 2). Mr. Wherry of the Unified Abrasives Manufacturers Association stated that water is applied to the blade for cooling and that "[i]f anything, dust control is a secondary benefit of water applied to the blade" (Document ID 2243, p. 1). This sentiment was echoed by Mr. Service of Saint Gobain Abrasives, on behalf of the Masonry and Concrete Saw Manufacturers Institute (SMI), and by Mr. Hammock, representing the Construction

Industry Safety Coalition (CISC) (Document ID 2316, pp. 1-2; 2319, p. 104). Mr. Johnson, representing MCAA, noted that "manufacturers of these saws are starting to explicitly state that the water used in this blade – in this system, is used for cooling the blade only and should not be used to suppress dust" (Document ID 3585, Tr. 2885).

However, Dr. Schulte of the National Institute for Occupational Safety and Health (NIOSH) observed that this statement by Mr. Johnson "overlooks manufacturers' literature stating the opposite" (Document ID 4233, pp. 5-6). NIOSH submitted examples of product literature for various types of saws from five major saw manufacturers; that literature highlights that the use of water application equipment suppresses dust (Document ID 3998, Attachment 12a, pp. 9, 15-16; 3998, Attachment 12e, p. 3; 3998, Attachment 12f; 3998, Attachment 12g; 3998, Attachment 12h). Mr. Walker, a World Floor Covering Association (WFCA) member, agreed that wall and floor tile and stone are almost always cut with water when using a stationary masonry saw, noting that "water not only keeps the temperature [of the blade] moderate, but it also suppresses the creation of any dust. The byproduct of the cutting is dirty water, not airborne particles of any sort" (Document ID 2359, Attachment 4, pp. 1-2).

At the public hearing, Mr. Cahill, a bricklayer from Arizona representing the International Union of Bricklayers and Allied Craftworkers (BAC), agreed that water systems have traditionally been for cooling saw blades; Mr. Cahill noted that the older style blades deteriorated rapidly if not constantly wetted, but he has observed that the wetting has the additional benefit of dust suppression. He stated that with the advent of modern wet/dry diamond blades, if "the water stops going, we keep right on cutting…. And the dust just gets worse and worse….I think the dusty, dirty conditions are mainly the result of development in [and] the rapid adoption of the wet/dry diamond blade" (Document ID 3585, Tr. 3042). Mr. Cahill further explained that the growing trend among workers is to cut masonry dry, rather than use the wet methods that used to be more universal. He stated that several decades ago (in the early days of his career, which started in 1959) his experience was that all masonry saws used water to protect the blade from overheating (Document ID 3585, Tr. 3041-3042).

Despite the mixed comments regarding the original intent of wetting the blade, OSHA received no comments disputing OSHA's understanding that workers sometimes perform dry cutting with stationary masonry saws. Nor did OSHA receive comments refuting that water has marked dust suppression properties when applied to masonry cutting blades. In fact, as OSHA describes later in this section, under the discussion of Additional Controls – Wet Methods, water-based cutting systems are the most effective means of suppressing dust emissions while cutting masonry.

The amount of time spent operating masonry saws during a work shift is a major determinant of a worker's 8-hour time-weighted-average (TWA) exposure to respirable crystalline silica. Many saw operators alternate cutting with laying masonry, mixing mortar, or pouring concrete, and thus cut for only a short portion of their shifts (Document ID 0231, p. 6; 0084, pp. 19, 33). At some worksites, however, saw operators cut masonry nearly continuously throughout their shifts; but even these workers typically pause between cuts to adjust the cut angle or pick up the next work piece (Document ID 1238, pp. 147-148).

NIOSH conducted a field study to evaluate exposures to silica among workers involved in the cutting of bricks and concrete masonry units. That study documented the amount of time workers spent cutting (Document ID 0231). NIOSH researchers collected eleven samples on five workers cutting masonry with stationary bench saws and portable chop saws at two construction sites (Document ID 0231, p. 5; 0223, p. 6). Only one (20 percent) of the five workers operated the saw for more than half the shift (that worker used the saw for 60 percent of the shift). The median percentage of shift time spent working with a stationary saw was 15 percent (i.e., 72 minutes of a 480-minute [8-hour] shift). All saw operators at these two NIOSH sites spent the remaining portion of their days laying brick, delivering mortar to other bricklayers, or preparing and making concrete pours, although one of the workers, who used a water-fed stationary saw for 25 percent of the shift, switched to a handheld masonry saw (operated dry) for an additional 10 percent of his shift (Document ID 0223, p. 7).

To further estimate the amount of time construction workers typically spend operating stationary masonry saws, OSHA reviewed information presented in a construction exposure database assembled by Flanagan (Document ID 0677, Attachments 1 and 2).[203] In the database, 17 of the 53 personal silica exposure samples for workers using “table mounted saws” (i.e., stationary masonry saws) contain information on the amount of time the worker spent on specific tasks. For this group, the percentage of work time spent using stationary masonry saws ranged from 7 percent to 60 percent. Using the information in the database, OSHA determined that the 17 workers spent 4 to 282 minutes using the saw during the period sampled. The median time spent using the saw was 69 minutes and the mean time was 81 minutes, indicating that most observed workers spent less than 1.5 hours per work shift operating a stationary masonry saw (Document ID 0677, Attachment 2).[204]

Mr. Humphrey, representing WFCA, explained that masonry cutters routinely spend little time on cutting and sawing activities during masonry or stone installation jobs because the overwhelming majority of the tile and stone comes pre-cut (Document ID 2359, Attachment 1, pp. 3-4). Mr. Humphrey stated that, based on information from WFCA members, tile and stone flooring are cut only intermittently and for short periods of time (often a minute or two) (Document ID 2359, Attachment 1, pp. 3-4).

Mr. Humphrey reported that, based on his organization’s members’ experience, even if an entire floor installation is performed by one worker, that worker would still spend less than one to two hours cutting or sanding stone, tile, or concrete for the job (Document ID

[203] The Flanagan dataset may contain a few masonry cutter results that are included in OSHA’s exposure profile, but individual data points in the Flanagan dataset are not attributed to specific sources. All 53 silica results recorded in the Flanagan dataset for workers using stationary saws were obtained between 1997 and 2002 by researchers, government regulatory agencies (primarily Oregon and Illinois), and private organizations (Document ID 0677, Attachment 2). For comparison, OSHA’s exposure profile contains 30 results, obtained mainly by OSHA and NIOSH, between 1990 and 2014.

[204] To calculate minutes spent on the task, OSHA multiplied the reported sample time (in minutes) by the percent of time the worker performed the task (as provided in the Flanagan dataset) to obtain the number of minutes spent on the task during the period sampled (Document ID 0677, Attachment 2). For example, if a worker spends 10 percent of a 480-minute sampling period using a table-mounted saw, OSHA calculated that the worker spent 0.10 x 480 minutes = 48 minutes using the saw. The sampling reported in the Flanagan dataset was conducted over periods ranging from 37 to 505 minutes (Document ID 0677, Attachment 2).

2359, Attachment 1, pp. 3-4). These comments are supported by written testimonials from several WFCA members (e.g., Document ID 2359, Attachment 2; 2359, Attachment 3, p. 1; Attachment 4, pp. 1-2). Additionally, the Bay Area Roofers and Waterproofers Training Center reported that workers in the roofing industry usually cut concrete roofing tiles or concrete roofing pavers for only about 30 to 45 minutes per day (Document ID 3581, Tr. 1598).[205]

Table IV.5.7-A summarizes the major activities and primary sources of silica exposure among workers in this job category.

Table IV.5.7-A Job Categories, Major Activities, and Sources of Exposure of Masonry Cutters Using Stationary Saws	
Job Category*	**Major Activities and Sources of Exposure**
Masonry Cutter Using Stationary Saw	Cutting block, brick, or stone. • Dust generated by abrasive cutting wheel during dry cutting. • Re-suspended dust particles released when dust-laden water or slurry from wet cutting dries and becomes airborne (particularly under extremely hot or dry conditions).
*Job categories are intended to represent job functions; actual job titles might differ, and responsibilities might be allocated differently, depending on the site. Source: Document ID 1720, p. IV-443.	

OSHA's exposure profile presents the best exposure monitoring data available to OSHA; it includes 30 sample results for stationary masonry cutting, including 28 samples described in the PEA and two exposure monitoring results from OSHA's Information System (OIS) (Document ID 1720, p. IV-445; 3958, Rows 1041, 1042). The 28 samples previously summarized in the PEA were drawn from eight OSHA special emphasis program inspections (SEP), and two NIOSH reports (Document ID 0040; 0084; 0092; 0102; 0103; 0144; 0158; 0181; 0223; 0231).

Table IV.5.7-B presents the exposure profile for masonry cutters using stationary saws under various conditions. Overall, the exposure profile in Table IV.5.7-B includes 30 samples of respirable crystalline silica for masonry cutters using stationary saws. The

[205] Although workers in this industry typically use handheld saws for cutting roofing materials, Mr. Smith did not specify what tools are used for cutting tile and pavers (Document ID 3581, Tr. 1598).

median is 50 μg/m^3, the mean is 217 μg/m^3, and the range is 11 to 2,005 μg/m^3. Of the 30 samples, 15 (50 percent) exceed 50 μg/m^3. The exposure profile values described in this section were obtained under both wet and dry working conditions and represent baseline exposures for workers using stationary saws.

Of the 30 total measurements summarized in Table IV.5.7-B, 13 sample results are for workers dry cutting outdoors with no controls. For these 13 sample results, the mean 8-hour time-weighted average (TWA) silica exposure is 329 μg/m^3, although the median is notably lower (45 μg/m^3). The two lowest results, 21 μg/m^3 and 12 μg/m^3 (limit of detection (LOD)), were obtained for a worker dry-cutting concrete block for approximately 45 minutes (10 percent of the shift) during each of two 8-hour sampling periods (Document ID 0231, pp. 6-7).[206] The concrete block being cut during these sampling periods contained four percent or less silica. The maximum silica exposure reported in this 13-sample subset was 2,005 μg/m^3 (an 8-hour TWA obtained over a 350-minute work period), and was associated with a sawyer dry-cutting concrete blocks containing 15 percent silica (Document ID 0114, pp. 119-120).

Exposure levels are considerably lower when workers use wet methods. For these workers, the profile shows exposures ranging from 11 μg/m^3 to 94 μg/m^3, with a median exposure of 34 μg/m^3 and a mean exposure of 41 μg/m^3 (based on eight sample results for workers using water-fed masonry saws to cut brick and block outdoors) (Document ID 1143, Row 7). In these eight samples, the median percentage of silica in the materials being cut was 9 percent.

The profile includes an additional nine samples for workers working under various other conditions. These results show a mean exposure of 211 μg/m^3, with a median exposure of 91 μg/m^3, and overall exposures ranging from 12 μg/m^3 to 824 μg/m^3. Mr. Hammock, for CISC, took exception to this category in the exposure profile, as it contains results from some samples that were not described in sufficient detail in source documents to be

[206] Results reported as "none detected" are assigned a value equal to the LOD. The LOD is determined individually for each sample based on the volume of air sampled and the method used to analyze the sample; therefore, the limit of detection varies between samples. See Section IV.2 – Methodology for additional information on LODs.

classified as wet or dry sawing samples (Document ID 2319, p. 53). Even though the detailed characteristics of the construction sites from which the samples were taken may not be known, OSHA retained this data in the exposure profile because the results represent exposures for workers who cut masonry using stationary saws in the United States.

The exposure profile values stem from samples that were obtained over varying lengths of time. In OSHA's judgment, the exposure profile reflects workers' full daily exposures because the vast majority of the samples covered most, if not all, of the workers' shifts. Although some shorter samples were included because they are relevant to baseline exposures, the median sampling duration among the samples included in the exposure profile was 450 minutes, indicating that half the samples were taken over periods of more than 7.5 hours. Two-thirds of the samples were taken over periods exceeding 6 hours. Thus, a majority of the samples in the profile were taken over a full shift and provided full-shift exposure values. These samples captured all silica in the workers' breathing zones during the sampling period, regardless of the source(s) of exposure.

CISC commented that OSHA should exclude one sample from the profile because it was taken over a period of only 16 minutes (Document ID 2319, p. 53). Because the OSHA compliance safety and health officer (CSHO) who obtained the 16-minute sample spent nearly seven hours at the construction site, and noted that the worker made only two or three cuts per day, OSHA believes that the 16-minute sample captured all, or nearly all, of that worker's exposures attributable to masonry cutting during that work shift (Document ID 0092, pp. 2, 15, 18). Therefore, OSHA concluded that the 16-minute sample reflects the observed duration of cutting tasks on the day the worker was sampled, and OSHA retained the sample in the FEA exposure profile.

Masonry saw cuts on brick typically take 1 to 2 minutes each (including the time it takes to pick up and position the brick), as confirmed in an iQ Power Tools air monitoring report indicating that a saw operator can, at the maximum work rate, cut 400 bricks per 8-hour day (i.e., one every 72 seconds) (Document ID 3501, p. 2).

CISC also asserted that OSHA's analysis of stationary saws did not take into account differences in the silica content of materials being cut (Document ID 2319, p. 53). OSHA acknowledges that the silica content of brick and block can vary greatly and has taken this into consideration. Among the data used for the exposure profile (Table IV.5.7-B), the respirable dust samples contained proportions of silica ranging from 3 to 22 percent, encompassing the range of materials used in brick and block masonry (Document ID 0084, p. 36; 0092, p. 17; 0102, p. 6; 0144, p. 10; 0159, pp. 50, 56, 62, 68; 0181, p. 21). Likewise, standard construction brick and block were used in every study upon which OSHA relied (some with moderate silica content, some with higher silica content).

In addition to the exposure data in the exposure profile, OSHA also reviewed extensive exposure data from other sources. These data, discussed below, were compiled in part from published studies and therefore included some of the same samples OSHA used to develop the exposure profile. The overall exposure results from these data for workers using stationary saws are consistent with the values in OSHA's exposure profile.

OSHA reviewed the Flanagan data, mentioned earlier in this section, which includes 53 personal silica sample results for workers using "table-mounted saws" to cut brick, concrete block and stone (Document ID 0677, Attachments 1 and 2). Location and control method information are not available for most of the samples in this dataset. Exposures ranged from 6 μg/m^3 to 2,750 μg/m^3, with a mean exposure of 210 μg/m^3 and a median exposure of 58 μg/m^3. Although these results represent exposure concentrations during the period monitored (rather than 8-hour time-weighted averages), these data are consistent with the exposure profile presented in Table IV.5.7-B. Sixteen of the samples from the Flanagan data were collected while the worker used wet-cutting methods and are associated with markedly lower exposure levels than were reported for all workers using table-mounted saws. Silica exposures among workers wet-cutting ranged from 6 μg/m^3 to 316 μg/m^3, with a mean exposure of 73 μg/m^3 and a median exposure of 46 μg/m^3. Although these results are higher than those in OSHA's exposure profile for wet cutting methods, this is likely because the results in the Flanagan data represent the concentrations during the periods sampled rather than 8-hour time weighted averages. Although most of the samples for workers using stationary saws in the Flanagan data were collected for periods of 3.5 hours to 8 or more hours (median 209 minutes), the highest of the wet-cutting exposure levels was obtained during one of the shortest sample times (just 12 minutes, suggesting a period of intense cutting, although no details are provided). The Flanagan data identify four wet-cutting samples collected during work indoors or in otherwise enclosed areas; these sample results were 18, 34, 61, and 139 μg/m^3 (with a mean exposure of 63 μg/m^3, and a median exposure of 48 μg/m^3).

Where available, Flanagan captured information on the percent of the sampled time that a worker spent on a specific task. For stationary saws, this information is available for 17 of the 53 samples and suggests that the workers most typically operated the saws for 15 percent of the period sampled (with a range of 7 to 60 percent of the sampled period) (Document ID 0677, Attachment 2). As noted above, the median sample period was 3.5 hours. OSHA notes that similar results (workers using stationary saws for approximately 15 percent of their shifts) were observed at the two NIOSH sites discussed previously (Document ID 0231, p. 6; 0223, p. 7).

In addition to the Flanagan study, OSHA also reviewed published summaries of an international database of silica construction exposure data assembled by Sauvé et al. (2013) and Beaudry et al. (2013a, 2013b) (Document ID 3778; 3797; 3803).[207] The underlying data in these studies were not made available to OSHA. The literature describing this dataset did not specifically separate exposure values for workers using stationary and handheld masonry saws, but OSHA judges the task described by Beaudry (2013b) as "sawing pieces of masonry" to apply most closely to masonry cutters using stationary saws. The investigators identified 74 samples, drawn from eight studies in which workers sawed pieces of masonry, then calculated a geometric mean exposure of 70 μg/m^3 for the samples presented as individual values (24 of the 74 results were individual values, the remainder were available as summarized rather than individual data) (Document ID 3797, pp. 83-84). Reviewing the data by type of tool (rather than

[207] This Canadian dataset includes references that OSHA consulted when developing the exposure profile and evaluating technologically feasible control methods. Individual data points are not attributed, but OSHA considers the similarity in source documents to suggest substantial overlap between this data set and the data that OSHA relied upon. Beaudry et al. also note a significant (20 percent) contribution from the Flanagan dataset (Document ID 3797, p. i; 0677, Attachment 2).

worker activity), the investigators found that five individual exposure results for workers (at any type of construction site) using bench-based masonry saws had a geometric mean exposure of 50 μg/m^3, similar to the overall median exposure of 50 μg/m^3 in OSHA's exposure profile (Table IV.5.7-B) (Document ID 3797, pp. 89-90).[208] These data provide corroborative evidence of worker exposure levels during the operation of stationary saws, although the effects of control methods and work environment (indoors/outdoors) on exposure levels were not reported for individual samples.

On the basis of the information in the record, OSHA has determined that baseline conditions for masonry cutters using stationary saws vary widely, with common conditions including wet cutting methods (indoors and outdoors) and dry cutting outdoors with no engineering controls. Although most masonry saws can be operated using wet methods, the number of stationary saw samples from dry cutting in Table IV.5.7-B indicates that saws are, at times, operated without active water flow.

Overall, the exposure profile in Table IV.5.7-B indicates that 50 percent of masonry cutters using stationary saws currently experience exposure levels of 50 μg/m^3 or below.

[208] The geometric mean of lognormally distributed data is equivalent to the median.

Table IV.5.7-B
Personal Respirable Crystalline Silica Exposure Range and Distribution of Results for Construction Workers: Masonry Cutters Using Stationary Saws

	Exposure Summary			Exposure Range			Exposure Profile				
Masonry Cutters Using Stationary Saws	**N**	**Mean (μg/m³)**	**Median (μg/m³)**	**Min (μg/m³)**	**Max (μg/m³)**		**<25 (μg/m³)**	**≥25 and ≤50 (μg/m³)**	**>50 and ≤100 (μg/m³)**	**>100 and ≤250 (μg/m³)**	**>250 (μg/m³)**
Masonry Cutter Using Stationary Saw (dry cutting outdoors, no engineering controls)	13	329	45	12	2,005		3 (23.1%)	4 (30.8%)	1 (7.7%)	1 (7.7%)	4 (30.8%)
Masonry Cutter Using Stationary Saw (dry cutting, other conditions)	9	211	91	12	824		2 (22.2%)	0 (0%)	4 (44.4%)	0 (0%)	3 (33.3%)
Masonry Cutter Using Stationary Saw (Wet cutting methods)	8	41	34	11	94		2 (25%)	4 (50%)	2 (25%)	0 (0%)	0 (0%)
Masonry Cutters Using Stationary Saws Total	**30**	**217**	**50**	**11**	**2,005**		**7 (23.3%)**	**8 (26.7%)**	**7 (23.3%)**	**1 (3.3%)**	**7 (23.3%)**

Notes: All samples are personal breathing zone (PBZ) results and represent 8-hour time-weighted average exposures.
Job categories are intended to represent job functions; actual job titles might differ, and responsibilities might be allocated differently, depending on the site.
Percentages may not always add to 100 percent due to rounding.

Sources: Document ID 1720; 3958; 0040; 0084; 0092; 0102; 0114; 0144; 0159; 0181; 0200; 0223; 0231; 1143; 1423.

5.7.3 Additional Controls

The exposure profile in Table IV.5.7-B shows that 50 percent (15 out of 30 samples) of masonry cutters using stationary saws have exposures above the final PEL of 50 µg/m^3. Therefore, OSHA finds that additional controls will be necessary to achieve the PEL for these overexposed workers. Based on the evidence in the record, OSHA has determined that the use of water suppression methods is both a feasible and highly effective means of dust control that can reduce workers' exposures to respirable crystalline silica during the use of stationary masonry saws. Where the use of such wet systems is not feasible for particular applications, employers can reduce worker exposures to a lesser extent using LEV-equipped saws (e.g., vacuum dust collection systems) or ventilated booths.

Wet Methods

The most reliable data showing substantial reductions in silica exposures involve the use of water when cutting (wet sawing method). As noted previously, OSHA identified eight respirable quartz samples for masonry sawyers using wet methods (Document ID 1720, p. IV-445; 3958, Row 1042). The mean exposure of 41 µg/m^3 associated with wet cutting is substantially lower than the mean exposure of 329 µg/m^3 for dry cutting operations with no engineering controls. Moreover, 75 percent of the samples taken for work done using wet methods show exposures less than 50 µg/m^3. When fully and properly implemented, wet cutting methods provide effective dust suppression. NIOSH found that use of wet methods can result in barely detectable levels of airborne respirable dust, even during the instant a mason starts the cut with a stationary saw. NIOSH found that the average airborne respirable dust concentration during wet cutting, as shown by area samples, is 154 times lower than the average concentration during dry cutting – a reduction of 99.3 percent (Document ID 1252, pp. 6, 7, 10).

When wet dust suppression is used properly, evidence in the record indicates that the reduction in worker exposure levels is substantial. A study to evaluate the effectiveness of dust controls was conducted under controlled conditions so that investigators could confirm that the control in use was fully and properly implemented. Meeker et al. (2009) ran trials to evaluate exposures during intensive masonry cutting done without controls compared to exposures while using saws with integrated water delivery systems and maximum flow rates of 2.3 and 2.4 liters per minute (0.6 and 0.63 gallons per minute).[209] The investigators reported that the stationary wet saws were associated with a 91-percent reduction in exposures (Document ID 2177, Reference 11, pp. 104, 107-108). They also separated results associated with stationary wet sawing into data obtained while a worker cut block (mean exposure of 260 μg/m^3 for the duration sampled) and data obtained while a worker cut brick (mean exposure of 90 μg/m^3 for the duration sampled). If these workers cut block or brick at this same intensity for the amount of time that a typical worker uses a stationary masonry saw (i.e., 15 percent of an 8-hour shift, or 72 minutes per day, as explained earlier), OSHA estimates that these workers would experience 8-hour TWA mean exposure levels of 13 to 38 μg/m^3.[210] Furthermore, applying a 91-percent reduction factor to the 13 dry cutting (outdoor) samples in the exposure profile (Table IV.5.7-B) would result in 9 sample results below 25 μg/m^3, 1 sample result between 25 and 50 μg/m^3, 2 sample results between 50 and 100 μg/m^3, and only one sample result between 100 and 250 μg/m^3.[211]

Differences in effectiveness have been observed among various wet cutting methods. Beamer et al. (2005) conducted experiments using a stationary saw to cut bricks in order to compare respirable dust suppression through free-flowing water (typical of stationary saws fitted with a water basin and pump) and water misting (Document ID 1555, p. 509). The highest dust suppression occurred with freely flowing water applied at a rate of 48 gallons per hour (0.8 gallons per minute), resulting in dust reduction of about 93 percent and confirming the benefits of water flowing over the stationary saw cutting blade. This is the most common configuration used for these saws. While not as effective in suppressing dust when compared to freely flowing water, the authors saw an important

[209] Because the samples were obtained under experimental conditions, with repeating trials, and did not capture the workers' total exposures for the day, these results are not included in OSHA's exposure profile.

[210] The 8-hour TWA is determined using OSHA's instructions for calculating an 8-hour TWA published in 29 CFR 1910.1000(d)(1)(ii). For example, the 8-hour TWA resulting from a 69-minute exposure at a concentration of 260 μg/m^3 would be (260 μg/m^3 x 69 minutes)/480 minutes = 37.4 μg/m^3.

[211] The impact of a 91-percent exposure reduction on an exposure level of 250 μg/m^3 is calculated (1-0.91) x 250 μg/m^3 = 22.5 μg/m^3.

benefit to misting, noting that as an aerosol, mist tends to dry much more quickly than freely flowing water (Document ID 1555, p. 509).[212] Among construction teams, rapid drying is considered a benefit because sawyers using brick or block often prefer to work with dry surfaces; however, OSHA notes that rapid drying can contribute to increased exposure from re-suspension of previously wetted dust. Rigorous housekeeping with a high-efficiency-particulate-filtered vacuum can limit exposures from re-suspended dust.

The value of wet cutting methods was also demonstrated in a laboratory study designed to compare, under otherwise identical conditions, the amount of respirable dust released during each of three different cutting conditions: wet masonry cutting, cutting with LEV, and cutting without controls (Document ID 3612, pp. 246-247, 249). This study used the same wet/dry 14-inch electric masonry table saw to test all three conditions. Dust samples were collected only during the 30-second cuts. Compared with no controls, operation of the saw at the manufacturer-recommended water flow rate (0.13 liters per second, equal to 2 gallons per minute) reduced respirable dust concentrations in the chamber from 49,700 $\mu g/m^3$ to 570 $\mu g/m^3$ when cutting flat roofing tiles, and from 39,200 $\mu g/m^3$ to 360 $\mu g/m^3$ when cutting curved tiles.[213] This represents a 99-percent reduction in respirable dust exposure. Additional trials were conducted at lower flow rates, down to less than one-quarter of the manufacturer-recommended water flow rate, which reduced respirable dust by 98 percent compared to dry cutting with no controls. The saw was also set up to test LEV dust controls (in separate, but similar trials), as described later in this section. Carlo et al. (2010) demonstrates how water application can effectively reduce respirable dust released during masonry cutting when the saw is equipped with a manufacturer's

[212] In the study by Beamer et al. (2005), water misting was tested at three water application rates: 4.8, 8.6, or 17.3 gallons per hour (equivalent to 0.08, 0.14, or 0.29 gallons per minute) (Document ID 1555, p. 503).

[213] Through all trials (involving eight repetitions at each water flow rate), the saw cut concrete roof tile (two shapes, all from the same two batches) at the steady rate of 0.013 meters per second (0.51 inch per second) in a chamber with a constant air flow through the chamber. The relative amount of respirable dust generated during actual cutting was measured in the air flowing out of the chamber through a single exhaust duct. In addition to trials at 0.13 L/sec (2 gal/min), the investigators also tested lower flow rates of 0.06 (0.95 gal/min), 0.03 (0.5 gal/min) or 0.02 L/sec (0.3 gal/min) (Document ID 3612, pp. 246-247).

standard water application equipment, even at flow rates much lower than the recommended flow rate (Document ID 3612, p. 245).

These findings are supported by a NIOSH study that found that wet masonry saw operators' silica exposures were routinely below 100 μg/m^3, and usually below 50 μg/m^3, even though some of the sampled workers also used a portable, dry cut, chop saw during the sampling period (Document ID 0223, pp. 5-7).

Even when wet methods are used, silica exposures can exceed 50 μg/m^3 if the wet methods are not fully or properly implemented or if other sources of exposure are present. Table IV.5.7-B shows that 2 of the 8 silica sample results from workers using stationary saws with wet methods exceeded 50 μg/m^3. However, both samples suffered from possible exposure bias. In the NIOSH study sample, researchers observed that the wet-cut saw dispersed a significant cloud about 20 feet in the air during cutting. The operator was also working in an area where a dry cut chop saw was being used (Document ID 0231, pp. 4, 6). The other sample was from the Shields dataset, which provides only limited information on the control method (wet saw) and was collected where tuck point grinding was also being performed (Document ID 1143, Rows 7, 8).

Some commenters expressed concern about saw operating parameters for wet dust control. Mr. Wherry, Unified Abrasives Manufacturers Association (UAMA), and Mr. Service of Saint Gobain Abrasives, representing the Masonry & Concrete Saw Manufacturers Institute (SMI), both stated that existing research has not determined the "specific requirement for applied water volume, velocity, and location" (Document ID 2243, p. 1; 2316, pp. 1-2). OSHA believes that there is no single optimum operating parameter for wet methods. Saw designs vary between manufacturers, and, as with other operating parameters, recommendations for optimizing wet methods are likely to vary somewhat with the size and design of the saw.

The rulemaking record contains several studies reporting water flow rates that effectively suppressed dust for stationary masonry saws. Three examples include the studies by Carlo et al. (2009), Meeker et al. (2009), and Beamer et al. (2005). As discussed previously, Carlo et al. (2009) reported that for a 14-inch (35.6 centimeter) stand-mounted masonry saw, dramatic dust suppression was accomplished using the 0.13 liters per second (2 gallons per minute) water flow recommended by the saw manufacturer. Although other saws were not tested in this study, other flow rates were, and flow rates below one-quarter of the recommended level (i.e., 0.03 liters per second, equivalent to 0.5 gallons per minute) were similarly effective for suppressing dust under the experimental conditions (Document ID 3612, pp. 245, 247). In Meeker et al. (2009), two other brands of 14-inch stationary masonry saws were tested using the manufacturers' maximum water flow settings of 2.3 and 2.4 liters per minute (0.6 and 0.63 gallons per minute); these settings suppressed 91 percent of the dust released by these saws. These investigators also tested a lower flow rate (0.73 liters per minute, equal to 0.12 gallons per minute) for one of these saws and found dust control somewhat diminished compared to the higher flow rate (Document ID 2177, pp. 107-108). A free-flowing water application rate of 0.8 gallons per minute (48 gallons per hour) was also reported by Beamer et al. (2005) to be an effective dust suppressant for a stationary saw, providing 93 percent reduction in respirable dust (Document ID 1555, p. 503). OSHA observes that all three of these studies found that flow rates of 0.5 to 0.8 gallons per minute provided notable dust reduction (greater than 90 percent), but the water application was more effective in some cases than in others. Under the final rule, OSHA has not specified a minimum flow rate, but rather anticipates that the water flow rates specified by the saw manufacturers will optimize dust reduction.

Commenters raised a number of issues related to the use of wet methods. Several commenters were concerned about how to deal with the potential for slurry in re-circulating water used to wet saw blades. OSHA's proposed entry on Table 1 provided that employers "prevent wet slurry from accumulating and drying" when using stationary saws (78 FR 56496). UAMA and CISC expressed concern over the lack of comprehensive research into the water change frequency (in the saw's water basin) necessary to prevent slurry accumulation, the definition of "accumulation", and whether minimizing slurry has a beneficial impact on worker exposure (Document ID 2243, p. 1; 2319, p. 6; 3580, Tr. 1360). While optimal water change frequency has not been researched, OSHA believes that the evidence in the record shows that preventing slurry containing silica from drying (and potentially becoming airborne) reduces employee exposure. As a practical matter, dried slurry is nothing more than dry masonry dust, which can be suspended in air if disturbed; therefore, slurry should be kept to the minimum amount that is practically achievable. Additionally, given that most masonry saws are already equipped with wet methods, OSHA believes that most employers know what "accumulation" is and have experience in preventing slurry accumulation. OSHA anticipates that the appropriate water change frequency will vary depending on the circumstances of the job, as the rate of slurry buildup depends on the amount the saw is used (specifically, the amount of material cut). As a practical matter, the control and cleanup of wet slurry is necessary when cutting concrete indoors (regardless of whether it contributes to silica exposure). Additionally, the Concrete Sawing and Drilling Association has published a Best Practice Guide for Management of Slurry, which may be useful for some employers (Document ID 3998, Attachment 12d). The Best Practice Guide provides practical advice on how to prevent the accumulation of slurry when using wet saws to cut concrete. OSHA notes that it has removed the requirement to prevent wet slurry from accumulating and drying from final Table 1, although the Agency anticipates that most employers will incorporate these preventive measures into their exposure control plans.

Several commenters were concerned about slurry disposal, including UAMA and the National Association of Home Builders (NAHB) (Document ID 2243, p. 1; 2296, p. 28). NAHB asked whether employers are supposed to dispose of the slurry in a wet or dry form (Document ID 2296, p. 28). OSHA believes that collecting and allowing slurry to dry is acceptable if the slurry is held during the drying process in a way that will prevent the resulting dust from being released into workers’ breathing zones once the slurry is dry. One example of an unacceptable practice would be to allow thick slurry to be spread as droplets from the saw (or to be intentionally poured) on the ground to dry, since the dry dust that will result might later be disturbed by passing foot traffic, releasing dust into the air.

Other commenters raised questions about the environmental implications of using wet methods. SMI, for example, commented that the rule does not recognize the existence of regulations regarding water/silt runoff imposed by other government agencies (Document

ID 2316, p. 2). OSHA has addressed the environmental implications of the standard in Chapter X – Environmental Impacts.

A number of commenters (e.g., CISC, NAHB, and Edison Electric Institute (EEI)) questioned the feasibility of using wet methods in freezing weather (Document ID 2319, pp. 53-54; 2296, p. 30; 4220, pp. 5-6; 2357, pp. 7, 24, 28). Although wet methods may not always be available in freezing temperatures, evidence in the record shows that in many situations, employers are able to use wet methods despite freezing temperatures. For example, Mr. Hoffner of the New Jersey Laborers' Health and Safety Fund described how construction contractors cope with freezing weather in his state, where there are restrictions on the dry-cutting of brick, block, and other silica-containing building materials: "Many contractors have dealt with the usual concerns about what to do in the winter by wrapping gutter heat tape around 55 gallon drums to make sure the water stays liquid in freezing temperatures" (Document ID 3589, Tr. 4214). OSHA believes that this is a feasible option for most employers. In response to a question about a scenario where electrical power is not available, Mr. Hoffner described how one contractor on a road construction project used an environmentally friendly antifreeze additive to prevent the water from freezing (Document ID 3589, Tr. 4230).

Additionally, some commenters explained that wet methods cannot always be used due to customer specifications or because of other hazards. The National Roofing Contractors Association noted that water can stain or discolor some building materials (Document ID 2319, p. 94; 2320; 3587, Tr. 3609-3610). Ms. Trahan, representing the BCTD/AFL-CIO, indicated that it is common for an employer to choose which set of tools offer the best opportunity to control a hazard while effectively completing the job to the customer's specifications. She said, "It is common for workers' assignments, and tools and control strategies they utilize, to vary. For example, an employer on one project could assign a worker to use a stationary masonry saw equipped with a water attachment to cut products containing silica, and on another project that same worker could be assigned to use a handheld masonry saw with a vacuum attachment to perform the same task" (Document ID 2371, p. 6). OSHA acknowledges that there are some situations where the use of water systems is contraindicated and that employers need to determine the silica control method that will offer the best protection for workers using masonry saws, while still being compatible with the work product and environment. OSHA concludes that in situations in which the use of wet methods is disfavored, employers will be able to use alternative tools with alternative controls, such as a saw fitted with LEV, as a feasible alternative for reducing silica exposure; the employer should be aware that LEV might not reduce exposures to the same extent as wet methods that are well implemented.

Construction managers representing NAHB and EEI commented that construction sites do not always have a water source (Document ID 2296; 4220; 2334; 2357; 3587, Tr. 3525). NAHB stated that it often takes two to three months after construction begins for a water meter to be hooked up on a residential construction site, and noted that it is the local municipality that controls when water service is provided (Document ID 3587, Tr. 3525).

OSHA recognizes that a residential contractor may not be able to control when a water meter is hooked up on a construction site, but does not view this as a major impediment to the use of wet methods on construction sites. Water tanks are already commonly available on many construction sites and could provide water for a stationary masonry saw. Additionally, stationary saws need not be connected to a continuous water supply because the saws are commercially available with a water basin and water recycling pump. Recirculating water-fed saws require just a few gallons of water per shift (Document ID 1431, p. 1-8); OSHA does not believe employers would need to bring large tanks of water to a jobsite, as asserted by one commenter (Document ID 2319, p. 94).

CISC also questioned whether the water delivery system on the stationary saw needed to be integrated. OSHA's proposed entry on Table 1 for masonry cutters using stationary saws required the use of an integrated water delivery system, and OSHA has retained this requirement in the final rule. CISC asked why a separate wet method (e.g., a hand operated hose or spray, not integrated into the tool) would not be acceptable (Document ID 2319, p. 104). The Power Tool Institute commented that the use of a water delivery system that is not specified by the tool manufacturer could result in a shock hazard with electrically operated tools (Document ID 1973, p. 2). And OSHA has determined that a separate wet method is unnecessary, because, as noted earlier in this section, and as observed by commenters from MCAA and BAC, nearly all models of stationary saws already are available from the manufacturers with integrated water delivery systems (Document ID 3585, Tr. 3041-3042; 2885; 2286, p. 2).

The comments in the record do not dispute that wet methods on stationary masonry saws can substantially reduce silica dust emissions; rather, the comments focus on describing difficulties that could be potentially encountered during implementation of wet methods at construction sites. OSHA believes that these concerns can be addressed through careful job planning to fully implement wet dust suppression methods, choosing appropriate equipment, and ensuring that the tool is used properly. Mr. Ward, a bricklayer from Detroit, Michigan, representing the International Union of Bricklayers and Allied Craftworkers, strongly supported this conclusion. In his experience, dry-cutting is not necessary, and, with advance planning, a construction firm can replace dry saws with water-fed stationary saws as a practical and economical option. He described working as a supervisor for his most recent construction contractor employer; he explained that they cut with wet saws equipped with a garden hose connection that prevents slurry and flow rate issues (Document ID 3585, Tr. 3018-3019).

The available evidence shows that wet cutting is a highly effective dust control option for stationary masonry saws. Table IV.5.7-B shows a median respirable silica dust value of 34 μg/m^3 when wet methods are used when cutting with stationary saws. Based on this evidence, OSHA concludes that the use of fully and properly implemented wet methods can reduce silica exposures to levels of 50 μg/m^3 or below for most workers using these saws to cut masonry, most of the time.

Local Exhaust Ventilation

Stationary saws equipped with local exhaust ventilation (LEV) are engineered to capture dust generated by the cut at the source (cutting blade), preventing dust from becoming airborne. ERG-C (2008) reviewed literature suggesting that additional controls for workers in some settings could include the use of LEV-equipped stationary masonry saws or stationary saws set into ventilated enclosures (e.g., a ventilation booth that permits the operator to stand outside the enclosure). There is evidence that workers who cut blocks using saws located in site-built ventilation booths throughout their shifts can experience silica exposures at levels below 100 μg/m^3 (Document ID 0165, pp. 47, 132). For example, OSHA observed 80-percent lower exposures to respirable quartz when workers used a site-built ventilated booth outdoors (mean exposure of 66 μg/m^3) compared with cutting outdoors with no booth (mean exposure of 329 μg/m^3 included on Table IV.5.7-B) (Document ID 0165, pp. 47-58; 0181, pp. 20, 26).

CISC questioned the effectiveness of ventilated enclosures, noting that the study OSHA relied upon showed a median exposure of 78 μg/m^3 when ventilated booths are used (Document ID 2319, p. 54). However, OSHA compliance inspection data from a construction site (such as that for the site-built ventilated booth described above) is a prime example of the type of exposure information that captures the worker’s silica exposures from all sources.

CISC also questioned OSHA’s reliance on laboratory data in evaluating the effectiveness of ventilated booths for stationary saws, noting that laboratory studies do not capture exposures from secondary or adjacent sources (Document ID 2319, p. 30). Certain types of experimental data are not intended to replicate workplace conditions, but OSHA believes these data are still relevant in evaluating the effectiveness of controls. Studies may be intentionally designed to eliminate extraneous factors that would interfere with a correct interpretation of a control method’s capacity to reduce silica emissions and associated exposure levels. Far from being a drawback, these experimental studies, under controlled conditions, typically are designed by the investigators to answer specific questions (hypotheses). The resulting data may be obtained under isolated conditions that ensure no additional sources of exposure are present. This exposure information can objectively show how well a control method works in an environment where other sources of silica are also controlled (e.g., as might occur on a well-controlled work site, or a site where only one source of silica exposure is active at a time). Sample results from the controlled condition are also routinely compared by investigators to the sample results for the uncontrolled condition. The resulting ratio shows the exposure reduction efficiency for the control method, independent of work rate variability, variations in construction materials, or other factors that do not relate to the individual control's functional performance. When available, this type of information is valuable for comparing the benefits of one control method to another. OSHA acknowledges that there are limitations to experimental data, but believes such data can also provide useful information. The following discussions of LEV controls fitted to stationary saws draw on data from a demonstration project and experimental conditions.

Although OSHA believes that controlling silica exposure during the use of stationary saws is best achieved by cutting brick and block with water suppression, NIOSH has noted that some construction methods specify dry cutting to avoid discoloration (staining) or because dry brick is desirable for subsequent processes (Document ID 0861, p. iv). OSHA received evidence during the rulemaking suggesting that the LEV technology for stationary masonry saws is advancing. For example, iQ Power Tools provided information on masonry saws fitted with LEV systems, including a saw table that adds an LEV option to a conventional stationary masonry saw mounted to the table. Mr. Joel Guth, president of iQ Power Tools, stated that these systems incorporate "dust collection and filter system on it to collect up to 90 percent of the dust" (Document ID 3585, Tr. 2972-2974).

Mr. Guth also submitted a personal exposure monitoring report for a worker using a stationary masonry saw fitted to the LEV table system just described. The report shows that during the 4-hour (241-minute) sampling period, a worker used the saw outdoors to dry-cut 100 units of concrete block (an average rate of approximately two blocks every five minutes), sawing through both parallel faces of each hollow 8 by 8 by 16-inch block. These blocks were of the size and shape typically used in constructing walls (Document ID 3501, p. 2). Although the sampling was conducted as a demonstration project at the saw manufacturer's site (not an active construction site), the work activity, work materials, cutting tool, and cutting frequency was consistent with heavy sawing by one masonry cutter on a construction site.[214] Air monitoring results show that the silica exposure level for this worker was 75 µg/m^3 during the period monitored, the equivalent of 38 µg/m^3 as an 8-hour time weighted average, assuming that the worker experienced no additional exposure during the unsampled portion of the shift (i.e., the worker did not cut additional blocks or have other sources of silica exposure outside the 4-hour sampling period). The air sample contained 16 percent silica in the respirable dust. In a corresponding area sample obtained during the same period of cutting, but 20 feet "down wind" from the saw, no silica was detected (in this case the limit of detection was 10 µg/m^3) (Document ID 3501, p. 3).[215] This result indicates that with active dust control in place, workers 20 feet down wind would have experienced no detectable silica exposures, even if they had worked in that position over the entire cutting period (4 hours).

The record also contains several studies that evaluated stationary saws fitted with vacuum suction. In one study, NIOSH used a test chamber to evaluate dry-cutting methods, with and without the use of LEV, using a commercially available 10-inch masonry saw factory-equipped with two exhaust take-offs (one below the blade and one surrounding the blade guard, with a different air mover attached to each exhaust take-off).[216] With the saw LEV turned off, the respirable dust concentration in air drawn from the test chamber was 13,000 µg/m^3 (13 mg/m^3). However, when the saw's LEV was activated, the measured respirable dust concentration was notably lower, at 50 µg/m^3 (0.05 mg/m^3) (Document ID 0861, p. iv). Although these concentrations do not relate directly to worker silica exposure levels, they do indicate that the LEV system captured respirable dust effectively during the tests. NIOSH concluded that exhaust ventilation can be used to reduce respirable dust emissions by at least 99 percent when LEV air flow rates are

[214] The sampling report lists the "typical" frequency for a tool operator performing masonry cutting as 25 to 400 cuts per 8-hour day. The worker who was the subject of this air monitoring report cut 100 blocks over 4 hours. There is no indication that the worker cut additional blocks during the unsampled portion of the day (Air Sampling Report - Document ID 3501, p. 2).

[215] The personal sample result was reported as "0.075 mg/m^3" silica as quartz (equal to 75 µg/m^3) and the area sample limit of detection was reported as " <0.0096 mg/m^3" silica (rounded to <10 µg/m^3) (Document ID 3501, pp. 2-3). Document ID 3501 also contains additional air monitoring results, but those relate to other types of masonry saws (not stationary saws).

[216] As standard features, this EDCO GMS-10 masonry saw is designed for use with both LEV and wet dust control methods (Document ID 0641).

sufficient (the total airflow was 206 cfm in this case).[217] However, NIOSH also recommended several improvements to prevent captured dust from settling where it could block air flow (Document ID 0861, p. iv).[218]

Carlo et al. (2010) also used a ventilated test chamber when they evaluated a wet/dry 14-inch electric table-mounted masonry saw used to cut concrete roofing tiles (50 to 60 percent sand and aggregate of varying silica content) at a constant cutting rate. This was the same saw and test chamber arrangement described earlier in the discussion of Carlo et al.'s (2010) evaluation of wet dust control methods. For this test of LEV, the water supply was disconnected and the saw manufacturer's LEV dust control system was installed on the saw. The LEV consisted of a dust hood and curtain assemblies, installed directly behind the saw and connected to an air filtration system. Dust emissions were recorded with the saw LEV system operating at 0.24 cubic meters per second (m^3/second) (509 cubic feet per minute [CFM], which is the rate recommended by the manufacturer), at a lower airflow rate of 0.13 m^3/second (approximately half of the manufacturer's recommended air flow), and with the saw LEV system turned off (no controls). Compared to uncontrolled cutting, the LEV system used at the manufacturer's recommended exhaust air flow rate (0.24 m^3/s) reduced the mean respirable dust levels in the test chamber from 49,700 µg/m^3 to 4,320 µg/m^3 for flat roofing tile, and from 39,200 µg/m^3 to 5,420 µg/m^3 for s-shaped tile, for an overall reduction in dust levels of 91 and 86 percent, respectively. When the LEV air flow was reduced to almost half the manufacturer's recommended rate (0.13 m^3/s), the respirable dust mean concentration was reduced by 87 percent for the flat tile and 79 percent for the s-shape tile (when compared to uncontrolled cutting) (Document ID 3612, pp. 247-250). These results demonstrate substantial respirable dust capture by the LEV system, although in comparison, the water application system reduced the dust to a greater extent (reducing respirable dust levels by a factor of 10 more than the LEV systems tested).

[217] In this case, the vacuums were equipped with "high efficiency filters (99.9 percent at 0.3 µm)" (Document ID 0861, p. iv).

[218] Improvements involved increasing the exhaust air channel air transport velocity to 4,500 feet per minute and enlarging the channel to reduce the pressure loss (Document ID 0861, p. iv).

OSHA also reviewed a brick-cutting experiment conducted by Croteau (2000), in which LEV used during concrete paver block cutting reduced respirable quartz in workers' breathing zones by 69 to 83 percent (depending on the air flow rate), and reduced the concentration 85 to 95 percent (Document ID 0613, p. 4). In a follow-up report, Croteau et al. (2002) elaborated on this study, testing LEV dust control methods for a stand-mounted stationary saw in an experimental indoor area (an enclosed ventilated tent with constant air flow velocity through the area equivalent to 40-60 feet per minute, comparable to a barely-detectable breeze) (Document ID 0611, pp. 459, 463).[219] Breathing zone air samples of 15 minutes duration were collected while apprentice brick and cement masons cut block and brick at a work rate of approximately three 12-inch square pavers or four to five 7-inch bricks every two minutes – a rapid sequential cutting rate.[220] In a series of trials cutting concrete block, the saw-based LEV reduced personal breathing zone silica sample results by up to 96 percent at the high ventilation rate, from a geometric mean silica exposure level of 22,520 μg/m^3 under uncontrolled conditions to a mean silica exposure level of 950 μg/m^3 with LEV (Document ID 0611, p. 463). Although silica levels remained extremely high in this simulated indoor environment during the period of intense cutting, OSHA notes that for a worker cutting block at this rate for half the shift, the use of LEV would bring the airborne silica concentration down to a level for which a respirator with an APF of 10 would provide adequate protection.[221]

[219] The tent enclosure was fitted with a fan providing a constant airflow through the area averaging 50 feet/minute air velocity. The gasoline-powered masonry saw's LEV system consisted of a tube running the length of the saw immediately below the blade. Dust was captured through a slot in the tube near the point of contact between the blade and the material being cut. The LEV performed as a push/pull system, with air currents generated by the blade pushing dust into the slot and the exhaust system pulling the dust away (Document ID 0611, p. 460).

[220] The investigators tracked the apprentices' work rate and determined it averaged 79 to 86 linear feet per hour for block and brick respectively (Document ID 0611, p. 462).

[221] If an intense cutting task with an airborne exposure concentration of 950 μg/m^3 were performed for half a shift (4 hours), the worker would experience an 8-hour TWA exposure of half the concentration measured during the task, for a total daily exposure of 475 μg/m^3 (assuming no additional exposure during the other 4 hours of the shift). Under the proposed PEL, the maximum use level for a respirator with an APF of 10 would be 500 μg/m^3. A half mask respirator would provide sufficient protection.

Work Practice Controls

OSHA's review of the literature also finds that worker exposures to airborne silica can be reduced by employing specific work practice controls. For example, integrated dust controls on saws work best when the equipment is maintained in good working condition (according to manufacturers' specifications), construction managers ensure workers know how to use the equipment to its best advantage (e.g., how to adjust water flow to minimize dust, when to empty vacuums and clean filters), and the equipment chosen is appropriate for the need (e.g., appropriately sized vacuums that will consistently provide sufficient suction) (Document ID 0933, pp. 7-12). Additionally, ERG-C (2008) noted that saws with either water filtration or LEV systems require regular maintenance and servicing to limit the clogging of hoses and filters (Document ID 0231, p. 5). Yereb (2003) noted that worn saw blades should be replaced to minimize the amount of fine particles produced (Document ID 1238, p. 150). Finally, when wet methods are used, housekeeping is needed to remove and dispose of dust-laden water before it dries to prevent possible re-entrainment of dust into the air. OSHA expects that these work practice controls will be used to supplement whichever engineering controls the employer selects to suppress dust.

Comments were received regarding replacing worn blades as an exposure management practice. CISC commented that OSHA's proposed requirement in Table 1 for masonry cutters using stationary saws to "ensure [that the] saw blade is not excessively worn" (78 FR 56496) was vague (Document ID 2319, p. 104; 3580, Tr. 1359). OSHA expects that any employer conscious of jobsite efficiency is already adept at recognizing worn blades, which cut more slowly and slow the work process. The Building and Construction Trades Division (BCTD) of the American Federation of Labor-Congress of Industrial Organizations (AFL-CIO) recommended that OSHA require replacing worn blades as a silica exposure management practice in the text of Table 1 (Document ID 4223, Appendix 1, p. 1). Ms. Vasquez, of Holes, Incorporated (a concrete coring contractor) indicated that it is her company's standard procedure (independent of silica exposure reduction) for the diamond blades used for concrete coring to be checked, and often replaced, during the day, as the particularly hard concrete used in Houston, Texas, causes blades to deteriorate quickly. Although related to a different piece of equipment, Ms. Vasquez's testimony indicates that employers are capable of recognizing when a blade is worn and already make this determination in order to cut more effectively and efficiently (Document ID 3580, Tr. 1440-1441). OSHA expects that employers will be able to determine when a blade becomes worn to the point of being less effective, and finds that changing the blade when it gets to that point is an effective work practice control that will reduce masonry cutters' exposures to silica during the use of stationary saws.

As mentioned previously in this section under the heading for Wet Methods, it is necessary to control and cleanup wet slurry when workers are using wet methods to cut silica-containing materials, particularly when the work is done indoors, as the slurry may be a source of silica exposure after drying. The Concrete Sawing and Drilling Association has published a Best Practice Guide for Management of Slurry, which may be useful for some employers (Document ID 3998, Attachment 12d).

5.7.4 Feasibility Finding

Paragraph (c) of the construction standard gives employers the option of following Table 1, which includes specified engineering and work practice controls for operating stationary masonry saws; alternatively, the employer must assess and limit exposures in accordance with the more traditional regulatory approach contained in paragraph (d). Table 1 requires employers to ensure the saw is operated using an integrated water delivery system that continuously feeds water to the blade. It also requires employers to ensure the tool is operated and maintained in accordance with the manufacturer's instructions to minimize dust emissions.

Based on the exposure profile in Table IV.5.7-B and other record evidence discussed previously, OSHA finds that the standard is technologically feasible for masonry cutters using stationary saws when baseline and additional controls previously discussed are used.

Stationary masonry saws equipped with integrated water delivery systems are the best available technology for controlling respirable crystalline silica. The effectiveness of wet cutting methods in controlling exposures is demonstrated in the exposure profile (Table

IV.5.7-B) by a median 8-hour TWA reading of 34 µg/m^3 for workers using wet methods to cut masonry with stationary saws. Thus, based on the information in the record, when wet sawing methods are fully and properly implemented, OSHA expects most respirable quartz exposures to be reduced to 50 µg/m^3 or below.

Stationary masonry saws with integrated water systems are readily available from several manufacturers including EDCO, Andreas Stihl, Hilte, Makita USA, Husqvarna, Wacker Group, MK Diamond, and Borsch (for tile cutting) (Document ID 4073, Attachment 4a; 4073, Attachment 4b; 3998, Attachment 12a; 3998, Attachment 12e; 3998, Attachment 12f; 3998, Attachment 12g; 3998, Attachment 12h). For those workers who are already using wet methods, but are not consistently using the controls effectively, further training is needed to fully and properly implement these methods in order to achieve optimal dust control (e.g., what level of water flow to use, how water flow should be directed on the blade, when to change dust-laden water in the basin, and how to recognize signs that exposure controls need to be checked). The final rule's Table 1 entry for using stationary masonry saws equipped with integrated water systems includes additional specifications that ensure that these dust control systems are fully and properly implemented (operating and maintaining the system in accordance with the manufacturer's instructions to minimize dust emissions).

OSHA is not requiring the use of respiratory protection when employers are using wet stationary saws in accordance with the Table 1. For stationary masonry saws used indoors or in otherwise enclosed areas, Flanagan 2009 reported a mean respirable crystalline silica exposure of 63 µg/m^3 and a median exposure of 48 µg/m^3 (range 18-139 µg/m^3) from four samples where water use was not described in any detail. There is no other evidence in the record that would suggest that using good water-based systems on saws, even when used indoors, will consistently result in exposures sufficiently high to warrant the use of respirators for all such situations.

Although most masonry cutters can use wet methods with good results, wet methods might not always be feasible (Document ID 1431, pp. 1-6 – 1-9). In the limited cases where wet methods, as prescribed in Table 1, cannot be applied, the use of LEV can substantially reduce silica exposure levels. Saws equipped with LEV systems are commercially available from iQ and EDCO (Document ID 4073, Attachment 4a). While the effectiveness of LEV systems for stationary masonry saws has not been widely evaluated, there is some evidence that LEV can reduce exposures to 50 μg/m^3 or below when used for typical cutting periods of 15 to 30 percent of a work shift (i.e., 72 to 144 minutes) (Document ID 3612).

OSHA concludes that half of masonry cutters using stationary saws are currently exposed to silica levels at or below 50 μg/m^3. For workers who are currently exposed above 50 μg/m^3, the controls described in this section can be implemented to reduce silica exposures to or below 50 μg/m^3 in most operations, most of the time. Therefore, OSHA finds that the standard is technologically feasible for masonry cutters using stationary saws. If an employer decides to comply with paragraph (d) and meet the PEL using methods other than the wet method prescribed by Table 1, OSHA finds that the use of LEV systems is technologically feasible, with the caveat that supplemental respiratory protection may be necessary in some cases to achieve personal exposures at or below the PEL.

5.8 MILLERS USING PORTABLE OR MOBILE MACHINES

5.8.1 Description

Millers are workers who use milling equipment to grate or grind solid surfaces, such as concrete floors, masonry walls, sidewalks, and asphalt roads. OSHA has divided this job category into two major subcategories:

- Workers who drive, tend, or help with drivable milling machines, including -
  - Workers who drive or operate large drivable (road) milling machines, half-lane or larger, from seats on top of the equipment;
  - Workers ("tenders") who tend the large milling machines while walking beside the equipment; and
  - Workers who operate small (less than half-lane) drivable milling machines from a position on the equipment, or who help with this equipment while walking nearby.
- Workers who operate or help with walk-behind milling machines.

Milling machinery often uses a rapidly rotating drum or a bit covered with nibs to abrade surfaces, although other mechanisms (including systems based on impact, shot-blast, or rotating abrasive cups) are common. An operator can drive larger models (half-lane-size and larger) from above; these models include road milling equipment used in recycling/resurfacing operations. An operator controls small, purpose-built road milling machines or small utility tractors, like a skid steer fitted with a milling tool, from a seat or platform on the machine. Still smaller milling equipment, such as walk-behind machines used for small pavement areas and floor work, is guided by hand. Laborers or construction workers operate the smaller machines during specialty tasks such as resurfacing floors, repairing pavement, or creating grooves for electrical cables (Document ID 0036, p. 15; 3958; 3959, p. 39).

Tenders and helpers can work at close range, assisting the operators of drivable and walk-behind machines. Mr. Zimmer of the International Union of Operating Engineers (IUOE), Local 478 in Connecticut, explained that crews supporting drivable milling machines generally include several laborers in addition to the operator, with the number of laborers depending on the size of the milling machine (one or two laborers for a small drivable milling machine, up to three or four for a large machine) (Document ID 3583, Tr. 2441). Walk-behind milling machine operators can also have helpers working in close association with the task. For example, helpers may vacuum debris behind the grinder (Document ID 3958).

In the Preliminary Economic Analysis (PEA), OSHA divided milling machine operators and tenders into three categories: 1) workers who operate large drivable milling machines; 2) workers who tend the large milling machines; and 3) workers who operate walk behind milling machines (Document ID 1720, p. IV-454).

The job categories associated with drivable milling machines have been slightly reorganized in the Final Economic Analysis (FEA) in response to commenters' recommendations. Commenters urged OSHA to divide the group of drivable milling machine operators into subgroups of operators of large milling machines and operators of small milling machines. Mr. Fore and Mr. Richmond, representing the National Asphalt Pavement Association (NAPA), asked OSHA to consider operators of larger road milling machines (with cutting drums of half-lane width and wider) separately from operators of smaller drivable milling machines (with cutting drums that are less than a half-lane wide) (Document ID 3583, Tr. 2171, Tr. 2212-2213).[222] Mr. Bodway of Payne & Dolan, an asphalt paving contractor, who also represented NAPA, made the same point in his written comments (Document ID 2181, pp. 4, 7, 9). Both Mr. Zimmer, representing the IUOE, and a road milling machine manufacturer categorized drivable milling machines as either small or large (half-lane or larger, with cutting drum about 79 inches or wider) (Document ID 3583, Tr. 2441; 1229). After considering the evidence, OSHA agrees with NAPA and has created an additional subgroup for workers (operators and helpers) using small drivable milling machines (with cutting tools that are less than a half-lane wide). This subgroup is added to the umbrella group for all workers using drivable milling machines. The preexisting category for workers who operate walk-behind milling

[222] "Half-lane" and larger road milling machines typically have cutting blades that are at least 79 inches (approximately six and one-half feet) wide. For example, NIOSH evaluated a milling machine with an 86-inch wide cutter drum and described it as a half-lane machine, and most large milling machines in one road milling machine manufacturer's online catalog are 79 inches wide or wider (Document ID 1229, pp. 3-5; 4149, p. 2).

machines is unchanged, except that OSHA has clarified that helpers closely associated with the machine are also included in this group.

Some smaller milling equipment is operated dry, creating dust. Almost all road milling machines, however, are designed with a water tank and water feed at the milling drum to cool the cutting blades (Document ID 3583, Tr. 2200; 3959, p. 39).

Regardless of the size of the equipment, operators may be assisted by helpers. Operators and helpers are often responsible for sweeping and disposing of debris after milling is complete, potentially exposing them to dust. For example, a NIOSH report described a worker who walked beside a large road mill to operate the lower (rear) controls on this machine (Document ID 0866, p. 8). On road milling sites, a vehicular street sweeper is often present and can create additional dust. The OIS dataset describes an indoor worksite where a helper with a vacuum assisted a walk-behind saw operator (Document ID 3958).

As with other construction tasks, the duration of milling activities might vary substantially from shift to shift. For example, at a site evaluated by NIOSH, workers milled a road for more than 8 hours the first day but only 3.5 hours the next (and final) day of the project (NIOSH-Swank, 1995, Document ID 1386, pp. 5-6). Time spent on milling activities varies even more (from less than 1 hour to more than 8 hours a day) for smaller milling equipment (both small drivable and walk-behind machines).[223]

[223] Small milling machines (both drivable and walk-behind) are used for short tasks, such as milling around a manhole. This task was described by Mr. Fore, representing NAPA, as requiring only “a very short duration” (Document ID 3583, Tr. 2213). Small walk-behind milling machines capable of removing up to 800 linear feet of striping per hour can be used to remove road paint stripes. As an example of the amount of time it takes to complete a stripe removal task, OSHA estimates that a 4-way intersection would have four stripes indicating where drivers should stop, each 30 feet wide and requiring two passes to remove. The operator of a small milling machine would need to push the machine for 20 minutes to remove all four stripes (4 stripes x 30 feet x 2 passes)/800 feet/hour = 0.3 hours) (Document ID 0642). The small machines can also be used for jobs that will take longer, such as removing road striping from a mile of roadway. It may take one hour to shallow (1/8-inch deep) mill the floor of a single small 300 square-foot room, and the worker or team could pack up the equipment and drive to another location to do another similar project or two in the same day. Some jobs done with small milling machines may take an entire work shift, such as when a worker (or worker and helper) mills a series of large rooms at one location using, for example, an 8-inch scarifier-type walk-behind machine capable of working 350 square feet per hour (Document ID 0642).

5.8) Millers Using Portable or Mobile Machines

Uncontrolled road milling releases a notable amount of dust and can become a source of exposure for other trades or bystanders in the immediate area. In written comments, NIOSH noted this potential for exposures among bystanders and other trades, including flagmen, in the immediate areas where dusty operations occur. NIOSH also noted (citing the Health and Safety Executive [2011]) that airborne concentrations tend to be lower (rarely exceeding 10 µg/m^3) outdoors where dust can disburse, including at the boundaries of construction sites (Document ID 3951, p. 2; 4233, pp. 12-13).

Table IV.5.8-A summarizes the job categories, major activities, and primary sources of silica exposure for millers.

Table IV.5.8-A
Job Categories, Major Activities, and Sources of Exposure of Millers Using Portable or Mobile Machines

Job Category	Major Activities and Sources of Exposure
Workers Using Drivable Milling Machines	Operating large drivable road milling equipment (half-lane or larger) for grating or grinding solid surfaces (such as pavement); operator is often seated on the machine. • Dust from action of cutting blades and conveyor. Tending/assisting with the operation of large milling machines while walking beside the equipment. • Dust from action of cutting blades. • Dust from related activities, such as sweeping or shoveling debris. Operating or helping with small drivable milling machines (less than a half-lane wide) for grating or grinding solid surfaces (such as pavement). • Dust from action of cutting blades. • Dust from related activities, such as sweeping or shoveling debris,
Workers Using Walk-Behind Milling Machines	Grating or grinding solid surfaces (such as concrete floors, masonry walls, and sidewalks); operator often guides from behind; helper works in close association with the machine and operator. • Dust from action of cutting blades. • Dust from related activities, such as sweeping or shoveling debris,

*Job categories are intended to represent job functions; actual job titles might differ, and responsibilities might be allocated differently, depending on the site.
Source: Document ID 1431, pp. 3-77—3-79.

5.8.2 Exposure Profile and Baseline Conditions

Data and Studies Used

The following section describes baseline conditions for each affected job category based on reports from OSHA, NIOSH, and Eastern Research Group (ERG). OSHA used the best available exposure information to develop the exposure profile for workers using milling machines and helpers performing associated tasks. These include personal breathing zone (PBZ) silica sample results reported in an OSHA Special Emphasis Program (SEP) Inspection Report, a 1995 NIOSH health hazard evaluation, five NIOSH dust control technology studies in the EPHB 282 series, and an ERG site visit report.[224,225] OSHA added eight sample results from the OSHA Information System (OIS) 2011 to April 2014 dataset (Document ID 3958). Of these eight OIS samples, two are for small drivable milling machine operators and six are for walk-behind milling machine operators and their helpers ("laborers"). Table IV.5.8-C presents the exposure profile and summarizes exposure results for workers in each job category.[226]

OSHA received comments from NAPA suggesting that exposure results from one NIOSH road milling machine study were improperly included in the exposure profile. Mr. Bodway cited the experimental nature of the wet methods applied for drum cooling during the two days of road milling to suggest this was not a good example of optimal dust controls. He also noted the possibility that multiple layers of different road materials

[224] References for these reports are as follows: OSHA Special Emphasis Program (SEP) Inspection Report 300442977 (Document ID 0036, pp. 34-37, 99); NIOSH-Swank, 1995 (Document ID 1386, p. 3); NIOSH studies (NIOSH EPHB 282-11b, 2004, Document ID 0866 [duplicate 3798], p. 8; NIOSH EPHB 282-12a, 2007, 1362, p. 23; NIOSH EPHB 282-14a, 2009, 1251, p. 17, Table 1; NIOSH EPHB 282-15a, 2009, 0869, p. 16, Table 1; NIOSH EPHB 282-16a, 2009, 0870, p. 16, Table 1); ERG site visit report (Document ID 0200, pp. 11-12, Tables 1 and 2). For purposes of the exposure profile, OSHA calculated the 8-hour TWA from the gravimetric concentrations when NIOSH presented personal exposure results for discrete segments of the worker's shift. In these cases, OSHA used the equation presented in 29 CFR 1910.1000(d)(1)(i) to calculate the 8 hour TWA.

[225] There are gaps in the numbering system for the NIOSH reports. While the EPHB 282 series, starting with EPHB 282-11b, is largely devoted to road milling machines, a few numbers in the series were used for other topics.

[226] As noted in Section IV.2 – Methodology, all results included in the exposure profile are 8-hour time-weighted averages (8-hour TWAs) calculated assuming no additional exposure during any unsampled portion of the shift. Unless explicitly stated otherwise, all results discussed in the additional controls section are also 8-hour TWAs calculated the same way. Assumptions made in calculating 8-hour TWAs are discussed in Section IV.2 – Methodology.

had been milled (rather than just asphalt) and the percentage of silica in the road material (12 to 28 percent silica, which, according to NAPA, is higher than is usually found in asphalt samples) (Document ID 2181, p. 15; 3798, pp. 1-2, 4-7, 10). Upon reviewing the study protocol and site descriptions provided in the NIOSH report in question, OSHA again concludes that these full-shift exposure data for milling machine operators and tenders, using an older 8-foot drum milling machine during contract roadwork, represent realistic exposure conditions for some milling machine operators who do not always have the advantage of newer equipment and may occasionally mill deeply and encounter multiple layers of varying road materials (including concrete). This test machine was fitted with the manufacturer's original-equipment water delivery system for wetting the cutting drum (which operated at lower pressure than some later models), and, during the testing, the operator intermittently switched between the manufacturer's original water spray nozzles and an alternate nozzle type (at varying water spray rates, always with the modest water pressure that this older machine could generate) (Document ID 3798, pp. 1-2, 4-7).

The hearing testimony of two other commenters supports OSHA's view. Mr. Zimmer, representing IUOE, noted that "it is expected that [asphalt] millers will occasionally come across concrete sub-base" within the depth of material being milled (Document ID 3583, Tr. 2352). And Mr. Turek, of Local 150 in Chicago, also representing IUOE, stated that grinding away unwanted pavement with a milling machine in order to re-route or realign a road is one option for this demolition task, signaling that he concurs that millers sometimes grind away concrete (although other methods exist for complete road removal) (Document ID 3583, Tr. 2364-2365).

The NIOSH report containing the data questioned by NAPA mentions that the road milling and removal contract allowed for the contractor to choose the removal method for the section of road to be realigned and the contractor "chose to mill the pavement because it was of value as a recycled product" (Document ID 3798, p. 2). This consideration suggests that other roadway construction companies likely make the same decision when it is economically advantageous. Furthermore, a road milling machine manufacturer actively advertises large milling machines with "deep cutting" capability, that is, 12 to 14 inches cutting depth (Document ID 1229, p. 4, see also, pp. 1-5). This reference suggests that road milling contractors may consider deep cutting capability when purchasing new machines.

OSHA agrees with NAPA that the milling conditions in this study were not ideal for evaluating the effectiveness of dust controls for steady, shallow milling of asphalt, and that the milling depth and frequent stops likely were not typical of day-to-day operations. OSHA finds, however, that the work performed indicates the range of non-routine conditions under which operators and tenders perform, particularly where they may encounter concrete or aggregate within the depth milled. The silica exposure results from this two-day study were 14 and 100 μg/m^3 (8-hour time weighted average (TWA)) for the operator, and 27, 42, and 66 μg/m^3 (8-hour TWA) for the tenders (one tender on one sampling date, two on the other), calculated from the silica concentrations reported for each of the personal sampling periods (Document ID 3798, pp. 8, 14, Table 2).[227] These exposures were slightly higher than other exposure levels obtained during the more controlled (strictly asphalt) milling conditions represented by the majority of the sample results in the exposure profile. Nevertheless, the samples from this study are well within the range reported in the exposure profile for other operators and tenders of large road milling machines under various conditions (Table IV.5.8-C). Therefore, OSHA has retained the sample results from this study in the exposure profile.

In addition to the sources previously described, two reports by Flanagan et al. (2003, 2006) provide summary, rather than individual, exposure data (Document ID 0676, p.

[227] On Day 1, the skid steer operator and foreman traded jobs mid-day, with each operating the rear controls on the milling machine (in the "tender" role) for part of the shift. For Day 1, the 8-hour TWA silica results for the workers appear in the text of Document ID 3798, p. 8 (3rd paragraph). For Day 2 , OSHA calculated the silica exposures by determining the time-weighted average of the four cumulative sampling sessions obtained for each worker (one session per use of each of the four nozzle types). On Day 2, the period monitored was 495 minutes for the operator and 457 minutes for the tender at the rear controls, demonstrating that the sampling periods on Day 2 represented most of (and in one case 15 minutes more than) an 8-hour shift. To calculate the workers' silica exposures for Day 2, OSHA used the equation for an 8-hour time-weighted average: 8-hr TWA= (C1*T1 + C2*T2+C3*T3+C4*T4)/480, where C1 is the silica concentration in μg/m^3 measured in the breathing zone of the worker during the time when the first nozzle type was in use and T1 is the cumulative amount of time over which C1 was sampled. C2 and T2 are the concentration and time that worker was sampled during use of the second nozzle type, and so on. As an example, for the tender (rear controls) on Day 2, TWA = ([23*105]+[65*111]+[18*134]+[76*107])/480=42 μg/m^3.

322, Table III; 0677, p. 149, Table IV). Further information comes from two other studies on pavement milling machine dust controls used in the Netherlands (Document ID 1184; 1216). Although these studies do not provide individual sample results suitable for inclusion in the exposure profile, as discussed in the following paragraphs, these reports offer additional insight into silica exposures among construction workers working with milling equipment. To avoid duplication, a large summary review of North American and international workplace silica exposure data compiled in Quebec by Beaudry et al. (2013) is not further addressed here because the included milling equipment operator studies are already described individually in this FEA (Document ID 2287, pp. 16, 30).

Substantial additional information on control technology for road milling machines has become available since the PEA was developed. NIOSH has published nine additional studies in the series on large asphalt milling machines, which contribute valuable information on control technology.[228] These nine studies are more experimental than the earlier reports in this series, and most of the tested concepts for equipment are not commercially available on milling machines. Four of the reports involve laboratory evaluations of idle machines (not actual milling), while the rest are highly randomized tests in the field (while road milling is conducted) or tests of control packages that are only just beginning to enter commerce. While the manufacturers of road milling equipment have committed to producing large milling machines with effective dust control features by the year 2017, OSHA understands that few such machines are currently in use; thus, exposure information for these machines does not represent typical exposures among workers using large road milling machines in the United States. As such, OSHA felt it inappropriate to include the exposure results from these studies in the exposure profile (Table IV.5.8-C) (Document ID 3583, Tr. 2222; 2181, pp. 20-29). However, the sample results for these NIOSH studies are discussed extensively under the heading Additional Controls (Section IV.5.8.3).

[228] The nine reports are: NIOSH EPHB 282-17a, EPHB 282-18a, EPHB 282-19a, EPHB 282-20a, EPHB 282-21a, EPHB 282-22a, EPHB 282-23a, EPHB 282-024a, EPHB 282-25a, which appear in the docket as Document ID 4141, 4142, 4143, 4144, 4145, 4146, 4147, 4148, and 4149.

Baseline Conditions and Exposure Profile for Workers Using Drivable Milling Machines

This group includes all machines operated by a worker from a position on the machine and tenders/helpers who assist the operator in close proximity to the machine. The exposure profile in Table IV.5.8-C includes 31 samples of respirable crystalline silica for workers using drivable milling machines (broken down into the following categories: large drivable milling machine operators; tenders associated with those large machines; and small drivable milling machine operators and helpers). The median exposure level for this group is 21 μg/m^3, the mean is 48 μg/m^3, and the range is 5 to 340 μg/m^3. Of the 31 samples, 9 (29 percent) exceed 50 μg/m^3, and 2 (6 percent) exceed 100 μg/m^3. Details of these exposures are presented below.

Baseline Conditions and Exposure Profile for Large Drivable Milling Machine Operators

The exposure profile in Table IV.5.8-C includes 14 samples of respirable crystalline silica for large drivable milling machine operators. The median exposure level is 17 μg/m^3, the mean is 39 μg/m^3, and the range is 5 μg/m^3 to 181 μg/m^3. Of the 14 sample results, 3 (21 percent) exceed 50 μg/m^3, and only one result (7 percent) exceeds 100 μg/m^3. Construction workers operating large drivable milling machines most commonly perform their duties from the tops of the machines. A typical asphalt milling machine has a built-in reservoir from which water is applied to the cutting drum (Document ID 0912, p. 1). The operators use the same water-fed equipment (with different cutting tools on the drum) for concrete milling, but as the vast majority of U.S. roadways are paved with asphalt, concrete milling is performed less frequently (Document ID 1231). The machines are available with or without cabs, although sources suggest that cabs are uncommon because of concerns about visibility and safety (Document ID 1353, pp. 717, 720; 1231). Various commenters supported OSHA's view that asphalt milling represents the majority of road milling jobs; Mr. Rice, of Fann Contracting, a heavy equipment contractor that also performs milling and road construction, described his asphalt road milling and paving operations at length, but did not mention concrete milling or paving. Mr. Richmond of Roadtec, representing NAPA, noted that while the machines his company manufactures can be used for milling concrete, that work constitutes "a relatively minor percentage of the work that we would see on a typical machine." (Document ID 3583, Tr. 2213-2214). Commenters such as Mr. Rice and Mr. Callahan, representing the IUOE, also agreed that cabs are not standard equipment for large milling machines (Document ID 2116, Attachment 1, pp. 6-7, 30; 2262, p. 25).

Exposures can be variable among operators of large drivable milling machines (with water designed primarily for cooling the drum). The contractor report used in developing the PEA (ERG-C, 2008) identified two sample results, both less than or equal to the limit of detection (LOD) (12 μg/m^3), for asphalt milling machine drivers performing wet milling (Document ID 1386, p. 3).[229]

The additional data in the current exposure profile come from five NIOSH reports on investigations performed during asphalt milling using adjustments to drum cooling water sprays (summarized in Table IV.5.8-B, below). All of these studies had an experimental component in which some aspect of the water spray was systematically varied. Eight-hour TWAs were calculated from consecutive samples, the majority of which were two hours or shorter, during which various water treatments were applied (e.g., high- and low-flow). The cumulative total duration of sampling for each operator was at least four hours for the majority of workers, that is, the consecutive short sampling times added up to at least four hours and the concentrations for the consecutive samples were used to calculate the eight-hour TWA. The calculations therefore only incorporated exposure levels during periods of active milling. In accordance with the study design, zero exposure was assumed for the unsampled portion of the shift. The exposure results from these studies were included in the exposure profile because working conditions reflect those actually experienced by milling operators on the job (contracted road work was performed during these studies), although on some dates the amount of time spent milling might have been on the low end of the normal range for milling machine operators.

[229] Results reported as "none detected" are assigned a value equal to the LOD. The LOD is determined individually for each sample based on the volume of air sampled and the method used to analyze the sample. See Section IV.2 – Methodology for additional information on LODs.

OSHA received no general comments on the exposure profile presented in the PEA for large milling machines, although, as mentioned earlier, NAPA objected to inclusion of exposure data from one of the NIOSH reports (NIOSH EPHB 282-11b) in the profile (Document ID 2181, p. 15; 3798, pp. 1-2, 4-7, 10). As previously discussed, OSHA reviewed the study conditions described in the report in question and determined that the conditions fall in the range of activities performed by operators of large milling machines. Therefore, OSHA has decided that the exposure data from that report should remain in the profile.

Table IV.5.8-B
Overview of Five NIOSH Asphalt Milling Machine Studies Conducted 2003 Through 2006

Study Date	Type of Milling	Average Water Spray	8-hour TWA PBZ Silica Sample Results[A]	Percent Silica	Important Findings and Conclusions	Report No. (Year)
Oct 2003	Road demolition (averages of 6 to 11-inch removals, and up to 12-inches)	Cutter drum: 6 to 9 gpm Conveyor:[B] 4 to 3.7 gpm	Operator: 14 to 100 µg/m^3 Tender: 27 to 66 µg/m^3	4 to 9 percent silica on filters 12 to 28 percent quartz in bulk samples	The deep cut created more dust than typical jobs because of the large gap it created between the bottom of the machine and the milled surface (allowing more dust to escape) and the greater quantity of material removed. This is not a typical asphalt “mill and fill” job.	Document ID 0555; NIOSH EPHB 282-11b (2004), 0866 (pp. 6-7, 8, 14 – Table 2)
Jul 2004	Typical “mill and fill” (1 to 4-inch removal)	Cutter drum: 5 to 9 gpm Conveyor: 2 to 3 gpm	Operator: 22 to 91 µg/m^3 Tender (foreman):: 15 to 25 µg/m^3	10 percent silica on filters	Increased water application rate resulted in 50 percent overall reductions in dust emissions.	Document ID 0555; NIOSH EPHB 282-12a (2007), 1362 (pp. 6, 8-11, 23 – Table 1).
Jun 2006	Typical “mill and fill” (1 to 4-inch removal; 1.5 inches most of the time)	Cutter drum: 16 to 18.5 gpm Conveyor: Not available	Operator 5 to 8 µg/m^3 Tender : 13 to 28 µg/m^3	4 to 6 percent silica on the filters 25 to 43 percent silica in bulk samples	No substantial difference in dust control was found between the two relatively similar flow rates.	Document ID 0555; NIOSH EPHB 282-15a (2009), 0869 (pp. iv, 7, 13, 16-Table 1).
Aug 2006	Typical “mill and fill” (1 to 4-inch removal (1 to 2 inches most of the time)	Cutter drum: 7 to 12 gpm Conveyor: 5 to 6.5 gpm	Operator: 15 to 20 µg/m^3 Tender: 15 to 20 µg/m^3	ND to 4 percent silica on filters 13 to 15 percent silica in bulk samples	Dust levels were reduced when water flow rate increased. The hot weather caused the asphalt to become sticky, which might have helped suppress dust.	Document ID 0555; NIOSH EPHB 282-14a (2009), 1251 (pp. 1, 7-8, 13-14, 17-Table 1).

Table IV.5.8-B
Overview of Five NIOSH Asphalt Milling Machine Studies Conducted 2003 Through 2006

Sep 2006	Typical "mill and fill" (1 to 4-inch removal)	Cutter drum and Conveyor (total):[C] 12.5 to 20 gpm	Operator: 39 to 181 µg/m³ Tender: 60 to 82 µg/m³	10 to 19 percent silica on filters	There was no correlation between water flow rates and dust levels. Pressure spray at higher flow rate might have stirred dust into the air. The cold weather might have caused the asphalt to become brittle, contributing to particularly high levels of dust.	Document ID 0555; NIOSH EPHB 282-16a (2009), 0870, pp. iv, 1, 8, 16 - Table1).

Notes: gpm = gallons per minute; ND = none detected.

[A] Daily 8-hour TWAs were calculated from two to four consecutive samples (the majority being 2 hours or shorter) obtained on the same shift, during which various water treatments were applied (e.g., high- and low-flow). The cumulative total duration of sampling on each day for each operator was at least 4 hours for the majority of workers, and only incorporated periods of active milling. Zero exposure was assumed for the unsampled portion of the shift.

[B] When water flow to the cutter drum increased, water flow to the conveyor decreased.

[C] Separate values for cutter drum and conveyor are not available.

In the first study (October 2003), NIOSH investigators collected air samples while evaluating an asphalt-milling machine water spray dust suppression system using two different types of nozzles, high-flow and low-flow (Document ID 0866). NIOSH obtained an exposure result of 14 µg/m^3 for the milling machine operator on the first day, which was a typical day of wet-milling (although water flow rate was not evaluated). A higher result of 100 µg/m^3 was obtained for the operator on the day that investigators evaluated nozzle types (average flow rates between 10 and 12.7 gpm). NIOSH noted that the effect of wind speed and direction is uncertain. At this site, workers removed 12 inches of pavement all at once. In this study, the removal of excess pavement during milling machine demolition-type work created a large gap between the road and the milling machine drum enclosure, allowing more dust to escape than during typical milling conditions (Document ID 0555, p. 1). Milling operators will rarely encounter these “worst case” conditions (Document ID 0555, p. 1).

Subsequently (in July 2004), NIOSH completed a similar study to determine if the engineering controls supplied with new asphalt milling machines, when operated according to the manufacturer’s recommendations, were adequate to control worker exposures. Two sample results of 91 µg/m^3 and 22 µg/m^3 were obtained for the milling machine operator during this typical “mill and fill” job, while water spray flow rate averages ranged from 5 gpm to 9 gpm at the cutting drum (Document ID 1362, p. 1). The system tested provided additional spray at the conveyor. The next study in this series (June 2006) compared several new milling machines manufactured with spray systems, which were tested at 80 percent and 100 percent of their respective maximum flow rates. All three operator quartz exposure levels were below the LOD (less than or equal to 10 µg/m^3 as 8-hour TWAs) (Document ID 0869, calculated from p. 16 – Table 1). Similarly low exposures were observed in the fourth study (August 2006), which tested a late-model mill retrofitted with the newest manufacturer spray system with average total (cutter drum and conveyor) water spray flow rates between 12 gpm and 19 gpm. The three operator quartz exposures were below the LOD (two sample results of less than or equal to 20 µg/m^3 and one result less than or equal to 15 µg/m^3) (Document ID 1251, calculated from p. 17 – Table 1). Although the percent of silica in the asphalt was relatively low (containing an average of 14 percent quartz), respirable dust also was well controlled (Document ID 1251, p. 13). NIOSH suggested that the high summer temperatures (85° to 100° Fahrenheit [F]) caused the asphalt to become sticky, which helped limit respirable dust emissions (Document ID 0555).

The final study in this series (September 2006) again tested a late-model milling machine retrofitted with the newest manufacturer spray system; average total water spray flow rates ranged between 12 gpm and 20 gpm. Quartz exposures among operators at this site, 39 μg/m^3 and 181 μg/m^3, were higher than those at the previous site (Document ID 0870, p. 8, calculated from p. 16 – Table 1). As previously noted, the PBZ exposure levels are composites of samples taken during both high- and low-flow trials, so they do not correlate with specific flow rates. Milling was conducted at nighttime when temperatures were very cool (in the 40s° F). NIOSH noted that it is unclear whether this influenced the silica sample results, although it is possible that the tendency of asphalt to fracture when cold contributed to the difference in results between this study and the warm weather trial of August 2006.

In a separate review of construction data from a variety of sources, Flanagan et al. (2006) summarized 48 respirable quartz samples associated with the use of road milling machines in construction and found a geometric mean of 110 μg/m^3 (Document ID 0677, p. 149, Table II – see Road mill). Flanagan's dataset was drawn from a variety of published and private data, not all of which are available to OSHA, but which likely overlap somewhat with OSHA's dataset. The Flanagan dataset is therefore not included in Table IV.5.8-C. The exposure levels in the larger, but earlier, Flanagan dataset (with sample results obtained from 1992 through 2002) are somewhat higher than the sample results in OSHA's exposure profile, for which most samples were obtained in 2002 or later and which shows that most milling machine operator exposures are currently below 50 μg/m^3 (Document ID 0677, p. 149, Table II – see Road mill).

OSHA also examined differences between asphalt and concrete milling and determined that exposures among operators milling concrete roads might be somewhat higher than exposures during the milling of asphalt, but not necessarily to the extent shown by the concrete milling data available to OSHA. In an extreme case, the New Jersey Department of Health and Senior Services (NJDHSS) reported that, while none of the eight asphalt road millers it evaluated were exposed to silica above the preceding permissible exposure level (PEL) for general industry, the average of the sample results for two concrete road millers was roughly 12 times the relevant PEL.[230, 231] In these cases, the asphalt milling was performed as a wet process while the concrete milling was a dry operation (Document ID 0912, pp. 1-5, 8; 1699). A milling machine manufacturer explained that its recommended operating procedures include wet processes for all road milling to protect the equipment. Because dry milling quickly results in costly equipment damage, it is not an accepted normal practice for asphalt or concrete (Wirtgen, 2010) (Document ID 1231).

Wirtgen (2010) also indicated that there are no practical contraindications to using water sprays during concrete milling, although, even with equivalent water spray, silica emissions could still be higher during concrete milling than they are during asphalt milling. This difference is due to the potential for the silica content to be higher in some concrete compared with some asphalts, and also due to the softness and "stickiness" of asphalt milled warm, which likely helps reduce separation of the pavement components and perhaps limits dust release in hot weather (Document ID 1251, p. 14; 1231). Because the same milling machines (fitted with different models of interchangeable teeth on the

[230] NJDHSS (2000) calculated the PEL using OSHA's general industry silica PEL equation based on the percent of quartz in a respirable dust sample (Document ID 0912, see footnote 3 on each page of the reference). The percent silica in the respirable dust samples varied, so the value of the PEL (as a concentration of respirable dust) ranged from 630 μg/m^3 to 5,000 μg/m^3 (0.63 mg/m^3 to 5.00 mg/m^3) for samples obtained during asphalt milling using wet methods. The value of the silica PEL (again as a concentration of respirable dust) was 670 μg/m^3 (0.67 mg/m^3) during dry concrete milling, while the measured 8-hour TWA respirable dust level was 7,620 μg/m^3 (7.62 mg/m^3), approaching 12 times the calculated PEL (Document ID 1699).

[231] In this case, although evaluating a construction industry activity, the investigator elected to compare silica exposure results using OSHA's gravimetric general industry PEL for silica (Document ID 0912, see footnote 3 on each page of the reference). This might be due to the fact that the construction industry PEL for silica is based on the unit "millions of particles per cubic foot" (mppcf), requiring an obsolete analytical method not available through most analytical laboratories. Instead, laboratories typically report silica air sampling results as mass-based gravimetric values (e.g., mg/m^3) for respirable dust, along with the percent silica. An alternative has been available since 2008, when OSHA published a compliance directive, National Emphasis Program (NEP)–Crystalline Silica CPL 03-00-007 (Appendix E), which provides a conversion factor to convert air sampling results between mppcf and mg/m^3 or μg/m^3. However, some investigators have continued to use the more familiar gravimetric units and compare construction industry air monitoring results with the gravimetric general industry PEL for silica.

milling drum) can be used to mill asphalt and concrete roads (Document ID 1230), OSHA expects that operators use these machines on both materials.

Based on information described above, OSHA concludes that the baseline conditions for large road milling machine operators consist of no cabs or open awnings (which would not provide substantial isolation from the outdoor environment) and the use of wet milling methods primarily intended for drum cooling (with varying degrees of attention to water flow). Furthermore, baseline conditions include primarily “mill and fill” asphalt replacement, with only occasional road demolition jobs (i.e., deeper milling action). Because the sample results included in the exposure profile represent a similar range of conditions, OSHA concludes that the exposure profile for large drivable milling machine operators represents normal baseline exposures for these workers (median exposure of 17 μg/m^3, mean exposure of 39 μg/m^3, range of 5 μg/m^3 to 181 μg/m^3). Operators of road milling machines typically experience silica exposure levels less than 50 μg/m^3, but airborne concentrations can be higher, depending on environmental conditions, the status and design of the water feed system, the depth milled, and whether workers mill concrete road surfaces.

Baseline Conditions and Exposure Profile for Large Drivable Milling Machine Tenders

The exposure profile in Table IV.5.8-C includes 15 samples of respirable crystalline silica for tenders of large milling machines. The median silica exposure is 27 μg/m^3, the mean is 57 μg/m^3, and the range is 11 μg/m^3 to 340 μg/m^3. Of the 15 samples, 5 (33 percent) exceed 50 μg/m^3, and one result (7 percent) exceeds 100 μg/m^3. Construction workers tending large milling machines most commonly perform their duties while walking beside the machines. Their duties can include operating the ground-based rear controls of the milling machine, which requires the worker to walk beside the equipment.

The two highest exposure results in this job category, 340 μg/m^3 and 97 μg/m^3 (from 504-minute and 202-minute samples, respectively), were obtained at a site where minimal water spray was used to cool the equipment. This was the job site where the highest milling machine operator exposures also were obtained, and where NIOSH had strongly suggested that the water spray volume and position needed to be improved (Document ID 1386, p. 4, Table 1 p. 5, and Table 2, p. 6).

The five initial EPHB 282 series of NIOSH studies investigating water spray dust suppression, described above, also measured exposures among milling machine tenders. In order to include personal sampling data from these studies, OSHA calculated 8-hour TWAs for tenders using all the available personal sampling results presented for a given worker during the trials of different water application rates. During the first study, two 8-hour TWA exposure results (66 $\mu g/m^3$ and 27 $\mu g/m^3$) were obtained for the foreman and a skid steer loader operator, respectively. NIOSH noted that both of these workers spent half of the first (most typical) day working at ground level while operating the rear controls of the milling machine, which were located on the side of the machine. They spent the remainder of their shifts on tasks elsewhere at the construction site. A sample result of 44 $\mu g/m^3$ was obtained on the second day of sampling for another crewmember; that worker operated the rear controls for the entire day (Document ID 0866, pp. 8, 14-Table 2). At another construction site, NIOSH investigators obtained two exposure results of less than or equal to 15 $\mu g/m^3$ and 25 $\mu g/m^3$ for a foreman (performing tender duties) who operated the ground-based rear controls of a milling machine (Document ID 1362, p. 23). A ground man performing these same duties during the third study had exposures of 28 $\mu g/m^3$, 18 $\mu g/m^3$, and 13 $\mu g/m^3$ on three consecutive days (Document ID 0869, p. 16, Table 1). At the fourth site, the foreman divided his time between operating the controls alongside the mill and driving the water truck. The exposures for this worker were below the LOD (two sample results of less than or equal to 20 $\mu g/m^3$ and one result of less than or equal to 15 $\mu g/m^3$) (Document ID 1251, pp. 8-9, 17, Table 1). Finally, the ground man at the last study site, who operated controls alongside the mills, had elevated exposures of 82 $\mu g/m^3$ and 60 $\mu g/m^3$ (Document ID 0870, p. 16- Table 1). As previously noted, during this study, water pressure sprays were operated at a higher flow rate, which might have stirred dust into the air, contributing to the higher exposures.

These reports from NIOSH suggest that water spray design, environmental conditions, and the depth of the milling can affect the exposures of ground-based construction workers near asphalt milling machines (just as they can affect exposures among operators).

Based on information described in this section, OSHA concludes that the baseline conditions for large road milling machine tenders consist of operating controls and performing other duties (such as sweeping or shoveling debris) alongside the milling machine where wet milling methods are in use (with varying degrees of attention to water flow). Furthermore, baseline conditions include primarily "mill and fill" asphalt replacement, with only occasional road demolition jobs (i.e., deeper milling action). OSHA concludes that the exposure profile for milling machine tenders represents baseline exposures among these workers. Tenders of road milling machines typically experience silica exposure levels less than 50 μg/m^3. However, exposures can be higher, depending on environmental conditions, the status and design of the water feed system, the depth of the milling, and whether the surface milled includes concrete.

Baseline Conditions and Exposure Profile for Small Drivable Milling Machine Operators and Helpers

The exposure profile in Table IV.5.8-C summarizes the available exposure information for small drivable milling machine operators and helpers. These workers use equipment with a cutting tool less than a half-lane wide, either purpose-built or created by attaching a milling tool (like a "planer") to a small utility tractor, skid-steer, or other similar equipment. Based on two sample results from one OSHA inspection site (21 and 63 μg/m^3), the median exposure level is 42 μg/m^3 and the mean exposure is 42 μg/m^3. OSHA believes this very small sample set does not represent the full range of exposures that these workers currently experience. Over the course of a shift, an uncontrolled small drivable milling machine produces less dust than an uncontrolled large drivable milling machine (small machines are used intermittently and have smaller cutting tools) (Document ID 1229, pp. 1-3; 3583, Tr. 2213). However, some small machines are more likely to be operated with no water application (even for drum cooling) and operators of the smaller machines can be positioned closer to the grinding tool (where dust is more concentrated). As a result, most workers using small drivable milling machines experience modest exposures, but the upper boundary of exposures from small milling machines is potentially similar to the highest exposure levels for large milling machines. OSHA finds that a surrogate exposure profile comprised of all sample results for drivable milling machine operators and helpers best represents the potential for a wide range of current exposures among workers using small drivable milling machines.

Construction workers using small drivable milling machines most commonly operate the equipment from an elevated position on the machine (like a seat or standing platform), although they are never elevated to the same extent as large road milling machine operators (Document ID 1229, pp. 1-3).

The smaller drivable milling machines are used for smaller jobs and detail work, e.g., milling around a manhole, adding rumble strips at the side of a highway, or grinding off unwanted road markings/paint (Document ID 1229, pp. 1-3). The work performed using small drivable milling machines is intermittent; these workers also perform a variety of other tasks during the same shift (Document ID 1229; 3958). Industry representatives agreed that small milling machines used for intermittent tasks (such as milling around a manhole) are typically used only for a “very short duration” during the shift, which would result in lower daily exposures when compared to the operators of large road milling equipment (typically used for 85 percent of the shift) (Document ID 3583, Tr. 2213-2215, 2217-2218). An industry representative agreed that small milling machines are capable of achieving low exposure levels (although this has not yet been demonstrated) (Document ID 3583, Tr. 2213-2215).

Workers operating small drivable milling machines perform a variety of tasks at construction sites. For example, two 2013 exposure results for this job category are for workers who milled a narrow trench in an asphalt highway using a small utility tractor with a milling attachment. They also operated a utility tractor with a sweeper attachment, and worked as flagmen to direct traffic at the site (Document ID 3958).

The smaller drivable machines mill a narrower strip of pavement than large milling machines (median of 20 inches compared to a minimum of 79 inches for large machines), and typically are capable of milling less depth (median 8 inches) than a large machine (median 13 inches) (Document ID 1229; 3958). The samples in OIS were obtained while workers milled a 1-foot wide strip of pavement (Document ID 3958). While the shallower cutting depth could limit the chance a small milling machine would inadvertently cut into a concrete layer below asphalt, OSHA finds that small drivable milling machines are actually more likely to be used (intentionally) to mill on or very near concrete because they are operated in specialty situations where concrete could be more prevalent (for example, the road edge where there might be a concrete curb). In any event, concrete milling occurs only occasionally (Document ID 1231).

Purpose-built equipment, essentially a smaller version of large road milling machines, includes a water tank and application system for drum cooling (Document ID 1229, pp. 1-3 [water weight is included in total weight of the machines]). Use of water likely suppresses dust to some extent. Table IV.5.8-B shows that with only drum cooling water (with minor adjustments), asphalt milling often results in exposures at or below 50 $\mu g/m^3$, although exposures as high as 181 $\mu g/m^3$ were reported. OSHA considers it unlikely that all workers routinely install a supplemental water kit when using smaller drivable milling machines with temporary milling attachments (water dust controls are not standard on that equipment). On small jobs, where the machine moves only in a very limited area, a helper may use a hose to apply water spray, as documented for other utility vehicles with demolition attachments (Document ID 0858, p. 3). See Section IV-5.3 – Heavy Equipment Operators and Ground Crew Laborers. OIS records for workers using small drivable milling machines at one site inspected by OSHA do not indicate that the operators used wet cutting methods, but do show that the workers were protected by an enclosed cab (although the cab likely was not ventilated with filtered air) (Document ID 3958). Therefore, OSHA finds that with respect to small drivable milling machines, the purposeful use of wet methods specifically for dust control is inconsistent.

While OSHA cannot rule out the use of small drivable milling machines indoors (since they can be used wherever small utility tractors might be used), OSHA finds that indoor work is rare if it occurs at all. The more portable walk-behind milling machines are the preferred tool for indoor milling work; both the PEA and OIS described indoor work performed by workers using walk-behind milling machines, but these sources contain no examples of drivable machines operated indoors (Document ID 1720, pp. IV-451 – IV-469; 3958).

Based on the information previously described, OSHA finds that small drivable milling machines are frequently operated without intentional dust controls, although supplemental water application kits are sometimes added. On small jobs, a helper with a hose may apply water spray to the grinding tool (as has been reported for other attachments to utility equipment) (Document ID 0858, p. 3). Additionally, purpose-built small drivable machines apply cooling water to the milling drum, which offers a recognized, but inconsistent, benefit (as shown in IV.5.8-B) (Document ID 0912, pp. 1-5, 8; 1386, p. 5; 1699). The fact that there is a lack of consistency when it comes to the intentional use of dust controls can increase the higher-end of the current exposures for operators and helpers, particularly those who use the equipment for extended periods of time. At the same time, most milling accomplished with the small drivable machines is intermittent, usually characterized by short bursts of activity (e.g., a few minutes spent milling around a man hole) followed by periods during which the operators and helpers perform other activities (sweeping, flagman) (Document ID 3958). The intermittent nature of the work greatly reduces silica exposures among these workers. As a result, OSHA has determined that the potential range of exposures associated with small drivable milling machine operators and helpers is substantially broader (at both the low and high ends) than indicated by the two samples available to OSHA and contained in the exposure profile.

OSHA has also determined that small milling machines are used primarily to mill asphalt, but, like the large machines, do encounter concrete occasionally. Furthermore, the workers operating small drivable milling machines can sit on top of the machine (but not at the same elevation as the operators of large road milling machines) or they can work sitting or standing at or near ground level (Document ID 1229, pp. 1-3). OSHA observes that when an operator is close to ground level, his or her position is similar to that of a machine tender.

OSHA concludes that, rather than relying on the very limited (two) existing data points for workers using small drivable milling machines, the exposure profile for this group is better represented by a surrogate data set comprising the more comprehensive and wide ranging profile for the entire group of workers using drivable milling machines (including operators and tenders/helpers of both large and small drivable milling machines). Thus, the exposure profile for small drivable milling machines shows a median exposure of 21 μg/m^3 and a mean exposure of 48 μg/m^3, with overall exposures ranging from 5 μg/m^3 to 340 μg/m^3.

The baseline conditions for workers using small drivable milling machines consist of either no dust controls, unpressurized cabs, or the use of wet milling methods (with varying degrees of attention to water flow; generally associated with drum cooling systems on purpose-built equipment, or occasionally applied with a hose by a helper or via a supplemental water kit for utility vehicles fitted with milling attachments).

Baseline Conditions and Exposure Profile for Walk-Behind Machine Operators and Helpers

The exposure profile in Table IV.5.8-C includes 12 samples of respirable crystalline silica for walk-behind milling machine operators and their helpers. The median exposure is 12 μg/m^3, the mean is 63 μg/m^3, and the range is 12 μg/m^3 to 504 μg/m^3. Of the 12 samples, 2 (17 percent) exceed 50 μg/m^3. The 504 μg/m^3 exposure reading, and another of 80 μg/m^3, are the only exposures exceeding 50 μg/m^3.

Millers in this second major division of workers using milling machines operate walk-behind machines or work closely assisting workers who operate such machines. Surface preparation jobs can be performed either outdoors or indoors. Workers using these machines are positioned more than arm’s length from the grinding action.

A related surface preparation activity, floor sanding, is described as a concrete finishing process using a sandpaper disk attached to equipment that is operated from a standing position (Document ID 0676, p. 328 [Figure 8]). OSHA has grouped floor sanding activities with walk-behind milling machine operations for the purpose of this analysis.

Sanding is similar to the final smoothing actions of other milling machines that have changeable abrasive units (Document ID 0676).

OSHA originally reviewed six sample results for walk-behind milling equipment operators as part of the PEA. Two of these sample results (both below the LOD of 12 μg/m^3) were obtained by ERG for workers using water-fed walk-behind milling machines indoors while producing a terrazzo floor (Document ID 0200, pp. 6-7, 10-12, Tables 1 & 2). OSHA collected two more sample results (14 μg/m^3 and 80 μg/m^3) while visiting a worksite at which workers used a gas-powered walk-behind router-style milling machine as part of asphalt road pavement repair.[232] Two additional follow-up monitoring sample results of 26 μg/m^3 and 48 μg/m^3 were obtained while workers of the same company used similar equipment on pavement at an airport. Average silica content in the respirable dust samples was 6 and 15 percent (the latter a time-weighted average from two shorter samples of 9 and 18 percent silica), while a bulk sample of the asphalt pavement contained 20 percent quartz. During the sampling period, another worker also used compressed air to clean the dust from the grooves. Dust controls were not mentioned on either occasion (Document ID 0036, pp. 15-16, 34-37, 42, 82, 99).

OSHA added to the original exposure profile six additional exposure results from two sites, as reported in OIS. The 504 μg/m^3 result (the highest in the exposure profile) was obtained in 2014 during an inspection of a worksite where an employee of a structural concrete contractor used a large electric floor grinding machine (with multiple grinding cups) to remove the top layer of concrete from an indoor floor. Notes associated with the sample indicate that local exhaust ventilation (LEV) was used and that a second worker used a small grinding tool (single grinding cup) to grind the corners and edges of the floor "at the same time 10-20 [feet] away" (Document ID 3958, Row 74).

At the second construction site, operators (three samples) and helpers (two samples) from a company that specializes in coating concrete floors used two types of walk-behind

[232] A variety of equipment is available for "chasing cracks," which was the type of road repair being performed at this worksite. Some walk-behind equipment models are similar to masonry saws. In this case, the OSHA representative called the machine a router, suggesting it was more closely related to milling equipment (Document ID 0036, p. 15).

milling machines (a scarifier and a floor grinder) to prepare the surface for repainting. The operators first used the scarifier to remove paint and roughen the floor. Then they leveled the freshly exposed material with a floor grinder. The operators used a series of grinding pads on the grinder (from coarse “chipping” pads to a fine “diamond” pad) to smooth the grooves made by the scarifier. Meanwhile, a helper moved hoses around to keep them away from the milling equipment and vacuumed the floor behind the milling machines. The OSHA inspector who visited the site reported that the milling equipment was operated with LEV. No silica exposures were recorded for either the operator or helper (Document ID 3958, Rows 209-211, 214-215).

OSHA reviewed an additional study designed to evaluate exposures to silica during common dust-producing construction activities. Flanagan et al. (2003) summarized nine sample results for concrete floor sanding activities and reported a geometric mean of 70 μg/m^3 (Document ID 0676, p. 322, Table II). However, as previously noted, the study did not provide individual sample results, so OSHA was unable to include them in the exposure profile for this job category.

In a separate experimental study, short-term exposures to silica for an operator using a walk-behind scabbler on a covered[233] (semi-enclosed) concrete parking garage floor were as high as 2,100 μg/m^3 over an 8-minute test period evaluating dry milling. During other test periods, exposures were controlled by an intense use of wet methods (involving water application at a rate of 15 gallons per minute).[234] This study showed that workers using certain types of particularly aggressive equipment indoors can encounter higher airborne silica concentrations during short periods of intensive milling without dust controls (Document ID 0633, p. 211, Table 1; also reported in 0860, p. 9, Table 1).

Vacuums can be connected to walk-behind milling machines to capture dust generated during milling. Although most walk-behind milling machines are currently manufactured

[233] The semi-enclosed configuration of the parking garage is inferred from photos of the milling trials that show support columns in the area being milled (Document ID 0860, p. 6, Figure 1).

[234] Samples from this study represent exposure concentrations during specific experimental test periods of 5 to 16-minutes in duration, alternating with and without controls; results are not 8-hour TWA values and do not cover the worker’s entire time milling on the test dates (Document ID 0633, p. 211, Table 1). Therefore, the samples are not included in the exposure profile.

with vacuum ports (to which a vacuum can be connected), older equipment might not include this feature (Document ID 1431, p. 3-82). Six of the sample results (for walk-behind equipment operators and their helpers) in the exposure profile (including the highest and lowest values) were collected with LEV in use; thus OSHA concludes that baseline conditions for walk-behind milling machine operators can include the use of LEV to control dust, but the vacuum systems are not always performing effectively (whether due to a mismatched vacuum or poor maintenance and cleaning).

In the PEA, OSHA preliminarily concluded that wet methods appeared to be used more commonly with certain types of walk-behind milling equipment, including terrazzo-milling equipment (Document ID 1720, p. IV-459). OSHA received comments on walk-behind milling machine operator exposures during floor sanding from Mr. Barrett, representing the International Union of Bricklayers and Carpenters (BAC). Mr. Barrett explained that within the past eight years, changes in the terrazzo industry have led to a switch from using lower-power wet methods of polishing to using higher-powered dry grinders with vacuum dust control. The higher-powered equipment can process twice as much floor area per day (1,000 to 1,100 [square] feet per day, compared to 500 [square] feet per day with the lower-powered equipment). The new system creates less of a mess to clean up, “assuming the machines and vacuum controls are properly maintained and used,” but in Mr. Barrett’s experience, “the vacuum systems were not always properly maintained, and/or the filters were not changed when necessary, leading to more dust exposure than with the prior system” (Document ID 4053, Attachment 5). OSHA notes that although the floor type is different (concrete rather than terrazzo), Mr. Barrett’s description is consistent with the operation involving a large floor grinder with LEV described in OIS, which resulted in an exposure of 504 $\mu g/m^3$ (Document ID 3958).

Based on the available information, OSHA concludes that the sample results in Table IV.5.8-C represent the baseline exposure levels for walk-behind milling machine operators and other workers engaged in this activity. However, OSHA acknowledges that this may underestimate exposures for workers using certain types of particularly aggressive equipment indoors.

OSHA finds that the use of either LEV or wet methods is in the range of normal baseline conditions for this diverse group of equipment, but that these methods are not used consistently (e.g., LEV was associated with half of the exposure results summarized in Table IV.5.8-C, while wet methods were associated with one-sixth of the exposure results). Nor do these methods appear to be fully implemented when they are used (the highest exposure level for this group, 504 $\mu g/m^3$, was associated with an LEV system (not described)).

Table IV.5.8-C
Personal Respirable Crystalline Silica Exposure Range and Distribution of Results for Construction Workers: Millers Using Portable or Mobile Machines

	Exposure Summary			**Exposure Range**			**Exposure Profile**				
Millers Using Portable or Mobile Machines	**N**	**Mean (µg/m³)**	**Median (µg/m³)**	**Min (µg/m³)**	**Max (µg/m³)**		**< 25 (µg/m³)**	**≥ 25 and ≤ 50 (µg/m³)**	**> 50 and ≤ 100 (µg/m³)**	**> 100 and ≤ 250 (µg/m³)**	**> 250 (µg/m³)**
Operator - Large Drivable Milling Machine (half lane or wider)	14	39	17	5	181		10 (71.4%)	1 (7.1%)	2 (14.3%)	1 (7.1%)	0 (0%)
Tender - Large Drivable Milling Machine (half lane or wider)	15	57	27	11	340		6 (40%)	4 (26.7%)	4 (26.7%)	0 (0%)	1 (6.7%)
Operator/Helper - Small Drivable Milling Machine (less than half lane)	2	42	42	21	63		1 (50%)	0 (0%)	1 (50%)	0 (0%)	0 (0%)
Workers Using Drivable Milling Machines Subtotal	*31*	*48*	*21*	*5*	*340*		*17 (54.8%)*	*5 (16.1%)*	*7 (22.6%)*	*1 (3.2%)*	*1 (3.2%)*
Workers Using Walk-Behind Milling Machine	*12*	*63*	*12*	*12*	*504*		*8 (66.7%)*	*2 (16.7%)*	*1 (8.3%)*	*0 (0%)*	*1 (8.3%)*
Millers Using Portable or Mobile Machines Total	**43**	**52**	**20**	**5**	**504**		**25 (58.1%)**	**7 (16.3%)**	**8 (18.6%)**	**1 (2.3%)**	**2 (4.7%)**

Notes: All samples are personal breathing zone (PBZ) results and represent 8-hour time-weighted average exposures.
Job categories are intended to represent job functions; actual job titles might differ, and responsibilities might be allocated differently, depending on the site.
Percentages may not add to 100 percent due to rounding.

Sources: Document ID 1720; 3958: 0036; 0200; 0866; 0869; 0870; 1251; 1362; 1386.

5.8.3 Additional Controls

The exposure profile in Table IV.5.8-C shows that approximately 26 percent (11 out of 43 samples) of millers using portable or mobile machines have exposures above the final PEL of 50 μg/m^3. Therefore, OSHA finds that additional controls will be necessary to achieve the PEL for these overexposed workers.

Additional Controls for Workers Using Drivable Milling Machines

Water spray and LEV are the primary dust controls for this job category. Because much of the research on dust controls for road milling machines was conducted by the Silica Milling Machine Partnership, the first subsection below describes this organization and its investigative process. After describing the Partnership, this section addresses wet dust control methods and then LEV as exposure controls for the operators of large drivable asphalt milling machines. Subsequent subsections relate the discussion of controls to tenders of large drivable milling machines, small drivable milling machines, and drivable milling machines used on concrete.

Additional controls for walk-behind milling machines are discussed separately below.

Overview of the Silica Milling Machines Partnership – a Silica Dust Control Effort Focused on Road Milling Machines

NIOSH publications document the extensive work of the Silica/Asphalt Milling Machine Partnership. Public comments submitted to the rulemaking record contain extensive information on the Silica Partnership and its accomplishments. The unique nature and success of this partnership warrants further attention here:

In his hearing testimony, Mr. Acott (president of NAPA), described the partnership's mission as an effort to develop innovative engineering controls "that all but eliminate dust and potential silica exposure," and methods "to retrofit existing milling machines to ensure a safe workplace" (Document ID 3583, Tr. 2153). Representatives of NAPA, including Mr. Acott, Mr. Bodway (of Payne & Dolan, an asphalt paving contractor), and Mr. Richmond (of Roadtec, a milling machine manufacturer) indicate that the Silica Partnership includes representatives from the road construction contractors industry, labor, academia, and government: NAPA, the Association of Equipment Manufacturers (AEM), the International Union of Operating Engineers (IUOE), the Laborer's International Union of North America (LIUNA), and major road milling machine manufacturers. In cooperation with another Silica Partnership member, NIOSH, this group has been studying dust controls for milling machines since 2003 (Document ID 2181, pp. 1-2; 3583, Tr. 2152, 2160).

Partnership members described their visit to a NIOSH research facility in Pittsburgh, Pennsylvania, in 2007 as the turning point in this effort. During that visit they "learned the similarity of mining dust suppressing and milling machines" and that if they could capture the dust, they would capture the silica contained in the dust (Document ID 3583, Tr. 2157). This partnership developed an effective control technology for milling machines. The technology captures 97 percent or more of the respirable dust and maintains worker exposure levels at less than 25 μg/m^3 respirable silica. With NIOSH's help, the partnership members tested multiple designs, evaluated the best-performing designs with several manufacturers' equipment, coordinated extensive laboratory and field testing on 10 road construction sites, collected 42 full-shift exposure samples, and published the testing and dust control design information to benefit the industry as a whole (Document ID 3583, Tr. 2156-2166). Many reports in the resulting series of NIOSH publications provide convincing evidence of the effectiveness of these large asphalt road milling machine dust controls in managing silica exposures among operators and tenders.[235]

Wet Dust Control Methods

Cooling water applied to the cutting drum helps reduce dust exposures among milling machine operators. All of the sample results in Table IV.5.8-C for road milling machine

[235] References that represent steady progress toward managing silica exposures are: Document ID 0866 [duplicate 3798]; 0869; 0870; 1362; 1251; 4143; 4144; 4145; 4146; 4147; and 4149. As with most research endeavors, not every avenue explored by the partnership showed great promise; some represent setbacks or described works in progress that had not yet achieved positive dust reduction results (Document ID 4141, 4142; and 4148). In addition, because the Partnership set a goal to reduce all dust, not all the reports contain worker exposure data, even when they show great efficiency for dust capture. Some of the reports contain only highly experimental field or lab data (area samples, dust analysis rather than silica results), which show the effectiveness of controls for dust capture, which in turn results in silica capture.

operators are associated with the use of wet dust suppression, and 71 percent of the results were 50 μg/m^3 or less. Purpose-built systems for wet dust suppression can be even more effective at reducing silica exposures.

In a study conducted in the Netherlands, a novel wet dust emission suppression system reduced the PBZ respirable quartz exposures of asphalt milling machine drivers to a mean of 20 μg/m^3 (n = 4), with a range of 9 μg/m^3 to 30 μg/m^3 (Document ID 1216, p. 4, Table 1). The system consists of 24 spray nozzles (located at the picks drum, collection conveyor, and loading conveyor), which spray aerosolized water containing an additive (likely a foam, based on the product name) onto the milled asphalt material (Document ID 1216, p. 3; 1217, Slide 4). The additive foam causes the dust to become tacky and aggregate, and expands rapidly to encompass small particles generated by the tool's aggressive action (Document ID 1216, p. 3). This technology can offer more effective dust suppression than plain water.[236] Milling machine tenders benefitted equally from the system, having a mean PBZ respirable quartz exposure of 8 μg/m^3 (n = 4) with a range of 4 μg/m^3 to 12 μg/m^3. Compared with a standard milling machine, which uses only cooling water (not aerosolized) on the blade, the use of the aerosolized water and foam system reduced the mean exposure for drivers and tenders combined by 97 percent.[237] Without the added controls (i.e., cooling water only), the mean exposure for drivers was 418 μg/m^3 (n = 2) and the mean exposure for tenders was 509 μg/m^3 (n = 1) (Document ID 1216, p. 4, Table 1).

Investigators Van Rooij and Klaasse (2007) also reported results for the use of aerosolized water without the additive foam. Aerosolized water alone provided a substantial benefit, giving PBZ respirable quartz exposures of 42 μg/m^3 and 57 μg/m^3 for

[236] Although more costly than a simple water spray, foams are more effective (by volume applied) than water spray. Foam can be adapted to control dust from most tasks, including applications that require a rugged design (Document ID 1360).

[237] OSHA calculated an average exposure of 448 μg/m^3 from three samples for the driver and tender beside the machine (range 39 to 509 μg/m^3) using "only cooling water," and an average exposure of 14 μg/m^3 from eight samples (range 4 to 30 μg/m^3) for the same workers in the same job titles using water aerosol with additive, for a 97 percent reduction in the average personal breathing zone concentration. Samples were obtained at four different road construction sites between September 2002 and December 2003 (Document ID 1216, pp. 3-5, Tables 1 and II).

drivers, and 56 µg/m^3 and 104 µg/m^3 for tenders. Aerosolized water reduced the mean exposure for drivers and tenders combined by 86 percent when compared with cooling water only; however, three of four exposures remained above 50 µg/m^3. The authors did not report individual sample durations, but the average sampling time for all 15 samples was 254 minutes (range: 60 to 388 minutes). The investigators concluded that exposure results were lower when the additive was used in the spray water (Document ID 1216, pp. 4-5, Table 1 and Appendix Table II).

Mr. Bodway, of Payne & Dolan (a road milling contractor), representing NAPA and the Silica/Asphalt Milling Partnership, agreed with OSHA that worker exposures from asphalt road milling machines will be reduced to levels at or below 50 µg/m^3 when milling machines are fitted with effectively designed water spray systems paired with surfactants (a type of water additive) and routine inspections (to be sure the system components are working properly). He noted that all six major road milling machine manufacturers have recently begun, or will soon be, offering dust control optimized water spray systems as standard equipment and/or retrofit kits (Document ID 2181, pp. 21-29). In support of these systems, Mr. Bodway stated:

> The [Silica/Asphalt Milling Machine] partnership is convinced that the water spray systems being provided by milling machine manufacturers for retrofitting older machines are effective at controlling worker exposures to below the proposed PEL, particularly when the water is amended [altered] using surfactants as described by Van Rooij and Klaasse (2007). The Rooij and Klaasse study demonstrated that amending the water used in an aerosol dust-suppression system with a foaming agent reduced worker exposures by 4–5 times when compared to water aerosol alone. ***A further level of protection is provided by the Partnership's recommendation that these control systems be inspected daily by a competent person and inspected annually by a qualified person with training from the appropriate milling machine manufacturer. Such inspections will ensure that the control systems are operating as designed and remain effective (Document ID 2181, p. 11).

Mr. Bodway also testified that, while calcium chloride, a typical additive used in other industries, is not a suitable additive for road milling water spray systems, milling machine operators have available for use an additive “that most people are familiar with as [trade name] dish soap that helps encapsulate [dust]” and helps prevent water from freezing in cold weather (Document ID 3583, Tr. 2187-2188).

The initial series of five NIOSH studies (described previously and summarized in IV.5.8-B) focused on water spray controls (without added dust suppressants) using the standard cooling water system available in milling machines at the time. Taken as a body of work, the results of these studies were inconclusive regarding the extent and reliability of this control in all situations encountered by road milling equipment. More recent studies offer more support for the efficacy and reliability of wet dust control methods.

NIOSH tested alternate designs involving equipment specially added to optimize water spray for dust suppression (Document ID 4148, p. v-vi; 4141, pp. vi-vii). One design, (sometimes referred to as test configuration “B2”) showed more promise than others, reducing dust release by 38 to 46 percent (an average of 43 percent) (Document ID 4141, p. 26). As described in NAPA’s post-hearing comments, the Silica/Asphalt Milling Machine Partnership has adopted this “B2” dust-control optimized water spray design as an industry standard and has placed detailed engineering designs for it in the public record for all milling machine manufacturers to use (Document ID 3749, PDF pp. 3, 5-8 Exhibit 1). During typical “mill and fill” type operations using this method of dust control, ERG’s study of supplemental engineering controls found that with this type of control (B2), the operator and tender experienced exposure levels of less than the limit of detection (12 $\mu g/m^3$ in this case) to 14 $\mu g/m^3$ (Document ID 2181, Appendix II, pp. 30, 45). Including a surfactant additive in the water is a practical way to reduce worker exposures to the lowest level achievable with this wet method (Document ID 1216, p. 3; 1217, Slide 4).

Water spray systems that optimize dust control have other benefits. One milling machine manufacturer indicated that its improved dust control system reduces machine maintenance requirements and improves visibility (by reducing emitted dust) on and around the milling machine (Document ID 1231). In his testimony, Mr. Richmond (of Roadtec, Inc., a road milling machine manufacturer), representing NAPA, confirmed that equipment manufacturers anticipate that spray systems that reduce dust will increase productivity by decreasing equipment down-time (Document ID 3583, Tr. 2204). Mr. Bodway (of Payne and Dolan, a paving contractor), representing NAPA, agreed that "if anything, we are a little more productive" as a result of using wet dust control methods (Document ID 3583, Tr. 2205). The same commenters (Mr. Richmond and Mr. Bodway) also agreed that water spray on milling machines does not create water runoff at road construction sites; rather, the water remains with the milled material, which is trucked to a recycling site (Document ID 3583, Tr. 2203-2204).

Milling concrete can pose additional challenges for controlling silica exposure compared with milling asphalt.[238] For example, one investigator suggested that the smaller teeth on concrete milling drums produce more fine dust (Document ID 1699). Despite these differences, some of the same milling machines (high-power equipment) can readily be adapted to mill either asphalt or concrete (Document ID 1230). Thus, OSHA expects that water spray nozzles applied to asphalt milling machines will function similarly when the same machine is used for concrete. Although the available data are not sufficient for OSHA to conclude with certainty that workers milling concrete roads would achieve the same exposure levels seen for asphalt millers, there is evidence suggesting wet methods work well for managing concrete dust. For example, in a study of tunnel construction workers, Blute et al. (1999) reported respirable silica exposures of 10 $\mu g/m^3$, 59 $\mu g/m^3$ (estimated), and 79 $\mu g/m^3$ for workers removing concrete with heavy equipment (forklifts, backhoes) having grinder or scabbler attachments (analogous action and worker positioning to milling machines). The authors posited that these relatively low exposures (not exceeding 100 $\mu g/m^3$)[239] resulted from the use of hoses to wet down the concrete and the distance between the source of the silica dust and the worker (Document

[238] In one evaluation, the percentage of silica on respirable dust sample filters was higher with concrete milling (16 percent) than with asphalt milling (7 percent) (Document ID 0912, pp. 5, 8). Wirtgen (2010) reported the silica content of concrete is generally higher than asphalt (Document ID 1231, p. 1). The silica exposure results from one NIOSH study where concrete and aggregate were also encountered along with asphalt within the depth milled were slightly higher than other exposure levels obtained during the more controlled (strictly asphalt) milling conditions represented by the majority of the sample results in the exposure profile (Document ID 3798, pp. 8, 14, Table 2).

[239] Blute et al. (1999) used the general industry equation to calculate the PEL for respirable dust containing silica (Document ID 0562).

ID 0562, pp. 636-637, Table III).[240] Therefore, OSHA concludes that wet methods are effective when milling concrete roadways, and that exposure levels will typically be at or below the PEL. The use of dust suppressants (e.g., foams that offer binding and surfactant properties, such as used in studies by Van Rooij and Klaasse [2007]) should further reduce exposures (Document ID 1217, p. 5).

Based on the information reviewed here, OSHA concludes that purpose-designed dust control water spray systems for large milling machines are commercially available (or soon will be available) for most models of large road milling machines in operation, either as original equipment or as a retrofit kit. For typical road milling operations, the water spray will maintain most operators' exposures to 50 μg/m^3 or less most of the time if a surfactant (soap) water additive is used.

TNO Bouw (2002), which evaluated dust controls for milling machines in the Netherlands, noted that blowback of dust released from an LEV-based dust control (specifically, from discharged dust introduced onto the long conveyor belt exiting the machine) can become a source of silica exposures if a breeze carries the dust back over the milling machine into the operator's breathing zone (Document ID 1184, p. 27). Based on their experience with limestone milling machines, the authors recommended that judicious use of water spray in the discharge pipe (for example, at a rate of 2.5 liters of water per hour) could control blowback, where it is a problem (Document ID 1184, p. 30).

Local Exhaust Ventilation

A particularly effective control option for drivable milling machine operators involves the use of LEV to minimize the release of dust from the machine. Since OSHA developed the PEA, NIOSH has completed additional studies in the EPHB 282 series on dust controls for road milling equipment, this time focusing primarily on LEV. The results of these studies, conducted with the Silica/Asphalt Milling Machine Partnership, consistently demonstrate silica exposure levels below 25 μg/m^3 during typical shallow

[240] Tunnel ventilation made this environment similar to working in open air (see Section IV-5.12, Underground Construction Workers).

("mill and fill") asphalt road milling operations. Additionally, the studies indicate that silica exposure levels can be effectively controlled to 25 $\mu g/m^3$ and below when making deeper cuts during asphalt milling. The LEV control (in addition to drum wetting for cooling) also results in consistently low respirable dust levels. This is an important point; it means that when used according to the manufacturers' recommendations during typical road milling jobs, this dust control equipment will keep workers' silica exposures below 50 $\mu g/m^3$ (and usually below 25 $\mu g/m^3$), even when there are higher levels of silica in the respirable dust sample.

Samples obtained while LEV was being used to control dust (with the highest percent silica measured by NIOSH) at a road milling site demonstrate the value of effective dust capture. Samples were taken during the milling of a parking lot where the pavement contained 23 percent silica. The respirable dust samples contained 14 percent silica, yet the lowest operator and ground man (tender) exposure levels were 9 and 8 $\mu g/m^3$ respectively and the highest exposures were only slightly higher. On this occasion, the respirable dust concentrations for the operator and ground man were 70 and 50 $\mu g/m^3$ (reported as 0.07 and 0.05 mg/m^3) (Document ID 4147, p. 13-14, Tables 1 and 2).[241] If the silica content of the pavement had been double the actual level (46 percent, with 28 percent silica in the respirable dust sample), the operator and ground man would have experienced silica exposure levels of 18 and 16 $\mu g/m^3$, respectively (calculated, for example, as 70 $\mu g/m^3$ respirable dust concentration multiplied by the portion that is silica (0.28) = 18 $\mu g/m^3$), instead of 9 and 8 $\mu g/m^3$. The silica content of the pavement in both the original scenario and the hypothetical is in the range of what workers typically encounter. Mr. Fore, representing the Silica/Asphalt Milling Machine Partnership, stated that the silica content of the material being milled varies from region to region and from site to site. "Typically, it would be in the range of say 10 to 30 percent, but it is as low as

[241] OSHA notes that respirable dust levels of 100 to 200 $\mu g/m^3$ were more typical in this LEV study, but the lower values most clearly demonstrate the value of effective respirable dust capture as a method of achieving good silica dust control (Document ID 4147, pp. 13-14, Tables 1 and 2). When respirable dust can be controlled to such low levels, silica values cannot exceed the PEL regardless of the silica content of the material.

0 and maybe as high as 50," depending on the nature of the aggregate used in the asphalt (Document ID 3583, Tr. 2177-2178).

Evidence of the effectiveness of LEV dust controls for road milling machines comes from both laboratory studies and tests performed on milling machines at construction sites. Under laboratory conditions, NIOSH tested the capture efficiency of LEV applied to the milling drum housing on large road milling machines provided by four different manufacturers. In these studies, machines were tested in a stationary position, with the drum spinning and belts moving, but without any reclaimed asphalt pavement moving through the system. The milling machines were set up to simulate the amount of open area around the drum that would be present during a typical milling job. Smoke and tracer gas were used as surrogates for silica dust, allowing NIOSH to evaluate capture efficiencies of the dust emission-control systems in a controlled setting, without exposing NIOSH investigators to silica dust. These studies allowed the Silica/Asphalt Milling Machine Partnership to confirm that the LEV system was effective on each brand of machine tested and to evaluate the effect of varying airflow rates on how well the system captured dust. Table IV.5.8-D presents an overview of the laboratory studies. For all machines, the LEV system captured at least 93.5 percent of the simulated dust particles released in the milling drum housing (at one or more of the tested air flow rates), with capture efficiency of 97 to 99 percent in three of the four machines.[242]

[242] References include NIOSH EPHB 282-19a (2011), Document ID 4143, p. v; NIOSH EPHB 282-21a (2013), Document ID 4145, p. v; and NIOSH EPHB 282-22a (2013), Document ID 4146, p. v.

Table IV.5.8-D
NIOSH Laboratory Tests of Capture Efficiency for LEV on Asphalt Milling Machines

Study Date (Machine)	Type of Study	Control Tested	Test Conditions	Important Findings and Conclusions	Report No. (Year)
Aug 2011 (Machine 1)	Laboratory test	Local exhaust ventilation in milling drum housing	Tested at one air flow rate	Average dust capture efficiency: 93.5%	NIOSH EPHB 282-19a (2011), Document ID 4143, p. v.
Aug 2011 (Machine 2)	Laboratory test	Local exhaust ventilation in milling drum housing	Tested at three air flow rates	Average dust capture efficiency:	NIOSH EPHB 282-20a (2011), Document ID 4144, p. v.
			600 CFM	97.4 to 98.2%	
			900 CFM	99.9%	
			1300 CFM	100%	
Apr 2012 (Machine 3)	Laboratory test	Local exhaust ventilation in milling drum housing	Tested at one air flow rate	Average dust capture efficiency: 99%	NIOSH EPHB 282-21a (2013), Document ID 4145, p. v.
Aug 2012 (Machine 4)	Laboratory test	Local exhaust ventilation in milling drum housing	Tested at four air flow rates:	Average dust capture efficiency:	NIOSH EPHB 282-22a (2013), Document ID 4146, p. v.
			980 CFM	88.6%	
			1250 CFM	94.7%	
			1450 CFM	97.5%	
			1675 CFM	98.1%	

Notes: Machines were tested in a stationary (laboratory) setting, with the drum spinning and belts moving, but without any reclaimed asphalt pavement moving through the system. Machines were set up to simulate the amount of open area around the drum that would be present during a typical milling job. Smoke and tracer gas (analyzed by Miran infrared spectrophotometer) were used as surrogates for silica dust to evaluate capture efficiencies of the dust emission-control systems.

CFM = cubic feet per minute

The Silica/Asphalt Milling Machine Partnership subsequently conducted field trials for large road milling machine LEV systems on machines produced by two different manufacturers. NIOSH evaluated exposures among workers associated with each machine on four to six road construction jobs, for a combined total of 11 construction sites and 21 days of steady asphalt milling (11 days for one machine, 10 for the other) (Document ID 4147, pp. v, 5-7, 13, Table 1; 4149, pp. v, 5-7, 13, Table 1). NIOSH deemed one sampling date and location (Site 3) atypical because little time was spent actually milling and discarded the sample results from that day (Document ID 4149, pp. 6, 13, Table 1). Therefore, the analysis considered 10 construction sites and 20 days of sampling. On those days NIOSH monitored silica exposures for operators and tenders (40 samples over the 20 days) who worked long days, up to almost 11 hours. Silica content ranged from 5 to 23 percent in the road material, which resulted in 2 to 14 percent respirable silica in the breathing zone samples. All 40 samples, for operators and tenders combined, showed that exposure levels never exceeded 25 $\mu g/m^3$ when workers used machines fitted with the LEV system, even when making cuts up to 11 inches deep in asphalt (Document ID 4147, pp. v, 6-7, 13, Table 1; 4149, pp. v, 5-7, 13, Table 1). In fact, the highest sample result (24 $\mu g/m^3$ for a "ground man" walking beside a milling machine removing 11 inches of pavement on each pass) was the only sample result to exceed 13 $\mu g/m^3$ during the two sampling dates (Document ID 4147, pp. v, 5-7, 13, Table 1; 4149, pp. v, 5-7, 13, Table 1). Table IV.5.8-E presents a summary of NIOSH's sample results.

Table IV.5.8-E NIOSH Asphalt Milling with LEV (water spray for drum cooling only)						
Study Date	**Type of Milling**	**Control type(s)**	**8-hour TWA PBZ Silica Sample Results**	**Percent Silica**	**Important Findings and Conclusions**	**Report No. (Year)**
Jun-Aug 2012	11 days at 4 road construction sites; activities ranging from typical “mill and fill” (1.5 to 4 inches removal) to total removal (5 to 7 inches)	Local exhaust ventilation in milling drum housing [Water spray system at cutting drum]	Operator: A <2 to 13 µg/m^3 (N=11) Tender: A <2 to 10 µg/m^3 (N=11) 279 to 700 minutes	In bulk: 7 to 23% In samples: 4 to 14%	This configuration of local exhaust ventilation maintained all sample results below 25 µg/m^3 for both the operator and the tender	NIOSH EPHB 282-23a (2013), Document ID 4147, pp. v, 5-7, 13 Table 1
Sep-Oct 2012	9 days at 6 road construction sites milling depths up to 11 inches (NIOSH excluded Site 3 as atypical; it is also excluded here)	Local exhaust ventilation in milling drum housing [Water spray system at cutting drum]	Operator: 2 to 11 µg/m^3 (N=9) Tender: 4 to 24 µg/m^3 (N=9) 482 to 685 minutes	In bulk: 5 to 12% In samples: 2 to 9%	This configuration of local exhaust ventilation maintained all sample results below 25 µg/m^3 for both the operator and the tender	NIOSH EPHB 282-25a (2013), Document ID 4149, pp. v, 5-7, 13 Table 1

Notes:
[A]All results are from personal breathing zone samples. A ground man has the same duties as a tender. For both the operator and tender, the lowest sample result was below the limit of detection (LOD), reported by NIOSH as 2 µg/m^3 (large sample volumes made low LOD possible).

The findings presented by NIOSH are generally consistent with earlier international studies of LEV designed for dust control on large drivable milling machines. The European Agency for Safety and Health at Work reported on a cooperative effort between a road construction company, a road milling machine manufacturer, labor organizations, and a governmental group in the Netherlands. This effort resulted in a prototype LEV system for road milling machines, after attempts at using wet methods did not provide the desired results (Document ID 0945, pp. 17-20). A preliminary study by TNO Bouw (2002), also in the Netherlands, measured TWA exposure levels for a milling machine operator (Bovenmachinist) over a 5-day period. With the exhaust system fitted on the machine, exposures ranged from less than 4 μg/m^3 to 28 μg/m^3.[243] The study found similar results for workers on the ground (rear control operator) (Ondermachinist), with exposures ranging from less than 3 μg/m^3 to 29 μg/m^3 (Document ID 1184, pp. 5, 25, Table 11). A street sweeper cleaned up loose debris behind the milling machine when milling involved less than the full road surface depth (Document ID 1184, pp. 9, 16). This housekeeping step can improve the effectiveness of controls during milling operations. Echt et al. (2002) reported that airborne dust increased when a walk-behind milling machine (in this case a scabbler) passed over previously milled areas. Milling debris should be cleaned up prior to making a second pass over an area. This step prevents the milling debris from interfering with the seal between the machine and the pavement and minimizes the gap (equally important for drivable milling machines as for the walk-behind machine that Echt et al. evaluated in this study). Additionally, it prevents debris from being re-suspended and acting as another source of contamination (Document ID 0633, pp. 812-813).

Initially, the construction company in the Netherlands started with an asphalt milling machine with a 2-meter (approximately 79-inch) drum. Modifications to the milling machine included improvements to make the milling drum compartment airtight and to add an air exhaust system that kept the drum compartment under negative pressure. Ductwork carried the dusty exhaust air from the milling drum to the long conveyor extending out from the front of the milling machine (used to transfer milled material to a dump truck or reprocessing equipment). The conveyor was covered, so dusty air followed the path of the conveyor to its terminal transfer point, adding distance and elevation between the point of road milling and the point where dusty air was released to the environment. The TNO Bouw (2002) report suggests that certain wind conditions could blow dusty air back to the milling machine, increasing operator exposures to respirable

[243] The multi-day test period covered by this report encompassed work on wet and dry pavement (due to rainy and clear weather); still and breezy days; highway, residential, and bicycle path pavements; and asphalt road grinding to several depths, ranging from 2 centimeters (top layer of about three-quarters of an inch removed) to 25 centimeters (nearly 10 inches, involving total demolition/removal of the road surface and some of the supporting layers). Actual road milling occurred over 35 to 67 percent of each monitoring session. Monitoring took place for 3 to 4 hours per morning session, and 2 to 3 hours per afternoon session (8-hour TWA calculated based on both sessions for the day, typically a total of 6 to 7 hours). In most samples, 6 to 13 percent of respirable dust on the sample filter was quartz, although values as low as 2 percent and as high as 28 percent quartz were recorded.

dust and silica. Nevertheless, OSHA notes that all sample results obtained were well below 50 μg/m^3.

The European Agency for Safety and Health at Work's follow-up article reported on the same construction company in the Netherlands and indicated that the firm subsequently retrofit all of its front-loader milling machines (various models) with LEV to improve dust control company-wide. The article states: "Using unmodified machines, exposure measurements were between 0.02 and 0.290 mg/m^3 [20 and 290 μg/m^3]. This has been reduced to between 0.0019 and 0.017 mg/m^3 [1.9 and 17 μg/m^3] for machines fitted with the exhaust system" (Document ID 0945, p. 19).[244] The exhaust system resulted in a 94 percent reduction in the highest reported exposure levels, and OSHA concludes that comparable results could be achieved by using a similar dust extraction system on milling machines in the United States. The uncontrolled exposure levels are comparable to the values reported in the United States. As of 2010, LEV, like the system used in the Netherlands, is coming into production on several models of front-loading milling machines in the United States (Document ID 1231). Furthermore, the model of road milling machine that the construction company in the Netherlands initially retrofit with LEV is commercially available in the United States, and the company is able to similarly modify other models of milling machines (Document ID 0945, p. 19; 1184, p. 5; 2181, p. 24).

TNO Bouw (2002) suggested that other improvements could further reduce exposures by minimizing airborne dust blow-back. These improvements include: 1) redesigning the exhaust duct outlet over the conveyor so released exhaust air does not create turbulence that kicks up more dust from material on the conveyor; and 2) adding water spray nozzles to the exhaust discharge to suppress dust (Document ID 1184, p. 30).[245] Additionally, the construction company was reportedly testing filtration systems to capture dust in exhaust air to minimize blow-back on operators even in a head-on wind (Document ID 0945, p.

[244] Low value of 0.0019 [1.9 μg/m^3] is as reported by the authors (Document ID 4072, p. 19). The article does not specify whether these exposure levels are time weighted for 8-hour shifts.

[245] Based on previous experience with a modified sandstone milling machine, the report suggests a water application rate of 5 liters per 2 hours, equal to a little more than one half-gallon per hour (Document ID 1184, p. 30).

20). Although the LEV system tested more recently by NIOSH in the United States did not incorporate a filtration system, Table IV.5.8-E shows that NIOSH and the Silica/Asphalt Milling Machine Partnership were able to build on the earlier research to further reduce worker exposure levels (maximum exposure result was 24 µg/m^3) (Document ID 4147, pp. v, 5-7, 13, Table 1; 4149, pp. v, 5-7, 13, Table 1).

When needed, a greater depth of milling can be accomplished by making additional passes, each pass removing successive shallow layers. The study conducted by TNO Bouw (2002) included sites where the road was completely removed by repeatedly milling over the same area in a series of passes. For example, during Monitoring Day 2, TNO Bouw reported on two half-day milling sessions in which sequential passes each removed 1.5 to 5 inches (4 to 12 centimeters) of material. Quartz exposure concentrations ranged from 3 to 28 µg/m^3 (respirable dust concentrations were usually around 100 µg/m^3, ranging up to an LOD of 180 µg/m^3) (Document ID 1184, pp. 12-13). Although the milling machine operated only about half the time (47 and 53 percent of the monitoring sessions), these exposure results indicate that even if the machine had been operated for 80 to 85 percent of the time (as NAPA comments indicate is usual in the U.S., Document ID 3583, Tr. 2216-2217), exposure levels would still have been below 50 µg/m^3. To make this determination, OSHA calculated the ratio of 85 percent operating time to (average) 50 percent operating time (a factor of 1.7) multiplied by the highest exposure measured at this site (28) for a maximum result of 48 µg/m^3 for the road demolition job. This exposure calculation does not take into consideration the possibility that a milling machine operating 85 percent of the session could have completed the job in less time.

The NIOSH studies of LEV for drivable milling machines were conducted using large asphalt road milling machines (half-lane or wider) during a variety of conditions and cutting depths. OSHA finds that these studies offer compelling evidence that exposure levels at or below 50 µg/m^3 (and even below 25 µg/m^3) can be achieved for workers operating this type of equipment during typical shallow “mill and fill” type road milling. In addition, the NIOSH data indicates that deeper cuts can be effectively controlled to exposure levels below 25 µg/m^3 provided that the material being milled is asphalt alone.

Work Practices

In addition to milling, other pavement removal methods are available for road demolition work. As noted previously, Mr. Turek, representing the IUOE, noted that milling is just one way to accomplish roadway removal. Construction companies can choose other methods, such as cutting the roadway into manageable size pieces or squares with a drivable masonry saw and lifting the pieces out intact, creating "substantially less dust than other forms of road demolition, including grinding" (Document ID 3583, Tr. 2364-2365).

OSHA observes that removing asphalt roadways in large pieces can involve heavy equipment operations. See Section IV-5.3 – Heavy Equipment Operators and Ground Crew Laborers. Where the roadway is constructed of concrete, the demolition can also involve concrete drilling with a dowel pack. See Section IV-5.9 – Rock and Concrete Drillers.

Applicability of Additional Controls to Large Milling Machine Tenders

OSHA finds, and breathing zone samples show, that drum-level dust control methods can reduce airborne silica concentrations for milling machine tenders to a similar extent as they can for machine operators. Of the twenty samples summarized in Table IV.5.8-E for tenders working alongside large milling machines fitted with LEV, all but one are 13 μg/m^3 or below. The exception, the highest exposure for a tender (24 μg/m^3), is still below 25 μg/m^3.[246] In these studies, "ground men" managed the lower controls while walking alongside the road milling machines (duties within the scope of milling machine tenders).

When milling machines are fitted with LEV or appropriate wet dust suppression systems at the grinding drum, dust release is controlled at the source, i.e., at ground level. The IUOE urged OSHA to consider whether operators (on top of machines) and tenders (on the ground alongside machines) should receive separate consideration, as tender exposures can be higher (Document ID 2262, p. 24). OSHA agrees that during the

[246] References include Document ID 4147, pp. v, 5-7, 13 Table 1; 4149, p. 13, Table 1.

intermittent periods when tenders work immediately adjacent to the drum, they can experience greater exposures during uncontrolled milling than do operators seated on top of the machine. This means that controls on the milling drum that reduce exposures from that source can particularly benefit tenders, by reducing these peak exposures. Effective control measures of this type benefit workers in both job categories, but operators on top of the machines might continue to experience exposures from more diffuse sources, while the primary source of exposure for tenders can be minimized by drum-level controls. The studies by Van Rooij and Klaasse (2007) and TNO Bouw (2002) in the Netherlands, described previously, reported that tender exposures were reduced at least as much as operator exposures when effective controls were used (exposures for both were well below 50 $\mu g/m^3$). Van Rooij and Klaasse (2007) used a water spray system and foam additive to reduce mean exposure levels for asphalt milling machine operators to 20 $\mu g/m^3$ (range 9 to 30 $\mu g/m^3$) and for tenders to 8 $\mu g/m^3$ (range 4 to 12 $\mu g/m^3$) (Document ID 1216, p. 4, Table 1). Additionally, TNO Bouw (2002) measured TWA exposure levels for workers using a milling machine fitted with LEV and found operator exposure levels ranging from less than 4 $\mu g/m^3$ to 28 $\mu g/m^3$ and exposures among tenders (operating rear controls) ranging from less than 3 $\mu g/m^3$ to 29 $\mu g/m^3$ (Document ID 1184, p. 25, Table 11). OSHA finds that the additional controls that are effective for milling machine operators are at least as effective for the tenders of large drivable milling machines and that these two groups of workers (operators and tenders) do not require separate treatment during controlled milling. Furthermore, in response to comments presented by NAPA and IUOE, OSHA finds that during typical asphalt road milling, available control methods can manage silica exposures sufficiently that respiratory protection is not required for either operators or tenders (Document ID 3583, Tr. 2170; 4234, Attachment 1, p. 30).

Applicability of Additional Controls to Small Drivable Milling Machines (Cutting Tool Less than a Half-Lane Wide)

Both wet methods and LEV have potential to suppress or collect dust generated by small machines equally as well as they suppress or collect dust generated by large road milling machines. Differences in how the large and small machines are used, however, can influence how effective the controls can be on the smaller machines.

The cutting tools on large and small milling machines are generally similar in function (high-energy abrading tools), but, by definition, the tools are narrower and mill to shallower depths on the smaller machines. Many small road milling machines have the same form/shape as large machines, but are smaller, lower, narrower, and more maneuverable (Document ID 1229, pp. 1-3). In other cases the cutting tool is attached to an articulated arm on construction equipment that is better known for being used for other purposes, such as when a grinding attachment is fitted to the movable arm of an excavator, front-end loader, or small utility tractor (Document ID 0562, p. 633; 3958).

Water spray can suppress dust during a wide variety of high energy operations (see related sections of this FEA on additional controls in Section IV-5.5 – Jackhammers and Other Powered Handheld Chipping Tools; Section IV-5.6 – Masonry and Concrete Cutters Using Portable Saws; and Section IV-5.7 – Masonry Cutters Using Stationary Saws. Because small drivable milling machines remove the same material using similar grinding/grating/abrading actions as the large machines, OSHA finds that dust generated by both the small and large machines is similar and water dust suppression will be equally effective on both types of machines. Use of a surfactant additive will increase the effectiveness of wet dust control methods equally well for large and small drivable milling machines. A wet dust emission suppression system with surfactant additive reduced the PBZ respirable quartz exposures among asphalt milling machine drivers to a mean of 20 μg/m^3 (n = 4), with a range of 9 μg/m^3 to 30 μg/m^3. Milling machine tenders benefitted equally from the system, with a mean PBZ respirable quartz exposure of 8 μg/m^3 (n = 4) and exposures ranging from 4 μg/m^3 to 12 μg/m^3. Compared with a standard milling machine, which uses only cooling water (not aerosolized) on the blade, the use of the aerosolized water and foam system reduced the mean exposure for drivers and tenders combined by 97 percent. Without the added controls (i.e., cooling water only), the mean exposure for drivers was 418 μg/m^3 (n = 2) and the mean exposure for tenders was 509 μg/m^3 (n = 1) (Document ID 1216, p. 4, Table 1).

Water delivery systems are already available on some models of small milling machines (online catalog listing indicates that “weight of water” is included in the total weight listed for these small machines) (Document ID 1229, pp. 1-3), and water upgrade kits area also available for utility tractors with milling attachments. Water spray systems optimized for dust control are becoming an industry standard for large milling machines and can be produced for small drivable milling machines. In testimony on behalf of NAPA and the Silica/Asphalt Milling Machine Partnership, industry representatives agreed that controls using protocols similar to those used on large machines were being developed for small milling machines, although the effectiveness of the controls on the small machines has not yet been tested by the industry (Document ID 3583, Tr. 2213-2215). OSHA finds that wet dust control methods using a foam system will reduce the exposures of most small drivable milling machine operators (and their helpers) to 50 $\mu g/m^3$ or less most of the time.

Local exhaust ventilation may also be effective for small drivable milling machines. OSHA finds that small drivable milling machine specifications show that when workers operate smaller machines, dust is released from a smaller area (only the width and depth of the cutting tool housing) than the area from which dust is released using larger drivable machines. Similarly, a smaller amount of pavement material will be removed (again, only the width and depth of the cutting tool). Evidence comes from a manufacturer’s online catalog, which shows small and large milling machine specifications, and indicates that more than half of small road milling machines (five out of nine) have cutting tools that are 20 inches wide or narrower (although the largest is substantially wider at 48 inches). The same catalog indicates that the median depth that a small drivable machine can mill (8 inches) is less than the median depth a large milling machine can mill (13 inches); one-third of the listed small road milling machines can mill a maximum of 1 to 4 inches in depth (Document ID 1229, pp. 1-3). OSHA finds that the smaller machines have less total dust potential than larger machines, and that LEV can be an effective control for the smaller machines when used on flat surfaces. However, the smaller size of these machines could make it challenging for manufacturers to add an LEV suction device of sufficient capacity. OSHA is not aware of small drivable milling machines currently fitted with LEV systems (and OSHA notes that, as discussed earlier, LEV is only just becoming commercially available for large drivable milling machines in the United States). Large walk-behind milling machines with LEV are increasingly common and can be tethered to a substantial vacuum suction system supported by a separate movable cart (Document ID 1276, p. 2). However, OSHA anticipates that operators of small drivable equipment would find a tethered system inconvenient.

Applicability of Additional Controls to Drivable Machines Milling Concrete

OSHA examined differences between asphalt and concrete milling. As previously noted, exposures among operators milling concrete roads may be somewhat higher than exposures among operators during asphalt milling, although not necessarily to the extent suggested by the dry concrete milling data available to OSHA from the NJDHSS (Document ID 1699). As also discussed previously, a NIOSH trial using only drum cooling water and alternate spray nozzles showed elevated silica exposure levels when the road milling machine intermittently ground through the asphalt layer into an aggregate and concrete underlayment (Document ID 3798, pp. 2, 14).[247] Mr. Bodway (representing NAPA and the Silica/Asphalt Milling Machine Partnership) concurred, stating that exposures are higher in concrete milling than asphalt milling (Document ID 2181, p. 15).

While uncontrolled concrete milling may emit more dust, and possibly more respirable silica, than is emitted during uncontrolled asphalt milling, the integrity of the material (very hard, soft, crumbling) is likely an important factor for determining the amount of respirable dust generated per unit of volume milled.

OSHA finds that wet dust suppression methods are effective for respirable silica generated from either asphalt or concrete milling. Moreover, as explained by NIOSH, the source of the dust makes little difference in terms of the effectiveness of controls. Silica is a mineral, and the primary considerations for mineral particle dust suppression are particle size and "wetting," rather than the source of the mineral dust. As NIOSH explains:

> In the vast majority of cases for mineral processing operations, the wet suppression system used is a water spray system. Although the use of water sprays is a simple technique, there are a number of factors that

[247] Another reason for the elevated dust levels was the depth of the milling (up to 10.9 inches), creating an uneven surface during subsequent passes of the machine (Document ID 3798, p. 19, Table 7).

> should be evaluated to determine the most effective design for a particular application. There are two methods to control dust using water sprays at mineral processing operations: • Preventing dust from becoming liberated and airborne by directly spraying the ore. • Knocking airborne dust down by spraying the dust cloud and causing the particles to collide with water droplets and fall out of the air. ***When considering sprays, one of the primary aspects is the droplet size. ***Uniformity of wetting is also a very important issue for an effective system (Document ID 1539, pp. 34-35).

Water amended with a surfactant performs even better for dust suppression; surfactants are essentially equivalent to dish soap. The soap breaks the surface tension and softens the water, which allows the water to better encapsulate (i.e., wet) the particles (Document ID 1360, pp. 1-2). Based on this information, OSHA finds that both attention to spray droplet size and the use of surfactant will improve silica dust capture, regardless of whether the origin is asphalt or concrete.

OSHA also considers LEV to be equally as effective for controlling silica in concrete dust as it is for controlling silica in dust from asphalt paving material. Airborne respirable size particles behave similarly in air, regardless of their source (Document ID 4146, p. 3). OSHA notes that the physical properties of respirable silica dust, which behaves like a gas regardless of its material of origin, explain why respirable silica particles from concrete will be captured as effectively by LEV as respirable silica particles from asphalt.

Additional Controls for Walk-Behind Milling Machine Operators

Additional controls for walk-behind milling machine operators include LEV and improved water application, both of which are commercially available on walk-behind milling machines (Document ID 0524, pp. 1A-11, 2A-8; 0642, p. 1; 3959, pp. 39, 40). These controls function effectively for large milling machines, as described previously, and similar controls exist for walk-behind milling machines. Control measures used with large milling machines (wet methods and LEV) can be scaled down and should provide similar results for smaller equipment performing analogous activities (like grating, grinding, and polishing) under comparable working conditions (on generally flat surfaces with a minimal gap between the surface and machine). Tenders of large drivable milling machines often stand or walk adjacent to the milling drum box, just as a walk-behind milling operator would. The milling drum on a drivable milling machine is frequently 10 or more times wider than the milling drum on a walk-behind model, and removes correspondingly more material. Therefore, OSHA expects that controls for drivable milling machines will work at least as well for walk-behind machines, and, in fact, dust from the smaller walk-behind equipment might be easier to control.

Wet Methods

Wet methods are widely used to protect equipment on most types of milling machines, such as drivable milling machines, walk-behind machines used for grinding and polishing terrazzo, and some types of stationary stone milling equipment used in cut stone fabricating shops (see Section IV.4.4 – Cut Stone in this technological feasibility analysis). In tests of road milling equipment, NIOSH has shown that water spray on the cutting drum can offer effective dust control under some working conditions. Water spray adjusted specifically for dust suppression on milling machines results in better dust control than water applied simply to wet surfaces (Document ID 1216, p. 4). Water attachments for walk-behind milling machines can be a standard or optional feature, depending on the equipment (Document ID 0524, p. 1A-11; 0642, p. 1; 3959, pp. 39, 40).

As described in the earlier discussion of wet method controls for drivable milling machines, adding a dust suppressant to the water improves the results. Compared with a standard milling machine, which uses cooling water on the blade only (no spray aerosol), the use of an aerosolized water and foam system can reduce mean exposures for drivers and tenders combined by 97 percent (from 449 μg/m^3 to 14 μg/m^3) (Document ID 1216, p. 4).

ERG (ERG MTF-A, 2000) measured exposure levels below the LOD (12 μg/m^3) for workers using wet methods while milling a newly installed terrazzo floor indoors (Document ID 0200, p. 11, Table 1).[248] Echt et al. (2002)[249] tested a custom-built water-

[248] Exposure is reported as none detected (“ND”), with a limit of detection of 10 μg per sample, which results in an 8-hour TWA of 12 μg/m^3 for a sample obtained using a cyclone operated at 1.7 liters per minute: 1000 liters/m^3*10 μg)/(1.7 L/min*480 min)=12 μg/m^3.

[249] This same study also is published as NIOSH EPHB 247-15d (2002) (Document ID 0860).

fed system that provided a copious amount of water (15 gpm) to the concrete work surface (not the cutting teeth) milled by a scabbler with an 8-inch cutting width. The investigators compared results from alternating 5-minute periods of milling with and without the water-feed activated. The water reduced average respirable dust levels by at least 80 percent. Because of low filter loading, respirable dust was often below the LOD in samples associated with the water control, and none of these samples could be analyzed for silica. However, one measurable PBZ respirable dust level of 400 $\mu g/m^3$ was obtained during the wet process, and OSHA estimates that the silica concentration in that sample would be substantially lower (likely 52 $\mu g/m^3$ or less, based on the maximum of 13 percent silica content in the respirable dust collected on the filters during dry milling at this test site).[250] Measurements taken during similar brief periods of intensive dry milling found respirable dust levels of 13,000 $\mu g/m^3$ and 17,000 $\mu g/m^3$ (13 mg/m^3 and 17 mg/m^3), with silica values of 1,700 $\mu g/m^3$ and 2,100 $\mu g/m^3$. Work practices also contributed to the operator's exposure during the scabbler study because the worker generated the most airborne dust when passing the machine over a previously milled area (Document ID 0633, p. 811, Table I).

OSHA notes that the copious water flow of 15 gpm (equal to 1.9 gpm per inch of cutting width) used by the investigators may be impractical and probably more than necessary for walk-behind milling machines. In general, however, carefully directed spray nozzles that deliver an optimally sized water mist can achieve better dust suppression with substantially less water than indiscriminant water spray. A spray nozzle manufacturer explains that "in most operations, drops less than 200 [micrometers] µm do a better job of suppressing airborne dust particles, which are also very small" (Document ID 1152, p. 2). Recent experience with drivable milling machines demonstrates this point. NIOSH reports that under common road milling conditions, water spray provided to the cutting drum area at 12 gpm is capable of suppressing dust generated by a 7-foot wide (84 inches) drivable milling machine cutting drum (an application rate of just 0.14 gpm per inch of cutting width) (Document ID 1251, pp. 7-9, 14). OSHA concludes that, with

[250] OSHA calculated the percent silica in the respirable dust sample by dividing the weight of quartz in the 7-minute sample by the weight of the respirable dust in the same sample: (0.050 mg/0.39 mg)*100 = 13 percent.

careful adjustment, water spray methods using a fraction of the water used in the Echt et al. (2002) scabbler study should prove at least as effective in reducing silica dust exposures generated by scabblers. As a simple example, if the same "gpm per inch of cutting width" ratio holds for both drivable and walk-behind milling machines, then an estimated water mist application rate of 1.1 gpm (0.14 gpm x 8 inches cutting width) would be appropriate for the walk-behind 8-inch scabbler used in the Echt et al. (2002) study (Document ID 0633, p. 809). OSHA recognizes that differences in the way these machines function and other environmental factors (e.g., use indoors versus outdoors) might mean that this model for estimating water flow is too simplistic. However, even if the water application rate is doubled to compensate for these uncertainties, the resulting estimated flow rate needed for the 8-inch scabbler is 2.2 gpm.

As discussed previously in conjunction with drivable milling machines, Blute et al. (1999) evaluated silica exposures among workers using wet dust control methods for scabbling and large-scale grinding tasks at an underground construction site. In this case, rather than being walk-behind equipment, the scabblers and grinders were attached to the articulated arm of heavy equipment (Document ID 0562. p. 633 [front end loaders fitted with grinder/scabbler attachments]). Although these workers are classified in the Final Economic Analysis as heavy equipment operators (addressed in Section IV-5.3 – Heavy Equipment Operators and Ground Crew Laborers), and they used drivable machines (removing more material than the typical walk-behind milling machine), their work (scabbling and grinding excess concrete from tunnel walls) demonstrates the value of wet methods when these activities are performed in enclosed spaces. This is particularly relevant to walk-behind milling machines that are frequently used indoors to mill concrete surfaces. In the underground work environment, all three workers experienced task-based silica concentrations below the previous PEL.[251] The authors suggested that this was "most likely due to the use of hoses to wet down the concrete and the greater distance from the source of silica dust to the worker"[252] (Document ID 0562, p. 636).

[251] The PEL was calculated using OSHA's preceding general industry PEL equation for silica in respirable dust (Document ID 0562).

[252] Blute, et al. (1999) did not mention the presence of equipment cabs as a control, and so these might not have been available or did not influence exposures because windows were open.

Although one of the sample results (79 μg/m^3) exceeded 50 μg/m^3 (Document ID 0562, p. 637, Table III (scabbler)), these values are substantially lower than sample results available for workers performing dry milling of any type, even above ground. As discussed below, adding LEV near the scabbling and grinding attachments, or increasing general dilution ventilation, would likely have further reduced exposures for all three workers.

Local Exhaust Ventilation

Local exhaust ventilation is an effective dust control option for millers (and helpers) using walk-behind equipment. OIS contains six exposure results for millers and helpers using walk-behind equipment at two indoor construction sites. OIS records indicate that workers used LEV at both locations. At one site, where a second piece of milling equipment operated in the same room and the LEV system may not have been used properly, the operator experienced an exposure to respirable crystalline silica of 504 μg/m^3 (the highest level reported for a miller). At the second site, the operator used sequential levels of milling equipment while a helper moved hoses out of the way and vacuumed behind the walk-behind concrete grinder (preventing re-entrainment of milling debris). At this second site, all sample results for both workers were below the limit of detection (12 μg/m^3).

The similarity between vehicular and walk-behind milling machines also supports the use of vacuum dust collection (exhaust suction) methods for the smaller form of milling equipment. As discussed previously, the TNO Bouw (2002) study found that when exhaust suction methods were applied to the milling drum area of drivable milling machines, exposure levels for operators obtained over a five-day period ranged from less than 4 μg/m^3 to 28 μg/m^3. The study also found similar exposure results for machine tenders, who walked next to the machines; sample results ranged from less than 3 μg/m^3 to 29 μg/m^3 (Document ID 1184, p. 25, Table 11). Additional exposure sources for tenders include conveyors and transfer points, neither of which are components of walk-behind milling machines; instead, on these smaller milling machines, the vacuum suction immediately carries all dust and small debris into the vacuum cleaner where the air is filtered before release. However, operators of walk-behind milling machines can experience additional exposures when they empty the vacuum cleaner and clean or change the dust filter. This type of exposure is illustrated by, for example, a concrete finisher using a handheld grinder at a construction site evaluated by NIOSH, who cleaned the vacuum filter by shaking it and banging it on the wall. These actions likely created a second source of dust exposure (Document ID 0857, p. 4). To the extent that vacuum emptying and debris disposal methods contribute to milling machine operator exposures, work practices that limit silica dust released during these activities will also help limit operator exposures.

In a European study of control equipment (Hallin, 1983), walk-behind floor-milling machines equipped with dust extractors (i.e., LEV) were tested indoors. The study estimated a median concentration of 280 μg/m^3 for five short-term samples taken over periods of 10 to 60 minutes. The machine still released a substantial amount of dust into the surrounding environment, however (Document ID 1391, p. 28).[253] The authors indicated that the position of the air release from the pneumatically powered equipment and the milling tool cover design could both be changed to improve the working environment. In the same study, indoor silica concentrations measured over 1 to 2 hour periods ranged from 80 to 240 μg/m^3 for floor grinding machines used with large-scale dust extractors and grinding tool enclosures. The authors also noted a dramatically greater silica concentration of 2,300 μg/m^3 (35 minute sample) when the floor grinding tool housing cover was removed, such as would occur if the worker removed the housing cover because its design interfered with grinding (Document ID 1391, p. 25).

Equipment designed for use near a wall or with an edger attachment for use near vertical surfaces is commercially available, and a better choice for work at room edges (Document ID 0642, p. 1). Using a vacuum fitted with a high-efficiency particulate air (HEPA) filter would also minimize silica concentrations by filtering out airborne particles prior to releasing the air back into the work environment. An alternative would be to exhaust the vacuum air outside the workplace. In addition, recent research suggests

[253] The value of 280 μg/m^3 (reported as 0.28 mg/m^3) is the median quartz concentration measured for five combinations of large floor milling machines/scabblers equipped with milling tool covers and large-capacity dust extractors. The five individual measurements were <0.09 (two samples), 0.28, 1.6 and 6.9 mg/m^3 (Document ID 1391, p. 28).

that studies such as this one might not have used vacuum suction equipment that provided an adequate or consistent level of exhaust ventilation. As discussed in more detail in Section IV-5.11 – Tuckpointers and Grinders, construction sites that use LEV must choose a portable vacuum with the capacity and design to offer consistent vacuum suction. Many of the challenges associated with tuckpointing also must be addressed for construction sites where workers perform aggressive floor milling with walk-behind machines. Specifically, both of these construction activities generate a quantity of debris that can rapidly reduce vacuum suction. To prevent this, vacuum cleaner design should protect filters from rapid dust loading (by, for example, cyclonic pre-separation) and offer sufficient suction (measured in inches of water gauge) to move air even when filters begin to load (Document ID 0600, pp. 878 [see Dust Control vacuum], 879-Airflow measurement section (and relationship to static pressure), 882-Table IV, 883-Figure 7, 885 [see section on flow rate maintenance]).[254]

One milling machine manufacturer that produces walk-behind scabblers specifically for removing layers of contaminated concrete from floor surfaces recommends the use of a vacuum source that provides at least 75 to 90 cubic feet per minute (cfm) suction for a 6-inch wide scabbler. The contaminants mentioned by the equipment manufacturer (like lead paint and radioactive materials) generally have occupational exposure limits similar to the PEL for silica, suggesting that this rate of exhaust would also be effective for silica (Document ID 1276, pp. 1-2).[255] Proportionally greater exhaust rates would be required for larger walk-behind milling equipment. For example, another manufacturer of commercially available scabblers recommends specific vacuums for use with specific scabblers: a 160 cfm vacuum with a smaller scabbler and a 500 cfm vacuum with a larger scabbler (for which an industrial dust control vacuum system is recommended as an alternative) (Document ID 0636, p. 7). Some scarifiers, particularly those intended for

[254] The suction of an industrial vacuum is influenced by numerous factors, such as filter loading, hose clogs, and the vacuum fan's strength (ability to pull against static pressure). Document ID 0600 relates to tuckpointing, but the same principles apply to industrial vacuums used to capture dust from other construction tools that also generate substantial volumes of dust (including walk-behind milling machines).

[255] The same company produces a remote control option for their milling equipment, allowing the operator to work a greater distance from the abrasive action, or even to stand in another room (Document ID 1276, pp. 1-2).

indoor use, are available with both a vacuum port (for connecting to a portable industrial vacuum system) and a water mist system as standard equipment (Document ID 0642).

However, there are several limitations to the use of LEV-equipped walk-behind milling machines. First, the vacuum suction device needs to be emptied frequently. Workers might need to empty the dust extractor as frequently as every 30 minutes in some work environments; emptying the dust extractor requires shutting down the vacuum (Document ID 0599). A vacuum with a pressure gauge can alert workers when the vacuum needs to be emptied and filters need to be cleaned. Second, a vacuum powerful enough to support most common walk-behind milling machines will be large and heavy. A vacuum with a cyclonic pre-separator that achieves sufficient airflow to support a scabbler can weigh 100 to 200 pounds when full (based on a collection volume of 10 to 19 gallons of concrete debris (Document ID 0628, p. 45 [PDF p. 15] – see collecting volume row). Furthermore, when operating milling machines outdoors, the dust collector generally needs a generator for power, and workers might need to transport the generator with an additional truck or heavy handcart (Document ID 0600, p. 878 –Table I [vacuums are mainly electric]; 3959, pp. 41-42 [photos showing large vacuum systems used in manufacturers' initial test of walk-behind milling equipment]; 0628, pp. 3, 5, 17 [photographs of dust collector size/electric for walk behind grinder, all are electric powered], p. 24 [pneumatic (compressed air) powered vacuum available]). Although gasoline and propane powered models are available, electrical powered vacuums are most common. The need for both a large vacuum and an electrical generator to operate it can be an impediment to the use of LEV outdoors, so this option is less common for outdoor work. For example, an 8-inch walk-behind scarifier promoted for sidewalk trip hazard repair comes with "water misting system standard", although the equipment is also equipped with a vacuum port; alternate listed uses for the machine include concrete floor preparation (Document ID 0642, p. 1).

The effectiveness of vacuum suction also depends on minimizing the gap between the bottom of the machine and the surface being milled (as discussed previously). To achieve acceptable dust control, milling must proceed in a manner that limits the gap between the bottom of the walk-behind milling machine and the surface being milled, for example, the floor. Construction sites will find it difficult to control dust emissions if walk-behind milling machines remove excessive depth in one pass; the resulting drop between milled and unmilled surfaces prevents the milling machine from sealing properly against the surface, allowing dust to escape (Document ID 0555, p. 4). Workers can achieve better dust control during deep removals by milling to the final desired depth in several incremental phases. Hallin (2003) observed: “If these machines are to function satisfactorily, the floor surface must be flat and cleaned. The wheels may not be run over electric cables or other uneveness” (Document ID 1391, p. 26). Because milling can dislodge settled dust and create high levels of airborne dust, employers can further reduce exposures by using a HEPA-filtered vacuum to clean up any loose dust on freshly milled surfaces prior to making additional passes over the area (Document ID 0633, pp. 812-813; 1391, p. 28).

Finally, unlike drivable milling machines, walk-behind machines can be used indoors where natural ventilation is poor and the surface being milled is likely to be concrete. Under these circumstances, special precautions will be needed to prevent airborne silica dust from accumulating. Supplemental general exhaust ventilation (in addition to vacuum exhaust or wet methods), in the form of large fans set in open windows or exhaust trunks creating air exchange similar to an outdoor environment, will help prevent silica dust from collecting in the space.

Little information is currently available on LEV in controlling respirable quartz levels associated with walk-behind milling operations. OIS contains samples for a walk-behind milling machine operator and helper (moving hoses, vacuuming behind the milling machine), both of whom had exposure levels below the limit of detection of 12 µg/m^3, with no respirable dust detected in the sample. At another site a worker with an exposure level of 504 µg/m^3 used a walk-behind milling machine with LEV that was not performing well (another milling machine was also used in the same room) (Document ID 3958).

OSHA believes that evidence from similar construction tasks supports LEV’s value for workers performing milling. Although walk-behind milling machines are larger than tuckpointing grinders, the milling blades operate at lower speeds[256] (dust particles are released at lower energy), and the worker's breathing zone is a greater distance from the point of dust release. Thus, OSHA believes that the LEV-dust control option will work at least as effectively for milling machines as it does for tuckpointing grinders. Collingwood and Heitbrink (2007) reported a 95-percent reduction in silica exposures associated with the use of LEV for tuckpointing (geometric mean exposure of 1,140 $\mu g/m^3$ reduced to 60 $\mu g/m^3$). Although the tuckpointers using LEV still experienced a geometric mean of 60 $\mu g/m^3$, walk-behind milling machine operators have the advantages of lower uncontrolled exposure levels, greater distance between the tool and their breathing zone, and equipment that is self-supporting (making it easier to keep the milling drum enclosure sealed against the floor) rather than handheld (Document ID 0600, p. 880, Table II). Therefore, an LEV system with an appropriately sized vacuum will likely reduce most walk-behind milling machine operator exposures to levels lower than those experienced by tuckpointers.

Housekeeping

Exposures among workers using walk-behind milling machines can be further reduced by cleaning up debris. Echt et al. (2002) reported that airborne dust increased when the scabbler described previously passed over previously milled areas (Document ID 0633, pp. 812-813). Milling debris should be cleaned up using a HEPA-filtered vacuum prior to making a second pass over an area when using a machine equipped with a dust collection system. This step prevents the milling debris from interfering with the seal between the machine and the floor and minimizes the gap. Additionally, it prevents debris from being re-suspended and acting as another source of contamination. OSHA's OIS contains a sample for a helper who vacuumed behind the operator of a walk-behind floor grinder and scarifier (indoors) to prepare a concrete floor for repainting (Document ID 3958, Row 211). The sample result detected no respirable dust, indicating that vacuuming

[256] As an example, one type of walk-behind scabbler drum rotates at 1,753 rotations per minute (rpm) (Document ID 1149, p. 1) compared with 11,000 rpm for a tuckpointing grinder blade (Document ID 0567).

effectively cleaned up dust and debris left by the grinder, which otherwise might be re-entrained in the workers' breathing zones.

5.8.4 Feasibility Finding

Feasibility Finding for Drivable Milling Machine Operations

Feasibility Finding for Large Drivable Milling Machine Operators and Helpers

OSHA concludes that more than 70 percent of large drivable milling machine operators and helpers are currently exposed to silica levels at or below 50 μg/m^3. For workers who are currently exposed above 50 μg/m^3, the controls described in this section can be implemented to reduce silica exposure levels to 50 μg/m^3 or below in most operations, most of the time. Therefore, OSHA finds that the standard is technologically feasible for these workers.

The construction standard at paragraph (c) requires employers operating large (one-half lane or wider) milling machines to implement the controls described in Table 1 unless they elect to assess and limit their workers' exposures in accordance with the more traditional regulatory approach contained in paragraph (d). The controls specified in Table 1 for cuts of four inches in depth or less are either: (1) use a machine equipped with exhaust ventilation on the drum enclosure and supplemental water sprays designed to suppress dust; or (2) use a machine equipped with supplemental water spray, combined with a surfactant, designed to suppress dust. For cuts of any depth when milling asphalt only, the control option specified in Table 1 is to use a machine equipped with exhaust ventilation on the drum enclosure and supplemental water sprays designed to suppress dust. When these controls are fully and properly implemented, TWA exposure levels are expected to remain at or below 50 μg/m^3 (Document ID 4147, pp. v, 6-7, 13, Table 1; 4149, pp. v, 5-7, 13, Table 1).

All of the major manufacturers of large milling machines currently provide dust-suppressing water spray systems on new equipment and as retrofit kits for older machines. In addition, as discussed previously, new machines will be equipped with both dust-suppressing water spray systems and LEV by 2017 (Document ID 2181, pp. 11, 21-29).

Based on the data in the record, OSHA concludes that exposures among large drivable milling machine operators can be reduced to 50 μg/m^3 or less most of the time. Sample results presented in the exposure profile Table IV-5.8-C indicate that 78.5 percent of all large drivable milling machine operators already experience silica levels at or below 50 μg/m^3 as a result of using water spray intended to cool the cutting drum. Similarly, exposure levels for 67 percent of tenders working alongside large milling machines are already below 50 μg/m^3. Based on the Agency's review of studies showing that low silica exposures can be achieved for both operators and tenders across varying water spray flow rates, OSHA concludes that improvements to cooling water spray systems can help reduce exposure levels of the remaining machine operators and tenders (those who currently experience exposures above 50 μg/m3) (see Tables IV.5.8-D and Table IV.5.8-E). However, information is insufficient to confirm that the use of water alone in existing systems will reliably control all workers' exposures. Based on the Agency's review of these and other studies, OSHA has determined that supplementing with a dust suppressant additive or with an exhaust ventilation on the drum enclosure will achieve levels at or below 50 μg/m^3 for all or almost all workers (operators and helpers) most of the time (see Table IV.5.8-E) (Document ID 1216, p. 4, Table 1; 4147, pp. v, 13, Table 1; 4149, pp. v, 13, Table1).

As discussed previously, a dust suppression system with a foam additive kept exposures below 30 μg/m^3, and the use of water sprays combined with LEV systems kept exposures under 25 μg/m^3 (Document ID 1184, pp. 5, 25, Table 11; 1217, p. 4, Table 1). OSHA concludes that these methods will control silica exposures among vehicular milling machine operators and tenders to 50 μg/m^3 or below during "mill and fill" operations under the typical range of conditions (e.g., day and night, warm and cool weather, asphalt and concrete road surfaces) when milling to a depth of 4 inches or less. OSHA also concludes that worker exposures can be maintained to 50 μg/m^3 or below when large milling machines equipped with both water-based dust suppression systems and LEV at the drum enclosure are used to make deeper cuts into asphalt material only.

Thus, OSHA concludes that the dust control measures specified in Table 1 can effectively reduce exposure to a 8-hour TWA of 50 µg/m^3 or less when operating large milling machines to mill asphalt or concrete.

Feasibility Finding for Small Drivable Milling Machine Operators and Helpers

OSHA concludes that 50 percent of small drivable milling machine operators and helpers are currently exposed to silica levels at or below 50 µg/m^3. For workers who are currently exposed above 50 µg/m^3, the controls described in this section can be implemented to reduce silica exposure levels to 50 µg/m^3 or below in most operations, most of the time. Therefore, OSHA finds that the standard is technologically feasible for these workers.

When following the control methods specified in Table 1, employers operating small drivable milling machines (less than a half-lane in width) on asphalt or concrete, are required to use machines equipped with supplemental water spray systems combined with an appropriate surfactant. When these controls are fully and properly implemented, TWA exposure levels for operators and helpers are expected to be 50 µg/m^3 or below.

Manufacturers of smaller drivable milling machines currently make such systems (Document ID 1229; 4073, Attachment 4a). Unlike for larger milling machines, however, Table 1 does not call for systems that combine water use with LEV, as it appears that such systems are not generally available currently.

Based on the data in the record, OSHA concludes that most of the time, construction employers can achieve exposure levels of 50 µg/m^3 or below for most workers operating small drivable milling machines or helping with that equipment. Fifty percent of these workers already have exposures of 50 µg/m^3 or below (Table IV.5.8-C). The similarities to large drivable milling machines are sufficient to indicate that the wet dust suppression control technology is transferable to the smaller drivable machines. Many of these machines are already fitted with water systems for cooling the cutting tool (Document ID 1229, pp. 1-3). Van Rooij and Klaasse (2007) showed that a wet dust emission suppression system used with a surfactant reduced the PBZ respirable quartz exposures below the action level (Document ID 1216, p. 4, Table 1). Even if these smaller machines do not achieve the same extent of dust suppression demonstrated for larger machines (because, for example, they perform specialty milling operations and not the flat "mill and fill" asphalt milling tasks typically performed by large drivable machines), the intermittent nature of operations for which small drivable milling machines are used will help to maintain worker 8-hour TWA exposure levels substantially lower than they would be for continuous operations (Document ID 3583, Tr. 2213-2215).

Feasibility Finding for Walk-Behind Milling Machine Operators

OSHA concludes that more than 80 percent of workers using walk-behind milling machines are currently exposed to silica levels below 50 μg/m^3. For workers who are currently exposed above 50 μg/m^3, the controls described in this section can be implemented to reduce silica exposure levels to 50 μg/m^3 or below in most operations, most of the time. Therefore, OSHA finds that the standard is technologically feasible for these workers.

Employers following Table 1 when operating walk-behind milling and floor grinding machines have two control options. Employers can use a machine equipped with an integrated water delivery system that continuously feeds water to the cutting surface. When the tool is operated and maintained in accordance with the manufacturer's instructions to minimize dust emissions, this equipment is expected to maintain exposure levels to 50 μg/m^3 or below, indoors and outdoors. Alternatively, employers must use a machine equipped with a dust collection system recommended by the machine manufacturer; the dust collector must provide the air flow recommended by the manufacturer and must have a filter with 99 percent or greater efficiency and a filter cleaning mechanism. When these controls are fully and properly implemented, TWA exposure levels are expected to be 50 μg/m^3 or below. When using a machine equipped with a dust collection system indoors or in an enclosed area, exposures can be further reduced to 50 μg/m^3 or below by cleaning up residue after each pass with a HEPA-filtered vacuum.

Walk-behind milling machines are currently available with water systems (e.g., Allen Engineering, Document ID 0524; EDCO, 0642, p. 1; 4073, Attachment 4a [among relevant examples is the record for Intertool walk-behind grinder with water feed]), and with vacuum ports or complete LEV systems (e.g., Pentek, Document ID 1276; EDCO, 0636, p. 6; 0642, p. 1; 4073, Attachment 4a [among examples are records for walk-behind scarifier with vacuum, and CONTRx Pro-polisher with vacuum]).

Based on the data described above, OSHA concludes that most of the time when employers provide equipment with vacuum suction dust collection or a wet system, workers operating small, walk-behind milling machines or helping with the equipment will experience exposure levels at or below 50 μg/m^3 as an 8-hour TWA. OSHA draws this conclusion from its exposure profile (Table IV.5.8-C) and from success with dust controls for larger milling machines and for tuckpointing and grinding equipment. From the exposure profile, 10 of 12 8-hour TWA sample results were below 50 μg/m^3, with the two highest sample results at 80 and 504 μg/m^3. The highest reading was from a worker using a floor grinder equipped with an LEV system indoors, with another worker grinding nearby. Details are not available from the record on the type of LEV system used, whether the LEV system was maintained and used properly, or whether appropriate housekeeping practices were employed. OSHA finds compelling evidence that controls effective for drivable milling machines are adaptable to the smaller (and thus potentially easier to control) walk-behind milling machines.

Even in indoor environments, exposure levels at or below 50 μg/m^3 can be achieved for most walk-behind milling machine operators most of the time through the proper use of controls, including the use of high-flow rate vacuum systems intended to serve the milling equipment and general ventilation that promotes good air circulation in the space.

In summary, most milling operation exposures are currently at or below 50 μg/m^3. Where exposures are currently above 50 μg/m^3, OSHA finds that feasible control methods, as described previously, exist to reduce respirable crystalline silica levels to 50 μg/m^3 or below for most operations most of the time. Therefore, OSHA finds that the standard is technologically feasible for these workers.

5.9 ROCK AND CONCRETE DRILLERS

5.9.1 Description

This section covers workers who use vehicle-mounted drilling rigs to produce deep holes in the ground or in concrete. The holes typically range from 1 inch to more than 6 inches in diameter and can reach a few inches to more than 100 feet deep. The workers typically guide and activate drill bits from control panels mounted on their vehicles and remove a substantial volume of rock or concrete over the course of a shift. This section also covers roof bolters who work at construction sites (but not those who work in the mining industry) and use rig-based drills to produce holes in tunnels (both overhead and in wall surfaces), and workers who use dowel drills (also referred to as gang drills) with one or more drill heads to drill holes in concrete for the placement of steel supports (e.g., a four-gang dowel drill can drill four holes at once) (Document ID 2177, Comment B, pp. 35-36).

When drilling rock, workers typically use rigs that are vertically oriented and equipped to produce a deep hole through the addition of bit extensions. Drill bits can be solid or hollow. These track-, truck-, or trailer-mounted rigs are frequently equipped with compressed bailing air, which is continuously forced through a bit's hollow core (when available) to "bail" rock or concrete dust and debris from the bottom of the deep hole (Document ID 1431, p. 3-10).

To drill concrete, workers often use rigs that consist of an array of drills fixed to the maneuverable arm of a construction vehicle (e.g., backhoe, bulldozer, forklift) or purpose-built mobile machine. This permits the operator to produce a series of precisely spaced mid-size holes, typically with a pre-set depth of a few inches to 4 feet, at any orientation. As with rock drilling, the drill bits can be solid or have a hollow core through which compressed air or water is forced to clear the hole (Document ID 0813). Workers who use these rigs routinely use handheld compressed air nozzles to blow debris from completed holes (Document ID 0871, p. 6). As a standard practice, some types of rock or concrete drill bits (e.g., diamond tip) are water fed to improve function and extend the useful life of the bit (Document ID 1720, p. IV-473).

Although the equipment used for each type of drilling varies, OSHA preliminarily determined, in the PEA, that workers using drilling rigs of all types on rock and concrete could be analyzed together because the workers' activities have much in common and the general methods of silica control are similar (Document ID 1720, p. IV-473). The Construction Industry Safety Coalition (CISC) objected to this grouping, commenting that the workers use different equipment, perform different tasks, and have different levels of exposure (Document ID 2319, Attachment 1, p. 59). CISC argued that OSHA did not analyze how relevant variables impacted baseline exposures (Document ID 2319, Attachment 1, p. 59). CISC contended that exposures would vary depending on the type of hole drilled, the substrate being drilled, and the location of the hole being drilled (Document ID 2319, Attachment 1, p. 59).

OSHA agrees that exposures vary based on differing workplace conditions, and the exposure profile contained in this section reflects a wide variety of those varying conditions. In addition, the studies and activities described in this section, which OSHA has used to make its final feasibility determinations, are representative of the variety of worker activities and the range of exposure conditions that typically occur in this industry. OSHA has determined that the general methods of silica control (ventilation, wet methods) for rock and concrete drilling are similar enough, despite some variability, to be addressed together in this section. An additional discussion of the impacts of varying workplace conditions on baseline exposures is presented in the subsection below (Section IV-5.9.2).

The National Association of Home Builders (NAHB) commented that workers in some job categories in the home building industry are exposed to silica because of their concrete drilling work, including electricians, HVAC installers, plumbers, carpenters, and rock/well drillers (Document ID 4220, pp. 7-10). OSHA agrees that these workers can be exposed to silica during the tasks identified by the NAHB; however, only those workers using rig mounted drills are addressed in this section. Other types of hand held drilling is addressed in Section IV-5.4 – Hole Drillers Using Handheld or Stand-Mounted Drills.

Workers using drilling rigs position and operate the drill rigs from control panels mounted on the vehicles or rigs. These workers may also perform intermittent tasks near the drilling point, such as fine-tuning the bit position, moving debris away from the drill hole, or working directly or indirectly with compressed air to blow debris from deep within the holes. Workers using drilling rigs can be exposed to dust generated by the action of the drill bit and to dust raised by bailing air or a compressed air nozzle. Although rig-based drilling is often a one-person job, some of the associated activities, such as fine-tuning the drill position and clearing debris from in or around the holes, can be performed by a second worker (Document ID 0908, p. 1; 1563, p. 3). OSHA received no comments regarding this description of job duties or tasks that pose potential silica exposure hazards and therefore adopts the description for purposes of this final analysis. Table IV.5.9-A presents job categories, major activities, and sources of silica exposure for workers using drilling rigs.

Table IV.5.9-A
Job Categories, Major Activities, and Sources of Exposure of Workers Using Rock and Concrete Drilling Rigs

Job Category*	Major Activities and Sources of Exposure
Worker Using Drilling Rigs	Position and operate drill rigs from control panel mounted on vehicle or rig. • Dust from action of drill bit. Adjust bit position. • Dust from action of drill bit and bailing air or compressed air nozzle. Clear tailings and dust from in or around the hole, during or after drilling. • Dust raised by bailing air or compressed air nozzle.

* Job categories are intended to represent job functions; actual job titles might differ, and responsibilities might be allocated differently, depending on the site.
Sources: Document ID 1720, p IV-474; 1431, p. 3-10.

5.9.2 Exposure Profile and Baseline Conditions

In the PEA, OSHA reviewed 39 exposure results associated with rock and concrete drilling. These results were from four OSHA SEP reports, four NIOSH investigations, unpublished data from a state health department, and a published article (Document ID 0022; 0034; 0090; 0226; 0228; 0512; 0784; 0904; 0908; 0912). These results involved various drilling rig configurations, including track-mounted rigs drilling holes 80 feet deep through granite and multi-drill sets (dowel packs) drilling a few inches into concrete

(Document ID 1720, p. IV-474). The sites where the samples were taken ranged from a concrete highway repair construction site to a 10-acre rock excavation site where drilling rig operators produced blast holes during demolition (Document ID 0022; 0034; 0090; 0226; 0228; 0512; 0784; 0904; 0908; 0912).

In the exposure profile presented in Table IV.5.9-B, OSHA supplements these data with one exposure result from the OSHA Information System (OIS) (for a worker operating an EZ Drill with an attached dust collector while drilling holes in concrete during highway/street construction work) and 11 sample results from two NIOSH reports (Document ID 3958; 4152, p. 14; 4154, p. 17). At the first site visited by NIOSH, two workers each operated a 4-drill slab-riding dowel drill equipped with a dust collection system to drill holes into a concrete runway (Document ID 4154, p. 4). At the second site, three workers drilled holes into a concrete runway with no controls in place. One worker operated a Minnich 4-drill, on-slab dowel-pin drill, while each of the other two workers operated an EZ Drill 4 drill, on-slab dowel-pin drill (Document ID 4152, p. 4). Samples were taken over multiple days at both sites.

Upon reviewing the data in the record, OSHA has determined that working conditions for construction workers (drillers as well as laborers) using drilling rigs vary from job to job. Significant sources of variability for both rock and concrete drilling include:

- The substrate being drilled (rock or concrete);
- The silica content of the substrate (silica levels often vary by 20 to 50 percent from site to site, with the greatest variation occurring between different types of rock);
- The type of hole being drilled, which influences the type of bit used (water-fed diamond/coring bits cut more slowly but are preferred when workers need to minimize chips and fractures in the substrate [“spalling”]);
- The work location and proximity of other activities (including whether the location requires dust emissions control and whether these controls are used effectively); and
- Whether the rig has an enclosed cab (Document ID 1720, pp. IV-474 – IV-475).

The National Ground Water Association (NGWA) stated that varying work conditions impact potential exposures, noting that silica exposure levels can vary during the water well drilling process depending on the geologic formations encountered (Document ID 1983, p. 1).

In the PEA, OSHA preliminarily determined that baseline conditions for workers using drilling rigs include a range of conditions, from no dust controls to systems that integrate one or more of the following: dust extraction (in the form of local exhaust ventilation [LEV]), wet methods at the drill hole, and dust management techniques (such as enclosure and wet methods) at the point where the system ultimately dumps extracted dust (Document ID 1720, p. IV-475). Based on conversations with industry sales representatives, OSHA also determined that water-fed bits are used frequently for many types of drilling, but dust extraction systems and augmented water pumps are less common (Document ID 1720, p. IV-475; 0625; 0813; 0814).[257] In light of that information, OSHA noted that the industry profile in the PEA may have underestimated the proportion of workers using drilling rigs that might require controls.

OSHA received many comments related to the baseline conditions among rock and concrete drillers. CISC noted that it is more common to use wet methods than it is to use dust collection systems when operating vehicle-mounted drilling rigs for rocks (Document ID 2319, Attachment 1, pp. 108-109). A number of other commenters noted the prevalence of using wet methods in the industry (e.g., Document ID 1983, pp. 1-2; 2116, Attachment 1, p. 33; 3496, p. 6). For instance, the Concrete Sawing and Drilling

[257] OSHA reported in the PEA that conversations with drilling rig manufacturers indicate that it is rare for new rigs to be ordered with the upgraded water pumps that permit optimal water flow for dust control (the water pumps provided as standard equipment support only water-fed bits, but not other uses, such as water mist spray in dusty areas above ground, for which a pump upgrade is helpful) (Document ID 1720, p. IV-475; 0625; and 0813). In contrast, hollow-core bits are relatively common in certain sectors of the rock drilling industry, such as for core drilling in granite, and when diamond-tipped bits are used, some water is added to the bailing air to protect the bit. Rock-drilling rig customers, however, rarely purchase the more versatile pumps that permit more than a minimal amount of cooling water to be added (Document ID 1720, p. IV-475; 0625). Water-feed kits for concrete drilling rigs are also purchased infrequently, in part because the process often requires up to 1 to 3 gallons of water per minute. One manufacturer indicated that these water-fed systems are used primarily in underground construction operations (Document ID 1720, p. IV-475; 0813). Furthermore, although diamond-tipped bits are more likely to be hollow, the slower action of these bits reduces their popularity (Document ID 1720, p. IV-475; 0814). Finally, among employers purchasing concrete drilling rigs, water-fed systems are being phased out in favor of dust collecting equipment.

Association (CSDA) commented that nearly 100 percent of CSDA contractors use water on every job in order to prolong the life of the diamond blade (Document ID 3496, p. 6). The National Ground Water Association (NGWA) noted that it is industry practice when drilling water wells to use foam as a wet control method:

> Industry practice is to use the engineering control of soap injection where water is mixed with foam. The foam mixtures of water and foam products are effective in mitigating the hazard of dust when properly used as they can carry particles ranging from .03 mm to the size of a quarter. There are multiple manufacturers of the foam products and these products have been approved for use when drilling sanitary water wells. The foam agents are NSF approved and have also been approved for use in many states (Document ID 1983, pp. 1-2).

NGWA also explained that all rotary drilling machines have been equipped with some type of water injection system since the early 1970s (Document ID 1983, p. 2).

The exposure profile in Table IV.5.9-B includes 23 samples of respirable crystalline silica for workers using drilling rigs with no controls (Document ID 0090, pp. 6-7; 0846, p. 7; 0904, p. 4; 0908, pp. 8-9; 0912, p. 12; 4152, p. 14). These results, summarized in Table IV.5.9-B, include 8-hour time-weighted average (TWA) exposure levels obtained at seven worksites for 18 workers using concrete drilling equipment and one worker using a rock drilling rig. These data indicate that in the absence of controls, 21.7 percent of these workers have silica exposure levels of 50 μg/m^3 or less, and 56.5 percent are exposed to levels above 100 μg/m^3. Substantially lower exposures have been reported for workers who use drilling rigs fitted with one or more features that reduce exposure, such as some form of wet methods, air exhausted from the bit entry point, or an enclosed cab. The data available to OSHA for workers using controls included sample results for 22 workers summarized in the PEA, one sample result (12 μg/m^3) from the OIS, and 4 sample results from a NIOSH EPHB submitted to the docket (Document ID 0022, pp. 8-10; 0034, pp. 23-44, 113-117; 0226, p. 11; 0228, p. 9; 0512; 0784, pp. 211-213; 3958, Row 809; 4154, pp. 15-17). Of the 27 sample results for drillers using controls, approximately 78 percent were below 50 μg/m^3. Just two (7.4%) of the 27 workers experienced exposures exceeding 100 μg/m^3 (Document ID 0784, p. 213; 4154, p. 17).

Overall, the final exposure profile shows that 27 of the 51 workers (53 percent) who use drilling rigs, with or without any controls, have exposure levels of 50 µg/m^3 or below.

The highest exposure for this job category (1,190 µg/m^3, based on an 8.5 hour sample) is associated with a drilling assistant who stood at the back of the rig to help position the drill during a highway construction project (Document ID 0908, p. 8). Other results for this job category are substantially lower, but still often exceed 100 µg/m^3 when dust controls are ineffective or not used. For example, an 8-hour TWA value of 540 µg/m^3 was reported for a drill operator dry drilling, with the dust collection system out of operation, to produce holes in rock that contained 17 to 42 percent quartz. This 8-hour TWA was based on a result of 800 µg/m^3 collected over 324 minutes (Document ID 0904, p. 4). Not unexpectedly, some of the lowest concentrations were associated with the use of dust controls at the drill hole. Results of 12, 31, 35, and 54 µg/m^3 were reported for workers who spent their entire shifts operating or assisting with drilling rigs fitted with water feeds or vacuum dust collection (or both) (Document ID 0034, pp. 23-26, 35-37, 39-42; 0228, p. 9).

OSHA was not able to obtain information on exposures among roof bolters (a type of drilling rig operator) at U.S. construction sites; however, mining data reviewed by NIOSH showed that, in coal mines, 70 percent of respirable dust samples for roof bolters in the United States contain more than 5 percent silica, with 25 percent of those samples (or 17.5 percent of total samples) exceeding 100 µg/m^3. NIOSH suggests that exposures from adjacent sources of silica dust could have caused the elevated exposures (Document ID 0711, p. 1). Although roof bolters work underground and most other drilling rig operators work above ground, the percentage of roof bolters exposed to silica at levels above 100 µg/m^3 is similar to, but slightly less than, the percentage of rock and concrete drillers exposed at those levels. Table IV.5.9-B shows that 29 percent of rock and concrete drillers experience exposure levels greater than 100 µg/m^3. Data available to OSHA shows that dust in drilling rig operator samples also routinely exceeds 5 percent silica (Document ID 1720, p. IV-476).

Roof bolter exposure levels may be generally comparable to the exposures of other drilling rig operators because, even though roof bolters work underground, ventilation is routinely installed at tunnel construction sites and roof bolters regularly use engineering controls, such as vacuum suction collector boxes. See Section IV-5.12 Underground Construction Workers for more detail on tunnel work and the associated ventilation requirements. Poor ventilation during these tasks, however, could result in higher exposures, as suggested by data submitted by the New York State Laborers' Health and Safety Fund (NYSLHSF) from a tunnel project in New York City. This study reported silica exposures for workers drilling and placing rock anchors. As noted in the study, ventilation for these workers was poor because they worked opposite the road header machines (RHMs) with the tunnel air always diverted to the RHMs (Document ID 3759, Attachment 1, p. 6). OSHA appreciates the summary exposure data submitted by NYSLHSF, but is unable to include the data in the exposure profile for drilling rig operators. The data provided is in summary form rather than as individual data points or TWAs, and OSHA could not determine exposures because no total respirable dust, percent of silica, or sample times were provided.[258]

CISC commented that the exposure data that OSHA relied on for rock and concrete drillers in the PEA was flawed and did not support OSHA's conclusions in its exposure profile and technological feasibility study (Document ID 2319, Attachment 1, pp. 59-62). Specifically, CISC argued that the majority of all samples were from the Linch (2002) study, which was based on just two construction worksites where concrete drilling was performed without dust control measures or enclosed cabs (Document ID 2319, Attachment 1, p. 59). OSHA notes, however, that the nine sample results taken from the Linch (2002) study are among a total of 51 sample results for operators of rock and concrete drilling rigs represented in OSHA's exposure profile. These 51 sample results are drawn from 13 reports and reflect exposure measurements taken at at least 14

[258] The data in this study was calculated using the OSHA General Industry PEL calculation ($10mg/m^3/\%SiO_2$ +2) and not the appropriate construction PEL (250 mppcf/$\%SiO_2$+5, where mppcf = million particles per cubic foot). In addition, rather than providing the PEL in a unit of measure (i.e., mg/m^3), which would differ for each sample under the calculation method, the commenter adjusted all the PELs to a standardized value of 1.0. (Document ID 3759). Because of this, OSHA is unable to identify actual quartz concentration values or calculate exposures for inclusion in the exposure profile.

construction sites visited by OSHA, NIOSH, or the State of New Jersey (Document ID 0784).[259]

CISC also believed that a number of the sample results used in the PEA were based on sample times of less than eight hours and therefore underestimated exposures. For instance, CISC argued:

- The NIOSH study (Breckenridge, 1992) consisted of only one 5.5 hour personal breathing zone (PBZ) sample, so if the worker had worked an eight-hour day, he would have been exposed at a level 16 times the PEL.
- The NIOSH study (Shelly, 1995) presented sample results ranging from 160 μg/m^3 to 1,190 μg/m^3 even though the drill was broken down for up to two hours each day.
- Exposure results presented in NJDHSS, 2000 were well over the proposed PEL for sample times of under five hours.
- The NIOSH road demolition study (Document ID 0226) consisted of only one sample, with a result less than 20 μg/m^3, but the worker only drilled for 20 percent of his time during the 7-hour sampling period (Document ID 2319, Attachment 1, pp. 59-60).

OSHA disagrees that any of these sample results underestimate exposures, noting that the amount of time workers spend using drilling rigs varies from day to day and job to job. The majority of the worksite samples presented in these studies fairly represent the exposures of workers drilling for more than half a day, but less than a full day. OSHA believes that the sample result from the NIOSH study, ECTB-233-120c, 1999, fairly represents the exposure of a worker who accomplished the necessary drilling in under 2 hours and spent the rest of the day performing other tasks (Document ID 0226).

CISC further argued that the one sample from the NIOSH study, ECTB-233-122c, 1999, was 31 μg/m^3, even though the sample was taken on a day that it rained and copious amounts of water and LEV were used (Document ID 2319, Attachment 1, p. 60; 0228).

[259] Other documents used to develop the exposure profile are Document ID 0022, 0034, 0090, 0226, 0228, 0512, 0846, 0904, 0908, 0912, 3958, 4152 and 4154.

OSHA notes that drilling occurs in all types of weather and believes that this sample represents the types of exposures that can occur in wet weather.

Finally, CISC was concerned about OSHA's reliance on NIOSH EPHB-334-11a, 2008 in assessing the effectiveness of LEV because the study was performed at the equipment manufacturer's plant and, according to CISC, was "not based on real-work conditions." CISC also criticized that study on the grounds that it evaluated only one piece of equipment, with a short drilling time, and collected only one area sample and no PBZ samples (Document ID 2319, Attachment 1, pp. 60-61, 0871). OSHA recognizes that the NIOSH EPHB 334-11a, 2008 study report evaluates an LEV system under controlled conditions; the study provides an estimate of the effectiveness of a 2008 commercially available LEV system and offers recommendations for improving the effectiveness of this control method. While the report contributes to the body of knowledge on control options, OSHA did not include the exposure results from this study in the exposure profile due to the experimental nature of the evaluation.

As noted above, OSHA based the exposure profile in Table IV.5.9-B on the best available data. OSHA reviewed all exposure studies submitted to the docket for inclusion in the exposure profile. While only two of those studies provided sufficient detail for inclusion in the profile (sampling time, respirable dust concentration and percent silica), those that were not included do generally support the profile.

OSHA considered several studies on workers performing dowel drilling operations on highways or runways: two where no controls were used and one where LEV was used. In the first study where no controls were used (NIOSH EPHB 347-14a), NIOSH collected PBZ samples for two workers operating four-gang dowel drills to drill holes in new concrete runways over a three day period. NIOSH reported six TWA crystalline silica sample results in this study ranging from 22.1 μg/m^3 to 675 μg/m^3, with a geometric mean exposure of 120 µg/m^3 (Document ID 4152, pp. 13-14).[260] Exposure results from this study were found to contain suitable data for inclusion in the profile. In the other study where exposure controls were not used, Valiante et al. reported two 8-hour TWA sample results of 50 µg/m^3 and 160 µg/m^3 for workers performing dowel drilling operations during highway repair (Document ID 3508, p. 878). Upon further review, OSHA determined that this information was already included in the exposure profile as part of the data contained in the NJDHSS 2000 Update of Silica Sampling Conducted under the New Jersey Silica Partnership (Document ID 0912).

In the study where exposure controls were implemented (NIOSH EPHB 347-16a), NIOSH collected PBZ samples for two workers operating four-gang dowel drills to drill holes in new concrete runways over a three day period. In this study, the dowel drills were equipped with LEV (each of the drill bits was surrounded by a close capture hood at the work surface). Respirable quartz exposure levels for these workers ranged from 24 µg/m^3 to 420 µg/m^3, with a geometric mean exposure of 130 µg/m^3 (Document ID 4154, p. 25).[261] Although these silica exposure levels were similar to those in NIOSH EPHB 347-14a, mentioned above, NIOSH reported that the average quartz content of the concrete in the runway at the site where LEV was used was over 4 times higher than that of the runway in the study where dust controls were not used (41 percent compared to 9.1 percent) (Document ID 4154, p. 25). OSHA determined that the exposure results contained in this study were suitable for inclusion in the profile.

Comparing TWA respirable dust exposures at the two sites, however, shows a significant reduction in exposures at the site that used LEV (exposures ranged from 38 µg/m^3 to 490 µg/m^3) compared to the site with no controls (exposures ranged from 445 µg/m^3 for a 501

[260] This study includes sample times ranging from 6 hours to over 10 hours. For those results where the sample time was less than 8 hours (three of the six results), the results are presented here as 8-hour TWAs (study authors assumed no exposure during the unsampled period). For those results where the sample time exceeded 8 hours, the results are presented as TWAs for the sampled time period. The geometric mean is based on the TWAs for the sampled time period.

[261] This study includes sample times ranging from 106 minutes to just over 8 hours. For those results where the sample time was less than 8 hours (four of the five results), the results are presented here as 8-hour TWAs (study authors assumed no exposure during the unsampled period). For those results where the sample time exceeded 8 hours, the result is presented as a TWA for the sampled time period. The geometric mean is based on the TWAs for the sampled time period.

minute sample, to an 8 hour TWA of 15,900 µg/m^3) (Document ID 4152, p. 13; 4154, p. 14). Although the studies demonstrate the potential effectiveness of controls, they also suggest that the exposure profile contained in the PEA may have underestimated exposures during drilling operations at sites where the rock or concrete has particularly elevated silica content. Inclusion of this new data in the FEA gives OSHA a more accurate representation of current exposures on which to base its technological feasibility analysis.

James Callahan of the International Union of Operating Engineers (IUOE) suggested that another NIOSH study of interstate highway repair, which was summarized in a 1996 NIOSH Alert, should be considered as relevant to rock and concrete drilling activities (Document ID 2262, p. 17). OSHA notes that data from this NIOSH Alert (obtained by NIOSH as part of a series of Environmental Surveillance studies conducted by NIOSH's Division of Respiratory Disease) are already included in OSHA's exposure profile discussed above.

The Concrete Saw and Drilling Association (CSDA) submitted data in the form of its Best Practices Silica Data Analysis chart, which is based on data collection from member jobsites and from NIOSH (Document ID 3497, p. 1). Patrick O'Brien of CSDA explained that the chart is based on all sawing and drilling data CSDA has collected over the last decade (Document ID 3585, Tr. 2900, 2907). OSHA commends CSDA (and BCTD) for taking a proactive stance in listing operations, control methods, and exposure levels. OSHA notes that much of the exposure data included in the CSDA matrix is drawn from NIOSH reports, which have been extensively reviewed by OSHA. Relevant exposure data from the NIOSH reports are included in OSHA's exposure profile. CSDA indicates that its members also contributed exposure data to this matrix, and OSHA agrees that this data might not be in its exposure profile; however, OSHA observed that none of the data in the CSDA matrix is specifically attributed to any source, so it is not possible to differentiate member data from NIOSH data already in OSHA's exposure profile. Furthermore, the CSDA matrix does not specify units of measurement; it appears (based on the accompanying NIOSH recommendations for respiratory protection) that the results column presents 8-hour TWA silica exposure levels in mg/m^3. For these reasons, OSHA has not included data from the CSDA matrix in the FEA exposure profile. However, the Agency finds that the data is supportive of the profile. For instance, the chart presents two exposure results for rock drilling (one with no controls and the other occurring in the rain with the drill rig equipped with a water supply). The exposure level with no controls was 66 μg/m^3 while the exposure level for the operation with a water supply was 31 μg/m^3 (Document ID 3497, p. 2) (as noted above, the units were not specified in the CSDA matrix; rather, OSHA made assumptions about the units based on NIOSH recommendations for respiratory protection). These exposure levels are consistent with the exposure profile in Table IV.5.9-B.

In its comments, CISC disagreed that the underlying data shows that rock and concrete drillers could meet the proposed PEL of 50 μg/m^3 in most operations most of the time. CISC believed that the exposure profile was flawed due to limited sampling times, and argued that OSHA had not considered dowel drilling operations in its analysis (Document ID 2319, pp. 20, 59-62). OSHA does not agree with CISC's position. As outlined in this chapter, OSHA based its exposure profile on the best available evidence and presented numerous additional studies that, while lacking sufficient detail for inclusion in the exposure profile, generally supported the profile. OSHA also summarized several studies in this chapter (including those considered in the original PEA and those submitted to the docket during the comment period) illustrating the effectiveness of controls (Document ID 0598; 0712; 0785; 0871; 0967; 1563; 1720; 3613; 3756, Attachment 9; 4150; 4151). In addition, several studies considered in this chapter address dowel drilling operations and found that the use of LEV when dowel drilling can significantly reduce exposures. However, OSHA recognizes that the available sampling data on dowel drilling operations indicate that use of LEV does not, in most cases, reduce exposures to or below 50 μg/m^3 (Document ID 0871; 1720; 3508; 4150; 4151; 4152; 4154; 4155).

Table IV.5.9-B
Personal Respirable Crystalline Silica Exposure Range and Distribution of Results for Construction Workers: Drilling Rig Operators, Rocks/Concrete

	Exposure Summary			**Exposure Range**			**Exposure Profile**				
Drilling Rig Operators, Rocks/Concrete	**N**	**Mean (μg/m³)**	**Median (μg/m³)**	**Min (μg/m³)**	**Max (μg/m³)**		**<25 (μg/m³)**	**≥25 and ≤50 (μg/m³)**	**>50 and ≤100 (μg/m³)**	**>100 and ≤250 (μg/m³)**	**>250 (μg/m³)**
Worker Using Drilling Rig (No Controls)	23	211	125	12	1,190		2 (8.7%)	3 (13%)	5 (21.7%)	7 (30.4%)	6 (26.1%)
Worker Using Drilling Rig (One or More Controls)	27	44	20	5	420		16 (59.3%)	5 (18.5%)	4 (14.8%)	1 (3.7%)	1 (3.7%)
Other	1	12	12	12	12		1 (100%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)
Drilling Rig Operators, Rocks/Concrete Total	**51**	**118**	**50**	**5**	**1,190**		**19 (37.3%)**	**8 (15.7%)**	**9 (17.6%)**	**8 (15.7%)**	**7 (13.7%)**

Notes: All samples are PBZ results and represent 8-hour time-weighted average exposures.
Job categories are intended to represent job functions; actual job titles might differ, and responsibilities might be allocated differently, depending on the site.
Percentages may not add to 100 percent due to rounding.

Sources: Document ID 1720; 3958; 0022; 0034; 0090; 0226; 0228; 0512; 0784; 0846; 0904; 0908; 0912; 4152; 4154.

5.9.3 Additional Controls

The exposure profile in Table IV.5.9-B shows that almost half (24 out of 41 samples) of drilling rig operators (rocks/concrete) have exposures above the final PEL of 50 μg/m^3. Therefore, OSHA finds that additional controls will be necessary to achieve the PEL for these overexposed workers. Additional controls for workers using drilling rigs could include environmentally controlled cabs for operators; more consistent use of wet methods specifically adjusted to maximize dust control; optimized dust collection systems involving adequate exhaust air, effective shrouds and shroud placement, and appropriate filtration; and worker position (staying out of the dust plume) (Document ID 1720, p. IV-478). In addition, OSHA finds that, when used together, wet methods and dust collection systems benefit workers as they perform all activities associated with rock drilling rigs.[262] Reducing workers' reliance on compressed air for cleaning holes will minimize another notable source of silica exposure. Worker exposures will be further reduced by supplemental controls on dust collector discharge points and the use of remote control devices that give operators the freedom to adjust their positions within the local work area.

CISC asserted that the data show that drillers cannot meet a PEL of 50 μg/m^3 in most operations most of the time and stated that OSHA provided limited or no evidence of the effectiveness of controls for drillers (Document ID 2319, pp. 59-62). OSHA does not agree. The following summaries demonstrate that wet methods and ventilation are capable of providing significant reductions in exposure to silica dust and that even greater reductions are experienced when these controls are used in conjunction with one another.

Wet Methods

Historically, construction and mining investigators have reported dust control efficiencies of 96 to 98 percent through the routine use of wet dust suppression methods, depending on the methods used; however, the water flow necessary for dust control created

[262] NIOSH commented that wet methods should not be used with a dust collector for concrete drilling rigs due to the fact that the water would add weight to the concrete dust and potentially cause it to solidify, clogging the dust control (Document ID 2177, Comment B, p. 34). Therefore, OSHA is only recommending this control for use with rock drilling.

problems under certain working conditions (e.g., moisture shortening life of certain drill bits [such as tricone roller bits], high-pressure water causing spalling of the drill hole wall) (Document ID 0967). Advances in recent decades have produced equipment that permits workers to use wet methods in a wider range of circumstances. New “water separator sub” designs extend bit life beyond the previous norm and reduce spalling in a variety of rock types (Document ID 0967, p. 6). Several commenters stated that wet methods are used frequently and are effective in controlling dust (Document ID 1983, pp. 1-2; 3580, Tr. 1435; 3496, p. 6).

Edison Electric Institute (EEI) expressed concern over the use of wet methods near electrical equipment or in subfreezing temperatures; additionally, EEI stated that it may be hard to get sufficient water supplies to remote drilling locations (Document ID 2357, Attachment 1, p. 28). OSHA’s exposure profile includes one sample result for a worker using wet methods in freezing weather to drill 60-foot holes in rock. This drill used 20 gallons of water per day, and the operator’s exposure was reported at 12 $\mu g/m^3$ (LOD) (Document ID 0034, pp. 106, 111). This sample confirms that in certain instances it is possible to implement wet methods in cold climates. Even with that evidence, OSHA understands that the use of wet methods may be limited due to other environmental concerns and conditions on the worksite. However, when it can be implemented it is an effective resource for dust control.

OSHA’s exposure profile contains 5 sample results for workers using wet methods with no other controls while drilling. The highest exposure was 57 $\mu g/m^3$, with two results below the LOD (Document ID 0034, 0226). These 5 sample results have a mean exposure of 24.2 $\mu g/m^3$ and a median exposure of 17.0 $\mu g/m^3$ (compared to a mean exposure of 80.9 $\mu g/m^3$ and a median exposure of 31.0 $\mu g/m^3$ for workers using LEV to drill rock, and an exposure of 540 $\mu g/m^3$ for an uncontrolled rock drilling operation), indicating that wet methods are potentially effective at reducing exposures, and potentially more effective than LEV.

A review of studies by NIOSH (2008) evaluated the use of wet methods in different types of drilling, including roof bolting (rock bolting) and surface rock drilling (Document ID

0967). NIOSH found that for roof (rock) bolting, silica dust was best controlled at its source through dust collection or wet drilling, similar to the standard practice in metal mines of using pneumatic percussion drills with water in addition to compressed air to flush the drill cuttings from the hole. This drilling method was found to be the best method of dust control, with dust reductions ranging from 86 percent to 97 percent (Document ID 0967, pp. 2, 4). The high dust reductions from wet drilling were confirmed in later studies that evaluated the use of water mists and foams injected through the drill steel and found that those controls reduced dust concentrations by 91 percent to 96 percent, respectively (Document ID 0967, p. 2). During this testing, it was also shown that large amounts of water are not required to produce good dust control and good penetration rate. A water flow rate of 0.41 L/min (0.11 gpm) was sufficient for dust control and good penetration rate (Document ID 0967, p. 3). NIOSH also found that for surface drilling, wet drilling techniques provided the best dust control. Wet drilling provided dust control efficiencies of up to 97 percent at a water flow rate of 4.5 L/min (1.2 gpm) (Document ID 0967, p. 6).

As previously stated, the highest exposure in OSHA's profile for a worker drilling rock using wet methods is 57 $\mu g/m^3$. Even though the surface ground was damp from rain, this worker was using 1 gallon of water per day, which is substantially less than the flow rates found effective by NIOSH above (Document ID 0034). Had more water been introduced during drilling, lower exposures may have resulted.

In OSHA's profile, the highest exposure result for rock drilling with no controls in place is 540 $\mu g/m^3$ (Document ID 0904, p. 4). The highest exposure result in the profile for concrete drilling with no controls in place is 1,190 $\mu g/m^3$. The median exposure in the profile for workers drilling with no controls is 125 $\mu g/m^3$. Based on the exposure reductions found by NIOSH (86 percent to 97 percent), OSHA anticipates that wet methods will reduce most exposures to or below 50 $\mu g/m^3$. However, OSHA recognizes that some elevated exposures may occur when drilling concrete using wet methods alone.

Based on the evidence in the record, OSHA concludes that wet methods can be used effectively for most drilling operations most of the time.

Shroud with Local Exhaust Ventilation (LEV)

Consistent use of dust extraction shrouds or hoods can reduce worker exposures at both rock and concrete drilling sites. NIOSH showed that dust collector efficiency is optimal when workers use an appropriate suction rate, maintain the shroud (surrounding a bit) in good condition, and keep the shroud positioned to fully enclose the bit as it enters the hole. NIOSH reviewed dust control research conducted from the 1910s through the early 2000s for mine rock drilling, which is nearly identical to rock drilling in the non-mining industry, and found that, when used properly, modern shroud designs now help achieve dust-control objectives more consistently for rock drilling rigs than they once did (Document ID 0967, pp. 5-9). OSHA finds that dust collectors and shrouds are commercially available (Document ID 0669; 0813).

Both rock and concrete drilling rigs are increasingly available with dust collectors that draw air from around the point where the drill bit(s) enter the rock or concrete. Organiscak and Page, 1995, found that enclosing the dust collector discharge area (with a shroud) can reduce respirable dust levels by 80 percent (Document ID 3613, p. 11). Research shows that in the vicinity of the rock drilling rig, dust collector dumping operations were the largest single contributor of airborne respirable particulates, contributing 38 percent of the respirable dust emissions (while the deck shroud contributed 28 percent, and the table bushing contributed 24 percent) (Document ID 0967, p. 5). An 80 percent reduction in the 38 percent of dust emissions attributed to discharge dumping operations could result in a 30 percent reduction in the overall level of respirable dust near the drilling rig (0.80 x 0.38 = 0.30).

NIOSH also tested a similar ventilation system: the dust collector boxes used by roof bolters in the mining industry (a vacuum system pulls dust through the drill steel back to the collector box, where it is captured on a filter). NIOSH concluded that when maintained properly, these systems can be “very effective in capturing and removing dust generated by drilling” (Document ID 0598, p. 7). These authors reported that the effectiveness of these controls can be enhanced by adding dust collector bags to the system. With collector bags added, filter loading was reduced by 80 percent (so the filter needs cleaning less often and lasts longer), and it was much easier for the bolter operator to service the box, resulting in far less dust exposure (Document ID 0598, p. 7). Listak and Beck (2008) reported that the collector (with bag) ran longer between filter cleaning and captured more than 99 percent of dust (Document ID 0785, pp. 3, 6).

Air curtains are another option for reducing silica exposures among roof bolters underground. In this case, a fan pulls air through a filter and releases this cleaned air over the worker, enveloping the worker in a curtain of clean air (Document ID 0598, pp. 7-8). Laboratory tests showed a 40 to 60 percent reduction in dust levels under the curtain, and respirable quartz concentrations that were 40 $\mu g/m^3$ lower than concentrations in a nearby area (Document ID 0712, p. 214).

In three studies, NIOSH sought to quantify the reductions in respirable dust emissions that were associated with LEV from dowel drilling machines in controlled settings. In these studies, NIOSH found that close-capture dust collection hoods ("boots") fitted onto each drill on the array reduced respirable dust concentrations by 87 to 94 percent (compared with drilling without the boots) (Document ID 0871; 4150; 4151). The equipment tested included both four- and five-gang drills and associated commercially-available hoods (Document ID 0871, pp. 4, 7; 4150, pp. vi, 4; 4151, pp. vi, 4-5).

NIOSH recommended several modifications to typical concrete drilling rig dust collection equipment. OSHA finds that these upgrades could help ensure that optimal dust collection efficiency is maintained over time. The modifications include using smooth ducts and maintaining a duct transport velocity of 4,000 feet per minute to prevent duct clogging; providing pipe clean-out points; installing pressure gauges across dust collection filters so the operator can clean or change the filter at an appropriate time; installing static pressure taps in hoods and vacuum gauges on the operator's panel, enabling the operator to confirm that the hoods are operating as designed; including instructions on hood placement in the operating instructions; and extending the height of discharge outlets from the dust collectors to aid in dispersal of emissions (Document 0871, p. 13; 4150, p. 13; 4151, pp. 20-21). In a 1995 U.S. Bureau of Mines (USBM) study, Organiscak and Page further illustrated the importance of proper set up/adjustments on the effectiveness of dust control systems. In this study, Organiscak and

Page conducted dust sampling around several truck-mounted rock drills equipped with Rotoclone exhaust systems. The study found that improving the drill deck shroud containment and increasing Rotoclone (i.e., fan) speed can reduce respirable dust levels by 63 percent, while vertically extending the Rotoclone exhaust can reduce downwind respirable dust levels by 62 percent (Document ID 3613, p. 11). NIOSH reported that improving dust shroud containment can improve dust reduction efficiencies by greater than 99 percent (Document ID 4156, p. 2). In the PEA, OSHA discussed a video of concrete drilling using dust collection equipment that showed an initial plume of dust lasting 5 to 15 seconds after the worker activated the drill (Document ID 0814). Based on this, OSHA determined that the overall collection efficiency of dust collection systems would also be improved by activating the exhaust suction prior to initiating drilling and deactivating it after the drill bit stops rotating to ensure dust is captured through the entire drilling process (Document ID 1720, p. IV-478). This was not disputed. Over the course of the work shift, modifications such as those suggested by NIOSH, USBM, and OSHA would all reduce worker exposure levels.

While the suggested dust collection system modifications can reduce worker exposure levels, OSHA understands that drilling operations are highly mobile and that operators perform drilling activities in a variety of conditions that depend on the worksite and equipment in use. Therefore, employers will need to evaluate dust collection systems to determine the specific additional modifications required to optimally control dust.

The highest sample result in the exposure profile associated with drilling concrete with LEV is 420 μg/m^3. The remaining workers on this job had exposures of 5 μg/m^3, 12 μg/m^3, 20 μg/m^3 and 58 μg/m^3, indicating that the additional task of emptying the dust collector and cleaning the filter was responsible for the elevated exposure and that respirators may be needed to protect some workers during discrete tasks (Document ID 4154, p. 17, 27).

OSHA only has four samples in the profile associated with workers drilling rock while using LEV alone. All four samples were reported as less than the LOD of 12 μg/m^3. However, the reports indicate sampling occurred during or following rainy weather, which may have resulted in underestimating the exposures for LEV alone due to already damp surfaces. Even though the surface ground was damp from rain, one report notes that visible dust was still being emitted from the dust collector itself (Document ID 0512).

The National Stone, Sand & Gravel Association (NSSGA) recommended that OSHA replace the term “shroud” in the Table 1 entry for rock drilling with “engineered fugitive dust control method, e.g., a shroud, water spray, etc.” (Document ID 2327, Attachment 1, p. 21). OSHA has decided not to incorporate the change as requested, but is requiring the use of a close capture hood or shroud around the drill bit. OSHA determined that the term change NSSGA requested was not specific enough to ensure that workers would be protected from elevated levels of silica.

Based on the information contained in the record, OSHA has determined that LEV can effectively reduce silica exposures to below 50 $\mu g/m^3$ for most drilling operations most of the time.

Combination of Wet Methods, Shroud, and LEV

A combination of wet methods and LEV can further reduce exposures to silica during drilling operations. A NIOSH survey of a rock drilling operation in a quarry obtained a sample result of 31 $\mu g/m^3$ for a rock drill operator using a combination of wet methods and LEV. The operator spent 100 percent of his/her time operating the drill rig approximately 8 feet from the drill site, occasionally moving to within 3 feet to check on drilling equipment (Document ID 0228, pp. 8-9). The drill was fitted with a 300 cfm hydraulic fan to draw air and debris from the drill hole through a 5-inch flexible duct, and included a two stage air cleaning system that removed the debris from the air stream. The finer rock dust was carried through the flexible ducting to the fan and a manifold with a bank of 20 air filters (4-inch diameter vertically threaded). These air filters accumulated dust on their surfaces, but when the drill stem was not engaged, a timer and relay controls reverse-pulsed air to clean the filters (Document ID 0228, p. 6). The water spray system included a 100-gallon pressurized tank (80-psi), hoses, and an injection system. Water was injected into the drill stem and released through ports in the drill bit (Document ID

0228, p. 6). NIOSH reported that in most drilling applications (including during this survey), both systems are used in combination (Document ID 0228, p. 6).

OSHA obtained sample results of 54.3 μg/m^3 and 34.9 μg/m^3, for two workers drilling in granite that contained 30-40 percent crystalline silica (Document ID 0034, pp. 8, 23-26, 35-38). Both drills were reportedly using water and LEV, although specific details about the configuration of the controls were not discussed (Document ID 0034, pp. 23, 89-93). A third sample of 12 μg/m^3 was collected on the same site for a laborer who helped with positioning the drills (Document ID 0034, pp. 39-42).

Organiscak and Page (1995) also illustrated the effectiveness of combined wet methods and dust collectors in their U.S. Bureau of Mines (USBM) study, which compared rock drilling using LEV with and without the addition of water for dust suppression. The addition of wet methods to the LEV system showed a 92 percent reduction in respirable dust and eliminated nearly all of the visible dust. Quartz results decreased from 142.8 μg/m^3 when the water was off (LEV alone) to 8.5 μg/m^3 when water was added.[263] USBM estimated that 100 gallons or less of water would be sufficient for 8 hours of continuous exposure using a 0.2 gallon per minute flow rate, noting that too much water can contribute to operational problems (Document ID 3613, pp. 7-8).

OSHA recognizes that in concrete drilling, combining wet methods and LEV at the point source may be problematic. In its written comments, NIOSH said that wet methods should not be used with a dust collector for concrete drilling rigs because adding water would add weight to the concrete dust and potentially cause it to solidify, clogging the dust control (Document ID 2177, Comment B, p. 34). OSHA acknowledges that applying water at the drilling point source has the potential to clog the LEV dust control and concludes that wet methods can be effectively implemented in conjunction with dust collection systems during concrete drilling only when water is applied at the downstream dust collection exhaust point (Document ID 0967, pp. 7-8).

[263] Silica dust levels were calculated by multiplying the dust concentration by the percentage quartz. Milligrams per cubic meter was converted to micrograms per cubic meter by multiplying by 1000.

While LEV and wet methods are able to reduce exposures individually, record evidence demonstrates that the proper combination of these controls can significantly increase the extent to which silica exposures can be reduced during drilling work. As previously mentioned, the highest exposure in the profile for drilling with no controls is 1,190 μg/m^3 and the median exposure is 125 μg/m^3. The highest exposure for a worker drilling using a combination of controls was 54.3 μg/m^3. Based on the exposures reported by NIOSH and the reductions found in the USBM study (92 percent), OSHA has determined that a combination of wet methods and LEV will reduce most exposures to 50 μg/m^3 or below.

Isolation

Wireless or tethered remote controls are available for some types of construction drilling equipment (Document ID 1720, p. IV-479; 0814; 0871, p. 8). A concrete drilling rig tested by NIOSH was fitted with a commercially available remote control that permitted the operator to activate the rig from a moderate distance (e.g., 5 to 20 feet) (Document ID 0871, p. 8; 0814). Though the NIOSH study did not specifically test for the effects of remote control usage on silica exposure, OSHA anticipates that when workers have access to wireless controls, this technology can help minimize workers' silica exposures by permitting the workers to move freely within the local work area. When given an opportunity, workers can step away from plumes of visible dust (Document ID 0784, p. 212; 0814; 0819, p. 2).

The IUOE endorsed the use of enclosed cabs as an effective engineering control that isolates operators from the source during rock and concrete drilling (Document ID 2262, p. 28). IUOE also suggested that if operator booths are determined to be a feasible control, OSHA could consider including them on Table 1 (Document ID 2262, p. 46). OSHA agrees that the use of an operator's booth could provide another effective alternative engineering control for workers using drilling rigs. While OSHA did not have enough information to include remote operation of drills and operator booths as a control option on Table 1, employers who believe that this is the most effective method for controlling exposures on their worksite have the option of using this control method and performing exposure assessments to determine compliance with the PEL.

Enclosed Cab

Cecala et al. (2005) studied modifications designed to lower respirable dust levels in an enclosed cab on a 20-year-old surface drill at a silica sand operation. The researchers studied respirable dust levels collected inside and outside the cab before and after modifications to improve performance and found that effective filtration and cab integrity (e.g., new gaskets, sealing cracks) to maintain a positive-pressure environment are the two key components necessary for dust control in an enclosed cab (Document ID 1563, p. 9). A study published by Bakke at al. (2010, originally published in 2002) on roof bolters using rock drilling rigs at the face of the tunnel at a Norwegian tunnel construction site concluded that the use of a drill rig with a closed cab reduced silica exposure by 85 percent compared to drill rigs with no cabs. The geometric mean respirable quartz exposures for operators in no cab, open cabs, or closed cabs were 273, 16, and 24 $\mu g/m^3$, respectively. Researchers concluded that these sample results were due in part to the fact that workers using drill rigs without cabs were positioned closer to the drill head (Document ID 3756, Attachment 9, p. 794).

The IUOE agreed that an enclosed cab was an effective control for rock and concrete drilling, noting that, “enclosed cabs not only protect operators from silica exposure, but provide the additional benefits of protecting workers from noise exposure and exposure to diesel particulates and other respirable contaminants, such as lead” (Document ID 2262, p. 28). The IUOE also cautioned however, that “since enclosed cabs isolate the operator from the silica source and do not control exposure at its source, cab integrity is essential to reduction of silica exposure to operators of enclosed cabs.” (Document ID 2262, pp. 28-29). The IUOE recommended inspection checklists to ensure that engineering controls are functional and that cab integrity is properly maintained (Document ID 2262, pp. 38-39). OSHA shares IUOE’s concerns and notes that to ensure effectiveness, cab interiors must be kept as free as practicable from settled dust; door seals and closing mechanisms must be maintained in proper working order; gaskets and seals must be in good condition and working properly; cabs must be maintained under positive pressure through continuous delivery of fresh air; intake air must be filtered through a pre-filter that is at least 95 percent efficient in the 0.3-10.0 μg range; and cabs must have heating and cooling capabilities (Document ID 2262, pp. 38-39).

In its written comments, NIOSH recommended that OSHA specify that incoming air for an enclosed cab of mobile equipment be filtered through a pre-filter and then either a Minimum Efficiency Reporting Value (MERV)-16 or HEPA filter, noting that recently-published NIOSH research found that a MERV-16 quality filter media may be more advantageous than a HEPA-quality intake filter on mobile equipment (Document ID 2177, Comment B, pp. 47-48). The information presented by NIOSH indicates that as MERV-16 filters load with dust they become more efficient at intake particle capture, whereas HEPA filters become more restrictive, placing more demand on the cab filtration system (including the intake fan) (Document ID 2177, Comment B, pp. 47-48). Therefore, OSHA is not requiring the use of HEPA filters on enclosed cabs for heavy equipment; where an enclosed cab is used to meet the Table 1 option, the cab must be equipped with an intake filter with a MERV 16 or higher rating.

An NUCA member cautioned that the use of an enclosed cab for drilling rigs limits the operator's ability to communicate with anyone outside the cab and therefore creates a hazard (Document ID 2171, Attachment 1, p. 10). OSHA acknowledges this concern, but believes that proper work procedures and worker training will control any potential hazards associated with communication issues. See Section IV-5.3 – Heavy Equipment Operators and Ground Crew Laborers for further discussion on the use of enclosed cabs as a control method in construction.

In the exposure profile, OSHA identified 10 samples for drill operators working in cabs; the sample results ranged from 10 $\mu g/m^3$ (LOD) to 110 $\mu g/m^3$, with a median exposure of 30 $\mu g/m^3$. These findings support OSHA's determination that the enclosed cabs offer protection against respirable silica dust. OSHA notes that cabs only benefit the operator when he or she remains in the cab and do not control worker exposures during positioning or hole-tending activities. Therefore, additional controls are necessary to protect workers from exposures to silica dust when performing activities outside of the cab. OSHA has determined that the use of water for dust suppression on the drill bit will effectively reduce exposures in these situations. As previously discussed, NIOSH found dust reductions ranging from 86 percent to 97 percent with the implementation of wet methods for dust control (Document ID 0967, pp. 2-4). This would offer protection for operators who must occasionally leave the cab and for other workers in proximity to the drill.

Work Practices

Work practice controls are an important component in reducing exposures to 50 μg/m^3 or below. By using a HEPA-filtered vacuum instead of compressed air to clean holes, worker exposures from this source could be eliminated, except when workers empty the vacuums. Because the vacuum nozzle must be inserted into each hole, workers using vacuums to clean holes are likely to require extra time to complete the task compared with workers using compressed air, which requires less precision (Document ID 1720, p. IV-480). In three surveys of dowel drilling operations, NIOSH observed workers using compressed air to clean holes at only one site; the other two epoxied the dowels without any cleaning (Document ID 4154, p. 26). Similarly, NIOSH found that, at the site where the drilling rig was equipped with LEV, workers used compressed air to clean the filter, resulting in some of the highest measured exposures to respirable dust (Document ID 4154, p. 26). NIOSH recommended prohibiting the use of compressed air in order to eliminate it as a source of exposure (Document ID 4154, p. 26). NIOSH also noted that using compressed air to clean filters could damage the filter (Document ID 4154, p. 26), and that the reverse pulse feature on the dust collector should preclude the need to remove filters for cleaning (Document ID 4154, p. 26). OSHA agrees that using compressed air to clean areas and materials containing silica dust can result in a significant source of exposure to silica and should be avoided. OSHA also realizes that there may be some instances where the use of compressed air is necessary, but notes that when compressed air is used to remove silica dust, it must be used in conjunction with engineering controls to protect employees from exposures to silica levels above the PEL.

5.9.4 Feasibility Finding

Paragraph (c) of the respirable crystalline silica standard for construction (1926.1153) gives employers the option of following Table 1: Specified Exposure Control Methods, which includes fully and properly implementing specified control measures when operating dowel drilling rigs for concrete, see paragraph (c)(1)(viii), and vehicle-mounted drilling rigs for rock and concrete, see paragraph (c)(1)(ix). Alternatively, employers who do not follow the requirements outlined under paragraph (c) must assess and limit employee exposures to silica in accordance with paragraph (d).

When using dowel drilling rigs for concrete, employers following Table 1 must use a shroud around the drill bit with a dust collection system and be equipped with a filter-cleaning mechanism. The dust collector must have a filter with 99 percent or greater efficiency. However, based on exposure sampling by NIOSH (Document ID 4154), OSHA finds that even with these controls, employees engaged in dowel drilling are likely to have silica exposures above 50 $\mu g/m^3$. As such, OSHA cannot find that the new PEL is technologically feasible for these workers, and Table 1 in the final rule requires the use of respiratory protection having an APF of at least 10 when dowel drills are operated. In addition, the specification on Table 1 is restricted to outdoor use and requires HEPA-filtered vacuums be used when cleaning holes.

When using a vehicle-mounted drilling rig for rock or concrete, employers following Table 1 must use a dust collection system with a close capture hood or shroud around the drill bit with a low-flow water spray to wet the dust at the discharge point from the dust collector. Table 1 provides the alternative option for workers to operate the drill from within an enclosed cab meeting the specifications of paragraph (c)(2)(iii) in conjunction with water applied at the drill bit for dust suppression. When these specified dust control methods are fully and properly implemented, TWA exposure levels are expected to remain below 50 $\mu g/m^3$, and therefore, Table 1 does not require the use of respiratory protection for this work.

Most manufacturers of vehicle-drilling rigs equip their machines with water delivery systems, shrouds with LEV filtration, or a combination of both, to minimize dust escaping into the work area (Document ID 0669; 0785; 0871; 2319; 3613; 4154). Accordingly, OSHA has determined that it is feasible for employers to obtain controls for these types of drilling equipment that meet the specifications in Table 1.

Based on the available data in the record, OSHA concludes that exposures among workers using vehicle-mounted drilling rigs, other than dowel drilling rigs, can be reduced to levels of 50 $\mu g/m^3$ or below, for most operations, most of the time. Thus, OSHA finds that the standard is technologically feasible for these workers. As summarized in Table IV.5.9-B and described earlier in this section,(see IV-5.9.3 addressing Additional Controls), OSHA finds exposure levels of 50 $\mu g/m^3$ or below have already been achieved for approximately 78 percent of drillers using one or more controls. And for workers currently exposed above 50 $\mu g/m^3$, the controls described in this section can be implemented to reduce silica exposure levels to 50 $\mu g/m^3$ or below in most operations, most of the time. Controls include: 1) wet dust suppression methods (water-fed drill bits, misting points of dust release, and in some cases using a more powerful water pump than typically provided with the drilling rig); 2) shrouds and hoods connected to dust extraction equipment; and 3) managing dust collection dump points. These controls will benefit all workers working around the drilling rig, not just rock and concrete drill operators. The evidence presented in this section shows that use of the specified control systems results in greatly reduced worker exposures to respirable crystalline silica.

5.10 MOBILE CRUSHING MACHINE OPERATORS AND TENDERS

5.10.1 Description

Crushing machines are used to reduce large rocks, concrete, or construction rubble down to sizes suitable for various construction uses.[264] Once crushed, the material exits the crusher and is carried along conveyor belts into a pile or into secondary and tertiary crushers. Crushing operations sometimes also include magnetic separation, powdering, and vibratory screening (sieving). Mobile crushers, are a subset of crushers, are typically used at construction sites that can be moved from project to project as opposed to larger crushers that are stationary and are used in general industry and at quarrying operations that fall under the jurisdiction of MSHA (Document ID 1431, p. 3-90). A crusher's typical use at a construction site ranges from a six to eight-week period (Document ID 2116, p. 31).

Workers can be exposed to respirable silica generated during crushing operations while they manage the machine's controls, oversee the operation, and signal the loader operator about dumping loads into the crusher hopper or onto the conveyors that lead to the crusher. At most construction sites, the operator overseeing machine function spends a substantial portion of the shift next to the primary hopper to allow the operator to view the inside of the hopper, at which point the operator's breathing zone is about five to ten feet from the edge of the hopper opening. The operator's platform is typically not enclosed and has an area of about ten square feet (Document ID 1431, p. 3-90; 0186, pp. 24-26, 37-38, 41-43, 45, 52-65).

The operator might also periodically tend the crushing machinery from platforms mounted on the side of the crusher or on the ground at various points along the moving conveyor belts to remove foreign material (wood, rebar, wire) from the stone or concrete to be crushed. These workers might also pick up debris that has fallen off the conveyor belts, or clear material that becomes impacted in the crusher, hoppers, or belts. At some

[264] Rock crushing operations at fixed sites associated with mining operations are considered quarrying operations and fall under the jurisdiction of the Mine Safety and Health Administration. Only "portable" crushing operations associated with construction sites are discussed in this subsection (Document ID 1431, p. 3-90).

construction sites, particularly where construction rubble contains a significant amount of foreign material or where multiple crushing machines are run in series, other workers perform these tasks near the crushing machine; such workers are typically referred to as tenders or, alternatively, laborers, belt pickers, ground personnel, or utility operators (Document ID 1431, pp. 3-90 - 3-91).

Table IV.5.10-A summarizes job categories, major activities, and sources of exposure of mobile crushing machine operators and tenders.

Table IV.5.10-A
Job Categories, Major Activities, and Sources of Exposure of Mobile Crushing Machine Operators and Tenders

Job Category*	Major Activities and Sources of Exposure
Worker(s) Operating and Tending Crushing Machines	Managing mobile crushing machine function while working at control position(s). • Dust from crushing, grinding, and screening operations. • Dust from open transfer of silica-containing materials (e.g., open conveyors, material loading or discharge points, sizing screens). Working at access points tending crushers and conveyors to clear foreign or impacted material. Keeping the area clean (picking up debris). • Dust from crushing, grinding, and screening operations. • Dust from open transfer of silica-containing materials (e.g., open conveyors, material loading or discharge points, sizing screens)

*Job categories are intended to represent job functions; actual job titles might differ, and responsibilities might be allocated differently, depending on the site.
Source: Document ID 1431, p. 3-90.

5.10.2 Exposure Profile and Baseline Conditions

The exposure information available to OSHA for concrete and rock crushers is limited to workers either controlling the machine or, alternately, controlling and tending the equipment to clear foreign or impacted material. OSHA has no exposure measurements from a worker strictly tending crushing machines in construction without also spending time operating them. Thus, an exposure profile for crusher tenders could not be presented. The exposure profile shown in Table IV.5.10-B summarizes the exposure results for all workers (operators and tenders) associated with crushing machines. These results come from one OSHA Special Emphasis Program (SEP) inspection report (Document ID 0030), which was included in the PEA, and two technical reports of demolition surveys submitted by the Building and Construction Trades Department, AFL-CIO (Document ID 4073, Attachments 9a and 10a). Another technical report of a demolition survey submitted by Building Construction Trades Department, AFL-CIO (Document ID 4073, Attachment 10b) was not included in the profile because the dust sampler was not set at the appropriate flow rate. OSHA removed from the profile in the PEA one measurement from an inspection of a crusher operation at an asphalt plant (Document ID 0186), since it did not represent the exposure of a construction worker, and two measurements from a case file that was inadvertently included and did not contain exposure measurements for crusher operators or tenders (Document ID 0101).

The OSHA Information System database covering 2011 to 2014 was reviewed and no additional mobile crusher operator data associated with construction operations were identified (Document ID 3958). Although limited, these values represent the best data available to OSHA for workers involved in mobile crushing operations.[265]

The exposure profile in Table IV.5.10-Bincludes eight samples of respirable crystalline silica for crushing machine operators and tenders. The median is 92.5 μg/m^3, the mean is 103.7 μg/m^3, and the range is 12 μg/m^3 to 300 μg/m^3. Of the eight samples, five (roughly 63 percent) are above 50 μg/m^3, and three (roughly 38 percent) exceed 100 μg/m^3.

At the one SEP construction site, where full-shift respirable quartz PBZ results of 172 μg/m^3 and 300 μg/m^3 were measured, workers stated that conditions were atypical on the day of sampling, in that the supply of asphalt, which was usually added to the primary hopper to control dust, had run out early in the day. A water hose was used on the hopper along with a water hose being used on the conveyor (Document ID 0030, pp. 34, 60, 62-64, 66-67; 1431, p. 3-91). Although these data might not represent typical conditions at this site, they indicate the potential for exposure in poorly controlled conditions.

[265] As noted in Section IV.2 – Methodology, all results included in the exposure profile are 8-hour time-weighted averages (8-hour TWAs) calculated assuming no additional exposure during any unsampled portion of the shift. Unless explicitly stated otherwise, all results discussed in the additional controls section are also 8-hour TWAs calculated the same way.

Data collected by the Construction Occupational Health Program of the University of Massachusetts Lowell on a crusher operator at a demolition site showed exposures on two separate days at the limit of detection (21 µg/m^3) and 95 µg/m^3, respectively (Document ID 4073, Attachment 9a, pp. 3-4). Data were reported by Pekron Consulting at a demolition site for two crusher operators each sampled on two days; one crusher operator worked on a crusher referred to as the processor which reduced large boulders to smaller size rocks, and the other crusher operator worked a mobile crusher that further reduced the smaller rocks. The two samples for the processor operator were less than the limit of detection. The mobile crusher operator exposures were 90 and 128 µg/m^3, respectively, over the two days (Document ID 4073, Attachment 10a, p. 4).

In Table IV.5.10-B, the exposure profile for workers operating crushing machines includes eight 8-hour TWA silica exposure results from these sources. The range of the exposure data is from 12 (the limit of detection) to 300 µg/m^3, the average exposure is 103.7 µg/m^3 and the median exposure is 92.5 µg/m^3.

Phillip Rice of Fann Contracting, Inc., commented on the large amount of dust created by uncontrolled crusher operations (Document ID 2116, p. 9). The testimony and post-hearing brief of International Union of Operating Engineers (IUOE) provide additional information and data concerning mobile crushing machines, which can create significant exposures during building and road demolition projects. IUOE identified concrete or rock crushing as a construction activity that occurs during demolition (Document ID 4234, Attachment 1, pp. 16-17). In addition, IUOE provided summary exposure data, not included in the profile, from a study of a large highway reconstruction project (Document ID 4025, Attachment 2C, p. 3).[266] The mean exposure from six personal samples[267] for respirable crystalline silica in crushing operations where water suppression was used was 320 µg/m^3 (Document ID 4025, Attachment 2C, p. 3) indicating high exposures for these

[266] The lead researchers are Norman Zuckerman, MS; Katya Wanzer, MPH, and Nancy Clark, MA, CIH, from the Mount Sinai Irving Selikoff Center; and Mark Goldberg, CIH, PHD, from Hunter College.

[267] The sampling time for these samples was not reported nor is it known whether the results represent 8-hour TWAs. Also, only mean levels were reported for these data so the distribution of exposures cannot be determined. Thus, they were not included in the exposure profile for this operation.

dusty operations. Four of these samples were taken at the operator platform next to the crushing operation where the operator was directly exposed to the dust emissions from the crusher hopper, resulting in a mean respirable crystalline silica exposure of 410 μg/m^3 (Document ID 4025, Attachment 2C, p. 3). Two of these samples were taken where the crusher operator used a remote control to operate the crusher from a distance, resulting in a mean silica concentration of 140 μg/m^3 (Document ID 4025, Attachment 2C, p. 3). No details were provided that described the use of water to suppress dust.

OSHA finds that baseline conditions when using crushing machines generally include the use of some form of dust suppression (e.g., water, asphalt) but application is either inconsistent or insufficient (Document ID 1431, p. 3-91; 4025, Attachment 2C, p. 4). Because the final Exposure Profile reflects a variety of conditions, OSHA generally considers the median exposure for workers using mobile crushers (92.5 μg/m^3) to be the best single statistic that characterizes exposure or workers who operate or tend mobile rock and concrete crushers. OSHA thus considers the sampling results reflected in the Exposure Profile below to be the best available evidence of mobile crusher operator and tender exposures.

Table IV.5.10-B
Personal Respirable Crystalline Silica Exposure Range and Distribution of Results for Construction Workers: Rock-Crushing Machine Operators and Tenders

	Exposure Summary			Exposure Range			Exposure Profile				
Job Category	**N**	**Mean (μg/m³)**	**Median (μg/m³)**	**Min (μg/m³)**	**Max (μg/m³)**		**< 25 (μg/m³)**	**≥ 25 and ≤ 50 (μg/m³)**	**> 50 and ≤ 100 (μg/m³)**	**> 100 and ≤ 250 (μg/m³)**	**> 250 (μg/m³)**
Rock-Crushing Machine Operators and Tenders	8	103.7	92.5	12	300		3 (37.5%)	0 (0%)	2 (25%)	2 (25%)	1 (12.5%)

Notes: All samples are personal breathing zone (PBZ) results and represent 8-hour time-weighted average exposures.
Job categories are intended to represent job functions; actual job titles might differ, and responsibilities might be allocated differently, depending on the site.
Percentages may not add to 100 percent due to rounding.

Sources: Document ID 0030; 4073, Attachments 9a and 10a.

5.10.3 Additional Controls

The exposure profile in Table IV.5.10-B shows that roughly 63 percent (5 out of 8 samples) of crushing machine operators and tenders have exposures above the final PEL of 50 μg/m^3. Therefore, OSHA finds that additional controls will be necessary to achieve the PEL for these overexposed workers. As discussed in more detail below, the primary additional controls for crushers include: water application methods that can include using foam and wetting agents; using remote controls to remove the worker from high respirable dust areas that can include simple distancing or the use of enclosed operator control booths supplied with fresh filtered, climate-controlled air; installing local exhaust ventilation (LEV) at the hopper and other locations along the conveyors; and using dust suppressant and hydroscopic materials on ground areas and roads.

Wet Methods

Use of water spray systems is particularly important for mobile crushing operations of concrete or rock since dust emitted from the operation can contribute to exposures of tenders and bystanders, such as employees who do not operate the crusher or who are performing jobs not associated with crusher operations elsewhere at the site. The California Air Resources Board cites rock crushing as a major source of fugitive emissions (Document ID 3583, Tr. 2396). If the crusher is not located away from areas where others are working, and if water spray applications are not properly implemented, a large dust cloud can be generated that can cause exposures to operators, tenders and other workers at the site. Donald Hulk of Manafort Brothers testified that advance planning is required to avoid secondary exposure to other workers (Document ID 3583, Tr. 2385-2386).

Evidence that water suppression on crushers can effectively reduce silica exposure levels is provided by a full-shift (PBZ) silica result of 54 μg/m^3 obtained for the operator of a stationary crusher at a temporary concrete recycling facility using fine-mist water spray

(Document ID 0203, p. 9).[268] The sampling was performed by the OSHA contractor, the Eastern Research

Group (ERG), on a site visit. Multiple water spray nozzles were located at the crusher hopper, the post-crusher conveyor, the sizing screens exit point, and each major transfer point, including the point where crushed material eventually fell to a pile on the ground. The crusher operator controlled the nozzles from a panel in the control booth. The number of nozzles in action varied according to site conditions; at the time of the visit, only the water spray at the jaw crusher hopper was used since the material being crushed was wet from thawing ice. The objective was to eliminate all visible dust using the least amount of water. Water sprayers were checked frequently and replaced if they became clogged, dripped, or squirted water, rather than producing a mist spray (Document ID 0203, pp. 3-6). At this site, the machine operator spent much of the shift inside a poorly sealed booth equipped with foam (as opposed to higher efficiency filters located directly over the crusher but left the booth frequently to spray extra water (large droplets from a hose with a garden nozzle) as material was dumped into the crusher. During the shift, this worker also inspected conveyors and shoveled dry impacted crushed concrete from clogged hoppers and conveyors (performed without dust suppression) (Document ID 0203, p. 8). Silica concentrations inside the booth (based on area samples, not PBZ samples) were below the limit of detection (LOD) (19 µg/m^3 in this case), while the concentration outside the booth was higher (103 µg/m^3) over the entire shift (Document ID 0203, p. 9) indicating this poorly maintained booth reduced exposure by 5 times or greater. The operator's level of exposure of 54 µg/m^3 was partially caused by the presence in the booth, reducing the operator's average exposure over the course of his shift.

OSHA has concluded that if the water hose (used by the operator at the crusher) had provided a finer mist, if water spray had been available at the clogged hoppers cleared by the operator, and if water sprays located around the conveyors had been activated to

[268] Although it could be disassembled and moved, this equipment was not mobile, and the crusher system size was more typical of an extensive fixed location crushing operation (Document ID 0203). Therefore, the exposure profile (Table IV.5.10-B) does not include exposure results associated with this crusher.

avoid the need to shovel dry material, then this operator's exposure level would have been below 50 μg/m^3 on this sampling date. Although wet ground conditions meant that the concrete being crushed was wetter than usual, which might have helped minimize airborne dust, OSHA notes that most of the water sprays installed on the system throughout the process were not being used because of the wet conditions encountered that day.

The Construction Industry Safety Coalition (CISC) was critical of OSHA not adjusting for the weather conditions encountered by ERG on the site visit (Document ID 2319, p. 27). OSHA notes that although surface ice and moisture combined with wet soil would help reduce exposures of crusher operators and workers in the vicinity, most of the water sprays were not in use that day (Document ID 0203, p. 11). OSHA contends that wet ground conditions alone, in the absence of water sprays, would not be sufficient to achieve control, because once crushed, the dry interior of the concrete pieces becomes exposed and can release dust. Supporting this contention, ERG observed that visible dust was generated when the operator shoveled impacted material from conveyors and removed rocks from hoppers (Document ID 0203, p. 8). OSHA also notes that bulk samples taken by ERG of accumulated dust contained 30 percent crystalline silica (Document ID 0203, p. 11), well in the range of most materials encountered in the construction industry.

During the rulemaking, additional data were introduced that described the successful use of wet methods. The BCTD submitted an internal progress report on an ongoing study of demolition dust and respirable silica dust control prepared by Anito Bello, Sc.D, and Susan Woskie, Ph.D, University of Massachusetts Lowell (Document ID 4073, Attachment 9a). Two measurements were taken on a crushing operator over two days. During the first measurement of the crusher operator's exposure, the crushed material was dry with a sampling result of 120 μg/m^{3}respirable crystalline silica over 378 minutes of sampling, or an 8-hour TWA of 95 μg/m^3. A second 203-minute sample of the crusher operator taken another day after it rained and the material being crushed was wet was below the LOD of 21 μg/m^3 (Document ID 4073, Attachment 9a, pp. 3-4), or 78 percent lower than the exposure when working with dry material. The authors concluded that

"[W]orkers on demolition sites were exposed to levels (of respirable silica) under 50 μg/m^3 with the exception of the crusher operators. Furthermore, our data show that crusher operator's exposures can be reduced significantly if water controls are used to increase the wetness of the materials being crushed" (Document ID 4073, Attachment 9a, p. 4).

Guidance on dust controls developed by the Health and Safety Executive of Great Britain contained in its publication, COSHH Essentials in Construction: Silica (CN4), Crushing and Screening Demolition Material recommends the use of equipment fitted with water suppression to minimize the amount of dust created at crushing and transfer points (Document ID 4073, Attachment 15g, p. 1). The document also states, "Respirator Protective Equipment (RPE) should not be needed if the controls work properly. However, RPE may be needed for work near the equipment while it is running and is often needed for maintenance and some cleaning jobs" (Document ID 4073, Attachment 15g, p. 2).

According to NIOSH, crusher operators' exposures can be reduced with more extensive and improved water delivery systems. A well designed water control system needs adequate flow volume, proper selection of nozzle type and proper nozzle direction and angle of impact. This can generally be obtained from the nozzle manufacturers' literature (Document ID 1152). The NIOSH Dust Control Handbook discusses water dust control techniques in greater depth and also explains nozzle selection for spray water controls (Document ID 3472, pp. 61-76).

Spray systems are commercially available as original equipment options on some mobile crushers and can be added as retrofits or can be added by the owner as shop installations (Document ID 0769; 0830; 0831; 0832). Replacement nozzles are readily available. It is important to match the nozzle type and spray pattern to the dust source, i.e., the location within the crushing machine, that is to be controlled (Document ID 0548; 1152). Spray systems can be installed for remote control activation (Document ID 0203, pp. 11, 12, 14; 0830).

Other wet dust suppression options that can offer a substantial benefit include foam, steam, compressed water fog, and wetting agents (surfactants added to water to reduce surface tension) (Document ID 1360; 1431, pp. 3-93—3-94). Based on evidence in the record, OSHA expects that when used properly and consistently, these wet methods could reduce silica concentrations at least as effectively and more consistently than directional water mist spray alone (i.e., dust suppressants such as foams can achieve an exposure reduction of 70 to 90 percent, or possibly greater) (Document ID 1360; 1431, p. 3-93).

Remote Control or Ventilated Control Booths

Mobile crushing machines are currently available with remote controls as standard equipment (Document ID 0770). The remote operation permits the operator to stand back from the crusher or move upwind of dust emissions. IUOE provided exposure data from large highway reconstruction projects showing the reductions in exposures from use of remote controls (Document ID 4025, Attachment 2C, p. 3). Four samples were collected where the operator platform was next to the crushing operation and the operator was directly exposed to the crusher emissions; the mean respirable crystalline silica exposure was 410 $\mu g/m^3$. Working from a remote location resulted in an approximately 66 percent reduction in exposure to respirable crystalline silica of the crusher operator, for a remote location mean exposure of 140 $\mu g/m^3$ (Document ID 4025, Attachment 2C, p. 3).

An isolated and ventilated operator control booth that provides fresh, climate-controlled air can significantly reduce the respirable silica exposures of workers associated with crushing to the extent that they are able to spend time in the booth. At its visit to a crusher facility, ERG found non-detectable levels of respirable crystalline silica inside the operator's control booth, compared to a concentration of 103 $\mu g/m^3$outside the booth, despite the facts that the booth had poor door seals, used recirculated rather than fresh air, and had foam (rather than higher efficiency) filters (Document ID 0203, pp. 12-13).

In a study of the Australian extractive (mining) industry, eight full-shift PBZ respirable silica samples obtained for rock crushing operators who controlled the dry process from inside air-conditioned cabins ranged from less than or equal to the limit of detection

(LOD) of 20 μg/m^3 to 400 μg/m^3, with a median of 65 μg/m^3 (Document ID 0647).[269] Four of the eight sample results were at or below 50 μg/m^3, and at least two of the sampled workers occasionally exited the cabins to free machinery blockages[270]. The investigators noted that, although air-conditioned cabins were widely used in the crushed granite industry, the air conditioning systems were inappropriate and poorly maintained, and housekeeping within the cabins was poor (Document ID 0644, p. 9). When compared with the measurement of 300 μg/m^3 reported above for the rock crushing operator using LEV but no cabin, the median of 65 μg/m^3 represents an exposure reduction of almost 80 percent. The Australian study also included a 40 μg/m^3 result for an operator of a mobile crusher who worked remotely in a pressurized cabin (Document ID 0647, (pdf) p. 34, sample # 7095). Other studies of operator cabs also report silica or dust exposure reductions ranging from 80 percent to greater than 90 percent (Document ID 0589; 0590; 1431, p. 3-95).

In the Preliminary Economic Analysis (PEA), OSHA recognized that control booths for crushers are commercially available, although they are not commonly used on construction sites[271] (Document ID 1720, p. IV-494). However, Kyle Zimmer, a master trainer with IUOE, stated during the hearings that “contractors report that they are using portable crusher control booths with air conditioning to operate the plant remotely” (Document ID 3583, Tr. 2341). The IUOE addressed the utility of remote controls in their comments on the proposed rule (Document ID 2262, p. 45; 3583, Tr. 2341), and requested OSHA to evaluate remote control technologies as an exposure control method and to include this type of control in Table 1. While OSHA believes that remote control

[269] The sample results representing crusher operators in air-conditioned cabins are as follow: sample # 7036 and 7026 on (pdf) p. 18; sample # 6549 on (pdf) p. 22; sample # 6507 on (pdf) p. 23; sample # 6511 on (pdf) p. 24; sample # 6521 on (pdf) p. 25; sample # 6411 on (pdf) p. 27; and sample # 7100 on (pdf) p. 42.

[270] These sample results could not be added to OSHA’s exposure profile, since they are for workers not regulated by OSHA. These samples were foreign data, and in addition, OSHA does not regulate the mining sector. Nonetheless, these exposure results demonstrate the effectiveness of ventilated booths in controlling exposures during rock crushing operations.

[271] Control booths are more commonly used at fixed plants and mining operations.

operations have significant potential to reduce exposures, the data shown above suggest that it may not achieve exposures at or below 50 µg/m³ by its independent use.

Local Exhaust Ventilation (LEV)

The use of LEV systems at feed hoppers and along conveyor belts can aid in reducing respirable quartz levels. The available data, however, suggest that LEV alone may not always be effective in substantially reducing exposure levels associated with mobile crushing equipment. One sample, obtained by Ellis Drewitt for an Australian worker crushing quartzite stone with a dust extraction system as the only control method, resulted in an 8-hour TWA respirable quartz result of 200 µg/m³ (Document ID 0647, (pdf) p. 25, sample # 6518). ERG-C (2008) describes this study in more detail (Document ID 1431, p. 3-94).

Another international report, this one from Iran, describes a site where workers used rock crushers with only LEV controls. Although the LEV reduced exposures more than 90 percent, exposures were still elevated (Document ID 1720, pp. IV-491--492; 1325).

Although LEV shows promise for some types of construction equipment, it has yet to be proven practicable for mobile construction crushing equipment and is not currently used extensively. William Turley of the Construction & Demolition Recycling Association stated, “While there are crushing operations that have used baghouses on the crusher, none use…ventilation equipment for conveyors” (Document ID 2220, p. 2).

As described below, a notable amount of air (6,500 to 8,500 cubic feet per minute [cfm], with a wet air scrubber system) must be exhausted from crushing machines used underground in the mining industry. A somewhat lesser amount might suffice above ground but other challenges would need to be overcome. The challenges include problems with maintaining airtight enclosures around the crusher and conveyors on this type of equipment, which vibrates violently, and with housing a power generator, fan, and air-cleaning device of sufficient size on the mobile crusher chassis (Document ID 1720, p. IV-492). Phillip Rice of Fann Contracting, Inc., contended that large crushing systems with multiple conveyor belts would make it very difficult to use local exhaust ventilation cost effectively (Document ID 2116, p. 31). In contrast, Mr. Zimmer of the

IUOE testified that employers are using dust collectors with baghouses at some crushing operations (Document ID 3583, p. 2341). Nevertheless, the record does not contain substantial and convincing evidence that LEV alone can be applied when using portable crushing machines to reduce exposure levels to or below 50 μg/m^3.

Combination of Controls

From the discussion above, it is clear that no single exposure control approach is likely to consistently achieve crusher operator exposures at or below 50 μg/m^3. It is not clear from the record whether water spray systems alone would be sufficient. Although one survey of a demolition project found no detectable silica exposure when the material being crushed was wet from rain (Document ID 4073, Attachment 10a), other surveys have found exposures to be in excess of 50 μg/m^3 when using water for dust suppression (Document ID 0030; 4025, Attachment 2C). However, it is not clear from these surveys that water was applied effectively. There are no data in the record that would provide good information on the effectiveness of properly designed water spray systems that follow spray nozzle manufacturers' recommendations or take advantage of foams or wetting agents. OSHA expects a properly designed system would demonstrate improved exposure reduction over the use of manual hoses, as used on the site visited by ERG (Document ID 0203).

It is clear that operators experience high exposure levels when they must operate the crusher unprotected from above the feed hopper where dust emissions are highest (Document ID 0030; 4073, Attachment 10a). Evidence in the record suggests that use of ventilated control booths alone is effective but might not be sufficient to maintain silica exposures at or below 50 μg/m^3. A study of crushers used in the Australian extraction industry found operator exposures ranged from 20 to 400 μg/m^3, with half of the samples below 50 μg/m^3, while crushing dry material and using control booths or cabs (Document ID 0647). OSHA had no data describing exposures to silica that result from using remote controls without water. The combination of water use and either remote controls or a ventilated booth for the operator appears to be the most effective control option for minimizing operator exposures. Summary data submitted by the IUOE shows that, with water use, the addition of remote control stations further reduced operator exposures by a factor of three (Document ID 4025, Attachment 2C, p. 3). At the crusher operation visited by ERG, the operator's TWA exposure was 54 μg/m^3 while working in a booth, and his exposure would have been lower had water been applied to dried material he was shoveling from under the conveyor.

Exposure and controls for crushing machine tenders (laborers)

The use of a tender would depend upon the complexity of the material being crushed. When there is a lot of unwanted debris that has to be removed prior to crushing, this would require the use of tenders. Likewise, when multiple crushers are in a series, it would be more likely that tenders would be used to assist the crusher operator.

OSHA identified one exposure measurement for a laborer working near a mobile crusher at an asphalt plant; the laborer was exposed to a respirable crystalline silica concentration of 43 μg/m^3 (8-hour TWA) based on a half-day of sampling (Document ID 0186, pp. 60-61). In addition to assisting with the crusher operation, he also mixed a blend of sand, crushed concrete, asphalt, and soil, which likely contributed to his exposure. The enforcement officer noted that he worked about 50 feet from the point of dust generation from the crusher and that his exposure from the crusher was "much lower" than that of the operator (Document ID 0186, p. 37). Bello and Woskie found exposures of all demolition workers except for the crusher operator to be below 50 μg/m^3 (Document ID 4073, Attachment 9a, pp. 3-4). The potential exposure of tenders and other workers who are in the vicinity of crusher operations underscores the importance of using water spray systems to reduce dust emissions. Such systems will reduce dust exposures generally, thereby reducing exposures for tenders and other workers in the vicinity of the crusher. Water spraying systems on the crusher and spill points of the belt will reduce exposures to the crusher operator, crusher tender, and other nearby worker bystanders. OSHA thus rejects the contention of CISC that the absence of direct evidence of exposures to tenders means that OSHA cannot regulate them or draw reasonable inferences about the technological feasibility of controlling their exposures (Document ID 2319, Attachment 1, p. 683).

5.10.4 Feasibility Finding

Paragraph (c) of the construction standard gives employers the option of following Table 1, which includes specified engineering controls for crushers; alternatively, the employer must assess and limit exposures in accordance with the more traditional regulatory approach contained in paragraph (d). For crushers, the two specified controls in Table 1 are as follows: (i) equipment designed to deliver water spray or mist for dust suppression at the crusher and at other points where dust is generated (e.g., hoppers, conveyors, sieves/sizing or vibrating components, and discharge points); and (ii) a remote control station or ventilated booth that provides fresh, climate-controlled air to the operator. When the controls described in Table 1 are implemented, the operator is not required to use a respirator even when performing tasks outside of the booth while the crusher is operating. Both water spray systems and remote stations or filtered booths are available for mobile crushers used on construction sites.

Wet spray methods can greatly reduce the exposure levels of operators and laborers who work near crushers, tending the equipment, removing jammed material from hoppers, picking debris out of the material stream, and performing other tasks. These systems are currently available and all crushers and associated machinery (conveyors, sizing screens, discharge points) can be retrofitted with water spray and foam systems (Document ID 1360; 0769; 0770; 0830). Information from the International Union of Operating Engineers, the Building Construction Trades, and the U.K. Health and Safety Executive show that water application can be expected to reduce exposure levels from 78 to 90 percent (Document ID 1330; 4025, Attachment 2C; 4073, Attachment 9a, pp. 1-4; 4073, Attachment 15g, p. 2). Using the mid-point of this exposure control range (84 percent) and applying it to the highest value in the exposure profile (300 μg/m^3), would yield an exposure of slightly less than 50 μg/m^3 TWA for an eight-hour work day. However, other evidence suggests that wet spray methods may not consistently achieve exposures at or below 50 μg/m^3 (Document ID 0030; 4025, Attachment 2C), although little detail was available on how water was applied. Therefore, OSHA finds that it is also necessary to require employers to use remote control stations or filtered booths to ensure the protection of crusher operators. With this combination of controls, OSHA finds that operator exposures will be maintained at or below 50 μg/m^3 and Table 1 does not require respirator use. Table 1 does not require respiratory protection for tenders or others working nearby because the use of water systems should serve to limit dust emissions and, hence, the exposure of nearby workers, to levels below the final PEL.

OSHA concludes that approximately 37 percent of crushing machine operators and tenders are currently exposed to silica levels at or below 50 μg/m^3. For workers who are currently exposed above 50 μg/m^3, the controls described in this section can be implemented to reduce silica exposure levels to 50 μg/m^3 or below in most operations, most of the time. Therefore, OSHA finds that the standard is technologically feasible for crushing machine operators and tenders.

5.11 TUCKPOINTERS AND GRINDERS

5.11.1 Description

Tuckpointers and other grinders work with masonry or concrete using handheld tools fitted with rotating abrasive grinding blades, discs, or small drums. Tuckpointers are a subset of grinders who specialize in removing deteriorating mortar from between bricks and replacing it with fresh mortar. Other grinders use various grinding tools to smooth, roughen, or reshape concrete surfaces (including forming recesses or slots). This second group also includes workers who use handheld power tools to remove thin layers of concrete and surface coatings, if present (e.g., performing small-scale spot milling, scarifying, scabbling and needle-gunning).[272] Although tuckpointing is most commonly performed for exterior wall maintenance and so generally occurs outdoors, construction workers who perform concrete surface grinding work both indoors and outdoors (Document ID 1431, pp. 3-16 – 3-17).

Tuckpointing work proceeds in two alternating phases: first, the dusty job of grinding old mortar from between bricks on a section of wall, and second, replacing it with fresh mortar, an activity that does not typically generate dust. At larger job sites, tuckpointing is performed by multiple workers standing a few feet apart, often working from platforms and scaffolding. In addition to grinding, the initial phase includes a cleaning step, during which the worker brushes dust and debris from the joints, although water or compressed air are sometimes also used for this purpose. The second phase involves at least one tuckpointer preparing batches of new mortar (sand, cement, and water), which is distributed to all of the site's tuckpointers who use it to refill the joints between bricks (Document ID 1431, p. 3-17). Using data on time spent on individual tasks and sample duration from a large data set compiled by Flanagan et al., OSHA calculated that the

[272] This section covers workers who use handheld tools. Workers performing large-scale milling, scarifying, and scabbling activities with driving or walk-behind equipment are covered in Section IV-5.8 – Millers Using Portable or Mobile Machines in this technological feasibility analysis.

median task time for mortar grinders during tuckpointing was 212 minutes (range 2-476 minutes) (Document ID 0677, Attachment 2).[273]

Workers who grind on concrete also do other work with concrete when they are not grinding. They might mix fresh concrete to repair damaged surfaces that they previously removed. At some sites, they also perform “sacking”—rubbing a porous sack of cement and silica flour over a damp concrete surface to seal small holes in the concrete surface (Document ID 1431, p. 3-16). The levels of exposure of workers who grind mortar or concrete are determined by work practices, the type of equipment used and environmental factors. When workers reach above shoulder height, debris can fall into their breathing zone, entraining fine particles in the same direction. Additionally, the speed with which dust disperses from the breathing zone of workers is limited at indoor sites or where tarp-style shrouding is erected around the workers to minimize the spread of dust from the construction site during tuckpointing or grinding (Document ID 1720, p. IV-499).

Based on the materials referred to above, including the Flanagan data set, OSHA concludes that handheld grinders are not normally operated for an entire shift, but more often for tasks lasting less than 4 hours (Document ID 1423, p. 833; 0677, Attachment 2). Scott Walker of Walker Flooring and Interiors, on behalf of the World Floor Covering Association (WFCA), stated:

It would be rare for an installer to cut and grind stone, concrete or tile for more than an hour or two on a job, depending on its size. In a given year, it is unlikely that any employee of our company or any employee of any independent installation contractor would cut or grind concrete, stone and tile for more than a total of 20 hours and never for more than 40 hours during that entire year (Document ID 2359, Attachment 4, p. 2). In the Preliminary Economic Analysis (PEA), OSHA preliminarily determined that the time

[273] Task duration calculated from information in Document ID 0677, Attachment 2 using sample duration (column S) multiplied by percent time on task (column O) for the 52 samples with valid information in both columns. Note that a value of 1000 in column O represents a lack of data, so those samples were omitted.

workers spend grinding varies widely, from 1 hour up to a full 8-hours or longer (Document ID 1720, p. IV-499).

Using data on time spent on individual tasks and sample duration, OSHA calculated that the median task time in this data set for cement finishers using surface grinders (described in Table IV.5.11-A as "Grinders") was 88 minutes (range 20-231 minutes) (Document ID 0677, Attachment 2).

Table IV.5.11-A presents a summary of the primary activities associated with silica exposure of workers in each job category.

Table IV.5.11-A
Job Categories, Major Activities, and Sources of Exposure of Tuckpointers and Grinders

Job Category*	Major Activities and Sources of Exposure
Tuckpointer	Using handheld angle grinders to remove deteriorating mortar from joints between bricks. • Dust from high speed abrasive grinding of mortar. • Dust disturbed when debris removed from newly ground joints (brushing or using compressed air).
Grinder	Using various handheld power grinding tools on concrete and other building materials to smooth or modify the surface (including cutting recesses). • Dust from abrasive action on concrete surfaces (e.g., grinding, milling). • Dust from sweeping and brushing (housekeeping). • Dust from "sacking" to seal imperfections in concrete surfaces (occasional).

*Job categories are intended to represent job functions; actual job titles might differ and responsibilities might be allocated differently, depending on the site.

Source: Document ID 1720, p. IV-499.

5.11.2 Exposure Profile and Baseline Conditions

In the PEA, OSHA reviewed 153 personal breathing zone (PBZ) samples associated with tuckpointing and 48 samples obtained for workers performing other types of grinding on concrete. These samples were obtained during NIOSH evaluations, OSHA Special Emphasis Program (SEP) inspection reports, and other published and unpublished sources. In developing its final exposure profile for tuckpointers and grinders, consistent with the procedures in Section IV-2 – Methodology, OSHA added 30 more recent exposure monitoring results obtained through OSHA's Information System (OIS) (Document ID 3958). In addition, OSHA added nine individual exposure results submitted to the rulemaking record by Francisco Antonio Trujillo of Miller and Long (Document ID 3498; 3499) that were identified as PBZ samples representing 8-hour TWA exposures. Two samples were added in a new category: grinding indoors with water. The final exposure profile table, Table IV.5.11-B, contains 168 exposure samples for tuckpointers and 72 samples for grinders, which constitute the best data available on baseline exposures for tuckpointers and grinders. The exclusion of the samples collected before 1990, along with the addition of more recent data in the final exposure profile, resulted in a slight decrease in the overall median exposures for tuckpointers and grinders, an increase in the percentage of samples at or under 50 μg/m^3, and a slight decrease in the percentage of samples over 250 μg/m^3.

Baseline Conditions for Tuckpointers

The OSHA contractor ERG reviewed working conditions for tuckpointers and determined that they typically work outdoors, with no special controls. They frequently work on scaffolding platforms or swing stages, and several tuckpointers often work in close proximity to each other. Tuckpointers also routinely brush dust and debris away from newly ground joints (Document ID 1431, pp. 3-19 – 3-20). The exposure profile in Table IV.5.11-B includes 168 samples of respirable crystalline silica for tuckpointers. The median is 313 μg/m^3, the mean is 1,477 μg/m^3, and the range is 10 μg/m^3 to 75,153 μg/m^3. Of the 168 samples, 133 (almost 80 percent) are above 50 μg/m^3, and 114 (approximately 68 percent) exceed 100 μg/m^3. Only 20.8 percent of tuckpointer exposures are less than or equal to 50 μg/m^3, with 35.7 percent of the samples representing use of local exhaust ventilation (LEV) on the mortar grinder. For 94 samples where tuckpointers worked outdoors with no exposure controls, levels were extremely high and 69.1 percent of the results exceeded 250 μg/m^3, with a median exposure of 591 μg/m^3 and a range of 12 μg/m^3 to 12,616 μg/m^3. These exposure levels are in the same range as those that have been reported or reviewed by Flanagan et al., Yasui et al., Flynn and Susi, Meeker et al., and in additional reports as summarized in the ERG analysis

(Document ID 0676, p. 322; 1237, p. 980; 0681, pp. 271 - 273; 0803, p. 108; 1431, pp. 3-17 - 3-19). One exception is the work from Ireland on stone and monument restoration work where 96 percent (22/23) of the lime mortar repointing exposure levels were less than the limit of detection of 20 μg/m^3 (Document ID 3608, p. 12).[274] Since lime mortar is softer than modern Portland cement mortar, removal may require less vigorous grinding producing less airborne dust.

Table IV.5.11-B shows that even higher sample results (12 samples, with a range of 147 μg/m^3 to 75,153 μg/m^3, a median 793 μg/m^3, and all exposures over 100 μg/m^3) were found when tuckpointing under “other conditions”, that is, indoors or in areas with limited air circulation. The “other conditions” category shown in Table IV.5.11-B also includes exposures where ineffective dust controls were used, for example wetting the wall before grinding, or using damaged LEV equipment. In contrast, the two workers, listed in the table under “mixing mortar”, who primarily mixed fresh mortar and delivered it to other tuckpointers, who then used the mortar to fill joints between bricks, had very low exposures a mean of 15 μg/m^3, and a medium of 15 μg/m^3 (< LOD of 12 μg/m^3 - 18 μg/m^3) indicating that silica concentrations are low during periods of the shift when workers are not grinding mortar.

Despite the potential for extremely high exposures when controls are not used, tuckpointers clearly experience a significant reduction of exposures with the use of LEV. The exposure profile in Table IV.5.11-B shows a range of 10 μg/m^3 to 6,196 μg/m^3, a mean of 348 μg/m^3, and a median when using LEV systems of 68 μg/m^3, with 40 percent of samples at 50 μg/m^3 or below, 60 percent of samples at 100 μg/m^3 or below, and only 25 percent exceeding 250 μg/m^3, for uncontrolled tuckpointing samples, only 9.6 percent were at 50 μg/m^3 or below and 17 percent were at 100 μg/m^3 or below, while 69.1 percent exceeded 250 μg/m^3.

[274] The sampling and analytical method used in this study had an 8-hour TWA LOD of 20 μg/m^3 because a flow rate of 2.2 liters per minute (lpm) was used with a Higgins-Dewell cyclone, and the analytical lab reported a sample LOD of 20 μg (Document ID 3608, pp. 9, 12). NIOSH Method 7500 permits use of a Higgins-Dewell cyclone at 2.2 l pm (Document ID 0901, p. 1).

Baseline Conditions for Grinders

Working either outdoors or indoors, grinders use various handheld grinding and milling equipment to smooth or abrade concrete. The exposure profile in Table IV.5.11-B shows that 67 percent of samples were taken indoors; however, Joe Bonifate of Arch Masonry, which engages in cutting, drilling and grinding, stated that 99.9 percent of their work is done outdoors (Document ID 3587, Tr. 3655, 3671), suggesting that OSHA may have overestimated the percentage of this work that is done indoors, where exposures are generally higher.
The exposure profile in Table IV.5.11-B includes 72 samples of respirable crystalline silica for grinders. The median is 121 μg/m^3, the mean is 353 μg/m^3, and the range is 5 μg/m^3 to 3,831 μg/m^3. Of the 72 samples, 54 (75 percent) are above 50 μg/m^3, and 41 (57 percent) exceed 100 μg/m^3. Overall, only 25 percent of surface grinder exposures are less than or equal to 50 μg/m^3, with 44.4 percent of those samples representing use of some kind of engineering control (Table IV.5.11-B). Sampling results summarized by Croteau et al.; Linch; Flynn and Susi; Flanagan et al.; and numerous other reports noted in ERG-C (2008) also indicate similarly elevated exposure among workers performing grinding (Document ID 0611, p. 463; 0784, pp. 213 - 215; 0681, pp. 271-273; 0676, p. 322; 1431, pp. 3-17 – 3-19).

The exposure profile in Table IV.5.11-B shows that when working outdoors, grinders use dust controls approximately 25 percent of the time. Table IV.5.11-B further shows that 38.9 percent (7 out of 18) of uncontrolled outdoor samples exceeded 250 μg/m^3, with a range of 12 μg/m^3 to 737 μg/m^3, a mean of 214 μg/m^3, and a median exposure of 134 μg/m^3. Grinding indoors produced higher exposures with a range of 117 μg/m^3 to 1730 μg/m^3, a mean of 427 μg/m^3, and a median of 223 μg/m^3 for 10 uncontrolled samples. The exposure profile for controlled outdoor grinding shows a range of 29 μg/m^3 to 96 μg/m^3, and a mean of 55 μg/m^3, with 50 percent of exposures at 50 μg/m^3 or below and 50 percent of exposures at 100 μg/m^3 or below (median 47 μg/m^3). Thus, exposures for grinders are generally lower outdoors than indoors. As OSHA noted in the PEA, indoor workers often lack even the natural ventilation that can help keep silica concentrations from building up to extremely high levels (Document ID 1720, p. IV-504).

The exposure profile also shows that exposure levels are generally much lower overall where effective controls like LEV are used. Shrouds for grinding equipment are increasingly available; however, at sites that implement LEV dust control, the NIOSH reports submitted to the record suggest that these methods are generally not implemented in the most effective manner. For example, in one NIOSH assessment of LEV systems, dust leaks at connections of the air handling system were observed for one system, while another system had a vacuum hose that needed to be taped in place, and which fell off during one sampling event (Document ID 1385, pp. 5-6, 14). A worker at another site evaluated by NIOSH cleaned the vacuum filter by shaking it and banging it on the wall, which likely created a second source of dust exposure (Document ID 0857, p. 4). Nevertheless, compared with workers who use no controls, the median values provided in Table IV.5.11-B for workers using LEV are notably lower, both outdoors (47 μg/m^3) and indoors (122 μg/m^3) and none of the samples with LEV in use exceeded 250 μg/m^3. The data summarized in Table IV.5.11-B also includes two samples taken when grinding indoors with water material with low silica content. Both of these samples were below the LOD for silica.

Some concrete grinders perform "sacking" as part of their normal activities. Flanagan et al. compiled 13 silica results for workers performing sacking and although the geometric mean was 30 μg/m^3, 40 percent of results (5 of 13) exceeded 50 μg/m^3. The respirable dust samples contained a mean quartz content of 11 percent (Document ID 0676, pp. 321-322). These results were provided in summary form and lacked sufficient detail to include them in the exposure profile in Table IV.5.11-B. NIOSH obtained an 8-hour silica sample associated with an exposure of 64 μg/m^3 (18 percent silica on the filter) for a worker performing only sacking during the shift. The same report indicated that three other workers performed sacking in addition to concrete grinding during their shifts (Document ID 0217, pp. 5-6). Based on the relatively lower concentration of respirable crystalline silica and frequency of task, OSHA concludes that sacking contributes only modestly to the overall silica exposure for concrete grinders who perform this task during a portion of their shift; however, controlling exposure levels during sacking would be necessary in order to reduce grinders' silica exposures to below 50 µg/m^3. Grinders performing sacking are not presented separately in OSHA's exposure profile, since this activity is commonly a part of a grinder's work activities.

Table IV.5.11-B
Personal Respirable Crystalline Silica Exposure Range and Distribution of Results for Construction Workers: Tuckpointers and Grinders

	Exposure Summary			Exposure Range		Exposure Profile				
Tuckpointers and Grinders	**N**	**Mean ($\mu g/m^3$)**	**Median ($\mu g/m^3$)**	**Min ($\mu g/m^3$)**	**Max ($\mu g/m^3$)**	**< 25 ($\mu g/m^3$)**	**≥ 25 and ≤ 50 ($\mu g/m^3$)**	**> 50 and ≤ 100 ($\mu g/m^3$)**	**> 100 and ≤ 250 ($\mu g/m^3$)**	**> 250 ($\mu g/m^3$)**
Tuckpointers (Outdoors, uncontrolled)	94	1,499	591	12	12,616	6 (6.4%)	3 (3.2%)	7 (7.4%)	13 (13.8%)	65 (69.1%)
Tuckpointers (Outdoors, LEV)	60	348	68	10	6,196	12 (20%)	12 (20%)	12 (20%)	9 (15%)	15 (25%)
Tuckpointers (Other conditions)	12	7,198	793	147	75,153	0 (0%)	0 (0%)	0 (0%)	1 (8.3%)	11 (91.7%)
Tuckpointers (Mixing mortar)	2	15	15	12	18	2 (100%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)
Tuckpointers Subtotal	*168*	*1,477*	*313*	*10*	*75,153*	*20 (11.9%)*	*15 (8.9%)*	*19 (11.3%)*	*23 (13.7%)*	*91 (54.2%)*
Grinders (Outdoors, no controls)	18	214	134	12	737	2 (11.1%)	0 (0%)	4 (22.2%)	5 (27.8%)	7 (38.9%)
Grinders (Outdoors, with controls)	6	55	47	29	96	0 (0%)	3 (50%)	3 (50%)	0 (0%)	0 (0%)
Grinders (Indoors, no or general ventilation)	10	427	223	117	1,730	0 (0%)	0 (0%)	0 (0%)	6 (60%)	4 (40%)
Grinders (Indoor with LEV)	16	141	122	12	460	2 (12.5%)	2 (12.5%)	2 (12.5%)	8 (50%)	2 (12.5%)
Grinders (Indoor, overhead grinding, no controls)	9	1,404	373	49	3,831	0 (0%)	1 (11.1%)	2 (22.2%)	1 (11.1%)	5 (55.6%)
Grinders (Indoor, overhead grinding, with LEV)	5	50	47	13	86	1 (20%)	2 (40%)	2 (40%)	0 (0%)	0 (0%)
Grinders (Indoors, with water)	2	12	12	12	12	2 (100%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)
Grinders (Tunnel, natural draft)	3	597	628	178	985	0 (0%)	0 (0%)	0 (0%)	1 (33.3%)	2 (66.7%)
Grinders (Tunnel, overhead with LEV/remote)	3	7	5	5	10	3 (100%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)
Grinders Subtotal	*72*	*353*	*121*	*5*	*3,831*	*10 (13.9%)*	*8 (11.1%)*	*13 (18.1%)*	*21 (29.2%)*	*20 (27.8%)*
Tuckpointers and Grinders Total	**240**	**1,140**	**200**	**5**	**75,153**	**30 (12.5%)**	**23 (9.6%)**	**32 (13.3%)**	**44 (18.3%)**	**111 (46.2%)**

Table IV.5.11-B
Personal Respirable Crystalline Silica Exposure Range and Distribution of Results for Construction Workers: Tuckpointers and Grinders

	Exposure Summary			**Exposure Range**			**Exposure Profile**				
Tuckpointers and Grinders	**N**	**Mean (µg/m^3)**	**Median (µg/m^3)**	**Min (µg/m^3)**	**Max (µg/m^3)**		**< 25 (µg/m^3)**	**≥ 25 and ≤ 50 (µg/m^3)**	**> 50 and ≤ 100 (µg/m^3)**	**> 100 and ≤ 250 (µg/m^3)**	**> 250 (µg/m^3)**

Notes: All samples are personal breathing zone (PBZ) results and represent 8-hour time-weighted average exposures.
Job categories are intended to represent job functions; actual job titles might differ, and responsibilities might be allocated differently, depending on the site.
Percentages may not add to 100 percent due to rounding.

Sources: Document ID 1720; 3498; 3499; 3958; 0010; 0015; 0016; 0023; 0031; 0032; 0058; 0066; 0069; 0136; 0149; 0217; 0229; 0238; 0241; 0243.

5.11.3 Additional Controls

Additional Controls for Tuckpointers

The final exposure profile in Table IV.5.11-B shows that approximately 79 percent (133 out of 168 samples) of tuckpointers have exposures above the final PEL of 50 μg/m^3. Therefore, OSHA finds that additional controls will be necessary to achieve the PEL for these overexposed workers, including local exhaust ventilation and work practices, as discussed below.[275]

Important attributes of effective local exhaust controls, described in the following sections, include use of shrouds, vacuum cleaners employing a cyclone to reduce the debris reaching the filter (pre-separation), larger vacuums, and larger vacuum hoses.

Extensive research demonstrates the effectiveness of local exhaust ventilation systems that include use of a shroud around the grinding blade combined with a vacuum cleaner system that is used to suction (exhaust) air from these hoods to collect dust and debris (Document ID 0600; 0728; 0731, pp. 374-375; 0863, p. 27-35). These shroud and vacuum combinations were estimated to produce dust reductions of 83 to 95 percent (Document ID 0600, p. 880; 1143). A more recent study evaluated a variety of combinations of tuckpointing grinder shrouds and vacuum systems and found respirable silica reductions of 95.6-98.7 percent for three of these selected systems, with task-based short-term measurements of 0.091, 0.276, and 0.823 μg/m^3 (Document ID 4073, Attachment 9h, pp. 11-17).

Grinding related to tuckpointing and surface smoothing may take place on scaffolds. There were comments from CISC that the addition of LEV systems or water hoses may be both difficult and add some additional hazards (i.e., fall/tripping) to the work at heights (Document ID 2319, pp. 106, 110). Dust collector systems are currently used on scaffolds, however, as evidenced by one building project evaluated by Cooper et al. where dust collectors were used on scaffolds to grind mortar from the exterior walls of a

[275] Wet methods are rarely used for dust control during mortar removal due to a number of factors, including problems related to slurry management when grinding on horizontal surfaces. Slurry can lead to discoloration and staining of the brick (Document ID 1431, 3-21).

12-story building (Document ID 4073, Attachment 9L, p. 1). OSHA concludes that while LEV systems may pose some practical challenges in some work performed at heights, employers can usually surmount those challenges using the same techniques that they routinely use to hoist equipment and building materials onto scaffolds.

Shroud and Local Exhaust Ventilation

Recent dust control efforts for tuckpointing have focused on using a dust collection hood (also called a shroud) that encloses most of the grinding blade and a vacuum cleaner system that is used to suction (exhaust) air from these hoods to collect dust and debris. These shroud and vacuum combinations (standard for tuckpointing LEV dust control) generally capture substantial amounts of debris. In hearing testimony, Tom Ward of the International Union of Bricklayers and Allied Craftworkers showed a video of local exhaust engineering controls for tuckpointing and described them as "extremely effective" (Document ID 3585, Tr. 3069).

However, although capable of significantly lowering exposures, a shroud-and-vacuum LEV system may not be fully effective to achieve the PEL. Air monitoring samples summarized in Table IV.5.11-B show that even with these controls, silica exposures often exceed 100 μg/m^3, usually by many times (e.g., 25 percent of results exceed 250 μg/m^3 when workers use LEV for outdoor tuckpointing). An additional survey added to the docket reported results at two tuckpointing sites using vacuum and shroud systems. Exposures were measured for durations from 201 to 385 minutes of mortar grinding. These results were all above 50 μg/m^3 (range from 74 to 1100 μg/m^3). However, these data could not be added to OSHA's exposure profile because the individual sampling points could not be correlated to the task categories used in Table IV.5.11-B (Document ID 4073, Attachment 9L, p. 4).

A series of studies has shown that LEV control methods for tuckpointers can be improved dramatically by improving air flow rates through shrouds, ensuring that the air flow rates are maintained over the course of the work, and taking steps to train workers to use tools correctly. Computational and laboratory studies found that an air flow rate of 80 to 85 cubic feet per minute (cfm) is needed to efficiently capture dust generated by angle grinders used for tuckpointing (Document ID 0728, p. 366; 0600, p. 877).[276] This air flow rate captures most dust, as long as the shroud fully encloses the grinding blade. For tuckpointing, this means that dust is efficiently captured only if the airflow rate remains steady at the recommended flow rate and if the shroud fits snuggly against the wall, with minimal gaps due to work practices or variations in the wall surface.

Even a small decrease in flow rate has a negative impact on shroud effectiveness. Laboratory tests conducted by Heitbrink and Bennett indicate that a vacuum and shroud used by tuckpointers during grinding can reduce respirable dust emissions by a factor of more than 400 under ideal circumstances,[277] but this reduction factor dropped to 10 when vacuum airflow was reduced to less than 80 cfm (Document ID 0728, p. 375). The authors reported observing excessive visible dust during grinding of mortar with air flow rates of 20- 30 cfm, and concluded that a higher air flow is needed to control the dust exposure generated by mortar removal (Document ID 0728, p. 367). Furthermore, computational modeling showed that even a modest decrease in the airflow rate, from 85 cfm to 70 cfm, cuts the shroud's ability to capture dust by more than half. This research demonstrates the importance of maintaining flow rates in accordance with the manufacturers' instructions for effective dust control when using vacuum systems.

During typical use of these grinders, however, many factors can cause the air flow rate to diminish, such as grinding debris clogging the vacuum, vacuum hoses or vacuums that are too small, incorrect direction of the grinding wheel, and having too large of a gap

[276] ACGIH (2010), in Figures VS-40-01 to VS-40-03, recommends 25 cfm to 60 cfm per inch of blade diameter. For a 4-inch tuckpointing blade, 25 cfm/inch of diameter is equivalent to 100 cfm, slightly higher than the 80 to 85 cfm used by Heitbrink and Bennett (2006) (Document ID 0728) and Collingwood and Heitbrink (2007) (Document ID 0600).

[277] In this case, "ideal circumstances" were defined as a gap between shroud and wall of no greater than 0.5 inch at any time. This means that the wall structure must be even and intact, and the mortar must be in good condition—not chipped, cracked, or recessed more than 0.5 inch at any point during the tuckpointing. This is considered the ideal circumstance for studying the effects of air flow rate on dust capture. Investigators recognize, however, that most walls requiring tuckpointing are not in good condition, and this factor cannot be controlled at construction sites. This limitation increases the importance of managing the vacuum air flow rate, which can be controlled by selecting appropriate equipment and encouraging workers to use it correctly.

between the lowest surface (mortar) and the shroud.[278] Controlling these factors can improve the performance of tuckpointing grinder shrouds. Other factors, such as work technique and wall condition, interfere with the way the shroud fits against the wall, but only some of these factors can be controlled.

OSHA received several comments that shrouds would prevent tool operators from seeing their work (Document ID 2183, p. 3; 2316, p. 2; 2243, p. 1). NIOSH notes that a number of tool manufacturers have commercially available shrouds designed to ensure that operators can see their work:

> The shroud evaluated by Collingwood and Heitbrink [2007] by Industrial Contractors Supply has a large open area to allow the bricklayer to see his work. A shroud by Bosch includes a clear plastic insert to serve that purpose, while a shroud by DeWALT has a large cut-out for visibility. A thorough search of tool catalogs would identify other devices that offer visibility and meet the safety standards" (Document ID 4233, p. 9).

A tool catalog submitted to the record shows a grinding shroud that allows for "complete blade visibility" that "installs on *your* angle grinder – no need to purchase a separate or specific angle grinder" and goes on to list seven brands of grinder that this shroud can be used with (Document ID 3998, Attachment 10, p. 47).

In addition, OSHA has determined that there are several vacuum features, including filtration technology such as cyclonic pre-separators, together with larger vacuum hoses, and larger vacuums, that can enhance the efficacy of vacuum cleaners to maintain proper air-flow rate and thus reduce worker silica exposure. These features are described below. Heitbrink and Santalla-Elias experimentally observed that air flows decreased substantially as grinding debris accumulated in the vacuum cleaner. They found that as

[278] Combinations of hoods and vacuums have been evaluated in the past and were typically found to offer some level of silica exposure reduction, but exposure levels remained high (Document ID 0829, p. 9; 0632, pp. 459-460; 0611, p. 463; 1237, p. 980; and 0803, p. 108). These studies focused on other aspects of grinder-shroud use and were usually less prepared to provide the higher air flow rates used in the studies described in this section, or to confirm that air flow rates remained constant throughout the test periods.

the vacuum filled with debris, an initial flow rate of 80 cfm fell to levels as low as 30 cfm (Document ID 0731, pp. 374, 380).

One option for reducing exposure during grinding is using vacuum cleaners that include cyclones to collect debris before the air reaches the filters. Cyclonic pre-separators minimize the accumulation of debris on filters in the vacuum, enhancing the ability of the vacuum cleaner to maintain the initial air flow rate. When testing a vacuum cleaner model equipped with a cyclonic pre-separator, Collingwood and Heitbrink showed that the collected debris caused the average air flow rate to decrease only from 90 cfm to 77 cfm (Document ID 0600, p. 884).

In addition, using actual grinding debris obtained from tuckpointing worksites, Heitbrink and Santalla-Elías experimentally confirmed that vacuum airflow is quickly affected by dust load on vacuum cleaner bags and filters. In vacuum cleaners designed with filters, laboratory tests showed large pressure losses across filter material as the filters became clogged with dust. Pressure losses from clogged filters translate into reduced air flow, which in turn limits how well a shroud attached to the vacuum captures dust. During particularly dusty activities (such as mortar removal), the vacuum is required to capture more than 20 pounds of debris, including fine dust that cakes onto filters (Document ID 0731, p. 379). As the vacuum collects debris, vacuum airflow diminishes rapidly until the filter is properly cleaned according to the vacuum manufacturer’s instructions (Document ID 0731, pp. 374, 377, 380 – 382).[279] Heitbrink and Santalla-Elías evaluated two different brands of commercially available vacuum cleaners incorporating cyclonic pre-separation, manufactured by Tiger-Vac and Dustcontrol. Air flow rates for both of these vacuums was “largely unaffected” by debris accumulation up to 35 pounds. Debris accumulation also had very little effect on the flow rate measured before and after the filter was cleaned (Document ID 0731, pp. 377, 380). Similarly, during the Collingwood and Heitbrink field trials, the Dustcontrol vacuum cleaner with cyclonic pre-separator did not lose as much air flow as the vacuum cleaners designed with vacuum cleaner bags (bags are a

[279] Industrial vacuum cleaners use filters that can be cleaned and reused many times. These vacuum cleaners often include a feature that allows the vacuum to clean its own filter using a beater or puffs of air blown in the reverse direction to dislodge dust.

more common pre-separation method but are subject to clogging) (Document ID 0600, pp. 883-884).

Cooper and Susi used a Dustcontrol 2900c vacuum with ICS Dust Director shroud and Bosch tuckpointing grinder to evaluate dust control in a field experiment and found that use of the LEV system produced a 98.7 percent reduction in respirable crystalline silica concentration compared to tuckpoint grinding without the LEV system. Collecting short-term samples of about 16 minutes resulted in a range of silica concentrations between 0.069 and 0.137 μg/m^3, which when extrapolated to 4 hours of continuous tuckpointing in an 8 hour day would produce exposures with a mean of 45.5 μg/m^3 (range of < 34.5 μg/m^3 to 68.5 μg/m^3). The authors reported that in 4 hours of continuous grinding up to 130 pounds of dust would be collected and that flow rates in the vacuum dropped from 90 cfm to 80 cfm in as little as 8 minutes. Thus, regular stops to conduct the proper reverse air pulse filter cleaning procedure were crucial to successful dust control (Document ID 4073, Attachment 9M, pp. 4-5, 7-9).

Gail and Robert Brandys of Occupational and Environmental Health Consulting Services, Inc. submitted comments emphasizing the importance of effective HEPA filtration in protecting workers from silica dust, and recommend that Table 1 require that dust collectors used with grinders be equipped with HEPA filters (Document ID 1953, pp. 3-4). The Power Tool Institute (PTI) also recommended that HEPA filters be required for tuckpointing and grinding LEV (Document ID 1973, pp. 2-3).

Where a vacuum will discharge into an occupied workspace, best practice dictates the use of HEPA-rated final filters (Document ID 3581, Tr. 1561, 1594, 1652). However, in the case of grinding, and particularly tuckpointing, under field conditions, HEPA filters may rapidly clog, leading to an increase in static pressure drop. As described in the numerous studies by Heitbrink et al., an increase in static pressure leads to the loss of the airflow needed for LEV to effectively capture silica dust at the point of generation (Document ID 0731, pp. 375, 384). Respirable sized particles can be captured with 99 percent efficiency using filters with a lower rating than HEPA filters, which must remove particles of the most penetrating particle size, 0.3 μm (Document ID 3883, pp. 8-36 – 8-39). OSHA reviewed the information submitted on options for commercially available vacuums and noted that that many provide a filter efficiency of at least 99 percent (Document ID 0628, 4073, Attachment 9h, p. 49). This would allow longer tool usage before significant drops in static pressure of the dust collection system. These filters can provide an acceptable protective range to contain the large quantities of silica containing dust generated during mortar removal (Document ID 3883, pp. 8-36 to 8-39). Therefore, OSHA has decided not to require HEPA filters in Table 1 for dust collection systems used to support grinding or tuckpointing. Instead, Table 1 requires dust collectors that have a filter with 99 percent or greater efficiency.

To achieve the air flow rates needed for capturing debris during the grinding phase of tuckpointing, vacuums equipped with a cyclonic pre-separator require a 2-inch inside-diameter hose (to reduce resistance in the hose, which slows airflow), rather than a 1.5-inch hose. Some vacuums might require a minor modification to adapt them for use with a 2-inch suction hose and air flow rates must remain above 76 cfm to maintain sufficient air velocity in the hose to prevent debris from accumulating and plugging the hose (Document ID 0600, p. 885). ACGIH recommends an air velocity of 3,500 feet per minute to prevent debris such as mortar from accumulating in the hose (Document ID 3883, p. 5-10). An air flow rate of 76 cfm provides this air velocity. OSHA notes that accumulated material in the hose would further decrease the air flow rate.

Another method for reducing exposure is using larger, more capable vacuum cleaners. NIOSH reported on a field trial of ventilated grinders (i.e., grinders fitted with shrouds) attached to an oversized vacuum cleaner, which used two vacuum cleaner motors in parallel and also includes a cyclonic pre-separator. These two features, combined with a large, 1.7 square meter filter area, allows the powerful vacuum to generate a greater air flow rate (111 cfm) than smaller vacuums, including an identical vacuum with just one motor, which only generated an air flow rate of 76cfm (Document ID 0863, p. 27).[280] The second motor also provides more power so the vacuum could be expected to maintain

[280] The vacuums were Dustcontrol DC3700 model vacuums (one with a second motor factory installed). This model has been replaced with the DC3800 in the company catalog (Document ID 0628;0630).

that flow rate for longer under the dust loads created by tuckpointing than is typical of smaller vacuums (Document ID 0863).

During the field trial of this large and powerful vacuum, NIOSH measured the amount of debris collected, the percent of silica in the collected debris, and the concentration of respirable dust in the surrounding air when two otherwise identical vacuums were run at two different flow rates (76 cfm and 111 cfm) (Document ID 0863, pp. 24-28). NIOSH made these measurements over two days while two construction workers performed grinding for tuckpointing, each using the vacuum at a different air flow rate (Document ID 0863, p. 24). Data show that at the higher 111 cfm air flow rate, the shroud captured more debris while maintaining breathing zone respirable dust exposure levels that were lower (by one-half) than the levels achieved at the 76 cfm air flow rate. On both days, estimated silica levels were also lower (19 $\mu g/m^3$ and 26 $\mu g/m^3$) for the worker using the 111-cfm flow rate compared with estimated silica levels for the worker using the lower flow rate (49 $\mu g/m^3$ and 60 $\mu g/m^3$) (Document ID 0863, pp. 24-35).

Work Practices

In addition to using vacuums equipped with features to optimize flow rates and minimize filter loading, employers must train workers on the specific measures the employer has implemented to protect employees from exposure to respirable crystalline silica, including proper work practices to minimize exposure, and how to operate and maintain engineering controls.

OSHA's proposed entry for tuckpointers on Table 1 of the construction standard incorporated a number of important work practice controls (78 FR 56274, 56497). Proposed Table 1 required that the grinder be operated flush against the working surface, with grinding operations performed against the natural rotation of the blade (i.e., mortar debris directed into the exhaust). Computational modeling showed that to efficiently capture particles, the direction of the grinding wheel must rotate from the uncut mortar into the exhaust takeoff section of the shroud. Workers also need to use care in adjusting the grinding depth to the minimum depth necessary and in holding the shroud close against the wall. Minimizing the space between the shroud and wall to the extent practical is critical for optimal capture of the pulverized dust emitted from the grinding point (Document ID 0728, p. 376; 0600, p. 876). These proposed specifications received extensive comment from the regulated community.

A number of commenters discussed the difficulties of complying with the work practice controls specified in the proposed entry for tuckpointers on Table 1. Western Construction Group commented that it is not possible to always keep the grinder flush with the surface because the blade will be spinning at its full speed when cutting into the wall and when the blade is extracted from the surface, and explained that it would be difficult to keep the blade flush when removing vertical mortar joints (Document ID 2183, p. 2). OSHA acknowledges there are circumstances that do not always permit the tool to be operated in this manner, and has therefore removed this requirement from Table 1. However, OHA expects full and proper implementation of Table 1 controls, which may include keeping the blade flush with the surface whenever possible, in order to optimize the effectiveness of local exhaust capture.

Western Construction Group also commented that it is not always possible to operate the grinder against the natural rotation of the blade, because a wall needs to be “prepped” in order to be in sufficient condition for mortar to be placed back into the wall (Document ID 2183, pp. 2-3). Western Construction Group explained that during final preparation, the blade needs to make short passes back and forth to clean the joint and prepare it, and that if workers only operated in one direction, they would place a significant burden on their shoulders and backs by having to make more passes on the wall to clean the joint (Document ID 2183, p. 3). Similarly, CISC commented that workers must move the grinder back and forth in short, deliberate motions when detailing the joint in order to provide the necessary quality finish (Document ID 2319, p. 106). OSHA recognizes that the requirement to operate against the direction of blade rotation may have an impact on job quality and may increase ergonomic stressors. While OSHA has removed this specification from Table 1, OSHA expects full and proper implementation of Table 1 controls, which may include operating against the direction of blade rotation, in accordance with manufacturers’ instructions, whenever practical.

The proposed entry for Table 1 also specified that the equipment must be operated such that no visible dust is emitted from the process, and that sufficient ventilation must be provided when working in enclosed spaces to prevent build-up of visible airborne dust (78 FR at 56497). OSHA has retained a specification in Table 1 requiring that for tasks performed indoors or in enclosed areas, the employer is to provide a means of exhaust as needed to minimize the accumulation of visible airborne dust. Western Construction Group noted that "the use of air scrubbers and fans … have been proven to be a very efficient, practical, tool in the control of silica exposures" and that "[t]hese control measures should [be] researched by OSHA as-an acceptable method in certain circumstances" (Document ID 2183, p. 3). OSHA is not specifically requiring the use of air scrubbers when working in enclosed spaces or indoors, but employers are free to use then in order to reduce visible airborne dust accumulations and comply with Table 1.

OSHA received many comments to the effect that the original specification that no visible dust be emitted from a process is not workable (Document ID 2563; 2169; 2171; 2183). For example, the Power Tool Institute commented that there will always be visible dust when tuckpointing when working around corners of a building (Document ID 1973, pp. 3-4). However, Power Tool Institute stated that an unusual amount of dust would signal to the operator that the dust collection system is not operating properly, and suggested that OSHA specify: "During operation, if excessive visible dust is emitted from the process, immediately stop work and verify that the dust control system is functioning properly" (Document ID 1973, p. 3). OSHA recognizes that brief, intermittent release of visible dust does not necessarily indicate that local exhaust ventilation controls are not performing optimally. Nonetheless, OSHA expects employers to train workers to ensure they can recognize unusual conditions that would be indicative of exhaust system performance degradation. The written exposure control plan required by the standard must include procedures to ensure the full and proper implementation of the engineering controls and work practices. In response to these comments, OSHA has modified Table 1 to no longer prohibit the emission of visible dust, but to require that employers use grinders equipped with commercially available shroud and dust collection systems that are operated and maintained in accordance with the manufacturer's instructions to minimize dust emissions.

Additional work practice controls include training workers to know when and how to clean vacuum filters to prevent caking. Filter caking causes pressure losses that eventually limit air flows in even the most powerful vacuums. These air flow limitations fluctuate in a predictable cycle: First, as debris accumulates, the pre-filter becomes caked with collected dust and air flow decreases; then, periodically, the worker shifts to a new position on the surface being worked and moves the vacuum cleaner or at least turns it off and on. These activities cause a modest portion of the caked debris to fall off the pre-filter, increasing flow rates temporarily. Unless the filter is properly cleaned following manufacturers' recommendations, these cyclic increases are short-lived, and airflows decline again rapidly (Document ID 0730). To assist workers in determining when it is time to run a filter cleaning cycle, vacuums can be fitted with a gauge indicating filter pressure (Document ID 0731, p. 885). Construction site policies must also ensure that vacuum equipment is routinely maintained and kept in good working order.

Studies have shown that worker training improves dust capture even for vacuum designs that do not maximize air flow rate. Even when workers used standard vacuums designed with bags, filters, and 1.5-inch hoses (all features that ultimately decrease air flow rates as debris accumulate), Collingwood and Heitbrink recommended workers periodically dislodge debris on filters, (Document ID 0600, p. 885). The authors reported a geometric mean result of 60 µg/m^3 when using grinders equipped with LEV, which represents a 95-percent reduction compared with the geometric mean of 1,140 µg/m^3 for a group of tuckpointing exposure levels obtained from numerous other construction worksites and used for comparison.[281]

OSHA finds that a key factor in ensuring control effectiveness is the full and proper implementation and maintenance of commercially available engineering controls designed for dust control when operating handheld grinders for tuckpointing or surface smoothing. To that end OSHA agrees with the approach recommended by NIOSH and other commenters who strongly endorse the role of a competent person in the

[281] For this comparison, Collingwood and Heitbrink (2007) report that they used a database of silica exposure values collected by OSHA and compiled during numerous construction site inspections. Qualifying data from this Shields (2000) database were included in ERG's exposure profile (ERG-C, 2008) and in OSHA's present exposure profile.

implementation of controls as well as the performance of regular checks to assure that required engineering controls are used, are functioning properly, and are maintained in proper operating condition; (Document ID 2177, Attachment B, p. 9; 2371, pp. 19-21).

Additional Controls for Grinders

The final exposure profile in Table IV.5.11-B shows that approximately 75 percent (54 out of 72 samples) of workers using handheld grinders to smooth surfaces or for uses other than mortar removal have exposures above the final PEL of 50 μg/m^3. Therefore, OSHA finds that additional controls will be necessary to achieve the PEL for these overexposed workers. Control options include wet grinding methods, LEV, remote operations, sustainable design, and, for grinders who perform sacking, substitution.

Wet Methods

Wet methods are an option when workers can use pneumatic grinders on concrete surfaces where emphasis is on structural integrity rather than aesthetics (e.g., parking garages, support columns, surfaces that will be covered during build-out). OSHA notes that the two exposure samples included in Table IV.5.11-B where wet grinding was performed, both indoors, were below the action level of 25 μg/m^3. Linch et al., (2002) found that silica exposures were below 100 μg/m^3 when a worker applied water from a sprayer can at the area where another worker was grinding a vertical concrete surface (Document ID 0784, p. 214). However, the 2007 and 2010 studies by Akbar-Khanzadeh et al. found that wet grinding in an enclosed test area with a retrofit system was significantly less effective than using LEV systems, and resulted in crystalline silica exposures between 331 and 929 μg/m^3 in one series of tests (Document ID 0522, p. 774), and between 270 and 2,080 μg/m^3 in the second (Document ID 3609, p. 707). These results indicate that the retrofit system studied by Akbar-Khanzadeh et al. was likely not as efficient as commercial wet grinding systems, and that the laboratory set-up reflected extremely confined conditions, with test conducted in a 24 by 15.4 by 17.3-foot space (Document ID 3609, p. 701).

The effectiveness of wet methods when using hand held grinders is demonstrated by sampling results from the cut stone industry where fabricators use hand held grinders to shape and polish granite counter tops. Simcox et al. reported that the 8-hour TWA exposures were reduced from 490 μg/m^3 when dry grinding to 60 μg/m^3 when using water-fed grinders on granite counter tops (Document ID 1146, pp. 578-579). Based on the exposure reductions observed when using wet grinders in the cut stone industry, along with the two measurements taken on workers using similarly equipped wet grinders in the exposure profile, OSHA concludes that the PEL of 50 μg/m^3 can be achieved most of the time through the use of wet methods when grinding outdoors.

OSHA received a number of comments related to the use of wet methods as a control for handheld grinders. Thomas Service from the Saw Manufacturers Institute (SMI) commented that use of a grinder that continuously feeds water to the cutting surface is not practical because “[t]here are no options available that are effective safety guards and feature water supply capability” (Document ID 2316, p. 2). SMI noted that “[w]hile some handheld spark-engine powered saws have coolant flow, coolant flow is not available for smaller electric and pneumatic grinders” (Document ID 2316, p. 2). SMI and CISC commented that some grinders equipped with a water delivery system are designed to cool the blade, rather than control the dust, and that the dust mitigation effects of the water are speculative (Document ID 2316, p. 2; 2320, p. 10) However, Dr. Paul Schulte of NIOSH reported that “several manufacturers of smaller grinders do offer electric grinders with integrated water supply capability” and included the catalog of such suppliers (Document ID 4233, Attachment 1, pp. 7-8; 3998, Attachment 10). OSHA concludes that there are commercially available grinders with integrated water supply capability, and that wet methods can be an effective control for grinding in many circumstances (Document ID 0522, p. 778; 1146, pp. 578-579).

Francisco Trujillo of Miller and Long commented that wet methods often present significant slip and fall hazards and present problems when the wet slurry dries and silica is introduced into the workplace through wind or foot traffic (Document ID 2345, p. 2). Mr. Trujillo also stated that attempting to apply wet methods to any non-horizontal surface has proven ineffective and often hazardous when using grinders (Document ID 2345, p. 2). Similarly, Stuart Sessions, testifying on behalf of CISC, noted that it is difficult to use wet methods in winter in locations where the water may freeze (Document

ID 3580, Tr. 1322). OSHA acknowledges that not every control option is practical in every situation. However, OSHA has concluded that wet methods represent a feasible and effective option in many settings.

CISC questioned the specification in the proposed Table 1 entry for handheld grinders to use a “water-fed” grinder when using water as an engineering control, asserting that there may be other ways to effectively deliver water through another mechanism (Document ID 2320, p. 10). The Power Tool Institute (PTI) commented that the use of a water feeding system not specified by the tool manufacturer could result in a serious personal injury and an electric shock for tools that are electrically operated (Document ID 1973, p. 1). Due to the potential electrical hazard from using a water delivery system not specified by the manufacturer, OSHA has modified Table 1 to require the use of integrated water controls that are operated and maintained in accordance with the manufacturer’s instructions to minimize dust emissions.

Based largely on the work of Akbar-Khanzadeh et al. described above, NIOSH recommended that respiratory protection be used to supplement the use of wet grinding systems even when used for less than four hours (Document ID 2177, Attachment B, p. 28). OSHA recognizes the precautionary principle in erring on the side of caution in respiratory protection recommendations; however, based on OSHA's conclusion, stated above, that wet methods are an effective control that will reduce grinders’ exposures to 50 $\mu g/m^3$ or below most of the time during outdoor grinding, OSHA is not requiring in Table 1 any respiratory protection when grinding outdoors and using an integrated water delivery system. However, OSHA acknowledges that confined and enclosed spaces may restrict air movement, resulting in higher exposures. Other than the experimental study by Akbar-Khanzadeh et al. and the two non-detect sample results for workers wet grinding a low-silica-containing material indoors, the record contains no evidence that would permit the Agency to determine the exposures to silica of workers using commercial wet grinding equipment indoors or in enclosed areas. Therefore, OSHA has not included an entry on Table 1 of the final rule for wet grinding indoors or in enclosed areas.

Shroud and Local Exhaust Ventilation

The LEV-based exposure controls for surface grinding function similarly to the LEV-based controls for tuckpointing described in the previous paragraphs, as tuckpointing is simply a specialized form of grinding. Tuckpointing is normally done on mortar between bricks, whereas grinding is performed on concrete; mortar and concrete are both mixtures of cement, sand, and water.[282] In both cases, a shroud encloses an abrasive disc- or wheel-style blade in order to capture the high-speed particles released from material pulverized by the blade.

Surface grinding differs from tuckpointing, however, in the shape and location of the surfaces that are worked. First, tuckpointing is generally limited to exterior masonry. Additionally, the aggressive cutting action of the tuckpointing blade tends to remove a greater volume of material at a faster rate than the smoothing action of the surface grinding blade, and so tuckpointing generates higher concentrations of dust. Tuckpointing and grinding are compared in Table IV.5.11-B.

The factors that influence vacuum flow rate for tuckpointing are equally important to LEV dust controls for all types of surface grinding, and for other hand-operated power tools as well. Collingwood and Heitbrink note that "vacuum cleaners will probably continue to be an important control option for respirable dust exposures in construction for dust exposure sources such as mortar removal, concrete grinding, hole drilling, and brick cutting where water application is impractical" (Document ID 0600, p. 884). Akbar-Khanzadeh & Brillhart and Echt & Sieber both reported reduced silica exposures when workers used LEV shrouds with vacuum attachments during surface grinding, although the silica exposure results were variable and some exceeded 50 μg/m^3 even with controls (Document ID 0521, pp. 344 - 345; 0632, pp. 459-460). Exposures measured within a test chamber during grinding operations confirm that high exposures result from grinding concrete indoors, even with good dust collection equipment, with mean task-based sample results generally falling between 100 and 200 μg/m^3 (Document ID 0522,

[282] The primary difference between concrete and mortar is the ratio of cement, sand, and other ingredients. Concrete is intended to stand alone and is fortified with stone aggregate, while mortar is intended to hold bricks together and so is created thin enough to be forced between bricks and is formulated to adhere well to masonry.

p. 774). However, older studies of LEV effectiveness have found reductions of 86 to 99 percent (Document ID 0611, p. 463; 0247, pp. 6, 8). A more recent study by Akbar-Khanzadeh et al. found 98 to 99 percent reductions, depending on the vacuum type used (Document ID 3609, p. 707). The use of ventilated overhead grinders on a cantilevered stand was reported not only to result in low dust exposures but also to improve the ergonomic stressors of overhead grinding (Document ID 1235, pp. 1-2).

OSHA received a number of comments from stakeholders about the effectiveness of using LEV dust control systems on handheld grinders. Miller and Long's Safety Director Francisco Antonio Trujillo stated "[D]ust collection systems used on hand grinders received very disappointing results. In fact, no hand grinder equipped with a dust collection system was capable of bringing exposure levels below the current PEL" (Document ID 3585, Tr. 2963). He further explained that this was due to the limited capabilities of the dust collection systems maintaining complete surface contact during the frequent grinding of columns and walls (Document ID 3585, Tr. 2963-2964.) But he also testified that a vacuum system designed for use with ceiling grinders "greatly reduced the amount of dust expelled from the process but did not completely eliminate it. It was a very, very dusty activity, and now it's moderately so" (Document ID 3585, Tr. 2962). Mr. Trujillo reported that although all sampling results were below the current 100 μg/m^3 PEL, three out of five samples were still above 50 μg/m^3. He also reported that none of the hand grinders with dust controls that Miller and Long evaluated were effective with columns and wall corners and that even with these LEV systems, Miller and Long had the same number of workers in its respiratory protection program (Document ID 3585, Tr. 2962-2964, 3012).

However, OSHA has reason to believe that the effectiveness of controls available today is likely higher than those that were used during the sampling included in the exposure profile. Gerry Scarano, Executive Vice President of the International Union of Bricklayers and Allied Craftsworkers, for instance, testified that since 2009, "the availability and effectiveness of control options have improved, adding force to OSHA's conclusion that it is feasible to reduce the dust in most cases down to the proposed PEL" (Document ID 3581, Tr. 1562).

Because the same factors that cause air flow to decline during tuckpointing affect air flow during other tasks such as surface grinding, the measures discussed for tuckpointing (e.g., larger vacuums and vacuum hoses, with effective means for preventing clogging of filters, such as cyclonic pre-separators) need to be used when surface grinding in order to minimize hose and filter clogging.

Echt and Sieber reported respirable quartz concentrations ranging from 44 μg/m^3 to 260 μg/m^3 during 2- to 3-hour surface grinding tasks with LEV at a construction site. Each day, one or two 18-pound bags of debris were collected in a vacuum cleaner. The investigators measured actual air flow rates three times over the course of five sampling days, reporting an air flow range from 86 to 106 cfm (Document ID 0632, pp. 459 - 460).[283] As noted in the discussion of LEV controls for tuckpointers, Heitbrink and Santalla-Elías also reported that portable shop vacuum air flow is affected by filter loading (Document ID 0731, p. 383). Using more extensive measurements (continuous data logging every 8 seconds), Collingwood and Heitbrink evaluated the same vacuum model used by Echt and Sieber and found that average initial air flow was 71 cfm, which declined to 48 cfm over the task-based work sessions during which trained workers performed normal tuckpointing, knocking the dust from filters using the manufacturer's recommended method as deemed necessary (Document ID 0600, p. 884).[284]

These changes in air flow can have a dramatic effect on dust capture. As discussed in the previous section on the review of additional controls for tuckpointers, experimental testing conducted by Heitbrink and Bennett indicates that a vacuum and shroud used for tuckpointing reduced the dust emission rates by a factor of more than 400 under ideal circumstances when air flow rates exceed 80 cfm. This factor dropped to approximately

[283] In this configuration, the vacuum did not use a cyclonic pre-filter (Document ID 0632, p. 460).

[284] OSHA notes that this comparison does not account for possible differences in hood entry loss for surface grinding shrouds compared to tuckpointing grinding shrouds (judged to be minor), or for other factors not reported in the reports by Echt and Sieber and by Collingwood and Heitbrink (Document ID 0632; 0600).

10 when vacuum air flow was less than 80 cfm (Document ID 0728, pp. 374-375).[285] The study authors reported that there was visible leakage of dust from the grinder shroud when the vacuum operated at flow rates between 20 to 30 cfm, and concluded a higher flow rate is needed for effective capture of dust generated by grinders during mortar removal (Document ID 0728, p. 367).

In some cases underpowered vacuums have been used to test grinder shroud effectiveness. Evaluating the effect of a standard shop vacuum (i.e., one not equipped with a filter-cleaning mechanism) and shroud on worker exposure during periods of intensive surface grinding, Akbar-Khanzadeh et al. (2007) determined that this LEV system significantly reduced geometric mean silica exposure levels compared with uncontrolled grinding by 99.7 percent; however, even with LEV controls, the average exposure measured over 6 trials was 155 µg/m^3 (Document ID 0522, pp. 774, 776). The grinder in this study was fitted with a 6-inch diameter blade and was equipped with a vacuum with a capacity of 105 cfm. Based on the ACGIH criteria air flow rate of at least 25 cfm per inch of blade diameter, an air flow of at least 150 cfm is recommended (Document ID 0515, p. 13-63).

Akbar-Khanzadeh et al. compared silica and respirable dust exposure samples during grinding in a test chamber with different vacuum systems: the Dustcontrol HEPA vacuum with cyclonic pre-separator (DC 2800c) and the tank based Eibenstock 1500 HEPA vacuum, and the 85L575 Shop-Vac Corp common shop vacuum. The study found that mean exposures when using the HEPA vacuums were lower (110 µg/m^3 and 170 µg/m^3 with and without general ventilation, respectively) than when the common shop vacuum system was used (120 µg/m^3 and 920 µg/m^3 with and without general ventilation, respectively). The Dustcontrol and Eibenstock systems operated with little maintenance during the experiments but the shop vacuum system experienced problems, including complete failure of 3 units (Document ID 3609, p. 707). Thus, similar to tuckpointing, surface-grinder LEV requires more capable vacuums than common shop vacuums. The

[285] Heitbrink and Santalla-Elías found that vacuum air flow rates declined from 80 to 30 cfm when vacuums captured 35 pounds of grinding debris in a laboratory test (Document ID 0731, p. 380-381). That study also showed that at a construction site, debris collected by vacuum bags during tuckpointing caused the average air flow rate to decrease from 80 cfm to 30 cfm (Document ID 0731, pp. 382-383).

effect is increasingly important when workers use larger grinding wheels. Akbar-Khanzadeh et al. (2010) also reported that when a 180mm grinding cup was used the mean silica task exposures were more than three times higher than when using a 100-125 mm grinding cup, even when using the stronger vacuum systems (Document ID 3609, p. 706).

OSHA received a number of comments about the proposed entry on Table 1 for handheld (or hand-operated) grinders using LEV. The proposed entry specified use of a grinder with a commercially available shroud and dust control system (78 FR at 56497). Several commenters questioned why shrouds need to be commercially available and whether appropriate shrouds are, in fact, commercially available (Document ID 2319, p. 105; 2316, p. 2; 2171, p. 9).

SMI and National Utility Contractors Association (NUCA) noted that use of non-compliant plastic shrouds could create a safety hazard for high-speed broken wheel fragments (Document ID 2316, p. 2; 2171, p. 9). OSHA agrees the shrouds which are not properly rated in accordance with the appropriate standards can pose a serious safety risk if grinding wheels break and has maintained the requirement for employers use commercially available shrouds.

SMI commented that there are no commercially available dust shrouds that currently meet ANSI B7.1 (and OSHA) guard design requirements (Document ID 2316, p. 2). SMI stated that available dust shrouds are plastic and are used in place of the original equipment’s steel guards but do not meet the requirements of ANSI B7.1, which is a safety design specification standard for grinding wheels (Document ID 2316, p. 2). However, NIOSH reported that several major tool manufacturers sell grinders with integrated dust shrouds designed to meet applicable safety standards and the tools are labeled accordingly. For example, the Underwriter’s Laboratory (UL) mark carried by the products of several manufacturers signifies that their tools meet the requirements of ANSI (American National Standards Institute)/UL/CSA 60745-2-3, which incorporates ANSI B7.1 by reference (Document ID 4233, p. 8). Catalogs of tool manufacturers submitted to the docket by NIOSH include grinders that meet this standard, and other tools that bear the SA approval mark of the Canadian Standards Association, an OSHA Nationally Recognized Testing Lab (NRTL, described under 29 CFR 1910.7) (Document ID 3998, Attachment 10, pp. 7-9, 15, 45). OSHA expects that, once there is a market demand, additional tool manufacturers will offer shrouds meeting these machine guarding requirements. Therefore, OSHA finds that compliant shrouds are commercially available, and will not create a greater hazard.

OSHA's proposed Table 1 entry for handheld grinders using LEV required the dust collection system to be equipped with a HEPA filter and operated at a 25 cfm or greater airflow per inch of blade diameter. CISC commented that for larger blades, it may be difficult to design and operate a system that pulls air flow at 25 cubic feet per minute per inch of blade diameter (Document ID 2319, p. 105). The Power Tool Institute (PTI) recommended revising the Table 1 entry for grinders to require use of vacuums equipped with a HEPA filter that operates at 80 cubic feet per minute or greater, noting that commercial dust collection systems are typically rated at approximately 130 cfm (Document ID 1973, pp. 2-3). The National Association of Home Builders (NAHB) expressed concern that a dust collector with a HEPA vacuum would need to be at least 112.5 CFM for a small, 4.5 inch grinder (Document ID 2296, Attachment 1, p. 29). The Building and Construction Trades Department of the AFL-CIO (BCTD) requested that OSHA specify flow rates for grinder LEV based on blade diameter (Document ID 2371, p. 32). In the proposed rule, OSHA set different cfm requirements for grinders and tuckpointers (25 cfm per inch for grinders, versus 80 cfm for tuckpointers). Since tools used for tuckpointing and other handheld grinding are so similar, OSHA finds that the same requirement is applicable to both. OSHA has opted for the 25 cfm per inch of blade diameter as the more protective approach, and more consistent with established engineering principles as reflected in the ACGIH Industrial Ventilation Manual, 28th Edition, which generally expresses minimum cfm requirements for a variety of (stationary) grinders in relation to the wheel diameter (Document ID 3883, pp. 13-147-13-152).

The exposure profile in Table IV.5.11-B shows that 60 percent of ceiling grinders who perform overhead grinding using LEV, and 50 percent of outdoor grinders using LEV or water have achieved exposures below 50 μg/m^3, while 25 percent of other grinders working indoors with LEV have achieved exposures below 50 μg/m^3. These results clearly demonstrate that the PEL of 50 μg/m^3 has already been widely achieved, with technology available at the time of sampling. Much of the data in the exposure profile reflects samples collected over ten years ago, before many of the engineering studies described in this chapter were conducted. OSHA expects that capture technology will continue to improve in response to market demand. When fully and properly implemented, as further described below under Work Practices, OSHA expects that exposures of 50 μg/m^3 or less can be achieved without reliance on respiratory protection for outdoor workers. OSHA notes that Table 1 specifies that exhaust ventilation must be used as needed to minimize accumulation of airborne dust when grinding indoors or enclosed areas. OSHA expects that these controls will be sufficient to protect workers during short-duration indoor grinding tasks, but has determined that respiratory protection will still be needed for indoor grinding tasks anticipated to last more than four hours per shift.

The conditions that cause the air flow rate of vacuum systems to decline during tuckpointing have the same effect on vacuum system air flow during surface grinding. As with tuckpointing, vacuum design components like cyclonic pre-separators, vacuums with two vacuum cleaner motors in parallel, and a gauge indicating filter pressure will all aid in maintaining adequate air flow rates during on-site usage. As these components are increasingly used in grinding applications it is expected that exposures will decline, particularly indoors and in enclosed areas.

Remote Operations and Combined Controls

Grinders who are able to distance themselves from the grinding point in addition to using LEV have substantially lower silica results than those whose breathing zone is within arm’s length of the grinder. Woskie provided information on a grinding tool fitted with LEV (shroud and HEPA-filtered vacuum, not described further) that was attached to a movable lever that allowed the worker to press the grinder against the overhead surface (at some distance ahead) by pressing down on the opposite end of the lever (Document ID 1235, p. 1). The three 1- to 2-hour personal breathing zone (PBZ) samples obtained were all below the LOD (29 μg/m^3 to 41 μg/m^3 in this case, based on an assumed 10 μg per sample LOD) for the period monitored, or 5 μg/m^3 to 10 μg/m^3 as 8-hour TWAs. Respirable dust results were between 9 μg/m^3 and 94 μg/m^3 during the period monitored, indicating that the workers experienced very little dust in their breathing zones during this task, as well as improved ergonomic considerations for the job. Although this dust control strategy appears highly effective, there is no other information in the record to indicate how broadly remote operations can be conducted or under what kinds of conditions it is feasible to employ remote operations. Therefore, although remote operations are not required, they remain an option for reducing exposures during overhead grinding.

Sustainable Design

When precast concrete is formed, design practices should indicate the placement of necessary grooves, cutouts, and contours so they can be cast into the concrete, nearly eliminating the need for high-silica-exposure activities such as grinding and cutting to produce these features. Similarly, WorkSafeBC supports work pre-planning as an effective strategy in eliminating the need for drilling holes in concrete (Document ID 4072, Attachment 14, p. 7). Careful form placement can also reduce the need for grinding to remove bulges and blemishes often caused by shifting or flawed forms. A factory evaluated by OSHA usually placed grooves in the precast concrete delivered to the construction site. On one occasion when the factory neglected to perform this task, workers experienced extremely elevated silica exposures while grinding overhead grooves at the construction site (Document ID 0031, pp. 27-33). These exposures (four results all between 2,420 μg/m^3 and 3,831 μg/m^3), the highest for workers grinding on concrete, would have been eliminated if the factory had placed the grooves in the precast product. Employers can drastically reduce grinders' silica exposures by selecting precast concrete that is formed to eliminate the need for grinding at the construction site. In hearing testimony, Mr. James Toscas of the Precast/Prestressed Concrete Institute stated that "[i]t's not typical for any fit-up work to be done that involves sawing or drilling concrete in the field. When that happens, it is usually because there was an error in the plans" (Document ID 3589, Tr. 4381). This suggests that preplanning is a practical and commonly used strategy for reducing the need for concrete grinding or use of other handheld power tools at a construction site, although grinding may be needed on occasion.

Substitution

Grinders that also perform “sacking” to seal imperfections in concrete surfaces can use alternate materials and methods to eliminate silica dust. Construction contractors can switch to concrete patching compounds that create the desired surface without labor-intensive finishing that involves rubbing dry concrete powder over the surface. Over the past decade, newer types of commercially available patching materials have begun replacing traditional sacking and patching methods previously used to repair concrete surface defects, thus eliminating that potential source of silica exposure (Document ID 1138, pp. 5-6). These patching compounds are suitable for patching both cast-in-place and precast concrete surfaces.

Where traditional methods are still in use, worker silica exposures can be reduced by using low-silica sacking powder (e.g., Portland cement) or by using mortar or concrete sacking powders made with silica sand that are larger than respirable size. For example, as part of the dry mix, some construction contractors performing sacking use 30-mesh sand instead of 60-mesh or smaller sand particles (Document ID 1138, p. 5). A 30-mesh sand contains a maximum particle size of approximately 230 micrometers (µm), compared with 100 µm for a 60-mesh sand or even smaller particles for sands with larger mesh numbers. As discussed in Section IV-4.9 – Glass Products, washing can remove the very fine respirable size particles (1 to 10 µm).

Mean quartz levels for sacking results reported by Flanagan et al. indicate that quartz was below the limit of detection in more than half (54 percent) of the samples for this activity, suggesting that many workers already use these alternate materials and methods (Document ID 0676, p. 322).

Work Practices

The same work practices described previously for tuckpointers are equally applicable for grinders. As with mortar grinding, it is equally important to maintain the grinder shroud as close as possible to the surface being worked, in order to better capture the maximum quantity of particles.

In the hearings, Francisco Antonio Trujillo of the Miller and Long concrete framing company testified that “there is no completely dustless method that I have personally observed in the real world” (Document ID 3585, Tr. 2960). CISC stated that “for certain types of tools, such as grinders and other handheld pieces of equipment, it is impossible to perform the work with the tool flush against the surface being impacted. At times, there may be a gap, this will mean some visible dust is emitted, even when local exhaust ventilation or wet methods are utilized” (Document ID 3580, Tr. 1356). OSHA recognizes that, due to corners and other changes in the work surface, gaps will momentarily occur.

OSHA also recognizes that brief, intermittent release of visible dust does not necessarily indicate that LEV systems are not performing optimally. OSHA expects that, in addition to as part of full and proper implementation of Table 1 controls and required training, workers will receive training to ensure they know how to effectively utilize controls to minimize dust release by minimizing gaps between the tool shroud and the work surface, and to recognize unusual conditions that would be indicative of exhaust system performance degradation. Where local exhaust is used, OSHA expects that employers will ensure that workers are trained in the proper use of grinders to ensure maximum capture efficiency of the shroud, and in when and how to clean vacuum filters to ensure that airflows are maintained, in order to ensure optimal performance of these engineering controls. In addition, the standard requires a competent person to make frequent and regular inspections of job sites, materials, and equipment to verify controls are properly implemented. In regards to wet methods that may be used for grinding activities, Table 1 specifies that water be applied at flow rates sufficient to minimize release of visible dust. OSHA intends that these work practice controls be used as part of the full and proper implementation of Table 1 controls.

5.11.4 Feasibility Findings

Paragraph (c) of the construction standard gives employers the option of following Table 1, which includes specified controls for tuckpointing and grinding activities; alternatively, the employer must assess and limit exposures in accordance with the more traditional regulatory approach of compliance with the PEL contained in paragraph (d). For handheld grinders used for mortar removal (i.e., tuckpointing), Table 1 requires employers to use a grinder equipped with a commercially available shroud and dust collection system. The tool must be operated and maintained in accordance with the manufacturer's instructions to minimize dust emissions. The dust collector must provide 25 cubic feet per minute (cfm) or greater of airflow per inch of wheel diameter and have both a filter with 99 percent or greater efficiency and either a cyclonic pre-separator or filter-cleaning mechanism. In addition, the entry for tuckpointing on Table 1 requires the use of respiratory protection (APF 25 for work that lasts more than four hours a shift; APF 10 for work of four hours or less). For handheld grinders used outdoors for other than mortar removal, Table 1 requires either a grinder equipped with an integrated water delivery system that continuously feeds water to the grinding surface or a grinder equipped with a commercially available shroud and dust collection system. In both cases the tool must be operated and maintained in accordance with the manufacturer's instructions to minimize dust emissions. If the employer uses the dust collection option, the dust collector must provide 25 cubic feet per minute (cfm) or greater of airflow per inch of wheel diameter and have both a filter with 99 percent or greater efficiency and either a cyclonic pre-separator or filter-cleaning mechanism. For tasks performed indoors or in enclosed areas, Table 1 requires that LEV systems be used and that respiratory protection (APF 10) be used for tasks performed more than four hours in a shift. Employers who choose to use wet grinding systems indoors or in enclosed areas must comply with the PEL and exposure assessment requirements in paragraph (d) of the final rule.

Feasibility Finding for Tuckpointers

Based on the evidence in the record, OSHA concludes that, for tuckpointing, commercially available shroud and vacuum LEV systems exist that significantly reduce exposures during mortar removal; manufacturers include Bosch, Hilti, Flex, Metabo, and others (see examples in Document ID 4073, Attachments 4a, 4b, and 9h; 3998, Attachment 10). Based on the exposure profile in Table IV.5.11-B, OSHA concludes that most tuckpointers (79.2 percent) currently experience exposures above 50 μg/m^3. Although some of the samples with exposure levels below the PEL are associated with mortar replacement and related tasks, 35.6 percent of those with low exposures were using mortar grinders with LEV systems while tuckpointing. OSHA notes that among tuckpointers using LEV outdoors, 40 percent of samples measured exposures below 50 μg/m^3.

When these systems are used in a manner consistent with the practices observed during the field trials reported by Collingwood and Heitbrink, silica exposures will be significantly reduced (Document ID 0600, p. 707). However, due to the high-intensity material removal associated with this task, the need to maintain a continuous air flow with the high volume of debris produced by tuckpointing, and the fact that mortar grinders cannot always be used flush with the surface, mortar grinding often results in exposures above the PEL even with proper implementation of engineering controls. For example, according to OSHA's exposure profile, tuckpointing outdoors with LEV systems will result in exposures exceeding 50 μg/m^3 more than half the time, and exceeding 250 μg/m^3 a quarter of the time, with a mean exposure of 348 μg/m^3. Task-based sampling of mortar grinding operations where modern dust collection equipment was used generally has shown exposures above 100 μg/m^3 (but not above 1000 μg/m^3) for the duration of the task (Document ID 4073, Attachments 9h and 9m). Based on these data, a worker engaged in mortar grinding for fewer than 4 hours per day can be expected to experience TWA exposures below 500 μg/m^3, while a worker performing this task more than 4 hours per day will be exposed up to nearly 1000 μg/m^3 TWA.

Thus, even using the controls described in this section, employers cannot attain the PEL of 50 μg/m^3 in most tuckpointing operations most of the time. As a result, OSHA cannot conclude that the final PEL is feasible for this type of work (Document ID 1720, p. IV-513). For employers following Table 1, the final rule requires, in addition to LEV, the use of respiratory protection having an assigned protection factor (APF) of at least 10 for operations taking less than 4 hours per day and an APF of 25 for longer operations. For tasks of less than four hours, OSHA has reduced the required APF from 25, as specified in the NPRM, to 10, but has added a general requirement that, for tasks performed indoors or in enclosed areas, employers implementing controls specified in Table 1 must provide a means of exhaust as needed to minimize the accumulation of visible airborne dust. OSHA anticipates that the addition of ventilation sufficient to prevent the accumulation of dust will result in exposures lower than those identified in the PEA (when an APF of 25 was proposed). Based on the evidence of continuing improvements in the effectiveness of LEV as reported in the literature, and the requirement to provide a means of exhaust as needed to minimize the accumulation of visible airborne dust, OSHA concludes that the reduction to an APF of 10 is appropriate for tasks of less than four hours duration.

OSHA notes that maximum exposures recorded in the profile for tuckpointers exceeded a tenfold multiple of the 50 $\mu g/m^3$ PEL. Whether employers follow the Table 1 option or the PEL option, the competent person and exposure control plan provisions apply and are essential in ensuring the effectiveness of engineering controls, work practice controls, and respiratory protection.

Feasibility Finding for Grinders

OSHA finds that 25 percent of grinders are currently exposed to silica levels at or below 50 $\mu g/m^3$. For workers who are currently exposed above 50 $\mu g/m^3$, the controls described in this section can be implemented to reduce silica exposure levels to 50 $\mu g/m^3$ or below in most operations, most of the time, with exceptions for grinding done indoors or in an enclosed area for more than four hours per shift. Both wet grinding and LEV systems described on Table 1 are commercially available; therefore, OSHA finds from the evidence in the record discussed above, that engineering controls, including LEV and wet methods, are feasible, effective in reducing exposures during grinding, and commercially available. There are several manufacturers of grinding tools equipped with dust collection or wet systems (Document ID 4073, Attachments 4a and 4b; 3998, Attachment 10). In addition, several participants testified about the commercial availability of such equipment, including Mr. Scarano of the Bricklayers; Mr. Johnson of the Operative

Plasterers and Cement Masons International Association; and Mr. Trujillo of Miller and Long (Document ID 3581, Tr. 1562; 3581, Tr. 1592-1593; 3585, Tr. 2962-2964). These sources indicate that Makita, DeWalt, Bosch, and Ostec all make grinding dust control systems.

When grinders are operated with controls outdoors, half of all grinders experience exposures below 50 μg/m^3, and OSHA expects exposures for most of the remaining grinders (outdoors) can be reduced to or below 50 μg/m^3 with increased use of more effective engineering and work practice controls. Based on the evidence in the record, OSHA concludes that both LEV and wet methods can be an effective control that will reduce grinders' exposures to 50 μg/m^3 or below most of the time during outdoor grinding. Therefore, OSHA finds that the standard is technologically feasible for workers using handheld grinders outdoors. However, unlike tuckpointing, surface grinding is a common indoor task. Based on task durations summarized by Flanagan, workers typically perform grinding tasks for less than four hours per shift (Document ID 0677). The available data presented in the FEA Table IV.5.11-B suggest that the mean indoor grinding exposure level with dust collection systems is about twice that for grinding outdoors, with 50 percent of exposures between 100 and 250 μg/m^3.

OSHA notes from its exposure profile that the vast majority of exposure samples taken during indoor grinding where dust controls were used made use of LEV systems rather than water-based dust control systems (21 out of 23 samples). Exposures measured within a test chamber during grinding operations confirm that high exposures result from grinding concrete indoors, even with good dust collection equipment (Document ID 3609), with mean task-based sample results generally falling between 100 and 200 μg/m^3. Based on the available data for indoor grinding, OSHA believes that, when grinding with a commercially available shroud and dust collection system for four hours or less per shift, resulting exposures should generally be no higher than grinding outdoors for a full shift and thus should not necessitate the use of respiratory protection. However, for indoor grinding with a shroud and dust collection system performed more than four hours per shift, the Agency believes that exposures would consistently exceed 50 μg/m^3, but that the use of the required means of exhaust sufficient to minimize the accumulation of visible airborne dust will ensure these exposures do not exceed 50 µg/m^3 by more than a factor of ten. Therefore, Table 1 requires respiratory protection with an APF of at least 10 when grinding with dust collection systems for more than four hours per shift indoors or in an enclosed area. OSHA also finds that there is inadequate evidence in the record to demonstrate that wet grinding indoors or in an enclosed area is as effective as using LEV. Accordingly, Table 1 permits the use of water-based dust control for grinding outdoors only.

5.12 UNDERGROUND CONSTRUCTION WORKERS

5.12.1 Description

Tunneling accounts for most of the construction work performed underground and includes the construction and renovation of underground tunnels, shafts, chambers and passageways.[286] Tunnel construction techniques include: tunnel boring, drilling and blasting; excavation; pipe jacking; and microtunneling.[287] In Chapter IV of the Preliminary Economic Analysis (PEA), OSHA preliminarily concluded that underground construction activities fell into three major groups: 1) activities related to explosive blasting (not addressed in this analysis for reasons discussed below); 2) construction activities that are also typically conducted aboveground (discussed in other sections of this analysis); and 3) activities related to tunneling with rapid excavation machines (discussed in this section). Only the third group of activities, which are unique to underground construction and a significant source of respirable crystalline silica exposure, are addressed in this section.

The Agency determined that workers are not exposed to respirable silica dust from explosive blasting. Explosive blasting is performed only when the tunnel is vacant and reentry is allowed only after exhaust systems clear the air. Therefore, explosive blasting activities are not included in the profile. This finding was not disputed by any commenters; accordingly, OSHA has not included these workers in the final analysis of underground construction work.

With respect to underground construction activities that are also typically conducted aboveground, OSHA preliminarily determined that it was appropriate to address those

[286] It should be noted that tunneling for the purpose of extraction (e.g., for coal or minerals) is considered a mining operation and falls under the jurisdiction of the Mine Safety and Health Administration. Tunneling for other purposes is regulated by OSHA.

[287] Pipe jacking is a tunneling technique in which powerful hydraulic jacks push (advance) specially designed pipe through the ground. Excavation of soil takes place at the front of the pipe string manually or mechanically. The process requires workers to occasionally enter into the pipeline being jacked to clear obstructions or to make connections at junctions (Document ID 0955, 0956; and 1720, p. IV-520). Pipe jacking is typically done with pipes 42 to 120 inches in diameter (Document ID 0582; 1720, p. IV-520). Microtunneling is used to construct smaller diameter pipelines, which are typically too small for humans to enter. Microtunneling uses a remotely controlled microtunnel boring machine (MTBM) with the pipe jacking technique to install pipelines (Document ID 0535; 1720, p. IV-520).

activities (like chipping, sawing, drilling, and grinding) in other sections of the PEA because they are not unique to underground construction. Controls for these activities, which are discussed in other sections, would not be unique to working above or below the ground. OSHA's preliminary determination to consider workers performing these activities in other sections of the PEA was based, in part, on a report by Blute et al. (1999), on the quartz-silica exposures of ten workers using chipping equipment during underground tunnel construction. Their mean respirable quartz exposure was 280 $\mu g/m^3$, with overall exposures ranging from10 $\mu g/m^3$ to 1,640 $\mu g/m^3$. These levels were lower than the results reported for 109 workers performing similar activities aboveground (operating jackhammers and impact drillers indoors and outdoors). See Section IV-C 26 Jackhammer and Impact Drillers of the PEA (Document ID 1720, p. IV-521).

The exposure profiles in this Final Economic Analysis (FEA) support OSHA's determination that the workers doing these activities underground are exposed to levels of respirable silica dust that are no greater than those to which workers doing the activities aboveground are exposed. The final exposure profile for workers using chipping hammers in this FEA contains 139 samples with exposures ranging from 12 $\mu g/m^3$ to 2,350 $\mu g/m^3$ and a mean of 243 $\mu g/m^3$; these levels of exposure are consistent with the exposure levels reported for underground chipping operators by Blute. See Section IV-5.5 – Jackhammers and Other Powered Handheld Chipping Tools.

Furthermore, the FEA exposure profile for grinders supports the determination that exposures for underground workers are no greater than those among their aboveground counterparts. Indeed, controls for underground grinders appear to be used more effectively to control respirable silica dust exposures than the controls used aboveground. The exposure profile for grinders includes six samples for workers grinding in a tunnel. See FEA Section IV-5.11 – Tuckpointers and Grinders. The tunnel construction workers using no additional controls were exposed to respirable silica levels of 178 $\mu g/m^3$, 628 $\mu g/m^3$, and 985 $\mu g/m^3$, compared to levels of 12 $\mu g/m^3$ to 737 $\mu g/m^3$ for workers grinding aboveground outdoors, and 117 $\mu g/m^3$ to 1,730 $\mu g/m^3$ for those grinding indoors with no controls.[288] Grinders using LEV in the tunnel had results of 5 μg/m³, 5 μg/m³ and 10 μg/m³, compared to a range of 12 μg/m³ to 460 μg/m³ for the aboveground equivalent (Table IV.5.12-B).

Even though underground workers perform tasks in an enclosed space, they experience exposures similar to their aboveground counterparts due to the ventilation requirements associated with underground and tunneling work. The ventilation provides sufficient air to mimic the working conditions of an aboveground work setting.[289] See 29 CFR 1926.800(k). In addition, most dust control techniques available to the general construction industry (wet methods, local exhaust ventilation [LEV]-equipped tools, enclosed operator cabs and booths (these terms are used interchangeably in this section), and increased general ventilation) are also available below ground to control dust exposures (Document ID 1431, p. 3-99; 1720, p. IV-521; 1423, p. 883; 1235, p. 1).

Because underground workers performing impact drilling and grinding experience exposures that are similar to or less than their aboveground counterparts, and because controls work equally well belowground and aboveground, OSHA maintains its original determination that it is appropriate to address workers who perform these underground construction activities is in other sections of the FEA. As further discussed in those sections, the Agency has determined that achieving the PEL is feasible for these activities. See Sections IV-5.3 – Heavy Equipment Operators and Ground Crew Laborers through IV-5.11 – Tuckpointers and Grinders.

While the Construction Industry Safety Coalition (CISC) did not disagree with OSHA's finding regarding the similarity of the tasks conducted aboveground and underground, or with the determination that underground tasks could be addressed in other sections of OSHA’s analysis, they commented that OSHA had not met its burden of showing

[288] Two additional sample results for outdoor grinding with no controls contained no silica and were reported as the limit of detection (12 μg/m³).

[289] 29 CFR 1926.800(k)(3) requires a linear velocity of air flow in the tunnel bore, in shafts, and in all other underground work areas of at least 30 feet (9.15 m) per minute where blasting or rock drilling is conducted, or where other conditions likely to produce dust, fumes, mists, vapors, or gases in harmful or explosive quantities are present.

technological feasibility for these tasks (Document ID 2319, p. 68). These feasibility concerns are addressed in the sections that discuss these activities in more detail.

The third category of underground construction activities – the category addressed in this section – is tunneling. During rapid, large-scale tunneling operations, construction workers use rapid excavation machines (such as roadheaders, continuous miners, and tunnel-boring machines [TBMs]) that use aggressive grating action to cut into the rock face (Document ID 1720, p. IV-520). Workers working on or supporting tunneling operations (tunnel borers) may be exposed to silica when they operate excavation or in-tunnel transportation equipment, tend the equipment (e.g., conveying belts, excavating machinery), lay track, extend utility lines as excavation machinery advances, or remove excavated material from the tunnel. These activities are never performed aboveground.[290]

CISC questioned OSHA's decision to focus its preliminary technological feasibility analysis for underground construction work on TBMs. Specifically, it questioned the extent to which TBMs are or could be used for all underground work, particularly to the exclusion of roadheaders, which can create a significant amount of very fine silica dust. CISC asserted that OSHA did not analyze the technological feasibility of the proposed PEL for all underground construction workers, but instead analyzed the feasibility of achieving the PEL only for workers using TBMs (Document ID 2319, p. 69).

The primary differences between the various types of excavators are in their cutting tool configurations, the rate at which they remove material, and the type of rock for which they are typically used (Document ID 1431, pp. 3-99 – 3-100). A review of the characteristics of the various types of excavators shows that the exposure levels found around TBMs are likely typical of, if not higher than, the levels found around the other types of excavators.

[290] Typical job titles for workers in the tunnel borer job category include rapid excavation machine operator, locomotive operator (carries workers and equipment between tunnel entrances and excavation machines), mechanic (maintains the rapid excavation machinery and conveyor belt systems), miner (lays track and extends water, air, and electrical lines as excavation machines advance), and bottom shaft worker (removes excavated material from the tunnel).

Roadheaders are configured for mobility and used for short distances to cut around tunnel corners or to refine hard rock tunnel shapes. These machines use cutting heads on a boom manipulated by the operator in a cab. The roadheaders' pine-cone shaped cutting heads are notably smaller and remove rock at a substantially lower rate than continuous mining machines or TBMs; the modest amount of rock debris created is typically carried away by truck. Due to the potential for air contaminants in the exhaust from mobile roadheaders, ventilation is typically provided near the cutting heads by the manual placement of ducts (Document ID 1431, pp. 3-99 – 3-100).

Continuous miners are configured to remove large quantities of material rapidly using a rotating drum with teeth that is driven into a soft rock face. This equipment is most frequently found in coal mines; however, workers can operate continuous miners at construction sites where roads are built through soft sandstone or limestone. These rock formations often have lower crystalline silica content, or produce less fine silica dust when abraded, than formations with harder rocks, resulting in lower exposures than those experienced with TBMs, which cut harder rock (Document ID 1431, pp. 3-99 – 3-100).

TBMs come in a wide range of sizes and cut the entire tunnel face in one pass. This extensively used equipment is only minimally maneuverable and usually cuts a straight line or a slightly curved tunnel. This type of excavator is typically cylindrical and similar in diameter to the tunnel being cut (Document ID 1431, pp. 3-99 – 3-100). TBMs cut a notably larger cross-section of rock face than other rapid excavation equipment and are used on the hardest material, creating the greatest potential quantities of dust (Document ID 3759, Attachment 1, p. 5).

No information on the frequency with which the various types of excavators are used was submitted to the Agency. The exposure and use information for TBMs summarized in the PEA therefore continues to represent the best available information for underground construction workers (Document ID 1720, pp. IV-521 – 528). In the absence of more detailed exposure information associated with the use of roadheaders and continuous miners, OSHA continues to consider the sampling data associated with the use of TBMs to be the best available information for analyzing exposures associated with tunnel operations.

OSHA has determined that the similarities in the various types of rapid excavation machines and their uses allow for the use of similar types of controls, such as water sprays and ventilation, to reduce exposures. Additionally, underground construction work includes all workers who perform activities related to tunneling, including the operation of rapid excavation machines (such as roadheaders, continuous miners, and TBMs) and support activities related to tunneling with rapid excavation machines (including workers who tend to the equipment (e.g., conveying belts, excavating machinery), lay track, extend utility lines as excavation machinery advances, and remove excavated material from the tunnel).

Underground construction workers involved in rapid excavation are exposed to dust that is generated by the rapid excavation of silica-containing dirt and rock. They are also exposed during the performance of related support activities (including the open transfer of silica-containing materials) and when working near ventilation system exhaust air.

Job categories, major activities, and sources of exposure for underground construction workers involved in rapid excavation are summarized in Table IV.5.12-A.

Table IV.5.12-A
Job Categories, Major Activities, and Sources of Exposure for Underground Construction Workers

Job Category*	Major Activities and Sources of Exposure
Underground Construction Worker (Tunnel Borer)	Excavating, removing debris, operating rapid excavation machines, transporting workers and equipment, laying track and installing/extending utility lines (air, water, electrical), performing maintenance and repair, and others. • Dust from rapid excavation and related support activities. • Dust from open transfer of silica-containing materials. • Dust from working in close proximity to ventilation system exhaust air.

*Job categories are intended to represent job functions; actual job titles might differ, and responsibilities might be allocated differently, depending on the site.
Source: Document ID 1720, p. IV-522.

5.12.2 Exposure Profile and Baseline Conditions

The exposure profile in Table IV.5.12-B for underground construction workers associated with tunnel excavating machines includes 27 full-shift, personal breathing zone (PBZ) samples of respirable crystalline silica. These exposure data were obtained at two tunnel construction sites, one evaluated by NIOSH (Document ID 0225) and one evaluated by OSHA (Document ID 0070). The median exposure is 12 μg/m^3, the mean is 41 μg/m^3, and the range is 7 μg/m^3 (the limit of detection (LOD)[291] to 257 μg/m^3. Of the 27 samples, 6 (22 percent) are above 50 μg/m^3.

The job titles of sampled workers included TBM operator, drill operator, mechanic, locomotive or brake operator, miner, welder, electrician, bottom shaft worker, and inspector. The TBMs were equipped with engineering controls that included water sprayers, LEV systems, and shields designed to reduce the release of rock fragments and dust as the TBM cut the rock face (Document ID 1720, p. IV-522; 0070, pp. 53, 72-84; 0225, p. 4-6, 8).

Two respirable quartz sample results (46 μg/m^3 and 38 μg/m^3) were obtained for workers inside a TBM's enclosed, ventilated operator booth. This result suggests that workers in enclosed booths already experience levels below 50 μg/m^3 (Document ID 1720, p. IV-523; 0070, pp. 31, 53, 72-84; 0225, pp. 6-9, 11).

Two additional sample results (136 μg/m^3 and 87 μg/m^3) were obtained for workers who spent part of their time in the enclosed booth and part of their time outside the TBM (Document ID 0070, p. 31). The OSHA report noted that the tunnel's ventilation system had not been extended the full length of the tunnel, providing less fresh air into the work area than required, and recommended an increase in the air flow through the TBM's LEV system and an increase in the amount of water sprayed on the machine's rotating cutting wheels (Document ID 0070, pp. 52-53). A combination of factors – insufficient general

[291] LODs are as reported by the original study author. LODs are discussed in further detail in Section IV.2 – Methodology.

ventilation, LEV, and water –likely contributed to the elevated exposures (Document ID 0070, pp. 52-53; 1720, p. IV-523).

The two remaining highest sample results (124 $\mu g/m^3$ and 257 $\mu g/m^3$) were obtained for two workers who loaded and unloaded locomotive flat cars and assisted with crane operations at the bottom of a tunnel shaft (Document ID 0225, pp. 9-11). NIOSH attributed these elevated results to the workers' positions near the tunnel shaft, which acted as the exhaust air duct for the tunnel's ventilation system, and, more significantly, to their proximity to the last transfer point of rock moving from the horizontal belt conveyor to the vertical bucket conveyor (Document ID 0225, p. 10). Although a water spray bar was reportedly located at each of the two other transfer points in the tunnel, engineering controls were absent from this last transfer point (Document ID 0225, p. 10). The other two elevated sample results (55 $\mu g/m^3$ and 75 $\mu g/m^3$) were obtained for two miners operating equipment in TBM trailing gear, laying track, and extending water and air lines (Document ID 0225, pp. 9, 11). NIOSH suggested that these two exposures might have been associated with a booster fan malfunction on the third sampling day, which reduced the tunnel's exhaust volume by 10 to 20 percent (Document ID 0225, p. 10).

The remaining 21 sample results showed exposures below 50 $\mu g/m^3$ (Document ID 0225, p. 11; 0070, p. 31).

In an attempt to collect more information, the Agency reviewed exposure sampling from studies for other underground construction workers, including electricians and pipe jacking operators (Document ID 0546; 0929; 0562; 3759, Attachment 1).

Bakke et al. (2002) evaluated the exposures of eleven TBM operators working on a Norwegian tunnel project and found exposures with a median of 490 $\mu g/m^3$ and a geometric mean of 390 $\mu g/m^3$ silica (n=43). The TBM had an enclosed operator cab; however, the operator kept the doors open in order to monitor the flow of material on the conveyor (Document ID 0546, pp. 786, 795). Bakke noted that the miscellaneous tasks of monitoring and loading broken rock onto conveyors were associated with higher exposure results (Document ID 0546, p. 790). While the study notes that 43 samples were evaluated, no individual results were available for inclusion in OSHA's profile.

Oliver and Miracle-McMahill (2006) sampled 51 workers involved in tunnel construction using the tunnel-jacking technique. The process consisted of a "jacking box" being propelled forward with cables and the use of roadheaders (Document ID 0929, pp. 984-985). Exposure results were reported in summary form as a percentage of the previous OSHA PEL *ranging from zero to 1,617 percent) and did not include enough information for inclusion in the exposure profile (Document ID 0929, pp. 985, 987). Limited information on working conditions was included in the report; the authors noted that wetting was used at the tunnel face. Operations continued, however, even during periods when water was not available for wetting. Additionally, a granite seawall and a manmade concrete obstruction were encountered during tunneling; these circumstances may explain some of the high exposures (Document ID 0929, pp. 987-988, 992).

Woskie et al. (1999), evaluated exposures for workers constructing a tunnel using "cut and cover" methods, where a wide trench is dug, decks and walls are established, a roof is poured, and, finally, the tunnel is covered with dirt (Document ID 0562, pp. 632-633). Equipment and tasks onsite included pneumatic chipping guns (hammers), grinders/scabbers, and pneumatic drills (Document ID 0562, p. 637). No tunneling machines were used, so this study contained no sample data for inclusion.

The New York State Laborers' Health and Safety Fund submitted an industrial hygiene study by Silverstein (2010). That study included 84 samples on TBM operations. Exposures ranged from 0.01 to 139, with a mean of 9.8. Sixty-six additional samples collected on roadheader operations showed exposures ranging from 0.035 to 19.5, with a mean of 2.2 (Document ID 3759, Attachment 1, pp. 4-5, 10). Because the underlying data (total dust, percent of silica, and sampling times) were not provided, the Agency was unable to include this data in the final exposure profile.[292]

[292] Exposure values in the Oliver and Miracle-McMahill (2006) and Silverstein (2010) studies were reported without units and represent the actual exposure divided by the previous OSHA PEL of (10-2*% silica)/10 (Document ID 3759, Attachment 1, p. 8; 0929, p. 987). The percent silica was not reported; therefore, OSHA was unable to determine respirable crystalline silica (RCS) values.

Even though these studies did not provide sufficient information for inclusion in the exposure profile (as outlined in Section IV-2 – Methodology), OSHA has determined that the studies do contain useful information establishing current exposure conditions and show that the elevated exposures identified were associated with poor dust controls and inadequate work practices.

No OSHA Information System (OIS) data were identified for inclusion in the exposure profile for underground construction work. So although limited, the data from the NIOSH site evaluation and the SEP inspection represent the best data available to OSHA for underground construction workers involved in tunneling. Because no exposure sampling data containing sufficient information (as outlined in the Methodology section, IV-2) was submitted to the docket, the Agency has not made any revisions to the exposure profile (Table IV.5.12-B**)** for underground construction work.

Providing further insight into baseline conditions for underground construction, the National Rural Electric Cooperative Association (NRECA) and the Laborers Health and Safety Fund of North America (LHSFNA) testified at the public hearings on the exposures for underground construction workers.

Brian Lazarchick from NRECA commented that the only potential exposures utility workers have are during the auguring of holes into the ground for the placement of utility poles and during the installation of underground lines. He stated that they use wet boring methods and mini enclosed-cab excavators to complete these tasks, resulting in no exposures to respirable-size crystalline silica dust for their workers (Document ID 3583, Tr. 2274, 2277). However, NRECA did not submit any sampling data to support this assertion. Other representatives from the utilities industry submitted written comments to the docket stating that the use of wet boring methods and enclosed, ventilated cab mini-excavators has allowed them to minimize dust exposures. Due to the use of water to inhibit dust creation, they do not expect their work to produce respirable crystalline silica (Document ID 2365, pp. 7, 15).

LHSFNA stated that the confined nature of tunneling work, the often-limited ventilation, and the ability of TBMs and other tunneling equipment to generate dust can lead to substantial silica exposures. Some of the most severe exposures for their union members occur during tunneling (Document ID 3589, Tr. 4207-4208).

Eddie Mallon from LHSFNA Local 147, who has experience working on multiple tunnel construction projects in New York City, testified about the working conditions, shift length, and the availability of controls in underground tunnel construction. He testified that exposures have increased due to the use of higher powered equipment in lieu of manual methods (Document ID 3589, Tr. 4209-4248). Mr. Mallon stated that the most common trades working in tunnels are laborers and operating engineers, and that these tunnel workers are typically exposed to respirable crystalline silica eight hours per day while actively tunneling. He added that it is not uncommon for workers to be 10 feet away from the dust-generating activities, and that while it is typical for operators to work from inside enclosed cabins, the laborers are not inside any enclosures and remain exposed to airborne silica dust. Depending on the equipment being used, a laborer may stand beside the operator with a water hose to control the dust (Document ID 3589, Tr. 4246-4248).

Mr. Mallon also stated that water is available for use on site and is most often used on the TBM and at the head of the tunnel. Although foam can also be used, Mr. Mallon has never seen it used; he attributed this to the cost of foam. Water is the primary control implemented to reduce dust in tunnels, but water also requires significant cleanup efforts. Mr. Mallon testified that it is not uncommon to arrive on a jobsite and see that no water has been used to control dust (Document ID 3589, Tr. 4230-4231).

Ventilation is another available control for underground construction. According to Mr. Mallon, most projects begin with functioning ventilation systems to remove the dust from the tunnel and exhaust it aboveground. Lack of maintenance, however, results in the decreased effectiveness of the ventilation systems. Without proper ventilation, tunnel work is excessively dusty. He testified that, generally speaking, work is stopped only to allow dust to clear when it becomes difficult to see other people - but “it’s like pulling teeth to have a job stop.” He has seen tunnel construction projects where ventilation controls were maintained properly and visible dust was minimal (Document ID 3589, Tr. 4242-4243, 4246).

OSHA agrees with the comments from the utility industry and LHSFNA that the effective use of ventilation, enclosed cabs and wet methods can reduce exposures to levels below the PEL.

Final Baseline Conditions and Exposure Profile

Based on the descriptions of tunneling workers' activities and rapid excavation operations discussed in the PEA and in the rulemaking record, OSHA concludes that baseline conditions for this group of workers include wet methods (water sprayers), LEV Systems (for tools, excavating equipment, and conveyor transfer points), general dilution ventilation (ventilation requirements in OSHA's underground construction standard), and enclosed operator cabs or booths. These controls are not always used properly. The results summarized in Table IV.5.12-B were obtained under these conditions and represent the best data available to the Agency. The final exposure profile for this industry shows that 78 percent of sample results fall below the PEL of 50 $\mu g/m^3$, 11 percent of samples results fall between 50 $\mu g/m^3$ and 100 $\mu g/m^3$, and the remaining 11 percent of sample results are over 100 $\mu g/m^3$.

Table IV.5.12-B Respirable Crystalline Silica Exposure Range and Distribution of Results for Construction Workers: Underground Construction Workers											
	Exposure Summary			**Exposure Range**			**Exposure Profile**				
Job Category	**N**	**Mean (μg/m³)**	**Median (μg/m³)**	**Min (μg/m³)**	**Max (μg/m³)**		**<25 (μg/m³)**	**≥25 and ≤50 (μg/m³)**	**>50 and ≤100 (μg/m³)**	**>100 and ≤250 (μg/m³)**	**>250 (μg/m³)**
Underground Construction Worker (tunnel borer)	27	41	12	7	257		16 (59%)	5 (19%)	3 (11%)	2 (7%)	1 (4%)
Total	**27**	**41**	**12**	**7**	**257**		**16 (59%)**	**5 (19%)**	**3 (11%)**	**2 (7%)**	**1 (4%)**

Notes: All samples are personal breathing zone (PBZ) results and represent 8-hour time-weighted average exposures
Job categories are intended to represent job functions; actual job titles might differ, and responsibilities might be allocated differently, depending on the site.
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Percentages may not add to 100 percent due to rounding.

Sources: Document ID 1431; 1720; 0070; 0225.

5.12.3 Additional Controls for Underground Construction Workers

The exposure profile in Table IV.5.12-B shows that 22 percent (6 out of 27 samples) of tunnel borers have exposures above the final PEL of 50 μg/m^3. Therefore, OSHA finds that additional controls will be necessary to achieve the PEL for these overexposed workers.

OSHA determined that the majority of tunnel borers work inside TBM trailing gear (that is, the equipment behind the bit or head, including the operator's booth or cab) or outside the TBM. The primary exposure controls for these workers include controls provided by the TBM, such as water sprays positioned at cutting heads and conveyor transfer points, and LEV at cutting heads.[293]

In those operations where elevated exposures still occur, employers will need to ensure the full operation of the TBM engineering controls and also ensure the optimum operation of ventilation systems installed inside tunnels, improve the application of water sprays wherever dust is generated, enclose conveyor transfer points, and take other steps to reduce dust from conveyors as necessary to reduce exposures.

Ventilation

OSHA enforces ventilation requirements in construction under 29 CFR 1926.800(k)(3), which provides that "the linear velocity of air flow in the tunnel bore, in shafts, and in all other underground work areas shall be at least 30 feet (9.15 m) per minute where blasting or rock drilling is conducted, or where other conditions likely to produce dust, fumes, mists, vapors, or gases in harmful or explosive quantities are present" (Document ID 1720, p. IV-521). NIOSH currently recommends 100 feet-per-minute air flow across the full diameter of the tunnel if the rock contains more than 10 percent silica (Document ID 0887, p. 105). Additionally, NIOSH recommends an air flow of at least 60 feet-per-minute for roadheaders, depending on the size of the tunnel, with the duct inlet five feet from the rock face and ten feet forward from the operator (Document ID 0887, p. 91).

[293] It should be noted that OSHA already has a standard in place requiring the use of controls (such as wet drilling, the use of vacuum collectors, or water mix spray systems) when drilling rock or concrete during underground construction activities. See 29 CFR 1926.800(k)(9).

Bakke et al. (2001), found that minimum flow rates of 40 to 70 cubic feet-per-minute resulted in arithmetic mean exposures of 11 μg/m^3 and 34 μg/m^3 for construction workers at four tunneling sites, demonstrating that the use of such ventilation rates can reduce average exposures below the mean exposure of 41 μg/m^3 reflected in Table IV.5.12-B (Document ID 1720, p. IV-528; 0545, pp. 251, 254).

Both industry and labor commented on the importance of having effective general ventilation during underground construction to reduce exposures (Document ID 2253, p. 5; 4073, Attachment 15i, p. 1; 3759, Attachment 1, pp. 2, 5-6). The Agency agrees.

The Agency also notes that proper maintenance of the ventilation system is essential to minimizing exposures. Dust collection systems with screens and filters can clog, and need to be properly maintained in order to ensure sufficient air movement to prevent the build-up of dust and overexposures to silica (Document ID 0887, p. 102; 4073, Attachment 15i). The effectiveness of the tunnel's general dilution ventilation system can be maintained by performing routine maintenance and by ensuring that the duct extends to the face of the tunnel and is free of leaks (Document ID 1720, p. IV-528; 4073, Attachment 15i, p. 1).

In conclusion, increasing general ventilation air flow rates has been shown to reduce exposures during tunnel excavation. Such changes in air flow rates are an additional control employers can use to reduce their workers' silica-dust exposures

Improved Material Transfer Systems

In addition to increased ventilation, NIOSH IC-9465, the *Handbook for Dust Control in Mining*, recommends improving controls along the material conveyor systems by enclosing conveyors and conveyor transfer points, adding effective clean up mechanisms (such as belt scrapers), and increasing exhaust ventilation to conveyors to minimize the conveyor belt as a source of silica exposure (Document ID 0887, pp. 97-106; 1720, p. IV-527).

NIOSH recommends enclosing transfer points and adding water sprays to reduce exposures from this source. However, if that alone is not enough, the addition of ventilation along enclosed conveyors exhausted to a dust collector can reduce exposures even further (Document ID 0887, p. 104).

Both the top and the bottom of conveyor belts should be wet for optimal dust suppression (Document ID 0887, p. 105). The addition of belt scrapers or a belt washing system can further reduce exposures by preventing wet material from sticking to the belts and becoming re-suspended (Document ID 0887, p. 104).

Enclosed Cabs and Booths

For workers who ride inside the machine, including drill operators and cutter-head mechanics, an enclosed, ventilated cab can reduce exposures.

Pannell and Grogin (2000) reported that pressurized, enclosed cabs without high-efficiency filtration can provide a high degree of protection for operators performing excavation work where the silica content of the soil is unusually high (Document ID 0952, pp. 14-16). The investigators obtained 44 samples associated with workers operating a water wagon and a scraper from these types of cabs, and reported mean respirable dust results of 72 $\mu g/m^3$ during sampling periods of approximately 4- to 5-hours (Document ID 0952, p. 15). These respirable dust values were roughly 80 to 90 percent lower than the results for operators of open-cab equipment, who had mean respirable dust exposures of 426 $\mu g/m^3$ (four results for grader operators), 672 $\mu g/m^3$ (40 results for dozer operators), and 837 $\mu g/m^3$ (10 results for workers operating a second dozer) (Document ID 0952, p. 15). Respirable dust samples collected inside and outside the scraper showed that this equipment reduced operators' exposures by nearly 90 percent (Document ID 0952, pp. 15-16). The project studied, construction of a solid low-level radioactive waste disposal facility, was unusual in that 64,000 cubic meters of soil, containing up to 65 percent silica, was excavated in a semi-arid environment, creating unusually high respirable silica dust exposures. Bulldozer operators routinely performed soil ripping, a task that is likely to abrade and fracture silica-containing rock. While this study was not conducted during tunneling operations, the abrading and removal of soil is a similar task; the use of pressurized enclosed cabs or booths to protect operators of rapid excavating equipment is expected to lead to similar reductions in exposures.

NIOSH recommends several design and operational features for cabs in order to minimize operators' exposures to respirable dust (Document ID 0839). Workers using cabs that follow these recommendations can experience exposures 90 percent lower than those experienced by workers in open cabs (Document ID 0590; 0844). The NIOSH recommendations are as follows:

- Cabs should be equipped with a recirculation filter that continuously filters the air circulating within the cab. This is the only way to eliminate dust that has entered the cab (e.g., on shoes, or through an open door);
- The inlet for intake air should be strategically located so that it avoids, as much as possible, the equipment's major dust sources;
- Cabs should avoid the use of floor heaters or any discharge of clean air that is low in the cab, which entrains dust from the floor and dirty work clothes before entering the worker's breathing zone. Ideally, air flow would circulate from the top of the cab to the bottom, and recirculation pick-up would occur low in the cab;
- Cabs must be well maintained and kept clean. Filters must be changed regularly so that they do not become overloaded with dust, and seals must be maintained to preserve pressurization inside the cab. A gritless, natural base sweeping compound should be applied to the floor of the cab to bind dirt and dust tracked in during normal work activities. The compound should also be used for regular housekeeping activities (Document ID 0839, pp. 1-3).

In addition, NIOSH recommends remote operation for roadheaders when available, as this is, in most cases, the most effective way to lower the operators' dust exposures (Document D 0887, p. 92).

OSHA estimates that improved filtration systems and improved work practices, such as operating only when doors are closed, should further lower exposures. While properly functioning enclosed, ventilated cabs offer the best protection for workers inside the booths or cabs, wet methods and LEV that suppress dust at the source benefit workers both inside and outside the cab (Document ID 1720, p. IV-525).

Wet Methods

Improving water spray quality, possibly reducing droplet size, modifying the direction and quantity of spray, and ensuring adequate pressure and filtration can increase the effectiveness of water as an exposure control.

Achieving optimal wetting at the cutting head offers the best opportunity for controlling dust at its source; wetted material is less likely to contribute to exposures (Document ID 0887, p. 103). NIOSH found that uniform wetting of the broken rock was the most important factor in reducing rock dust as a source of exposure and that increasing the number of water sprays can promote uniform wetting of the material. An increase in from 17 to 46 sprays resulted in a 60 percent decrease in respirable dust, even when the total water flow and pressure remained the same (Document ID 0887, p. 103). While the best moisture content can be as high as 5 percent, even one percent moisture has been shown to result in significant reductions in dust levels (Document ID 0887, p. 103). NIOSH has also found that spray location is important in reducing exposures. TBM sprays directed at the rotating head and at falling rock are more effective than those directed at the face or the crown (Document ID 0887, p. 103).

Using foam spray or other wetting agents increases particle agglomeration and can reduce airborne dust levels another 20 to 60 percent when compared with plain water (Document ID 0887, pp. 105-106). Foam used at belt transfer points averaged a 30 percent reduction in dust compared to water alone (Document ID 0887, p. 105).

For roadheaders, NIOSH recommends lowering spray pressures to reduce air turbulence (which can actually increase exposures). The sprays on the boom head should be located close to the cutting head, wetting the broken rock falling down from it, and the water pressure should be maintained at 50 psi or less. Hole and Belle (1999), as cited by NIOSH, found that a roadheader wet head operating at 20 psi led to a 40 percent reduction in dust compared to external sprays (Document ID 0887, pp. 92-93). If this is not enough to reduce exposures, or if it is determined that more water is necessary, larger orifice nozzles can be used (Document ID 0887, p. 92). For the gathering pan where material is collected, high volume, low pressure nozzles should be used (Document ID 0887, p. 92).

CISC questioned whether water was available as a control for use with non-TBM excavators (Document ID 2319, p. 69). Two documents submitted to the docket show that various types of excavation equipment used in underground construction can be equipped with water sprays. First, NIOSH discussed the use of water sprays on various types of tunnel equipment, including continuous miners, longwall shearers and roadheaders, in NIOSH IC-9465, the *Handbook for Dust Control in Mining*, and made recommendations on adjusting or improving existing manufacturer sprays for optimal dust reduction (Document ID 0887, pp. 8, 92, 103). And second, the 2010 Silverstein study noted the use of water sprays on roadheaders, stating: “Worker exposures to silica during roadheader machine operations are controlled by two methods, water sprays at the cutting head and ventilation in the tunnel” (Document ID 3759, Attachment 1, p. 5).

Combination of Controls

OSHA expects that it will require a combination of the controls listed above to consistently maintain exposures below the PEL. This is seen in a report by NIOSH where silica-containing excavated tunnel material was wetted at the area removed with water from four spray hoses directed at the cutting heads (50 gallons per minute), and wetted again along the conveyor line at transfer points. In addition, LEV with an air scrubber was used, and the operator worked from inside a control booth (Document ID 0225, pp. 5-6, 8). All but four of the exposures (27 total samples were taken) were below the PEL (Document ID 0225, p. 11). NIOSH attributed two of the overexposures to a reduction in tunnel exhaust air due to a booster fan failure and the other two overexposures to the fact that spillage had been allowed to accumulate at the transfer point between the vertical and horizontal conveyors (Document ID 0225, p. 10). The workers with the overexposures (“miners” and “bottom men”) also had exposure samples under the PEL during the same visit, confirming that it is possible to reduce their exposures to levels at or below 50 $\mu g/m^3$ (Document ID 0225, p. 11).

5.12.4 Feasibility Finding

As previously noted, workers performing underground activities not specific to tunneling (such as grinding, hole drilling, or chipping) have silica exposures similar to those faced by workers who perform the same activities aboveground. See Sections IV-5.3 – Heavy Equipment Operators and Ground Crew Laborers, IV-5.4 – Hole Drillers Using Handheld or Stand-Mounted Drills, IV-5.5 – Jackhammers and Other Powered Handheld Chipping Tools, IV-5.6 – Masonry and Concrete Cutters Using Portable Saws, IV-5.8 – Millers Using Portable or Mobile Machines, IV-5.9 – Rock and Concrete Drillers, and IV-5.11 – Tuckpointers and Grinders for OSHA's findings related to those types of activities.

CISC commented that OSHA's analysis failed to demonstrate that the PEL was feasible for all of the various operations involved in underground construction because OSHA relied on "a limited scope of activities [TBMs] in concluding that the proposed PEL of 50 μg/m^3 is capable of being done in most underground operations most of the time" (Document ID 2319, p. 69). OSHA relied on the best available evidence of tunnel workers' exposures (i.e., the sampling exposures described in the final exposure profile) and compared that information with studies that included samples associated with other types of equipment (even though those samples could not be used in the final exposure profile). OSHA finds that TBMs, due to their larger size and their ability to cut through harder materials, have the potential to create more silica-containing dust than other types of machines. Thus, if anything, TBM data overestimates current exposures for workers using other types of machines. OSHA specifically found that the operation of TBMs result in higher exposures then roadheaders. And finally, the dust sources for the various types of machines are the same or similar. These sources are the broken rock removed from the tunnel face and its movement to the rear and out of the tunnel along conveyors or other types of conveyances. Irrespective of the type of machine being used, water sprays and dust suppressants, ventilation, and proper maintenance of controls, can control dust levels in order to keep silica exposures below 50 μg/m^3 for most underground construction activities most of the time (Document ID 0225, p. 11).

OSHA concludes that exposure levels are already below the PEL of 50 μg/m^3 for most workers inside excavating machines that have pressurized enclosed cabs or booths and fully functioning water spray, general ventilation systems, and LEV (as necessary). Where exposures exceed 50 µg/m^3, improved maintenance of the cab, cab filtration, and increased ventilation and water spray systems in the tunnel can reduce exposures. And with respect to tunnel workers who work outside the cabs or booths, OSHA concludes that silica exposures of 50 µg/m^3 or lower can be achieved for most of the workers most of the time by making sure that the controls, including water sprays and LEV, as well as the tunnel's dilution ventilation system, operate optimally.

Due in part to the complexity of excavating machines, dust controls, and the ventilation systems required to control dust for underground operations, OSHA did not include underground construction and tunneling operations in Table 1 of paragraph (c) of the construction standard. OSHA received no comments requesting that tunneling machines be included on Table 1.

Additionally, OSHA has determined that TBMs and other types of tunneling machines are often operated at the same job site for extended periods of time and that, for this work, periodic air monitoring is the best method to accurately evaluate exposures. And there are numerous other hazards that must be routinely monitored in accordance with 29 CFR 1926.800(j)-Air quality and monitoring. Therefore in this context, the sampling required by the rule to evaluate silica exposures will not be overly burdensome because employers are already conducting routine on-site sampling.

For the reasons discussed above, OSHA determined that rapid excavating machines will not be included on Table 1. Employers who use these machines will therefore be required to assess and monitor exposures to respirable crystalline silica in accordance with paragraph (d) of the standard. Employers will also be required to establish a worker control plan describing necessary controls. For underground construction workers who are involved in a task listed on Table 1 (e.g., drilling, grinding, chipping), employers can implement the controls in Table 1 without also needing to sample those employees for respirable crystalline silica and are considered to be in compliance with the table for those workers, even if they are working in the proximity of tunnel boring work covered by this section of the analysis.

5.12) Underground Construction Workers

OSHA concludes that most workers performing underground construction activities are currently exposed to silica levels below the PEL of 50 μg/m^3. For workers who are currently exposed above 50 μg/m^3, the additional controls described in this section can be implemented to reduce silica exposure levels to 50 μg/m^3 or below in most operations, most of the time. Therefore, OSHA finds that the standard is technologically feasible for workers performing underground construction activities.

APPENDIX 1 – OSHA INFORMATION SYSTEM (OIS) RESPIRABLE CRYSTALLINE SILICA DATA

This appendix contains the results of air samples obtained from the OSHA Information System (OIS) that were taken to assess exposure to respirable crystalline silica. The OIS sampling results include 964 personal breathing zone (PBZ) samples taken during compliance inspections conducted between January 1, 2011 and April 17, 2014. The OIS sampling results were submitted to the silica rulemaking docket as Document ID 3958, and used to update the final exposure profiles presented in the FEA.

The OIS samples were taken to assess compliance with the preceding PEL, and therefore, the sampling results were reported as respirable dust concentrations in units of milligrams per cubic meter of air (mg/m^3). The final PEL is expressed in units of micrograms per cubic meter of air (μg/m^3) of respirable crystalline silica. Therefore, the respirable dust concentrations from the OIS report were converted to respirable silica dust concentrations for comparison with the final PEL and for inclusion in exposure profiles. (See IV-2.0 Methodology for details). This appendix presents the results of the OIS samples as respirable silica concentration in units of μg/m^3 grouped by general industry sector, or by application group for construction.

Table IV.A-1
OIS Data Description

HEADING	CONTENTS DESCRIPTION
Sec.	The FEA Chapter IV section number in which the record is included. NA means “not applicable" - the record is not included in a specific exposure profile.
Section Name	The title for the indicated section of FEA Chapter IV. For records not included in an exposure profile, this column indicates whether the sample was obtained in general industry or the construction industry.
Job Category	The worker group to which OSHA assigned the record, based on the available information about the worker's job function within the sector or application group. Worker exposure data within a job category share similar source(s) of silica exposure and control options. Some Job Categories are further divided into subcategories based on available information regarding the types of controls in use.
Sample Duration (min.)	The number of minutes over which the silica sample was collected. This information is not shown in Document ID 3958. OSHA retrieved the sample durations for individual records at a later date and has included them here to provide more complete information on individual samples.
Resp. Dust (mg/m^3)	The 8-hour TWA PBZ concentration of Respirable Dust reported in column N of Document ID 3958. Most results are reported in milligrams of respirable dust per cubic meter (mg/m^3); ten samples were reported in mppcf, and are noted as such.
Pct. Silica	The percentage of crystalline silica in the respirable dust collected on the sample filter. The percent silica values presented in this appendix were calculated from the PEL reported in column P of Document ID 3958 as described in the methods section.
PEL (mg/m^3)	The individual sample PEL calculated by the OSHA compliance officer using the equations described above, and reported in column P of Document ID 3958 (e.g., for General Industry the PEL = 10 ÷ [% silica + 2] for samples reported in mg/m^3).
Severity	The ratio of the calculated PEL and the measured respirable dust level, as reported in column R of Document ID 3958 (i.e., Severity= PEL/[respirable dust concentration]). A severity greater than 1.0 means the sample exceeded the calculated PEL for respirable silica.
Resp. Silica (µg/m^3)	The 8-hour TWA PBZ respirable crystalline silica concentration, in µg/m^3, which was calculated from the percent silica and the respirable dust concentration reported in column N of Document ID 3958.
Included in Profile	"Yes" indicates that OSHA was able to associate the silica sample result with an identifiable job category within a sector (or application group) and that the sample is included in the exposure profile for that sector (or application group). Samples in NAICS for which the available information did not demonstrate systematic silica exposure to a recognizable group of employees (job category) could not be included in an exposure profile, although they may be summarized in general statistics regarding general industry or the construction industry; these samples are listed as "No" in this column.
Inspec. ID	The number assigned by OSHA to the establishment inspection during which the sample was collected.
Opening Date	The date OSHA opened the establishment inspection under which the sample was collected. Samples were typically obtained on that date, or shortly thereafter.
NAICS	The North America Industrial Classification System (NAICS) code reported for the establishment employing the sampled worker, which is used in determining the sector in general industry.
Docket File Row #	The row in which this sample appears in Document ID 3958.

Table IV.A-2 OIS Health Sampling Data for Respirable Crystalline Silica 2011-2014 (Document ID 3958)														
Sec.	**Section Name**	**Job Category**	**Sample Duration (min.)**	**Resp. Dust (mg/m^3)**	**Pct. Silica**	**PEL (mg/m^3)**	**Severity**	**Resp. Silica (µg/m^3)**	**Included in Profile**	**Inspec. ID**	**Opening Date**	**NAICS**	**Docket File Row #**
4.3	Concrete Products	Abrasive Blasting Operators	231	0.440	16.0	0.556	0.80	70	Yes	860463	1/29/2013	327390	306
4.3	Concrete Products	Abrasive Blasting Operators	360	1.300	41.0	0.233	5.73	533	Yes	761381	11/27/2012	327390	366
4.3	Concrete Products	Finishing Operators	431	0.048	0.0	5.000	0.01	<12	Yes	954791	1/15/2014	327390	253
4.3	Concrete Products	Finishing Operators	483	0.038	0.0	5.000	0.01	<12	Yes	959858	2/25/2014	327390	340
4.3	Concrete Products	Finishing Operators	480	4.400	15.0	0.588	7.55	660	Yes	694098	10/18/2012	327390	261
4.3	Concrete Products	Finishing Operators	478	0.036	0.0	5.000	0.01	<12	Yes	959858	2/25/2014	327390	338
4.3	Concrete Products	Finishing Operators	451	0.110	0.0	5.000	0.02	<12	Yes	954791	1/15/2014	327390	254
4.3	Concrete Products	Finishing Operators	444	0.350	0.0	5.000	0.07	<12	Yes	954791	1/15/2014	327390	252
4.3	Concrete Products	Finishing Operators	482	0.036	0.0	5.000	0.01	<12	Yes	959858	2/25/2014	327390	339
4.3	Concrete Products	Finishing Operators	431	1.526	1.8	2.632	0.58	27	Yes	603938	8/28/2012	327390	287
4.3	Concrete Products	Finishing Operators	449	0.055	0.0	5.000	0.01	<12	Yes	954791	1/15/2014	327390	255
4.3	Concrete Products	Forming Operators	453	0.298	0.0	5.000	0.06	<12	Yes	110983	1/5/2012	327332	1005
4.3	Concrete Products	Forming Operators	54	0.520	0.0	5.000	0.10	<12	Yes	661485	10/2/2012	327331	243
4.3	Concrete Products	Forming Operators	283	0.400	0.0	5.000	0.08	<12	Yes	608998	8/31/2012	327390	174
4.3	Concrete Products	Forming Operators	200	0.160	0.0	5.000	0.03	<12	Yes	678539	10/10/2012	327999	909
4.3	Concrete Products	Forming Operators	420	0.081	0.0	5.000	0.02	<12	Yes	727601	11/8/2012	327331	262
4.3	Concrete Products	Forming Operators	48	0.240	0.0	5.000	0.05	<12	Yes	770762	12/3/2012	327999	153
4.3	Concrete Products	Forming Operators	480	0.710	0.0	5.000	0.14	<12	Yes	927563	8/7/2013	327991	232
4.3	Concrete Products	Forming Operators	95	0.150	0.0	5.000	0.03	<12	Yes	608998	8/31/2012	327390	173
4.3	Concrete Products	Forming Operators	433	1.000	2.2	2.381	0.43	22	Yes	603938	8/28/2012	327390	289
4.3	Concrete Products	Forming Operators	430	1.613	1.6	2.778	0.58	26	Yes	603938	8/28/2012	327390	292
4.3	Concrete Products	Forming Operators	413	0.210	0.0	5.000	0.04	<12	Yes	603938	8/28/2012	327390	291
4.3	Concrete Products	Forming Operators	435	1.200	1.7	2.703	0.43	20	Yes	603938	8/28/2012	327390	290
4.3	Concrete Products	Forming Operators	463	0.195	0.0	5.000	0.04	<12	Yes	110983	1/5/2012	327332	1007
4.3	Concrete Products	Forming Operators	264	0.082	15.0	0.588	0.14	12	Yes	949151	11/19/2013	327390	198
4.3	Concrete Products	Forming Operators	471	0.170	0.0	5.000	0.03	<12	Yes	956197	1/22/2014	327331	284
4.3	Concrete Products	Forming Operators	178	0.270	0.0	5.000	0.05	<12	Yes	678539	10/10/2012	327999	910
4.3	Concrete Products	Forming Operators	110	0.310	20.0	0.455	0.69	62	Yes	606798	8/30/2012	327390	149
4.3	Concrete Products	Forming Operators	480	0.825	1.6	2.778	0.00	13	Yes	534498	7/13/2012	327390	148
4.3	Concrete Products	Forming Operators	478	0.680	0.0	5.000	0.14	<12	Yes	956197	1/22/2014	327331	282
4.3	Concrete Products	Forming Operators	100	0.260	0.0	5.000	0.05	<12	Yes	606798	8/30/2012	327390	150
4.3	Concrete Products	Forming Operators	461	1.100	0.0	5.000	0.21	<12	Yes	941439	9/16/2013	327390	492
4.3	Concrete Products	Forming Operators	410	0.420	0.0	5.000	0.09	<12	Yes	727601	11/8/2012	327331	263
4.3	Concrete Products	Forming Operators	262	0.088	0.0	5.000	0.02	<12	Yes	949151	11/19/2013	327390	199

Table IV.A-2 OIS Health Sampling Data for Respirable Crystalline Silica 2011-2014 (Document ID 3958)

Sec.	Section Name	Job Category	Sample Duration (min.)	Resp. Dust (mg/m³)	Pct. Silica	PEL (mg/m³)	Severity	Resp. Silica (µg/m³)	Included in Profile	Inspec. ID	Opening Date	NAICS	Docket File Row #
4.3	Concrete Products	Material Handlers	288	0.610	0.0	5.000	0.12	<12	Yes	948505	11/14/2013	327999	161
4.3	Concrete Products	Material Handlers	448	0.330	0.0	5.000	0.07	<12	Yes	941439	9/16/2013	327390	497
4.3	Concrete Products	Material Handlers	439	0.130	10.5	0.799	0.17	14	Yes	782321	12/13/2012	327331	939
4.3	Concrete Products	Material Handlers	305	0.891	2.4	2.270	0.39	21	Yes	457413	6/6/2012	327331	559
4.3	Concrete Products	Material Handlers	653	0.190	0.0	5.000	0.04	<12	Yes	524893	7/10/2012	327331	204
4.3	Concrete Products	Material Handlers	337	0.930	0.0	5.000	0.19	<12	Yes	695338	10/19/2012	327331	569
4.3	Concrete Products	Material Handlers	433	4.100	0.5	3.947	1.04	22	Yes	782321	12/13/2012	327331	937
4.3	Concrete Products	Material Handlers	507	0.260	0.0	5.000	0.05	<12	Yes	956197	1/22/2014	327331	283
4.3	Concrete Products	Material Handlers	441	0.140	20.0	0.455	0.31	28	Yes	782321	12/13/2012	327331	938
4.3	Concrete Products	Material Handlers	454	0.274	0.0	5.000	0.05	<12	Yes	110983	1/5/2012	327332	1006
4.3	Concrete Products	Material Handlers	439	2.200	7.4	1.064	2.04	163	Yes	925867	8/6/2013	327390	873
4.3	Concrete Products	Material Handlers	448	0.330	0.0	5.000	0.07	<12	Yes	941439	9/16/2013	327390	498
4.3	Concrete Products	Material Handlers	223	0.490	0.0	5.000	0.10	<12	Yes	959119	2/20/2014	327390	603
4.3	Concrete Products	Material Handlers	448	0.480	0.0	5.000	0.10	<12	Yes	925867	8/6/2013	327390	871
4.3	Concrete Products	Material Handlers	445	0.850	2.0	2.500	0.34	17	Yes	925867	8/6/2013	327390	872
4.3	Concrete Products	Mixer Operators	60	0.140	0.0	5.000	0.03	<12	Yes	585258	8/21/2012	327390	168
4.3	Concrete Products	Mixer Operators	222	0.210	0.0	5.000	0.04	<12	Yes	959119	2/20/2014	327390	601
4.3	Concrete Products	Mixer Operators	49	0.120	0.0	5.000	0.02	<12	Yes	770762	12/3/2012	327999	152
4.3	Concrete Products	Mixer Operators	424	0.230	0.0	5.000	0.05	<12	Yes	757402	11/28/2012	327991	350
4.3	Concrete Products	Mixer Operators	442	0.520	4.6	1.515	0.34	24	Yes	941439	9/16/2013	327390	500
4.3	Concrete Products	Mixer Operators	280	0.071	0.0	5.000	0.01	<12	Yes	950730	12/4/2013	327390	885
4.3	Concrete Products	Mixer Operators	396	1.400	4.3	1.587	0.86	60	Yes	608998	8/31/2012	327390	172
4.3	Concrete Products	Mixer Operators	60	0.150	13.0	0.667	0.23	19	Yes	585258	8/21/2012	327390	169
4.3	Concrete Products	Mixer Operators	460	3.100	0.0	5.000	0.62	<12	Yes	941439	9/16/2013	327390	495
4.3	Concrete Products	Mixer Operators	68	1.700	0.0	5.000	0.35	<12	Yes	741762	11/16/2012	327390	151
4.3	Concrete Products	Mixer Operators	405	0.439	2.8	2.083	0.21	12	Yes	603938	8/28/2012	327390	288
4.3	Concrete Products	Mixer Operators	480	1.000	1.7	2.703	0.38	17	Yes	927563	8/7/2013	327991	230
4.3	Concrete Products	Mixer Operators	73	2.400	6.5	1.176	2.04	156	Yes	959119	2/20/2014	327390	599
4.3	Concrete Products	Mixer Operators	600	0.056	26.5	0.350	0.16	15	Yes	900987	4/15/2013	327331	968
4.3	Concrete Products	Mixer Operators	552	0.062	17.6	0.509	0.12	11	Yes	900987	4/15/2013	327331	970
4.3	Concrete Products	Mixer Operators	598	0.042	23.8	0.388	0.11	10	Yes	900987	4/15/2013	327331	967
4.3	Concrete Products	Mixer Operators	79	7.400	0.0	5.000	1.48	<12	Yes	661485	10/2/2012	327331	241
4.3	Concrete Products	Mixer Operators	82	14.000	0.0	5.000	2.75	<12	Yes	661485	10/2/2012	327331	242
4.3	Concrete Products	Mixer Operators	73	0.002	6.5	1.176	0.00	12	Yes	959119	2/20/2014	327390	600

Table IV.A-2 OIS Health Sampling Data for Respirable Crystalline Silica 2011-2014 (Document ID 3958)														
Sec.	**Section Name**	**Job Category**	**Sample Duration (min.)**	**Resp. Dust (mg/m^3)**	**Pct. Silica**	**PEL (mg/m^3)**	**Severity**	**Resp. Silica (μg/m^3)**	**Included in Profile**	**Inspec. ID**	**Opening Date**	**NAICS**	**Docket File Row #**
4.3	Concrete Products	Mixer Operators	475	0.067	0.0	5.000	0.01	<12	Yes	608418	8/31/2012	327331	623
4.3	Concrete Products	Mixer Operators	480	0.180	0.0	5.000	0.04	<12	Yes	888803	2/14/2013	327331	265
4.3	Concrete Products	Mixer Operators	588	0.026	76.4	0.128	0.20	20	Yes	900987	4/15/2013	327331	969
4.3	Concrete Products	Finishing Operators	420	1.400	0.0	5.000	0.27	<12	Yes	608998	8/31/2012	327390	175
4.3	Concrete Products	Finishing Operators	483	0.087	0.0	5.000	0.02	<12	Yes	959858	2/25/2014	327390	341
4.3	Concrete Products	Finishing Operators	396	1.238	2.2	2.381	0.52	27	Yes	603938	8/28/2012	327390	285
4.3	Concrete Products	Finishing Operators	437	2.822	1.6	2.778	1.02	45	Yes	603938	8/28/2012	327390	286
4.4	Cut Stone	Abrasive Blaster	206	2.600	1.8	2.632	0.98	47	Yes	604832	8/30/2012	327991	257
4.4	Cut Stone	Abrasive Blaster	420	0.443	0.0	5.000	0.09	<12	Yes	943377	10/30/2013	327991	235
4.4	Cut Stone	Abrasive Blaster	310	2.492	5.4	1.360	1.83	133	Yes	694438	10/17/2012	327991	294
4.4	Cut Stone	Fabricator	425	2.300	8.5	0.952	2.43	195	Yes	953839	1/7/2014	337110	334
4.4	Cut Stone	Fabricator	480	0.100	0.0	5.000	0.02	<12	Yes	932711	8/20/2013	238340	1090
4.4	Cut Stone	Fabricator	120	0.190	0.0	5.000	0.04	<12	Yes	714918	10/24/2012	327991	176
4.4	Cut Stone	Fabricator	74	0.000	0.0	5.000	0.00	<12	Yes	940740	9/10/2013	327991	391
4.4	Cut Stone	Fabricator	397	0.260	0.0	5.000	0.05	<12	Yes	915125	6/26/2013	327991	390
4.4	Cut Stone	Fabricator	433	0.149	11.0	0.770	0.19	16	Yes	281315	3/16/2012	327991	1015
4.4	Cut Stone	Fabricator	448	0.140	9.6	0.862	0.17	13	Yes	948574	11/14/2013	327991	1076
4.4	Cut Stone	Fabricator	440	0.700	19.0	0.476	1.47	133	Yes	954228	1/10/2014	327991	936
4.4	Cut Stone	Fabricator	414	2.000	31.0	0.303	6.48	620	Yes	913045	6/21/2013	327991	932
4.4	Cut Stone	Fabricator	474	0.068	35.0	0.270	0.25	24	Yes	898361	3/27/2013	327991	53
4.4	Cut Stone	Fabricator	459	0.231	12.1	0.710	0.32	28	Yes	281315	3/16/2012	327991	1017
4.4	Cut Stone	Fabricator	297	17.000	20.0	0.455	36.68	3400	Yes	927280	8/9/2013	327991	927
4.4	Cut Stone	Fabricator	460	0.160	0.0	5.000	0.03	<12	Yes	891393	2/22/2013	327991	645
4.4	Cut Stone	Fabricator	415	0.220	0.0	5.000	0.04	<12	Yes	551399	8/2/2012	327991	609
4.4	Cut Stone	Fabricator	425	0.260	7.2	1.086	0.24	19	Yes	919531	7/15/2013	238340	1088
4.4	Cut Stone	Fabricator	327	0.000	0.0	5.000		<12	Yes	559078	8/6/2012	327991	378
4.4	Cut Stone	Fabricator	425	0.190	0.0	5.000	0.04	<12	Yes	551399	8/2/2012	327991	607
4.4	Cut Stone	Fabricator	405	0.027	0.0	5.000	0.01	<12	Yes	551399	8/2/2012	327991	608
4.4	Cut Stone	Fabricator	459	0.076	0.0	5.000	0.02	<12	Yes	890845	2/19/2013	327991	1033
4.4	Cut Stone	Fabricator	439	12.000	17.0	0.526	23.53	2040	Yes	927280	8/9/2013	327991	926
4.4	Cut Stone	Fabricator	467	0.261	8.9	0.920	0.28	23	Yes	110284	12/13/2011	327991	1004
4.4	Cut Stone	Fabricator	422	0.220	30.0	0.313	0.71	66	Yes	924159	7/31/2013	327991	1062
4.4	Cut Stone	Fabricator	327	0.000	0.0	5.000		<12	Yes	559078	8/6/2012	327991	379
4.4	Cut Stone	Fabricator	20	6.700	14.0	0.625	10.78	938	Yes	900208	4/12/2013	423320	370

Table IV.A-2 OIS Health Sampling Data for Respirable Crystalline Silica 2011-2014 (Document ID 3958)														
Sec.	**Section Name**	**Job Category**	**Sample Duration (min.)**	**Resp. Dust (mg/m^3)**	**Pct. Silica**	**PEL (mg/m^3)**	**Severity**	**Resp. Silica ($\mu g/m^3$)**	**Included in Profile**	**Inspec. ID**	**Opening Date**	**NAICS**	**Docket File Row #**
4.4	Cut Stone	Fabricator	307	0.230	0.0	5.000	0.05	<12	Yes	906547	5/14/2013	327991	1043
4.4	Cut Stone	Fabricator	458	1.100	21.0	0.435	2.58	231	Yes	915125	6/26/2013	327991	389
4.4	Cut Stone	Fabricator	270	9.100	8.8	0.929	9.77	797	Yes	626738	9/12/2012	327122	626
4.4	Cut Stone	Fabricator	67	0.250	0.0	5.000	0.05	<12	Yes	915937	7/2/2013	337110	869
4.4	Cut Stone	Fabricator	435	0.120	0.0	5.000	0.02	<12	Yes	954228	1/10/2014	327991	934
4.4	Cut Stone	Fabricator	460	0.510	18.0	0.500	1.03	92	Yes	913045	6/21/2013	327991	933
4.4	Cut Stone	Fabricator	454	0.150	0.0	5.000	0.03	<12	Yes	891393	2/22/2013	327991	646
4.4	Cut Stone	Fabricator	360	0.070	0.0	5.000	0.01	<12	Yes	921825	7/19/2013	327991	1053
4.4	Cut Stone	Fabricator	461	1.500	31.0	0.303	4.88	465	Yes	953112	12/23/2013	327991	680
4.4	Cut Stone	Fabricator	452	0.510	27.0	0.344	1.48	138	Yes	953112	12/23/2013	327991	679
4.4	Cut Stone	Fabricator	453	0.073	0.0	5.000	0.01	<12	Yes	890845	2/19/2013	327991	1035
4.4	Cut Stone	Fabricator	343	0.000	0.0	5.000		<12	Yes	559078	8/6/2012	327991	377
4.4	Cut Stone	Fabricator	379	3.100	7.9	1.010	3.02	245	Yes	953084	12/19/2013	444110	979
4.4	Cut Stone	Fabricator	116	0.290	0.0	5.000	0.06	<12	Yes	900449	4/11/2013	327991	64
4.4	Cut Stone	Fabricator	362	0.056	0.0	5.000	0.01	<12	Yes	921825	7/19/2013	327991	1055
4.4	Cut Stone	Fabricator	449	0.066	0.0	5.000	0.01	<12	Yes	891393	2/22/2013	327991	647
4.4	Cut Stone	Fabricator	425	2.500	0.0	5.000	0.51	<12	Yes	919531	7/15/2013	238340	1087
4.4	Cut Stone	Fabricator	460	0.640	23.4	0.394	1.63	150	Yes	953112	12/23/2013	327991	678
4.4	Cut Stone	Fabricator	428	0.229	10.0	0.830	0.28	23	Yes	281315	3/16/2012	327991	1018
4.4	Cut Stone	Fabricator	82	0.000	0.0	5.000	0.00	<12	Yes	940740	9/10/2013	327991	394
4.4	Cut Stone	Fabricator	347	0.234	15.0	0.588	0.40	35	Yes	823201	1/8/2013	238340	1027
4.4	Cut Stone	Fabricator	443	0.033	0.0	5.000	0.01	<12	Yes	890845	2/19/2013	327991	1032
4.4	Cut Stone	Fabricator	507	0.740	12.0	0.714	1.04	89	Yes	916063	6/27/2013	327991	1098
4.4	Cut Stone	Fabricator	282	22.000	11.7	0.728	29.79	2583	Yes	898361	3/27/2013	327991	54
4.4	Cut Stone	Fabricator	419	0.190	26.0	0.357	0.53	49	Yes	947466	11/7/2013	327991	401
4.4	Cut Stone	Fabricator	85	4.100	25.9	0.359	11.32	1061	Yes	961530	3/7/2014	327991	135
4.4	Cut Stone	Fabricator	459	0.338	10.0	0.830	0.41	34	Yes	110284	12/13/2011	327991	1003
4.4	Cut Stone	Fabricator	358	0.077	0.0	5.000	0.02	<12	Yes	946462	11/5/2013	327991	1073
4.4	Cut Stone	Fabricator	385	0.048	0.0	5.000	0.01	<12	Yes	910569	6/7/2013	327991	1051
4.4	Cut Stone	Fabricator	464	0.610	10.8	0.782	0.78	66	Yes	900993	4/17/2013	327122	650
4.4	Cut Stone	Fabricator	51	0.530	0.0	5.000	0.11	<12	Yes	943768	10/22/2013	327991	883
4.4	Cut Stone	Fabricator	390	0.230	0.0	5.000	0.05	<12	Yes	938344	9/3/2013	327991	1071
4.4	Cut Stone	Fabricator	446	2.044	12.0	0.714	2.86	245	Yes	330139	3/27/2012	327991	164
4.4	Cut Stone	Fabricator	390	0.078	0.0	5.000	0.02	<12	Yes	283798	3/28/2012	327991	30

Table IV.A-2 OIS Health Sampling Data for Respirable Crystalline Silica 2011-2014 (Document ID 3958)														
Sec.	**Section Name**	**Job Category**	**Sample Duration (min.)**	**Resp. Dust (mg/m^3)**	**Pct. Silica**	**PEL (mg/m^3)**	**Severity**	**Resp. Silica ($\mu g/m^3$)**	**Included in Profile**	**Inspec. ID**	**Opening Date**	**NAICS**	**Docket File Row #**
4.4	Cut Stone	Fabricator	446	0.310	21.0	0.435	0.71	65	Yes	948574	11/14/2013	327991	1077
4.4	Cut Stone	Fabricator	451	0.210	18.0	0.500	0.42	38	Yes	952626	12/19/2013	327991	1078
4.4	Cut Stone	Fabricator	120	0.290	0.0	5.000	0.06	<12	Yes	714918	10/24/2012	327991	178
4.4	Cut Stone	Fabricator	465	4.200	17.0	0.526	8.01	714	Yes	913045	41446	327991	931
4.4	Cut Stone	Fabricator	75	0.000	0.0	5.000	0.00	<12	Yes	895098	3/12/2013	327991	369
4.4	Cut Stone	Fabricator	376	0.052	0.0	5.000	0.01	<12	Yes	891393	2/22/2013	327991	644
4.4	Cut Stone	Fabricator	379	0.017	0.0	5.000	0.00	<12	Yes	910569	6/7/2013	327991	1052
4.4	Cut Stone	Fabricator	397	0.200	30.0	0.313	0.63	60	Yes	923434	7/29/2013	238340	1058
4.4	Cut Stone	Fabricator	288	0.860	38.0	0.250	3.44	327	Yes	903728	5/15/2013	327991	1093
4.4	Cut Stone	Fabricator	409	0.730	25.0	0.370	1.97	182	Yes	952626	12/19/2013	327991	1079
4.4	Cut Stone	Fabricator	445	0.668	8.3	0.971	0.69	55	Yes	330139	3/27/2012	327991	163
4.4	Cut Stone	Fabricator	428	0.320	19.0	0.476	0.68	61	Yes	924159	7/31/2013	327991	1061
4.4	Cut Stone	Fabricator	253	1.200	4.4	1.563	0.77	53	Yes	626738	9/12/2012	327122	624
4.4	Cut Stone	Fabricator	438	0.190	21.0	0.435	0.44	40	Yes	947466	11/7/2013	327991	400
4.4	Cut Stone	Fabricator	448	0.896	13.0	0.667	1.34	116	Yes	330139	3/27/2012	327991	162
4.4	Cut Stone	Fabricator	359	0.063	0.0	5.000	0.01	<12	Yes	946462	11/5/2013	327991	1074
4.4	Cut Stone	Fabricator	211	0.000	0.0	5.000	0.00	<12	Yes	944061	10/24/2013	337110	329
4.4	Cut Stone	Fabricator	476	1.000	44.0	0.217	4.62	440	Yes	898361	3/27/2013	327991	52
4.4	Cut Stone	Fabricator	351	0.190	0.0	5.000	0.04	<12	Yes	283798	3/28/2012	327991	32
4.4	Cut Stone	Fabricator	151	3.700	15.3	0.579	6.36	566	Yes	895687	3/12/2013	327991	946
4.4	Cut Stone	Fabricator	480	0.150	9.4	0.877	0.17	14	Yes	932711	8/20/2013	238340	1091
4.4	Cut Stone	Fabricator	451	0.257	10.8	0.780	0.33	28	Yes	109867	12/7/2011	327991	1001
4.4	Cut Stone	Fabricator	394	0.380	10.0	0.833	0.45	38	Yes	938344	9/3/2013	327991	1070
4.4	Cut Stone	Fabricator	513	1.000	7.9	1.010	1.04	79	Yes	916063	6/27/2013	327991	1097
4.4	Cut Stone	Fabricator	445	2.000	12.0	0.714	2.86	240	Yes	949137	11/19/2013	327991	402
4.4	Cut Stone	Fabricator	450	0.860	15.5	0.571	1.51	133	Yes	895687	3/12/2013	327991	944
4.4	Cut Stone	Fabricator	429	1.400	11.0	0.769	1.88	154	Yes	953839	1/7/2014	337110	333
4.4	Cut Stone	Fabricator	390	0.170	0.0	5.000	0.03	<12	Yes	283798	3/28/2012	327991	31
4.4	Cut Stone	Fabricator	425	0.210	0.0	5.000	0.04	<12	Yes	919531	7/15/2013	238340	1086
4.4	Cut Stone	Fabricator	360	0.028	0.0	5.000	0.01	<12	Yes	921825	7/19/2013	327991	1054
4.4	Cut Stone	Fabricator	383	0.160	0.0	5.000	0.03	<12	Yes	915937		337110	870
4.4	Cut Stone	Fabricator	120	0.430	0.0	5.000	0.09	<12	Yes	714918	10/24/2012	327991	177
4.4	Cut Stone	Fabricator	392	0.140	0.0	5.000	0.03	<12	Yes	938344	9/3/2013	327991	1069
4.4	Cut Stone	Fabricator	467	0.780	13.0	0.667	1.18	101	Yes	895301	3/13/2013	327991	1038

Table IV.A-2 OIS Health Sampling Data for Respirable Crystalline Silica 2011-2014 (Document ID 3958)													
Sec.	**Section Name**	**Job Category**	**Sample Duration (min.)**	**Resp. Dust (mg/m^3)**	**Pct. Silica**	**PEL (mg/m^3)**	**Severity**	**Resp. Silica ($\mu g/m^3$)**	**Included in Profile**	**Inspec. ID**	**Opening Date**	**NAICS**	**Docket File Row #**
4.4	Cut Stone	Fabricator	443	0.347	11.3	0.750	0.46	39	Yes	109867	12/7/2011	327991	1002
4.4	Cut Stone	Fabricator	440	4.300	13.1	0.663	6.49	562	Yes	900993	4/17/2013	327122	651
4.4	Cut Stone	Fabricator	247	0.140	0.0	5.000	0.03	<12	Yes	626738	9/12/2012	327122	625
4.4	Cut Stone	Fabricator	331	0.600	13.0	0.667	0.89	78	Yes	898905	3/29/2013	327991	15
4.4	Cut Stone	Fabricator	124	0.240	0.0	5.000	0.05	<12	Yes	900449	4/11/2013	327991	62
4.4	Cut Stone	Fabricator	459	0.120	0.0	5.000	0.02	<12	Yes	901784	4/22/2013	327991	485
4.4	Cut Stone	Fabricator	439	0.480	2.7	2.128	0.23	13	Yes	901784	4/22/2013	327991	486
4.4	Cut Stone	Fabricator	431	0.400	0.0	5.000	0.08	<12	Yes	901784	4/22/2013	327991	487
4.4	Cut Stone	Fabricator	450	0.170	13.0	0.667	0.26	22	Yes	948574	11/14/2013	327991	1075
4.4	Cut Stone	Fabricator	461	0.190	9.8	0.848	0.22	19	Yes	895301	3/13/2013	327991	1040
4.4	Cut Stone	Fabricator	424	0.360	18.0	0.500	0.73	65	Yes	924159	7/31/2013	327991	1063
4.4	Cut Stone	Fabricator	286	0.200	11.0	0.769	0.26	22	Yes	895301	3/13/2013	327991	1039
4.4	Cut Stone	Fabricator	346	0.159	10.0	0.833	0.19	16	Yes	823201	1/8/2013	238340	1026
4.4	Cut Stone	Fabricator	480	1.100	0.0	5.000	0.23	<12	Yes	896647	3/20/2013	337110	67
4.4	Cut Stone	Fabricator	209	0.000	0.0	5.000	0.00	<12	Yes	944061	10/24/2013	337110	328
4.4	Cut Stone	Sawyer	367	0.025	0.0	5.000	0.01	<12	Yes	925124	8/7/2013	238340	372
4.4	Cut Stone	Fabricator	463	0.160	39.0	0.244	0.64	62	Yes	923434	7/29/2013	238340	1056
4.4	Cut Stone	Fabricator	466	0.200	41.0	0.233	0.84	82	Yes	923434	7/29/2013	238340	1057
4.4	Cut Stone	Machine Operator	441	0.320	0.0	5.000	0.06	<12	Yes	915937	7/2/2013	337110	868
4.4	Cut Stone	Fabricator	359	0.210	0.0	5.000	0.04	<12	Yes	925124	8/7/2013	238340	373
4.4	Cut Stone	Sawyer	328	0.106	0.0	5.000	0.02	<12	Yes	823201	1/8/2013	238340	1025
4.4	Cut Stone	Sawyer	432	0.130	18.0	0.500	0.27	23	Yes	924159	7/31/2013	327991	1060
4.4	Cut Stone	Sawyer	167	0.000	0.0	5.000	0.00	<12	Yes	910569	6/7/2013	327991	1050
4.4	Cut Stone	Sawyer	378	0.360	46.1	0.208	1.73	166	Yes	740781	11/14/2012	327991	1024
4.4	Cut Stone	Sawyer	455	0.107	12.9	0.670	0.16	14	Yes	908989	5/30/2013	327991	1045
4.4	Cut Stone	Sawyer	288	0.330	12.0	0.714	0.47	40	Yes	916063	6/27/2013	327991	1096
4.4	Cut Stone	Sawyer	465	1.500	16.0	0.556	2.72	240	Yes	913045	6/21/2013	327991	930
4.4	Cut Stone	Sawyer	446	0.110	71.0	0.137	0.79	78	Yes	958662	2/12/2014	327991	1084
4.4	Cut Stone	Sawyer	398	0.095	0.0	5.000	0.02	<12	Yes	283798	3/28/2012	327991	29
4.4	Cut Stone	Sawyer	284	0.000	0.0	5.000	0.00	<12	Yes	943762	10/23/2013	327991	399
4.4	Cut Stone	Sawyer	331	0.140	28.0	0.333	0.43	39	Yes	924159	7/31/2013	327991	1059
4.4	Cut Stone	Sawyer	378	0.835	38.0	0.250	3.34	317	Yes	740781	11/14/2012	327991	1023
4.4	Cut Stone	Sawyer	458	2.600	7.3	1.075	2.44	190	Yes	950219	11/27/2013	327991	981
4.4	Cut Stone	Sawyer	382	0.630	13.0	0.667	0.95	82	Yes	895687	3/12/2013	327991	945

Table IV.A-2 OIS Health Sampling Data for Respirable Crystalline Silica 2011-2014 (Document ID 3958)													
Sec.	**Section Name**	**Job Category**	**Sample Duration (min.)**	**Resp. Dust (mg/m^3)**	**Pct. Silica**	**PEL (mg/m^3)**	**Severity**	**Resp. Silica (µg/m^3)**	**Included in Profile**	**Inspec. ID**	**Opening Date**	**NAICS**	**Docket File Row #**
4.4	Cut Stone	Sawyer	450	0.210	63.0	0.154	1.34	132	Yes	958662	2/12/2014	327991	1083
4.4	Cut Stone	Sawyer	458	0.066	0.0	5.000	0.01	<12	Yes	954228	1/10/2014	327991	935
4.4	Cut Stone	Sawyer	488	1.300	18.0	0.500	2.66	234	Yes	950219	11/27/2013	327991	983
4.4	Cut Stone	Sawyer	392	0.042	0.0	5.000	0.01	<12	Yes	281315	3/16/2012	327991	1016
4.4	Cut Stone	Sawyer	455	0.590	30.0	0.313	1.89	177	Yes	958662	2/12/2014	327991	1085
4.4	Cut Stone	Sawyer	393	0.844	40.9	0.233	3.62	345	Yes	740781	11/14/2012	327991	1022
4.4	Cut Stone	Sawyer	368	0.230	0.0	5.000	0.05	<12	Yes	938344	9/3/2013	327991	1072
4.4	Cut Stone	Sawyer	389	1.756	48.0	0.200	8.78	843	Yes	740781	11/14/2012	327991	1021
4.4	Cut Stone	Sawyer	383	0.034	0.0	5.000	0.01	<12	Yes	890845	2/19/2013	327991	1034
4.4	Cut Stone	Sawyer	299	0.000	0.0	5.000		<12	Yes	559078	8/6/2012	327991	376
4.4	Cut Stone	Fabricator	329	0.018	0.0	5.000	0.00	<12	Yes	925124	8/7/2013	238340	371
4.5	Dental Equipment	Production Operator	453	0.057	0.0	5.000	0.01	<12	Yes	915909	7/2/2013	339114	274
4.5	Dental Equipment	Production Operator	426	0.086	0.0	5.000	0.02	<12	Yes	915909	7/2/2013	339114	275
4.6	Dental Laboratories	Dental Technicians	462	0.110	0.0	5.000	0.02	<12	Yes	952613	12/17/2013	339116	281
4.6	Dental Laboratories	Dental Technicians	372	0.000	0.0	5.000	0.00	<12	Yes	952613	12/17/2013	339116	280
4.6	Dental Laboratories	Dental Technicians	452	0.085	57.0	0.170	0.50	48	Yes	952613	12/17/2013	339116	278
4.6	Dental Laboratories	Dental Technicians	15	0.000	0.0	5.000	0.00	<12	Yes	837284	1/16/2013	339116	61
4.6	Dental Laboratories	Dental Technicians	459	0.250	0.0	5.000	0.05	<12	Yes	952613	12/17/2013	339116	279
4.7	Engineered Stone	Production Worker	105	0.180	0.0	5.000	0.04	<12	Yes	646719	9/20/2012	238350	940
4.7	Engineered Stone	Production Worker	477	0.460	0.0	5.000	0.09	<12	Yes	904365	5/2/2013	327991	272
4.7	Engineered Stone	Production Worker	478	0.400	0.0	5.000	0.08	<12	Yes	904365	5/2/2013	327991	271
4.8.1	Foundries - Ferrous	Abrasive Blasting Operator	446	1.400	4.6	1.515	0.93	64	Yes	947464	11/7/2013	331511	502
4.8.1	Foundries - Ferrous	Abrasive Blasting Operator	175	0.589	8.2	0.980	0.60	48	Yes	765461	12/11/2012	331511	39
4.8.1	Foundries - Ferrous	Abrasive Blasting Operator	451	2.900	5.6	1.316	2.20	162	Yes	110406	12/15/2011	331511	442
4.8.1	Foundries - Ferrous	Abrasive Blasting Operator	406	1.200	13.0	0.667	1.85	156	Yes	954795	1/15/2014	331511	593
4.8.1	Foundries - Ferrous	Abrasive Blasting Operator	419	0.400	7.3	1.075	0.38	29	Yes	835024	1/18/2013	331511	123
4.8.1	Foundries - Ferrous	Abrasive Blasting Operator	462	1.232	8.3	0.970		102	Yes	444333	5/25/2012	331511	844
4.8.1	Foundries - Ferrous	Abrasive Blasting Operator	360	1.601	10.0	0.833	1.92	160	Yes	110406	12/15/2011	331511	439
4.8.1	Foundries - Ferrous	Abrasive Blasting Operator	464	0.420	6.7	1.149	0.37	28	Yes	947464	11/7/2013	331511	503
4.8.1	Foundries - Ferrous	Abrasive Blasting Operator	421	0.540	11.0	0.769	0.70	59	Yes	835024	1/18/2013	331511	122
4.8.1	Foundries - Ferrous	Abrasive Blasting Operator	424	3.268	3.4	1.853	1.76	111	Yes	109180	11/17/2011	331513	701
4.8.1	Foundries - Ferrous	Cleaning/Finishing Operator	390	1.200	25.0	0.370	3.16	300	Yes	781042	12/11/2012	331511	414
4.8.1	Foundries - Ferrous	Cleaning/Finishing Operator	463	0.410	0.0	5.000	0.08	<12	Yes	941089	9/11/2013	331511	434
4.8.1	Foundries - Ferrous	Cleaning/Finishing Operator	445	2.100	2.1	2.440	0.86	44	Yes	77317	6/30/2011	331511	757

Table IV.A-2 OIS Health Sampling Data for Respirable Crystalline Silica 2011-2014 (Document ID 3958)													
Sec.	**Section Name**	**Job Category**	**Sample Duration (min.)**	**Resp. Dust (mg/m³)**	**Pct. Silica**	**PEL (mg/m³)**	**Severity**	**Resp. Silica (μg/m³)**	**Included in Profile**	**Inspec. ID**	**Opening Date**	**NAICS**	**Docket File Row #**
4.8.1	Foundries - Ferrous	Cleaning/Finishing Operator	480	0.970	14.0	0.625	1.55	136	Yes	110849	1/4/2012	331513	704
4.8.1	Foundries - Ferrous	Cleaning/Finishing Operator	468	2.500	8.5	0.952	2.66	212	Yes	947464	11/7/2013	331511	505
4.8.1	Foundries - Ferrous	Cleaning/Finishing Operator	456	9.310	5.8	1.282	7.26	540	Yes	110849	1/4/2012	331513	708
4.8.1	Foundries - Ferrous	Cleaning/Finishing Operator	465	1.120	4.6	1.515	0.00	52	Yes	444333	5/25/2012	331511	845
4.8.1	Foundries - Ferrous	Cleaning/Finishing Operator	470	0.450	12.0	0.714	0.63	54	Yes	947464	11/7/2013	331511	504
4.8.1	Foundries - Ferrous	Cleaning/Finishing Operator	465	6.300	17.0	0.526	11.94	1071	Yes	110406	12/15/2011	331511	445
4.8.1	Foundries - Ferrous	Cleaning/Finishing Operator	399	1.300	13.0	0.667	1.91	169	Yes	781042	12/11/2012	331511	413
4.8.1	Foundries - Ferrous	Cleaning/Finishing Operator	400	0.290	0.0	5.000	0.06	<12	Yes	746842	11/20/2012	331511	410
4.8.1	Foundries - Ferrous	Cleaning/Finishing Operator	360	1.448	14.0	0.625	2.32	203	Yes	111166	1/12/2012	331511	539
4.8.1	Foundries - Ferrous	Cleaning/Finishing Operator	458	2.600	11.0	0.769	3.33	286	Yes	110406	12/15/2011	331511	444
4.8.1	Foundries - Ferrous	Cleaning/Finishing Operator	425	1.200	1.7	2.700	0.63	20	Yes	77317	6/30/2011	331511	756
4.8.1	Foundries - Ferrous	Cleaning/Finishing Operator	394	3.900	9.1	0.901	4.34	355	Yes	954795	1/15/2014	331511	595
4.8.1	Foundries - Ferrous	Cleaning/Finishing Operator	450	1.253	2.6	2.174	0.58	33	Yes	460413	6/4/2012	331511	783
4.8.1	Foundries - Ferrous	Cleaning/Finishing Operator	495	0.859	2.6	2.170	0.40	22	Yes	460413	6/4/2012	331511	789
4.8.1	Foundries - Ferrous	Cleaning/Finishing Operator	399	2.400	5.5	1.333	1.80	132	Yes	835024	1/18/2013	331511	126
4.8.1	Foundries - Ferrous	Cleaning/Finishing Operator	389	0.630	4.5	1.538	0.41	28	Yes	781042	12/11/2012	331511	415
4.8.1	Foundries - Ferrous	Cleaning/Finishing Operator	362	0.127	13.0	0.667	0.19	17	Yes	111166	1/12/2012	331511	541
4.8.1	Foundries - Ferrous	Cleaning/Finishing Operator	394	3.400	3.1	1.961	1.71	105	Yes	835024	1/18/2013	331511	128
4.8.1	Foundries - Ferrous	Cleaning/Finishing Operator	457	0.559	3.9	1.695	0.33	22	Yes	110849	1/4/2012	331513	707
4.8.1	Foundries - Ferrous	Cleaning/Finishing Operator	402	2.300	15.0	0.588	3.95	345	Yes	954795	1/15/2014	331511	591
4.8.1	Foundries - Ferrous	Cleaning/Finishing Operator	422	1.500	0.0	5.000	0.30	<12	Yes	916302	7/5/2013	331513	655
4.8.1	Foundries - Ferrous	Cleaning/Finishing Operator	480	8.400	11.0	0.769	10.92	924	Yes	110849	1/4/2012	331513	705
4.8.1	Foundries - Ferrous	Cleaning/Finishing Operator	393	5.400	4.1	1.639	3.27	221	Yes	835024	1/18/2013	331511	127
4.8.1	Foundries - Ferrous	Cleaning/Finishing Operator	359	0.462	13.0	0.667	0.69	60	Yes	111166	1/12/2012	331511	540
4.8.1	Foundries - Ferrous	Cleaning/Finishing Operator	454	2.500	6.9	1.124	2.26	172	Yes	110406	12/15/2011	331511	443
4.8.1	Foundries - Ferrous	Cleaning/Finishing Operator	466	1.049	4.9	1.449	0.72	51	Yes	444333	5/25/2012	331511	847
4.8.1	Foundries - Ferrous	Coremaker	449	0.400	0.0	5.000	0.08	<12	Yes	835024	1/18/2013	331511	114
4.8.1	Foundries - Ferrous	Coremaker	448	0.580	12.0	0.714	0.81	70	Yes	907214	5/16/2013	331513	664
4.8.1	Foundries - Ferrous	Coremaker	432	0.670	5.5	1.333	0.50	37	Yes	954756	1/15/2014	331511	1000
4.8.1	Foundries - Ferrous	Coremaker	480	0.131	0.0	5.000	0.03	<12	Yes	436371	5/15/2012	331511	717
4.8.1	Foundries - Ferrous	Coremaker	441	0.141	13.0	0.667	0.21	18	Yes	436371	5/15/2012	331511	716
4.8.1	Foundries - Ferrous	Coremaker	159	0.065	0.0	5.000	0.01	<12	Yes	765461	12/11/2012	331511	35
4.8.1	Foundries - Ferrous	Coremaker	459	0.150	0.0	5.000	0.03	<12	Yes	835024	1/18/2013	331511	113
4.8.1	Foundries - Ferrous	Furnace Operator	386	0.844	1.6	2.780	0.30	13	Yes	436371	5/15/2012	331511	715

Table IV.A-2 OIS Health Sampling Data for Respirable Crystalline Silica 2011-2014 (Document ID 3958)													
Sec.	**Section Name**	**Job Category**	**Sample Duration (min.)**	**Resp. Dust (mg/m^3)**	**Pct. Silica**	**PEL (mg/m^3)**	**Severity**	**Resp. Silica (μg/m^3)**	**Included in Profile**	**Inspec. ID**	**Opening Date**	**NAICS**	**Docket File Row #**
4.8.1	Foundries - Ferrous	Furnace Operator	427	0.000	0.0	5.000	0.00	<12	Yes	77317	6/30/2011	331511	759
4.8.1	Foundries - Ferrous	Furnace Operator	317	0.476	0.0	5.000	0.10	<12	Yes	436371	5/15/2012	331511	714
4.8.1	Foundries - Ferrous	Knockout Operator	427	3.000	2.3	2.326	1.27	69	Yes	567706	8/8/2012	331511	849
4.8.1	Foundries - Ferrous	Knockout Operator	452	0.530	3.5	1.826	0.29	18	Yes	936046	8/28/2013	331511	99
4.8.1	Foundries - Ferrous	Knockout Operator	430	1.200	3.1	1.961	0.61	37	Yes	567706	8/8/2012	331511	850
4.8.1	Foundries - Ferrous	Knockout Operator	480	0.379	24.0	0.385	0.98	91	Yes	436371	5/15/2012	331511	718
4.8.1	Foundries - Ferrous	Knockout Operator	422	0.600	16.0	0.556	1.08	96	Yes	954756	1/15/2014	331511	999
4.8.1	Foundries - Ferrous	Knockout Operator	585	0.563	22.0	0.417	1.35	124	Yes	436371	5/15/2012	331511	712
4.8.1	Foundries - Ferrous	Knockout Operator	455	0.806	3.9	1.695	0.48	31	Yes	110849	1/4/2012	331513	703
4.8.1	Foundries - Ferrous	Maintenance Operator	420	0.350	0.0	5.000	0.07	<12	Yes	940732	9/10/2013	331511	427
4.8.1	Foundries - Ferrous	Material Handler	431	0.210	14.0	0.625	0.34	29	Yes	567706	8/8/2012	331511	851
4.8.1	Foundries - Ferrous	Material Handler	434	0.330	12.0	0.714	0.47	40	Yes	907214	5/16/2013	331513	670
4.8.1	Foundries - Ferrous	Material Handler	474	0.620	12.0	0.714	0.87	74	Yes	907214	5/16/2013	331513	668
4.8.1	Foundries - Ferrous	Material Handler	412	0.490	3.0	2.000	0.25	15	Yes	835024	1/18/2013	331511	120
4.8.1	Foundries - Ferrous	Molder	431	0.270	0.0	5.000	0.05	<12	Yes	954756	1/15/2014	331511	998
4.8.1	Foundries - Ferrous	Molder	432	0.370	5.6	1.319	0.28	21	Yes	835024	1/18/2013	331511	116
4.8.1	Foundries - Ferrous	Molder	486	1.271	2.0	2.500	0.51	25	Yes	460413	6/4/2012	331511	787
4.8.1	Foundries - Ferrous	Molder	436	0.000	0.0	5.000	0.00	<12	Yes	835024	1/18/2013	331511	115
4.8.1	Foundries - Ferrous	Molder	441	0.190	0.0	5.000	0.04	<12	Yes	916302	7/5/2013	331513	653
4.8.1	Foundries - Ferrous	Molder	377	1.106	5.1	1.408	0.79	56	Yes	110406	12/15/2011	331511	441
4.8.1	Foundries - Ferrous	Molder	469	2.200	0.8	3.589	0.61	17	Yes	109180	11/17/2011	331513	697
4.8.1	Foundries - Ferrous	Molder	454	0.210	0.0	5.000	0.04	<12	Yes	916302	7/5/2013	331513	652
4.8.1	Foundries - Ferrous	Molder	439	0.150	0.0	5.000	0.03	<12	Yes	916302	7/5/2013	331513	654
4.8.1	Foundries - Ferrous	Molder	158	0.202	0.0	5.000	0.04	<12	Yes	765461	12/11/2012	331511	37
4.8.1	Foundries - Ferrous	Molder	472	0.570	4.2	1.613	0.35	24	Yes	936046	8/28/2013	331511	96
4.8.1	Foundries - Ferrous	Molder	455	0.000	0.0	5.000	0.00	<12	Yes	460413	6/4/2012	331511	786
4.8.1	Foundries - Ferrous	Molder	464	0.000	0.0	5.000	0.00	<12	Yes	460413	6/4/2012	331511	784
4.8.1	Foundries - Ferrous	Molder	431	0.510	0.0	5.000	0.10	<12	Yes	835024	1/18/2013	331511	117
4.8.1	Foundries - Ferrous	Molder	455	0.000	0.0	5.000	0.00	<12	Yes	460413	6/4/2012	331511	788
4.8.1	Foundries - Ferrous	Molder	210	0.530	6.4	1.190	0.45	34	Yes	603518	8/31/2012	331511	170
4.8.1	Foundries - Ferrous	Molder	472	0.380	9.3	0.885	0.43	35	Yes	909667	5/30/2013	331513	921
4.8.1	Foundries - Ferrous	Molder	478	0.682	1.8	2.660	0.26	12	Yes	109180	11/17/2011	331513	698
4.8.1	Foundries - Ferrous	Molder	466	0.490	8.4	0.962	0.51	41	Yes	909667	5/30/2013	331513	920
4.8.1	Foundries - Ferrous	Molder	464	0.699	1.8	2.660	0.26	12	Yes	109180	11/17/2011	331513	699

Table IV.A-2 OIS Health Sampling Data for Respirable Crystalline Silica 2011-2014 (Document ID 3958)

Sec.	Section Name	Job Category	Sample Duration (min.)	Resp. Dust (mg/m^3)	Pct. Silica	PEL (mg/m^3)	Severity	Resp. Silica ($\mu g/m^3$)	Included in Profile	Inspec. ID	Opening Date	NAICS	Docket File Row #
4.8.1	Foundries - Ferrous	Molder	420	0.190	0.0	5.000	0.04	<12	Yes	835024	1/18/2013	331511	118
4.8.1	Foundries - Ferrous	Molder	420	0.300	0.0	5.000	0.06	<12	Yes	835024	1/18/2013	331511	119
4.8.1	Foundries - Ferrous	Molder	459	0.362	0.0	5.000	0.07	<12	Yes	436371	5/15/2012	331511	719
4.8.1	Foundries - Ferrous	Molder	210	0.400	11.0	0.769	0.52	44	Yes	603518	8/31/2012	331511	171
4.8.1	Foundries - Ferrous	Molder	415	0.980	4.1	1.639	0.60	40	Yes	954795	1/15/2014	331511	594
4.8.1	Foundries - Ferrous	Molder	435	0.500	3.8	1.724	0.29	19	Yes	954795	1/15/2014	331511	597
4.8.1	Foundries - Ferrous	Molder	465	1.468	6.7	1.156		98	Yes	444333	5/25/2012	331511	846
4.8.1	Foundries - Ferrous	Molder	398	3.300	0.0	5.000	0.66	<12	Yes	945054	10/24/2013	331511	978
4.8.1	Foundries - Ferrous	Molder	429	0.300	9.2	0.893	0.34	28	Yes	954795	1/15/2014	331511	592
4.8.1	Foundries - Ferrous	Molder	358	0.000	0.0	5.000	0.00	<12	Yes	77317	6/30/2011	331511	755
4.8.1	Foundries - Ferrous	Pouring Operator	384	1.400	8.8	0.926	1.51	123	Yes	954795	1/15/2014	331511	596
4.8.1	Foundries - Ferrous	Pouring Operator	451	0.560	2.5	2.216	0.25	14	Yes	835024	1/18/2013	331511	121
4.8.1	Foundries - Ferrous	Sand Systems Operator	480	0.430	8.2	0.981	0.44	35	Yes	936046	8/28/2013	331511	98
4.8.1	Foundries - Ferrous	Sand Systems Operator	425	0.700	0.0	5.000	0.14	<12	Yes	835024	1/18/2013	331511	125
4.8.1	Foundries - Ferrous	Sand Systems Operator	318	0.350	14.0	0.625	0.55	49	Yes	907214	5/16/2013	331513	672
4.8.1	Foundries - Ferrous	Sand Systems Operator	467	0.370	16.0	0.556	0.66	59	Yes	907214	5/16/2013	331513	666
4.8.1	Foundries - Ferrous	Sand Systems Operator	136	0.140	16.0	0.556	0.25	22	Yes	907214	5/16/2013	331513	674
4.8.1	Foundries - Ferrous	Sand Systems Operator	480	0.490	16.0	0.556	0.89	78	Yes	936046	8/28/2013	331511	97
4.8.1	Foundries - Ferrous	Sand Systems Operator	460	0.440	0.0	5.000	0.09	<12	Yes	950776	12/4/2013	331511	277
4.8.1	Foundries - Ferrous	Shakeout Operator	420	0.690	3.9	1.695	0.40	27	Yes	835024	1/18/2013	331511	124
4.8.1	Foundries - Ferrous	Shakeout Operator	462	0.360	7.5	1.053	0.35	27	Yes	954795	1/15/2014	331511	598
4.8.1	Foundries - Ferrous	Shakeout Operator	472	0.650	9.0	0.909	0.71	58	Yes	909667	5/30/2013	331513	918
4.8.1	Foundries - Ferrous	Shakeout Operator	460	0.620	8.3	0.971	0.64	51	Yes	909667	5/30/2013	331513	917
4.8.1	Foundries - Ferrous	Shakeout Operator	440	1.900	19.0	0.476	3.89	361	Yes	950776	12/4/2013	331511	276
4.8.1	Foundries - Ferrous	Shakeout Operator	469	1.778	4.0	1.660	1.07	72	Yes	444333	5/25/2012	331511	843
4.8.1	Foundries - Ferrous	Shakeout Operator	461	2.166	2.0	2.494	0.87	44	Yes	109180	11/17/2011	331513	700
4.8.1	Foundries - Ferrous	Shakeout Operator	435	0.830	5.2	1.389	3.39	43	Yes	460413	6/4/2012	331511	785
4.8.1	Foundries - Ferrous	Shakeout Operator	438	1.138	3.3	1.890	0.60	37	Yes	77317	6/30/2011	331511	758
4.8.1	Foundries - Ferrous	Shakeout Operator	468	0.340	11.0	0.769	0.45	37	Yes	909667	5/30/2013	331513	919
4.8.1	Foundries - Ferrous	Shakeout Operator	447	1.507	6.4	1.190	1.27	96	Yes	110849	1/4/2012	331513	702
4.8.2	Foundries - Nonferrous	Abrasive Blasting Operator	456	0.480	8.9	0.917	0.52	43	Yes	820741	1/11/2013	331524	855
4.8.2	Foundries - Nonferrous	Cleaning/Finishing Operator	74	0.000	0.0	5.000	0.00	<12	Yes	807241	1/3/2013	331521	6

Table IV.A-2 OIS Health Sampling Data for Respirable Crystalline Silica 2011-2014 (Document ID 3958)													
Sec.	**Section Name**	**Job Category**	**Sample Duration (min.)**	**Resp. Dust (mg/m^3)**	**Pct. Silica**	**PEL (mg/m^3)**	**Severity**	**Resp. Silica (μg/m^3)**	**Included in Profile**	**Inspec. ID**	**Opening Date**	**NAICS**	**Docket File Row #**
4.8.2	Foundries - Nonferrous	Cleaning/Finishing Operator	67	0.300	0.0	5.000	0.06	<12	Yes	785923	12/14/2012	331524	821
4.8.2	Foundries - Nonferrous	Cleaning/Finishing Operator	258	0.099	0.0	5.000	0.02	<12	Yes	448534	5/30/2012	331524	848
4.8.2	Foundries - Nonferrous	Cleaning/Finishing Operator	487	0.000	0.0	5.000	0.00	<12	Yes	110341	12/15/2011	331524	778
4.8.2	Foundries - Nonferrous	Cleaning/Finishing Operator	424	0.000	0.0	5.000	0.00	<12	Yes	92454	7/19/2011	331524	767
4.8.2	Foundries - Nonferrous	Cleaning/Finishing Operator	456	0.220	12.0	0.714	0.31	26	Yes	820741	1/11/2013	331524	856
4.8.2	Foundries - Nonferrous	Cleaning/Finishing Operator	428	0.000	0.0	5.000	0.00	<12	Yes	92454	7/19/2011	331524	762
4.8.2	Foundries - Nonferrous	Cleaning/Finishing Operator	472	0.280	4.4	1.552	0.18	12	Yes	737142	11/15/2012	331524	576
4.8.2	Foundries - Nonferrous	Cleaning/Finishing Operator	299	0.000	0.0	5.000	0.00	<12	Yes	279756	3/8/2012	331524	549
4.8.2	Foundries - Nonferrous	Cleaning/Finishing Operator	294	0.000	0.0	5.000	0.00	<12	Yes	279756	3/8/2012	331524	550
4.8.2	Foundries - Nonferrous	Cleaning/Finishing Operator	355	0.600	0.0	5.000	0.12	<12	Yes	923505	7/29/2013	331528	490
4.8.2	Foundries - Nonferrous	Cleaning/Finishing Operator	412	0.770	2.0	2.500	0.31	15	Yes	770321	12/6/2012	331524	473
4.8.2	Foundries - Nonferrous	Cleaning/Finishing Operator	60	0.240	0.0	5.000	0.05	<12	Yes	923505	7/29/2013	331528	491
4.8.2	Foundries - Nonferrous	Cleaning/Finishing Operator	293	0.000	0.0	5.000	0.00	<12	Yes	279756	3/8/2012	331524	551
4.8.2	Foundries - Nonferrous	Cleaning/Finishing Operator	510	0.503	4.2	1.610	0.31	21	Yes	279756	3/8/2012	331524	552
4.8.2	Foundries - Nonferrous	Cleaning/Finishing Operator	280	0.120	29.0	0.323	0.36	35	Yes	737142	11/15/2012	331524	572
4.8.2	Foundries - Nonferrous	Cleaning/Finishing Operator	451	0.480	5.3	1.370	0.35	25	Yes	785802	12/14/2012	331525	475
4.8.2	Foundries - Nonferrous	Coremaker	445	0.065	0.0	5.000	0.01	<12	Yes	283502	3/28/2012	331528	711
4.8.2	Foundries - Nonferrous	Coremaker	438	0.067	0.0	5.000	0.01	<12	Yes	190470	2/1/2012	331528	1014
4.8.2	Foundries - Nonferrous	Coremaker	408	0.200	0.0	5.000	0.04	<12	Yes	952302	12/17/2013	331524	510
4.8.2	Foundries - Nonferrous	Coremaker	447	0.340	4.4	1.563	0.22	15	Yes	785802	12/14/2012	331525	476
4.8.2	Foundries - Nonferrous	Coremaker	518	0.000	0.0	5.000	0.00	<12	Yes	110341	12/15/2011	331524	774

Table IV.A-2 OIS Health Sampling Data for Respirable Crystalline Silica 2011-2014 (Document ID 3958)														
Sec.	**Section Name**	**Job Category**	**Sample Duration (min.)**	**Resp. Dust (mg/m³)**	**Pct. Silica**	**PEL (mg/m³)**	**Severity**	**Resp. Silica (µg/m³)**	**Included in Profile**	**Inspec. ID**	**Opening Date**	**NAICS**	**Docket File Row #**
4.8.2	Foundries - Nonferrous	Coremaker	445	0.110	0.0	5.000	0.02	<12	Yes	792242	12/19/2012	331528	478
4.8.2	Foundries - Nonferrous	Coremaker	450	0.000	0.0	5.000	0.00	<12	Yes	92454	7/19/2011	331524	761
4.8.2	Foundries - Nonferrous	Coremaker	457	1.600	6.1	1.235	1.30	98	Yes	785802	12/14/2012	331525	474
4.8.2	Foundries - Nonferrous	Coremaker	452	4.708	0.0	5.000	0.94	<12	Yes	111193	1/13/2012	331524	451
4.8.2	Foundries - Nonferrous	Coremaker	445	0.343	3.9	1.695	0.20	13	Yes	111193	1/13/2012	331524	449
4.8.2	Foundries - Nonferrous	Furnace Operator	408	0.250	6.3	1.205	0.21	16	Yes	732964	11/7/2012	331525	102
4.8.2	Foundries - Nonferrous	Knockout Operator	464	1.000	8.4	0.960	1.08	84	Yes	737142	11/15/2012	331524	574
4.8.2	Foundries - Nonferrous	Knockout Operator	438	0.880	8.1	0.990	0.89	71	Yes	785802	12/14/2012	331525	477
4.8.2	Foundries - Nonferrous	Knockout Operator	452	0.443	3.5	1.818	0.24	15	Yes	111193	1/13/2012	331524	450
4.8.2	Foundries - Nonferrous	Knockout Operator	119	0.068	0.0	5.000	0.01	<12	Yes	952302	12/17/2013	331524	509
4.8.2	Foundries - Nonferrous	Knockout Operator	252	0.200	0.0	5.000	0.04	<12	Yes	952302	12/17/2013	331524	508
4.8.2	Foundries - Nonferrous	Knockout Operator	470	0.450	8.2	0.983	0.46	37	Yes	737142	11/15/2012	331524	577
4.8.2	Foundries - Nonferrous	Knockout Operator	397	0.496	5.0	1.428	0.35	25	Yes	943027	10/7/2013	331524	830
4.8.2	Foundries - Nonferrous	Maintenance Operator	469	0.000	0.0	5.000	0.00	<12	Yes	110341	12/15/2011	331524	776
4.8.2	Foundries - Nonferrous	Material Handler	467	0.230	15.0	0.588	0.40	35	Yes	820741	1/11/2013	331524	857
4.8.2	Foundries - Nonferrous	Molder	413	0.170	14.0	0.625	0.27	24	Yes	732964	11/7/2012	331525	103
4.8.2	Foundries - Nonferrous	Molder	431	0.100	0.0	5.000	0.02	<12	Yes	960814	3/3/2014	331528	436
4.8.2	Foundries - Nonferrous	Molder	380	0.190	9.4	0.877	0.22	18	Yes	956270	1/22/2014	331524	896
4.8.2	Foundries - Nonferrous	Molder	405	0.200	0.0	5.000	0.04	<12	Yes	956270	1/22/2014	331524	894
4.8.2	Foundries - Nonferrous	Molder	424	0.650	8.4	0.962	0.68	55	Yes	960814	3/3/2014	331528	435
4.8.2	Foundries - Nonferrous	Molder	461	0.730	7.6	1.042	0.71	55	Yes	737142	11/15/2012	331524	578

Table IV.A-2 OIS Health Sampling Data for Respirable Crystalline Silica 2011-2014 (Document ID 3958)													
Sec.	**Section Name**	**Job Category**	**Sample Duration (min.)**	**Resp. Dust (mg/m^3)**	**Pct. Silica**	**PEL (mg/m^3)**	**Severity**	**Resp. Silica (μg/m^3)**	**Included in Profile**	**Inspec. ID**	**Opening Date**	**NAICS**	**Docket File Row #**
4.8.2	Foundries - Nonferrous	Molder	443	0.129	0.0	5.000	0.03	<12	Yes	190470	2/1/2012	331528	1013
4.8.2	Foundries - Nonferrous	Molder	415	0.780	3.2	1.913	0.41	25	Yes	768061	12/3/2012	331524	107
4.8.2	Foundries - Nonferrous	Molder	472	0.180	14.0	0.625	0.29	25	Yes	737142	11/15/2012	331524	575
4.8.2	Foundries - Nonferrous	Molder	465	0.260	12.0	0.714	0.37	31	Yes	737142	11/15/2012	331524	571
4.8.2	Foundries - Nonferrous	Molder	480	0.000	0.0	5.000	0.00	<12	Yes	279756	3/8/2012	331524	554
4.8.2	Foundries - Nonferrous	Molder	523	0.406	4.5	1.540	0.26	18	Yes	110341	12/15/2011	331524	773
4.8.2	Foundries - Nonferrous	Molder	512	0.000	0.0	5.000	0.00	<12	Yes	110341	12/15/2011	331524	775
4.8.2	Foundries - Nonferrous	Molder	415	0.870	0.0	5.000	0.17	<12	Yes	952302	12/17/2013	331524	507
4.8.2	Foundries - Nonferrous	Molder	422	0.470	0.0	5.000	0.09	<12	Yes	935060	8/21/2013	331529	1068
4.8.2	Foundries - Nonferrous	Molder	457	0.930	0.0	5.000	0.19	<12	Yes	862863	2/1/2013	331529	812
4.8.2	Foundries - Nonferrous	Molder	485	0.110	23.0	0.400	0.28	25	Yes	802521	12/27/2012	331524	793
4.8.2	Foundries - Nonferrous	Molder	390	0.260	8.0	1.000	0.26	21	Yes	732964	11/7/2012	331525	104
4.8.2	Foundries - Nonferrous	Molder	480	0.593	2.9	2.040	0.29	17	Yes	279756	3/8/2012	331524	553
4.8.2	Foundries - Nonferrous	Molder	429	0.000	0.0	5.000	0.00	<12	Yes	92454	7/19/2011	331524	766
4.8.2	Foundries - Nonferrous	Molder	447	0.190	11.0	0.769	0.24	21	Yes	737142	11/15/2012	331524	570
4.8.2	Foundries - Nonferrous	Molder	418	0.135	0.0	5.000	0.03	<12	Yes	190470	2/1/2012	331528	1011
4.8.2	Foundries - Nonferrous	Molder	432	0.000	0.0	5.000	0.00	<12	Yes	92454	7/19/2011	331524	764
4.8.2	Foundries - Nonferrous	Pouring Operator	480	0.000	0.0	5.000	0.00	<12	Yes	279756	3/8/2012	331524	557
4.8.2	Foundries - Nonferrous	Pouring Operator	481	0.140	12.0	0.714	0.19	17	Yes	802521	12/27/2012	331524	792
4.8.2	Foundries - Nonferrous	Pouring Operator	498	0.000	0.0	5.000	0.00	<12	Yes	279756	3/8/2012	331524	556
4.8.2	Foundries - Nonferrous	Pouring Operator	424	0.210	7.6	1.042	0.21	16	Yes	732964	11/7/2012	331525	106

Table IV.A-2 OIS Health Sampling Data for Respirable Crystalline Silica 2011-2014 (Document ID 3958)													
Sec.	**Section Name**	**Job Category**	**Sample Duration (min.)**	**Resp. Dust (mg/m^3)**	**Pct. Silica**	**PEL (mg/m^3)**	**Severity**	**Resp. Silica ($\mu g/m^3$)**	**Included in Profile**	**Inspec. ID**	**Opening Date**	**NAICS**	**Docket File Row #**
4.8.2	Foundries - Nonferrous	Pouring Operator	480	0.000	0.0	5.000	0.00	<12	Yes	279756	3/8/2012	331524	555
4.8.2	Foundries - Nonferrous	Sand Systems Operator	452	0.200	8.2	0.980	0.20	16	Yes	768061	12/3/2012	331524	109
4.8.2	Foundries - Nonferrous	Sand Systems Operator	263	0.130	18.0	0.500	0.26	23	Yes	740721	11/16/2012	331529	470
4.8.2	Foundries - Nonferrous	Shakeout Operator	499	0.450	4.5	1.538	0.29	20	Yes	768061	12/3/2012	331524	111
4.8.2	Foundries - Nonferrous	Shakeout Operator	487	0.000	0.0	5.000	0.00	<12	Yes	110341	12/15/2011	331524	777
4.8.2	Foundries - Nonferrous	Shakeout Operator	450	0.420	8.2	0.979	0.42	35	Yes	792242	12/19/2012	331528	480
4.8.2	Foundries - Nonferrous	Shakeout Operator	412	1.500	0.0	5.000	0.30	<12	Yes	952302	12/17/2013	331524	506
4.8.2	Foundries - Nonferrous	Shakeout Operator	350	0.180	0.0	5.000	0.04	<12	Yes	792242	12/19/2012	331528	479
4.8.2	Foundries - Nonferrous	Shakeout Operator	455	0.959	2.2	2.380	0.40	21	Yes	283502	3/28/2012	331528	709
4.8.2	Foundries - Nonferrous	Shakeout Operator	473	0.240	0.0	5.000	0.05	<12	Yes	552240	8/2/2012	331524	691
4.8.2	Foundries - Nonferrous	Shakeout Operator	460	0.630	5.8	1.280	0.49	37	Yes	283502	3/28/2012	331528	710
4.8.2	Foundries - Nonferrous	Shakeout Operator	420	0.130	13.0	0.667	0.20	17	Yes	732964	11/7/2012	331525	105
4.8.2	Foundries - Nonferrous	Shakeout Operator	336	0.000	0.0	5.000	0.00	<12	Yes	279756	3/8/2012	331524	548
4.8.2	Foundries - Nonferrous	Shakeout Operator	482	0.560	10.0	0.835	0.67	56	Yes	737142	11/15/2012	331524	573
4.8.3	Foundries - Non-sand Casting	Abrasive Blasting Operator	406	0.190	7.3	1.071	0.18	14	Yes	756821	11/28/2012	331524	635
4.8.3	Foundries - Non-sand Casting	Abrasive Blasting Operator	412	3.178	12.0	0.714	4.45	381	Yes	109670	11/30/2011	331525	771
4.8.3	Foundries - Non-sand Casting	Abrasive Blasting Operator	452	1.600	13.6	0.640	2.52	218	Yes	899532	4/8/2013	331525	648
4.8.3	Foundries - Non-sand Casting	Abrasive Blasting Operator	478	0.636	4.2	1.613	0.39	27	Yes	109670	11/30/2011	331525	772
4.8.3	Foundries - Non-sand Casting	Cleaning/Finishing Operator	410	0.630	0.0	5.000	0.13	<12	Yes	897475	3/25/2013	331512	798
4.8.3	Foundries - Non-sand Casting	Cleaning/Finishing Operator	96	10.000	0.0	5.000	2.06	<12	Yes	109829	12/1/2011	331524	27
4.8.3	Foundries - Non-sand Casting	Cleaning/Finishing Operator	424	1.500	1.7	2.703	0.56	25	Yes	552538	8/2/2012	331512	406

Table IV.A-2 OIS Health Sampling Data for Respirable Crystalline Silica 2011-2014 (Document ID 3958)														
Sec.	**Section Name**	**Job Category**	**Sample Duration (min.)**	**Resp. Dust (mg/m³)**	**Pct. Silica**	**PEL (mg/m³)**	**Severity**	**Resp. Silica (μg/m³)**	**Included in Profile**	**Inspec. ID**	**Opening Date**	**NAICS**	**Docket File Row #**
4.8.3	Foundries - Non-sand Casting	Cleaning/Finishing Operator	341	1.200	0.0	5.000	0.25	<12	Yes	897475	3/25/2013	331512	796
4.8.3	Foundries - Non-sand Casting	Cleaning/Finishing Operator	433	2.800	0.0	5.000	0.55	<12	Yes	552538	8/2/2012	331512	408
4.8.3	Foundries - Non-sand Casting	Cleaning/Finishing Operator	452	0.720	0.0	5.000	0.15	<12	Yes	912913	6/21/2013	331512	737
4.8.3	Foundries - Non-sand Casting	Cleaning/Finishing Operator	455	0.630	0.0	5.000	0.13	<12	Yes	912913	6/21/2013	331512	736
4.8.3	Foundries - Non-sand Casting	Cleaning/Finishing Operator	425	1.700	1.6	2.778	0.63	27	Yes	552538	8/2/2012	331512	405
4.8.3	Foundries - Non-sand Casting	Cleaning/Finishing Operator	406	0.190	15.9	0.559	0.34	30	Yes	756821	11/28/2012	331524	633
4.8.3	Foundries - Non-sand Casting	Cleaning/Finishing Operator	422	0.640	0.0	5.000	0.13	<12	Yes	897475	3/25/2013	331512	797
4.8.3	Foundries - Non-sand Casting	Cleaning/Finishing Operator	418	2.500	0.0	5.000	0.50	<12	Yes	552538	8/2/2012	331512	407
4.8.3	Foundries - Non-sand Casting	Coremaker	390	0.038	0.0	5.000	0.01	<12	Yes	924714	8/2/2013	331521	246
4.8.3	Foundries - Non-sand Casting	Furnace Operator	320	0.360	0.0	5.000	0.07	<12	Yes	892387	2/26/2013	331528	156
4.8.3	Foundries - Non-sand Casting	Furnace Operator	302	6.900	0.0	5.000	1.37	<12	Yes	892387	2/26/2013	331528	154
4.8.3	Foundries - Non-sand Casting	Knockout Operator	405	7.400	8.3	0.971	7.62	614	Yes	912913	6/21/2013	331512	740
4.8.3	Foundries - Non-sand Casting	Knockout Operator	447	4.800	8.4	0.962	5.03	403	Yes	912913	6/21/2013	331512	739
4.8.3	Foundries - Non-sand Casting	Knockout Operator	399	0.500	5.4	1.351	0.37	27	Yes	912913	6/21/2013	331512	738
4.8.3	Foundries - Non-sand Casting	Molder	373	0.901	2.6	2.170	0.42	23	Yes	242914	2/28/2012	331521	546
4.8.3	Foundries - Non-sand Casting	Molder	390	0.170	0.0	5.000	0.03	<12	Yes	924714	8/2/2013	331521	247
4.8.3	Foundries - Non-sand Casting	Molder	478	0.620	8.3	0.971	0.64	51	Yes	746821	11/20/2012	331524	409
4.8.3	Foundries - Non-sand Casting	Molder	390	0.170	0.0	5.000	0.03	<12	Yes	924714	8/2/2013	331521	244
4.8.3	Foundries - Non-sand Casting	Molder	430	0.310	0.0	5.000	0.06	<12	Yes	619058	9/6/2012	331521	469
4.8.3	Foundries - Non-sand Casting	Molder	430	0.430	0.0	5.000	0.09	<12	Yes	619058	9/6/2012	331521	468
4.8.3	Foundries - Non-sand Casting	Molder	464	0.130	0.0	5.000	0.03	<12	Yes	954132	1/9/2014	331525	980

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Sec.	**Section Name**	**Job Category**	**Sample Duration (min.)**	**Resp. Dust (mg/m^3)**	**Pct. Silica**	**PEL (mg/m^3)**	**Severity**	**Resp. Silica ($\mu g/m^3$)**	**Included in Profile**	**Inspec. ID**	**Opening Date**	**NAICS**	**Docket File Row #**
4.8.3	Foundries - Non-sand Casting	Pouring Operator	386	0.260	0.0	5.000	0.05	<12	Yes	895641	3/14/2013	331525	814
4.8.3	Foundries - Non-sand Casting	Pouring Operator	391	0.110	0.0	5.000	0.02	<12	Yes	895641	3/14/2013	331525	813
4.8.3	Foundries - Non-sand Casting	Pouring Operator	385	1.585	0.0	5.000	0.32	<12	Yes	897475	3/25/2013	331512	795
4.8.4	Foundries - Captive	Abrasive Blasting Operator	459	0.490	0.0	5.000	0.10	<12	Yes	908299	5/24/2013	332710	388
4.8.4	Foundries - Captive	Abrasive Blasting Operator	180	7.000	19.0	0.476	14.71	1330	Yes	915210	6/26/2013	332999	315
4.8.4	Foundries - Captive	Abrasive Blasting Operator	21	0.000	0.0	5.000	0.00	<12	Yes	945337	10/31/2013	332710	301
4.8.4	Foundries - Captive	Abrasive Blasting Operator	357	0.000	0.0	5.000	0.00	<12	Yes	242809	2/29/2012	336212	686
4.8.4	Foundries - Captive	Abrasive Blasting Operator	448	8.100	3.4	1.844	4.38	277	Yes	913042	6/21/2013	331210	95
4.8.4	Foundries - Captive	Cleaning/Finishing Operator	410	0.000	0.0	5.000	0.00	<12	Yes	191755	2/22/2012	333412	544
4.8.4	Foundries - Captive	Cleaning/Finishing Operator	420	0.000	0.0	5.000	0.00	<12	Yes	191755	2/22/2012	333412	543
4.8.4	Foundries - Captive	Cleaning/Finishing Operator	434	1.100	3.1	1.961	0.57	34	Yes	895574	3/14/2013	331111	418
4.8.4	Foundries - Captive	Cleaning/Finishing Operator	419	1.400	3.9	1.695	0.83	55	Yes	895574	3/14/2013	331111	420
4.8.4	Foundries - Captive	Cleaning/Finishing Operator	247	0.840	2.9	2.041	0.41	24	Yes	794821	11/27/2012	332111	637
4.8.4	Foundries - Captive	Cleaning/Finishing Operator	125	0.150	0.0	5.000	0.03	<12	Yes	896217	3/19/2013	332710	521
4.8.4	Foundries - Captive	Cleaning/Finishing Operator	480	0.690	0.0	5.000	0.14	<12	Yes	895715	3/14/2013	332611	929
4.8.4	Foundries - Captive	Cleaning/Finishing Operator	436	0.280	10.0	0.833	0.33	28	Yes	895574	3/14/2013	331111	417
4.8.4	Foundries - Captive	Cleaning/Finishing Operator	431	0.780	8.8	0.926	0.84	69	Yes	895574	3/14/2013	331111	419
4.8.4	Foundries - Captive	Cleaning/Finishing Operator	298	0.000	0.0	5.000	0.00	<12	Yes	895574	3/14/2013	331111	416
4.8.4	Foundries - Captive	Coremaker	469	0.410	3.3	1.887	0.22	14	Yes	749501	11/28/2012	336510	629
4.8.4	Foundries - Captive	Furnace Operator	457	0.670	0.0	5.000	0.14	<12	Yes	942968	10/2/2013	331111	656
4.8.4	Foundries - Captive	Furnace Operator	150	0.630	11.0	0.769	0.82	69	Yes	909056	5/30/2013	332510	71
4.8.4	Foundries - Captive	Furnace Operator	350	0.480	0.0	5.000	0.10	<12	Yes	942968	10/2/2013	331111	657
4.8.4	Foundries - Captive	Knockout Operator	351	0.300	12.6	0.685	0.44	38	Yes	889183	2/14/2013	331314	266
4.8.4	Foundries - Captive	Knockout Operator	465	0.140	0.0	5.000	0.03	<12	Yes	899857	4/9/2013	331492	649
4.8.4	Foundries - Captive	Knockout Operator	491	0.340	0.0	5.000	0.07	<12	Yes	889183	2/14/2013	331314	270
4.8.4	Foundries - Captive	Housekeeping	443	0.520	5.8	1.282	0.41	30	Yes	820221	1/10/2013	332919	221
4.8.4	Foundries - Captive	Maintenance Operator	118	0.130	0.0	5.000	0.03	<12	Yes	896217	3/19/2013	332710	520
4.8.4	Foundries - Captive	Maintenance Operator	434	0.580	0.0	5.000	0.12	<12	Yes	942968	10/2/2013	331111	658
4.8.4	Foundries - Captive	Maintenance Operator	434	0.430	0.0	5.000	0.09	<12	Yes	942968	10/2/2013	331111	659
4.8.4	Foundries - Captive	Maintenance Operator	250	1.300	63.0	0.154	8.21	819	Yes	954093	1/9/2014	332111	995
4.8.4	Foundries - Captive	Maintenance Operator	170	1.100	67.0	0.145	7.38	737	Yes	954093	1/9/2014	332111	996
4.8.4	Foundries - Captive	Maintenance Operator	250	1.400	51.0	0.189	7.34	714	Yes	954093	1/9/2014	332111	994

Table IV.A-2 OIS Health Sampling Data for Respirable Crystalline Silica 2011-2014 (Document ID 3958)

Sec.	Section Name	Job Category	Sample Duration (min.)	Resp. Dust (mg/m^3)	Pct. Silica	PEL (mg/m^3)	Severity	Resp. Silica (μg/m^3)	Included in Profile	Inspec. ID	Opening Date	NAICS	Docket File Row #
4.8.4	Foundries - Captive	Maintenance Operator	467	1.700	0.0	5.000	0.34	<12	Yes	889183	2/14/2013	331314	269
4.8.4	Foundries - Captive	Maintenance Operator	255	1.200	2.1	2.440	0.50	25	Yes	889183	2/14/2013	331314	268
4.8.4	Foundries - Captive	Maintenance Operator	455	0.530	0.0	5.000	0.11	<12	Yes	889183	2/14/2013	331314	267
4.8.4	Foundries - Captive	Maintenance Operator	250	2.800	52.0	0.185	15.29	1456	Yes	954093	1/9/2014	332111	997
4.8.4	Foundries - Captive	Molder	460	0.200	0.0	5.000	0.04	<12	Yes	914915	6/27/2013	333992	745
4.8.4	Foundries - Captive	Molder	384	0.520	6.5	1.176	0.45	34	Yes	638358	9/14/2012	333511	627
4.8.4	Foundries - Captive	Molder	380	0.000	0.0	5.000	0.00	<12	Yes	191755	2/22/2012	333412	545
4.8.4	Foundries - Captive	Molder	459	0.670	2.0	2.500	0.27	13	Yes	749501	11/28/2012	336510	631
4.8.4	Foundries - Captive	Shakeout Operator	388	0.830	3.5	1.818	0.46	29	Yes	638358	9/14/2012	333511	628
4.8.4	Foundries - Captive	Shakeout Operator	420	0.750	4.7	1.493	0.50	35	Yes	954093	1/9/2014	332111	990
4.8.4	Foundries - Captive	Shakeout Operator	465	0.200	14.0	0.625	0.31	28	Yes	862483	2/1/2013	332911	695
4.8.4	Foundries - Captive	Shakeout Operator	430	1.200	9.5	0.870	1.39	114	Yes	954093	1/9/2014	332111	992
4.8.4	Foundries - Captive	Shakeout Operator	423	0.560	10.0	0.833	0.67	56	Yes	954093	1/9/2014	332111	993
4.8.4	Foundries - Captive	Shakeout Operator	463	0.530	3.7	1.754	0.30	20	Yes	749501	11/28/2012	336510	630
4.8.4	Foundries - Captive	Shakeout Operator	420	1.100	11.0	0.769	1.42	121	Yes	954093	1/9/2014	332111	991
4.8.4	Foundries - Captive	Housekeeping	480	0.130	0.0	5.000	0.03	<12	Yes	424395	5/2/2012	332991	461
4.9	Glass Products	Batch Operations and Associated Workers	361	0.360	39.0	0.244	1.47	140	Yes	881383	2/12/2013	327212	382
4.9	Glass Products	Batch Operations and Associated Workers	459	0.029	0.0	5.000	0.01	<12	Yes	854323	1/23/2013	327212	264
4.10	Jewelry	Jeweler	433	0.650	0.0	5.000	0.13	<12	Yes	953897	1/6/2014	423940	59
4.10	Jewelry	Jeweler	450	0.630	0.0	5.000	0.13	<12	Yes	953897	1/6/2014	423940	60
4.10	Jewelry	Jeweler	469	0.190	0.0	5.000	0.04	<12	Yes	953897	1/6/2014	423940	58
4.11	Landscaping Services	Landscape Worker	409	0.900	1.9	2.564	0.35	17	Yes	805162	1/2/2013	561730	732
4.11	Landscaping Services	Landscape Worker	104	0.110	0.0	5.000	0.02	<12	Yes	805162	1/2/2013	561730	731
4.12	Mineral Processing	Production Worker (Before engineering improvements)	425	0.729	5.9	1.266	0.58	43	Yes	110529	12/21/2011	327910	447
4.12	Mineral Processing	Production Worker (Before engineering improvements)	426	0.260	0.0	5.000	0.05	<12	Yes	190040	1/25/2012	327910	453
4.12	Mineral Processing	Production Worker (Before engineering improvements)	444	0.000	0.0	5.000	0.00	<12	Yes	110529	12/21/2011	327910	448
4.12	Mineral Processing	Production Worker (Before engineering improvements)	457	0.845	7.4	1.064	0.79	63	Yes	110529	12/21/2011	327910	446

Table IV.A-2 OIS Health Sampling Data for Respirable Crystalline Silica 2011-2014 (Document ID 3958)													
Sec.	**Section Name**	**Job Category**	**Sample Duration (min.)**	**Resp. Dust (mg/m^3)**	**Pct. Silica**	**PEL (mg/m^3)**	**Severity**	**Resp. Silica ($\mu g/m^3$)**	**Included in Profile**	**Inspec. ID**	**Opening Date**	**NAICS**	**Docket File Row #**
4.12	Mineral Processing	Production Worker (Before engineering improvements)	428	1.300	0.0	5.000	0.27	<12	Yes	190040	1/25/2012	327910	452
4.12	Mineral Processing	Production Worker (Before engineering improvements)	457	0.058	0.0	5.000	0.01	<12	Yes	456174	6/5/2012	327999	464
4.12	Mineral Processing	Production Worker (Before engineering improvements)	200	0.130	29.0	0.323	0.41	38	Yes	563718	8/2/2012	325314	136
4.12	Mineral Processing	Production Worker (Before engineering improvements)	225	0.061	40.0	0.238	0.26	24	Yes	563718	8/2/2012	325314	137
4.12	Mineral Processing	Production Worker (Before engineering improvements)	190	0.340	10.7	0.787	0.43	36	Yes	563718	8/2/2012	325314	140
4.12	Mineral Processing	Production Worker (Before engineering improvements)	338	0.160	12.0	0.714	0.23	19	Yes	456174	6/5/2012	327999	465
4.12	Mineral Processing	Production Worker (Before engineering improvements)	97	0.066	0.0	5.000	0.01	<12	Yes	761743	11/28/2012	327999	471
4.12	Mineral Processing	Production Worker (Before engineering improvements)	190	0.160	26.0	0.357	0.44	42	Yes	563718	8/2/2012	325314	138
4.12	Mineral Processing	Production Worker (Before engineering improvements)	190	0.000	0.0	5.000	0.00	<12	Yes	946838	11/5/2013	327992	356
4.12	Mineral Processing	Production Worker (Before engineering improvements)	96	0.038	0.0	5.000	0.01	<12	Yes	761743	11/28/2012	327999	472
4.12	Mineral Processing	Production Worker (Before engineering improvements)	75	0.240	8.4	0.962	0.25	20	Yes	563718	8/2/2012	325314	139
4.12	Mineral Processing	Production Worker (With engineering controls)	451	0.092	18.0	0.500	0.18	17	Yes	456174	6/5/2012	327999	467
4.12	Mineral Processing	Production Worker (With engineering controls)	449	0.000	0.0	5.000	0.00	<12	Yes	907249	5/14/2013	339999	295
4.12	Mineral Processing	Production Worker (With engineering controls)	427	0.289	5.1	1.408	0.21	15	Yes	907249	5/14/2013	339999	300
4.12	Mineral Processing	Production Worker (With engineering controls)	421	0.154	9.3	0.885	0.17	14	Yes	907249	5/14/2013	339999	298
4.12	Mineral Processing	Production Worker (With engineering controls)	465	0.069	21.0	0.435	0.16	14	Yes	456174	6/5/2012	327999	466
4.12	Mineral Processing	Production Worker (With engineering controls)	405	0.000	0.0	5.000	0.00	<12	Yes	907249	5/14/2013	339999	296
4.13	Paint and Coatings	Material Handler	410	0.300	0.0	5.000	0.06	<12	Yes	912246	6/18/2013	325510	533

Table IV.A-2 OIS Health Sampling Data for Respirable Crystalline Silica 2011-2014 (Document ID 3958)

Sec.	Section Name	Job Category	Sample Duration (min.)	Resp. Dust (mg/m^3)	Pct. Silica	PEL (mg/m^3)	Severity	Resp. Silica ($\mu g/m^3$)	Included in Profile	Inspec. ID	Opening Date	NAICS	Docket File Row #
4.13	Paint and Coatings	Material Handler	422	0.830	0.0	5.000	0.17	<12	Yes	912246	6/18/2013	325510	534
4.13	Paint and Coatings	Material Handler	422	0.620	0.0	5.000	0.12	<12	Yes	912246	6/18/2013	325510	532
4.13	Paint and Coatings	Mixer Operator	475	0.354	67.0	0.145	2.45	237	Yes	958068	2/10/2014	325510	238
4.13	Paint and Coatings	Mixer Operator	479	0.097	50.0	0.192	0.51	49	Yes	958068	2/10/2014	325510	239
4.15	Pottery	Finishing Operator	179	0.350	0.0	5.000	0.07	<12	Yes	846024	1/23/2013	327111	964
4.15	Pottery	Finishing Operator	140	1.100	0.0	5.000	0.23	<12	Yes	846024	1/23/2013	327111	963
4.15	Pottery	Finishing Operator	428	0.320	6.0	1.250	0.26	19	Yes	951568	12/11/2013	327112	589
4.15	Pottery	Finishing Operator	403	0.480	6.6	1.163	0.41	32	Yes	951568	12/11/2013	327112	587
4.15	Pottery	Finishing Operator	411	0.390	8.1	0.990	0.39	32	Yes	951568	12/11/2013	327112	590
4.15	Pottery	Coatings Preparer	169	0.730	10.0	0.833	0.87	73	Yes	846024	1/23/2013	327111	966
4.15	Pottery	Coatings Preparer	159	2.800	8.4	0.962	0.00	235	Yes	846024	1/23/2013	327111	965
4.17	Ready-Mix Concrete	Batch Operator	460	1.287	1.2	3.112		16	Yes	472062	6/18/2012	327320	560
4.17	Ready-Mix Concrete	Batch Operator	465	0.310	5.3	1.370	0.22	16	Yes	949452	11/21/2013	327320	222
4.17	Ready-Mix Concrete	Batch Operator	460	1.826	1.3	2.990		25	Yes	472062	6/18/2012	327320	561
4.17	Ready-Mix Concrete	Batch Operator	460	0.028	0.0	5.000	0.01	<12	Yes	914843	6/25/2013	327320	273
4.17	Ready-Mix Concrete	Batch Operator	463	0.760	10.0	0.833	0.91	76	Yes	949452	11/21/2013	327320	223
4.17	Ready-Mix Concrete	Material Handler	460	3.063	4.3	1.594		131	Yes	472062	6/18/2012	327320	562
4.17	Ready-Mix Concrete	Material Handler	470	3.579	1.3	3.019		47	Yes	472062	6/18/2012	327320	563
4.17	Ready-Mix Concrete	Material Handler	460	0.976	1.3	3.000		13	Yes	472062	6/18/2012	327320	564
4.17	Ready-Mix Concrete	Material Handler	340	0.000	0.0	5.000	0.00	<12	Yes	925665	8/7/2013	327320	248
4.17	Ready-Mix Concrete	Material Handler	410	0.390	6.2	1.220	0.32	24	Yes	930361	8/15/2013	327320	249
4.17	Ready-Mix Concrete	Quality Control Technician	455	0.076	0.0	5.000	0.02	<12	Yes	907391	5/17/2013	327320	158
4.17	Ready-Mix Concrete	Quality Control Technician	449	0.180	0.0	5.000	0.04	<12	Yes	907391	5/17/2013	327320	159
4.18	Refractories	Forming Operator	425	0.830	4.1	1.650	0.50	34	Yes	903169	4/30/2013	327125	526
4.18	Refractories	Forming Operator	420	1.500	4.7	1.483	1.00	71	Yes	903169	4/30/2013	327125	528
4.18	Refractories	Forming Operator	433	0.350	13.0	0.666	0.52	46	Yes	903169	4/30/2013	327125	530
4.18	Refractories	Forming Operator	410	0.160	22.1	0.415	0.38	35	Yes	903169	4/30/2013	327125	529
4.18	Refractories	Forming Operator	315	2.100	0.0	5.000	0.42	<12	Yes	903169	4/30/2013	327125	531
4.18	Refractories	Forming Operator	480	1.100	3.8	1.724	0.64	42	Yes	850764	1/28/2013	327124	824
4.18	Refractories	Forming Operator	435	0.420	4.3	1.590	0.27	18	Yes	903169	4/30/2013	327125	525
4.18	Refractories	Forming Operator	425	0.640	5.5	1.334	0.48	35	Yes	903169	4/30/2013	327125	527
4.18	Refractories	Material Handler	467	2.300	0.0	5.000	0.47	<12	Yes	876583	2/6/2013	327125	961
4.18	Refractories	Material Handler	447	0.230	0.0	5.000	0.05	<12	Yes	876583	2/6/2013	327125	960
4.18	Refractories	Material Handler	480	0.460	0.0	5.000	0.09	<12	Yes	850764	1/28/2013	327124	822

Table IV.A-2 OIS Health Sampling Data for Respirable Crystalline Silica 2011-2014 (Document ID 3958)													
Sec.	**Section Name**	**Job Category**	**Sample Duration (min.)**	**Resp. Dust (mg/m^3)**	**Pct. Silica**	**PEL (mg/m^3)**	**Severity**	**Resp. Silica (μg/m^3)**	**Included in Profile**	**Inspec. ID**	**Opening Date**	**NAICS**	**Docket File Row #**
4.18	Refractories	Packaging Operator	452	5.400	0.0	5.000	1.09	<12	Yes	876583	2/6/2013	327125	962
4.19	Refractory Repair	Refractory Worker	467	2.300	0.0	5.000	0.47	<12	Yes	697738	10/16/2012	238290	943
4.20	Shipyards	Painter	23	1.800	0.0	5.000	0.36	<12	Yes	722342	10/31/2012	336611	217
4.20	Shipyards	Painter	74	1.300	0.0	5.000	0.26	<12	Yes	950492	12/3/2013	336611	332
4.21	Structural Clay	Grinding Operators	398	0.250	0.0	5.000	0.05	<12	Yes	583278	8/16/2012	327122	616
4.21	Structural Clay	Grinding Operators	476	3.200	13.7	0.637	5.07	438	Yes	583278	8/16/2012	327122	610
4.21	Structural Clay	Grinding Operators	480	0.490	15.5	0.572	0.86	76	Yes	583278	8/16/2012	327122	613
4.22	Hydraulic Fracturing	Ancillary Support Workers	244	0.100	0.0	5.000	0.02	<12	Yes	899235	4/4/2013	213112	180
4.22	Hydraulic Fracturing	Ancillary Support Workers	349	0.340	25.0	0.370	0.91	85	Yes	939349	9/4/2013	213112	188
4.22	Hydraulic Fracturing	Fracturing Sand Workers	35	0.000	0.0	5.000	0.00	<12	Yes	741241	11/15/2012	213112	220
4.22	Hydraulic Fracturing	Fracturing Sand Workers	391	0.322	40.0	0.238	1.35	129	Yes	893563	3/6/2013	213112	1036
4.22	Hydraulic Fracturing	Fracturing Sand Workers	124	0.750	39.0	0.244	3.09	293	Yes	942381	9/24/2013	213112	194
4.22	Hydraulic Fracturing	Fracturing Sand Workers	154	0.067	71.0	0.137	0.49	48	Yes	943011	10/4/2013	213112	196
4.22	Hydraulic Fracturing	Fracturing Sand Workers	376	1.233	57.0	0.170	7.27	703	Yes	893563	3/6/2013	213112	1037
4.22	Hydraulic Fracturing	Fracturing Sand Workers	250	0.540	27.0	0.345	1.57	146	Yes	902898	4/26/2013	213112	182
4.22	Hydraulic Fracturing	Fracturing Sand Workers	352	0.400	23.0	0.400	1.00	92	Yes	939349	9/4/2013	213112	189
4.22	Hydraulic Fracturing	Fracturing Sand Workers	371	0.039	0.0	5.000	0.01	<12	Yes	894562	3/7/2013	213112	906
4.22	Hydraulic Fracturing	Fracturing Sand Workers	231	0.590	23.2	0.397	1.47	137	Yes	899235	4/4/2013	213112	181
4.22	Hydraulic Fracturing	Fracturing Sand Workers	454	0.490	27.0	0.345	1.43	132	Yes	842583	1/24/2013	213112	880
4.22	Hydraulic Fracturing	Fracturing Sand Workers	352	0.100	19.0	0.476	0.22	19	Yes	939349	9/4/2013	213112	190
4.22	Hydraulic Fracturing	Fracturing Sand Workers	128	0.240	44.0	0.217	1.09	106	Yes	942381	9/24/2013	213112	193
4.22	Hydraulic Fracturing	Fracturing Sand Workers	202	0.260	28.0	0.333	0.78	73	Yes	939349	9/4/2013	213112	187
4.22	Hydraulic Fracturing	Fracturing Sand Workers	366	0.120	16.0	0.556	0.21	19	Yes	894562	3/7/2013	213112	904
4.22	Hydraulic Fracturing	Fracturing Sand Workers	230	0.260	22.9	0.402	0.66	60	Yes	899235	4/4/2013	213112	179
4.22	Hydraulic Fracturing	Fracturing Sand Workers	540	0.049	31.0	0.303	0.16	15	Yes	894562	3/7/2013	213112	907
4.22	Hydraulic Fracturing	Fracturing Sand Workers	348	0.530	33.0	0.286	1.87	175	Yes	939349	9/4/2013	213112	186
4.22	Hydraulic Fracturing	Fracturing Sand Workers	454	0.610	28.0	0.333	1.83	171	Yes	842583	1/24/2013	213112	882
4.22	Hydraulic Fracturing	Fracturing Sand Workers	303	0.470	30.0	0.313	1.51	141	Yes	902898	4/26/2013	213112	183
4.22	Hydraulic Fracturing	Remote/Intermittent Workers	140	0.420	27.0	0.345	1.23	113	Yes	679378	10/10/2012	213112	901
4.22	Hydraulic Fracturing	Remote/Intermittent Workers	216	0.280	0.0	5.000	0.06	<12	Yes	955880	1/22/2014	213112	1081
4.22	Hydraulic Fracturing	Remote/Intermittent Workers	43	0.000	0.0	5.000	0.00	<12	Yes	842583	1/24/2013	213112	877

Table IV.A-2 OIS Health Sampling Data for Respirable Crystalline Silica 2011-2014 (Document ID 3958)														
Sec.	**Section Name**	**Job Category**	**Sample Duration (min.)**	**Resp. Dust (mg/m^3)**	**Pct. Silica**	**PEL (mg/m^3)**	**Severity**	**Resp. Silica ($\mu g/m^3$)**	**Included in Profile**	**Inspec. ID**	**Opening Date**	**NAICS**	**Docket File Row #**
4.22	Hydraulic Fracturing	Remote/Intermittent Workers	63	1.800	25.0	0.370	4.89	450	Yes	842583	1/24/2013	213112	879
4.22	Hydraulic Fracturing	Remote/Intermittent Workers	54	0.029	0.0	5.000	0.01	<12	Yes	942381	9/24/2013	213112	191
4.22	Hydraulic Fracturing	Remote/Intermittent Workers	165	0.380	37.0	0.256	1.47	141	Yes	943011	10/4/2013	213112	197
4.22	Hydraulic Fracturing	Remote/Intermittent Workers	62	0.000	0.0	5.000	0.00	<12	Yes	842583	1/24/2013	213112	878
4.22	Hydraulic Fracturing	Remote/Intermittent Workers	213	0.000	0.0	5.000	0.00	<12	Yes	955880	1/22/2014	213112	1082
4.22	Hydraulic Fracturing	Remote/Intermittent Workers	60	0.570	38.0	0.250	2.27	217	Yes	842583	1/24/2013	213112	881
4.22	Hydraulic Fracturing	Remote/Intermittent Workers	223	0.570	0.0	5.000	0.12	<12	Yes	955880	1/22/2014	213112	1080
NA	General Industry - Other	Abrasive Blasting	50	6.670 (mppcf)	13.0	13.889 (mppcf)	0.48	87	No	909304	5/31/2013	333414	20
NA	General Industry - Other	Abrasive Blasting	434	21.000	37.9	0.251	81.91	7957	No	897086	3/21/2013	811310	93
NA	General Industry - Other	Abrasive Blasting	50	2.600	13.0	0.667	3.87	338	No	909304	5/31/2013	333414	19
NA	General Industry - Other	Abrasive Blasting	128	0.506	15.9	0.560	0.90	80	No	97372	8/9/2011	562991	770
NA	General Industry - Other	Abrasive Blasting	445	1.113	0.0	5.000	0.22	<12	No	457173	6/6/2012	333132	908
NA	General Industry - Other	Abrasive Blasting	32	20.000	0.0	5.000	4.00	<12	No	924505	7/23/2013	325510	1094
NA	General Industry - Other	Abrasive Blasting	306	19.000	60.7	0.159	118.80	11540	No	836624	1/15/2013	811121	368
NA	General Industry - Other	Abrasive Blasting	383	2.900	0.0	5.000	0.57	<12	No	881083	12/12/2013	332994	481
NA	General Industry - Other	Abrasive Blasting	239	0.062	0.0	5.000	0.01	<12	No	916507	7/1/2013	332813	922
NA	General Industry - Other	Abrasive Blasting	190	0.753	14.0	0.625		105	No	482598	6/22/2012	332420	900
NA	General Industry - Other	Abrasive Blasting	85	0.845	5.0	1.430	0.59	42	No	111204	1/13/2012	332813	1008
NA	General Industry - Other	Abrasive Blasting	321	0.620	4.1	1.631	0.38	26	No	751541	11/26/2012	423830	632

Table IV.A-2 OIS Health Sampling Data for Respirable Crystalline Silica 2011-2014 (Document ID 3958)													
Sec.	**Section Name**	**Job Category**	**Sample Duration (min.)**	**Resp. Dust (mg/m^3)**	**Pct. Silica**	**PEL (mg/m^3)**	**Severity**	**Resp. Silica (μg/m^3)**	**Included in Profile**	**Inspec. ID**	**Opening Date**	**NAICS**	**Docket File Row #**
NA	General Industry - Other	Abrasive Blasting	302	13.509	24.9	0.372	36.32	3361	No	718699	10/30/2012	332813	902
NA	General Industry - Other	Abrasive Blasting	161	94.000	0.1	4.849	19.38	59	No	906276	5/8/2013	332812	76
NA	General Industry - Other	Abrasive Blasting	309	0.280	15.0	0.588	0.47	42	No	588299	8/21/2012	332312	362
NA	General Industry - Other	Abrasive Blasting	92	0.056	0.0	5.000	0.01	<12	No	945488	11/1/2013	332420	375
NA	General Industry - Other	Abrasive Blasting	451	2.200	0.0	5.000	0.44	<12	No	461493	6/7/2012	423510	687
NA	General Industry - Other	Abrasive Blasting	210	28.200	25.0	0.370		7058	No	718699	10/30/2012	332813	903
NA	General Industry - Other	Abrasive Blasting	241	0.450	27.8	0.336	1.33	125	No	906354	5/10/2013	332813	913
NA	General Industry - Other	Abrasive Blasting	241	0.036	0.0	5.000	0.01	<12	No	916507	7/1/2013	332813	923
NA	General Industry - Other	Abrasive Blasting	115	1.300	5.9	1.272	1.00	76	No	945488	11/1/2013	332420	374
NA	General Industry - Other	Abrasive Blasting	398	9.400	3.4	1.854	5.05	319	No	900231	4/10/2013	332812	129
NA	General Industry - Other	Abrasive Blasting	465	0.410	6.8	1.132	0.36	28	No	954407	1/9/2014	333131	100
NA	General Industry - Other	Abrasive Blasting	444	3.740	4.1	1.645		153	No	492799	6/27/2012	332812	256
NA	General Industry - Other	Abrasive Blasting	365	0.800	0.0	5.000	0.16	<12	No	881083	12/12/2013	332994	482
NA	General Industry - Other	Abrasive Blasting	454	0.060	0.0	5.000	0.01	<12	No	906266	5/10/2013	333291	888
NA	General Industry - Other	Abrasive Blasting	80	3.700	11.0	0.769	4.80	407	No	911950	6/13/2013	332312	866
NA	General Industry - Other	Abrasive Blasting	249	35.012	23.0	0.400		8053	No	482598	6/22/2012	332420	899
NA	General Industry - Other	Abrasive Blasting	280	4.900	1.2	3.140	1.55	58	No	615359	9/5/2012	332813	818
NA	General Industry - Other	Abrasive Blasting	242	0.190	15.0	0.588	0.32	29	No	916507	7/1/2013	332813	924
NA	General Industry - Other	Abrasive Blasting	472	0.820	1.6	2.794	0.29	13	No	642138	9/19/2012	333111	819
NA	General Industry - Other	Abrasive Blasting	211	0.466	0.0	5.000	0.09	<12	No	947873	11/8/2013	333415	131
NA	General Industry - Other	Abrasive Blasting	289	0.085	0.0	5.000	0.02	<12	No	881083	12/12/2013	332994	484

Table IV.A-2 OIS Health Sampling Data for Respirable Crystalline Silica 2011-2014 (Document ID 3958)													
Sec.	**Section Name**	**Job Category**	**Sample Duration (min.)**	**Resp. Dust (mg/m^3)**	**Pct. Silica**	**PEL (mg/m^3)**	**Severity**	**Resp. Silica ($\mu g/m^3$)**	**Included in Profile**	**Inspec. ID**	**Opening Date**	**NAICS**	**Docket File Row #**
NA	General Industry - Other	Abrasive Blasting	61	22.000	2.5	2.222	9.73	550	No	954985	1/13/2014	326122	335
NA	General Industry - Other	Abrasive Blasting	135	6.400	2.8	2.083	3.06	179	No	911950	6/13/2013	332312	865
NA	General Industry - Other	Abrasive Blasting	211	1.100	0.0	5.000	0.21	<12	No	947873	11/8/2013	333415	130
NA	General Industry - Other	Abrasive Blasting	262	0.000	0.0	5.000	0.00	<12	No	906266	5/10/2013	333291	889
NA	General Industry - Other	Abrasive Blasting	95	0.430	28.0	0.333	1.29	120	No	906354	5/10/2013	332813	914
NA	General Industry - Other	Abrasive Blasting	191	0.620	8.1	0.990	0.63	50	No	916507	7/1/2013	332813	925
NA	General Industry - Other	Abrasive Blasting	103	1.700	10.0	0.833	2.03	170	No	911950	6/13/2013	332312	867
NA	General Industry - Other	Abrasive Blasting	471	6.800	2.3	2.326	2.93	156	No	642138	9/19/2012	333111	820
NA	General Industry - Other	Abrasive Blasting	403	0.140	0.0	5.000	0.03	<12	No	881083	12/12/2013	332994	483
NA	General Industry - Other	Abrasive Blasting	236	1.800	46.0	0.208	8.87	828	No	938124	9/4/2013	332312	928
NA	General Industry - Other	Abrasive Blasting	298	0.039	69.0	0.141	0.28	27	No	588299	8/21/2012	332312	365
NA	General Industry - Other	Bagger	474	0.000	0.0	5.000	0.00	<12	No	110404	12/16/2011	325320	438
NA	General Industry - Other	Batcher	308	0.120	0.0	5.000	0.02	<12	No	708318	10/18/2012	444190	141
NA	General Industry - Other	Carman	298	0.000	0.0	5.000	0.00	<12	No	957651	2/6/2014	488210	887
NA	General Industry - Other	Clamp Truck Driver	253	0.021	0.0	5.000	0.00	<12	No	956024	1/17/2014	326199	134
NA	General Industry - Other	Clerk	388	0.540	3.9	1.708	0.32	21	No	943865	10/24/2013	923140	987
NA	General Industry - Other	Clerk	392	0.092	0.0	5.000	0.02	<12	No	943865	10/24/2013	923140	986
NA	General Industry - Other	Compounder	345	0.063	0.0	5.000	0.01	<12	No	953110	12/23/2013	314110	250
NA	General Industry - Other	Compounder	319	0.330	0.0	5.000	0.07	<12	No	953110	12/23/2013	314110	251
NA	General Industry - Other	Compounder	355	0.211	0.0	5.000	0.00	<12	No	190676	2/3/2012	326113	68
NA	General Industry - Other	Cook/Blender	170	0.880	0.0	5.000	0.18	<12	No	914441	6/26/2013	311999	583

Table IV.A-2 OIS Health Sampling Data for Respirable Crystalline Silica 2011-2014 (Document ID 3958)													
Sec.	**Section Name**	**Job Category**	**Sample Duration (min.)**	**Resp. Dust (mg/m^3)**	**Pct. Silica**	**PEL (mg/m^3)**	**Severity**	**Resp. Silica ($\mu g/m^3$)**	**Included in Profile**	**Inspec. ID**	**Opening Date**	**NAICS**	**Docket File Row #**
NA	General Industry - Other	Cook/Blender	185	1.600	0.0	5.000	0.32	<12	No	914441	6/26/2013	311999	581
NA	General Industry - Other	Core Knock Out	384	0.320	13.0	0.667	0.48	42	No	927223	8/8/2013	331523	185
NA	General Industry - Other	Coremaker	447	0.038	0.0	5.000	0.01	<12	No	278978	3/2/2012	334416	454
NA	General Industry - Other	Coremaker	438	0.066	0.0	5.000	0.01	<12	No	278978	3/2/2012	334416	455
NA	General Industry - Other	Coremaker	435	0.095	0.0	5.000	0.02	<12	No	278978	3/2/2012	334416	456
NA	General Industry - Other	Coremaker	462	0.330	5.6	1.324	0.25	18	No	544939	7/27/2012	331523	606
NA	General Industry - Other	Crusher Operator	242	0.350	0.0	5.000	0.07	<12	No	950510	12/3/2013	212319	538
NA	General Industry - Other	Deburr/Tumbler	480	0.000	0.0	5.000	0.00	<12	No	908008	5/22/2013	332322	1044
NA	General Industry - Other	Drawing Operator	363	0.170	0.0	5.000	0.03	<12	No	941626	9/17/2013	333992	876
NA	General Industry - Other	Dry Blender	305	0.000	0.0	5.000	0.00	<12	No	283763	3/29/2012	311513	782
NA	General Industry - Other	Dry Blender	310	0.000	0.0	5.000	0.00	<12	No	283763	3/29/2012	311513	781
NA	General Industry - Other	Electrician	311	0.000	0.0	5.000	0.00	<12	No	957651	2/6/2014	488210	886
NA	General Industry - Other	Finisher	431	2.400	2.0	2.512	0.96	48	No	912133	6/13/2013	339920	972
NA	General Industry - Other	Finisher	452	1.600	3.7	1.760	0.93	59	No	912133	6/13/2013	339920	971
NA	General Industry - Other	Finisher	277	0.280	0.0	5.000	0.06	<12	No	715898	10/29/2012	326199	226
NA	General Industry - Other	Foreman	420	0.091	0.0	5.000	0.02	<12	No	716478	11/1/2012	327991	348
NA	General Industry - Other	Fork truck driver	254	0.020	0.0	5.000	0.00	<12	No	956024	1/17/2014	326199	133
NA	General Industry - Other	Fork truck driver	60	0.300	0.0	5.000	0.06	<12	No	956222	1/24/2014	484110	200
NA	General Industry - Other	Fork truck driver	124	0.000	0.0	5.000	0.00	<12	No	907505	5/17/2013	331316	184
NA	General Industry - Other	Framer	409	1.300	0.0	5.000	0.26	<12	No	755401	11/27/2012	332321	411
NA	General Industry - Other	Furnace Operator	312	0.030	0.0	5.000	0.01	<12	No	544939	7/27/2012	331523	605

Table IV.A-2 OIS Health Sampling Data for Respirable Crystalline Silica 2011-2014 (Document ID 3958)													
Sec.	**Section Name**	**Job Category**	**Sample Duration (min.)**	**Resp. Dust (mg/m^3)**	**Pct. Silica**	**PEL (mg/m^3)**	**Severity**	**Resp. Silica ($\mu g/m^3$)**	**Included in Profile**	**Inspec. ID**	**Opening Date**	**NAICS**	**Docket File Row #**
NA	General Industry - Other	Furnace Operator	457	0.320	0.0	5.000	0.07	<12	No	544939	7/27/2012	331523	604
NA	General Industry - Other	Furnace Worker	57	0.720	3.6	1.786	0.40	26	No	660278	9/20/2012	335991	92
NA	General Industry - Other	Furnace Worker	465	2.300	3.4	1.858	1.26	78	No	660278	9/20/2012	335991	91
NA	General Industry - Other	GCU Operator	373	0.410	0.0	5.000	0.08	<12	No	329259	3/30/2012	562920	457
NA	General Industry - Other	Glass Blowing Instructor	284	0.000	0.0	5.000	0.00	<12	No	894703	3/5/2013	611519	10
NA	General Industry - Other	Glass Blowing Instructor	288	0.027	0.0	5.000	0.01	<12	No	894703	3/5/2013	611519	12
NA	General Industry - Other	Glass Sorter	435	0.600	0.0	5.000	0.12	<12	No	329259	3/30/2012	562920	458
NA	General Industry - Other	Glass Sorter	365	2.000	0.0	5.000	0.41	<12	No	698938	10/4/2012	337125	985
NA	General Industry - Other	Heavy Equipment Operator	428	0.670	7.4	1.064	0.63	50	No	943932	10/23/2013	562920	884
NA	General Industry - Other	Helper	420	0.120	0.0	5.000	0.02	<12	No	716478	11/1/2012	327991	349
NA	General Industry - Other	Inspector	455	0.330	11.0	0.769	0.43	36	No	436371	5/15/2012	331511	713
NA	General Industry - Other	Knock Off	131	0.651	26.0	0.357	1.82	169	No	588720	6/6/2012	561311	727
NA	General Industry - Other	Knock Off	454	0.563	22.0	0.417	1.35	124	No	588720	6/6/2012	561311	726
NA	General Industry - Other	Laborer	232	0.039	0.0	5.000	0.01	<12	No	860463	1/29/2013	327390	307
NA	General Industry - Other	Laborer	379	0.000	0.0	5.000	0.00	<12	No	941133	9/11/2013	327390	974
NA	General Industry - Other	Laborer	480	0.210	11.0	0.769	0.27	23	No	906329	5/7/2013	327331	309
NA	General Industry - Other	Laborer	410	0.270	0.0	5.000	0.05	<12	No	898904	4/3/2013	325211	229
NA	General Industry - Other	Laborer	101	6.900	3.5	1.818	3.77	242	No	906329	5/7/2013	327331	308
NA	General Industry - Other	Laborer	378	0.350	3.5	1.818	0.19	12	No	954798	1/15/2014	331511	751
NA	General Industry - Other	Laborer	474	0.041	0.0	5.000	0.01	<12	No	608418	8/31/2012	327331	622
NA	General Industry - Other	Laborer	441	1.900	1.3	3.030	0.61	25	No	943870	10/23/2013	326199	326

Table IV.A-2 OIS Health Sampling Data for Respirable Crystalline Silica 2011-2014 (Document ID 3958)

Sec.	Section Name	Job Category	Sample Duration (min.)	Resp. Dust (mg/m³)	Pct. Silica	PEL (mg/m³)	Severity	Resp. Silica (µg/m³)	Included in Profile	Inspec. ID	Opening Date	NAICS	Docket File Row #
NA	General Industry - Other	Laborer	380	0.000	0.0	5.000	0.00	<12	No	941133	9/11/2013	327390	975
NA	General Industry - Other	Laborer	445	0.240	0.0	5.000	0.05	<12	No	954798	1/15/2014	331511	750
NA	General Industry - Other	Laborer	275	0.330	0.0	5.000	0.07	<12	No	785081	12/13/2012	331524	854
NA	General Industry - Other	Laborer	186	0.250	0.0	5.000	0.05	<12	No	893780	3/5/2013	331524	859
NA	General Industry - Other	Laborer	240	0.160	0.0	5.000	0.03	<12	No	446593	5/31/2012	331524	33
NA	General Industry - Other	Laborer	397	0.720	3.5	1.804	0.40	26	No	941133	9/11/2013	327390	977
NA	General Industry - Other	Laborer	375	0.320	6.6	1.163	0.28	21	No	909015	5/30/2013	212322	1048
NA	General Industry - Other	Laborer	468	0.000	0.0	5.000	0.00	<12	No	329766	4/5/2012	325320	801
NA	General Industry - Other	Laborer	407	9.800	0.0	5.000	1.97	<12	No	755401	11/27/2012	332321	412
NA	General Industry - Other	Laborer	423	0.220	0.0	5.000	0.04	<12	No	954798	1/15/2014	331511	754
NA	General Industry - Other	Laborer	382	1.700	34.5	0.274	6.06	586	No	909015	5/30/2013	212322	1046
NA	General Industry - Other	Laborer	374	0.250	0.0	5.000	0.05	<12	No	954798	1/15/2014	331511	752
NA	General Industry - Other	Laborer	148	0.190	0.0	5.000	0.04	<12	No	893780	3/5/2013	331524	860
NA	General Industry - Other	Laborer	452	1.100	6.1	1.235	0.93	67	No	943870	10/23/2013	326199	324
NA	General Industry - Other	Laborer	22	2.100	0.0	5.000	0.42	<12	No	893332	3/5/2013	327390	75
NA	General Industry - Other	Laborer	377	0.290	6.6	1.163	0.25	19	No	954798	1/15/2014	331511	753
NA	General Industry - Other	Laborer	442	0.370	0.0	5.000	0.07	<12	No	943870	10/23/2013	326199	322
NA	General Industry - Other	Laborer	378	0.000	0.0	5.000	0.00	<12	No	941133	9/11/2013	327390	973
NA	General Industry - Other	Laborer	395	0.320	0.0	5.000	0.06	<12	No	392122	4/19/2012	327390	841
NA	General Industry - Other	Laborer	105	0.053	0.0	5.000	0.01	<12	No	941133	9/11/2013	327390	976
NA	General Industry - Other	Laborer	581	0.692	6.9	1.120		48	No	524893	7/10/2012	327331	203

Table IV.A-2 OIS Health Sampling Data for Respirable Crystalline Silica 2011-2014 (Document ID 3958)													
Sec.	**Section Name**	**Job Category**	**Sample Duration (min.)**	**Resp. Dust (mg/m^3)**	**Pct. Silica**	**PEL (mg/m^3)**	**Severity**	**Resp. Silica ($\mu g/m^3$)**	**Included in Profile**	**Inspec. ID**	**Opening Date**	**NAICS**	**Docket File Row #**
NA	General Industry - Other	Laborer	480	6.300	2.8	2.083	3.02	176	No	401343	4/20/2012	423930	2
NA	General Industry - Other	Laborer	150	0.078	0.0	5.000	0.02	<12	No	694438	10/17/2012	327991	293
NA	General Industry - Other	Laborer	381	1.800	39.4	0.242	7.49	708	No	909015	5/30/2013	212322	1049
NA	General Industry - Other	Laborer	198	0.850	21.3	0.429	0.00	181	No	542498	7/24/2012	561730	404
NA	General Industry - Other	Laborer	383	0.000	0.0	5.000	0.00	<12	No	242914	2/28/2012	331521	547
NA	General Industry - Other	Laborer - crushing	480	1.800	12.0	0.714	2.52	216	No	401343	4/20/2012	423930	3
NA	General Industry - Other	Laborer - crushing	487	0.520	12.0	0.714	0.72	62	No	938039	9/4/2013	423930	57
NA	General Industry - Other	Laborer - crushing	491	0.520	14.0	0.625	0.84	73	No	938039	9/4/2013	423930	56
NA	General Industry - Other	Laborer - crushing	494	0.760	14.0	0.625	1.21	106	No	938039	9/4/2013	423930	55
NA	General Industry - Other	Line Operator	462	0.810	3.3	1.887	0.43	27	No	941089	9/11/2013	331511	428
NA	General Industry - Other	Line Operator	411	0.640	5.1	1.408	0.45	33	No	940732	9/10/2013	331511	425
NA	General Industry - Other	Line Operator	459	0.510	19.0	0.476	1.07	97	No	941089	9/11/2013	331511	433
NA	General Industry - Other	Line Operator	465	1.100	5.9	1.266	0.86	65	No	941089	9/11/2013	331511	430
NA	General Industry - Other	Line Operator	464	0.700	19.0	0.476	1.47	133	No	941089	9/11/2013	331511	429
NA	General Industry - Other	Line Operator	428	0.920	7.9	1.010	0.92	73	No	940732	9/10/2013	331511	422
NA	General Industry - Other	Line Operator	428	0.630	6.0	1.250	0.51	38	No	940732	9/10/2013	331511	424
NA	General Industry - Other	Line Operator	412	0.560	7.3	1.075	0.52	41	No	940732	9/10/2013	331511	426
NA	General Industry - Other	Line Operator	391	0.890	0.0	5.000	0.18	<12	No	940785	9/11/2013	562920	45
NA	General Industry - Other	Line Operator	465	0.370	11.0	0.769	0.49	41	No	941089	9/11/2013	331511	431
NA	General Industry - Other	Line Operator	435	0.730	7.6	1.042	0.70	55	No	940732	9/10/2013	331511	421
NA	General Industry - Other	Line Operator	391	0.000	0.0	5.000	0.00	<12	No	940785	9/11/2013	562920	47

Table IV.A-2 OIS Health Sampling Data for Respirable Crystalline Silica 2011-2014 (Document ID 3958)													
Sec.	**Section Name**	**Job Category**	**Sample Duration (min.)**	**Resp. Dust (mg/m^3)**	**Pct. Silica**	**PEL (mg/m^3)**	**Severity**	**Resp. Silica ($\mu g/m^3$)**	**Included in Profile**	**Inspec. ID**	**Opening Date**	**NAICS**	**Docket File Row #**
NA	General Industry - Other	Line Operator	457	0.240	12.0	0.714	0.33	29	No	941089	9/11/2013	331511	432
NA	General Industry - Other	Loader Operator	255	0.090	0.0	5.000	0.02	<12	No	912649	6/17/2013	327310	314
NA	General Industry - Other	Machine Operator	475	0.000	0.0	5.000	0.00	<12	No	110404	12/16/2011	325320	437
NA	General Industry - Other	Machine Operator	427	0.130	0.0	5.000	0.03	<12	No	956270	1/22/2014	331524	890
NA	General Industry - Other	Machine Operator	427	0.071	0.0	5.000	0.01	<12	No	956270	1/22/2014	331524	892
NA	General Industry - Other	Maintenance	348	0.190	0.0	5.000	0.04	<12	No	914541	6/26/2013	331410	355
NA	General Industry - Other	Maintenance	401	0.000	0.0	5.000	0.00	<12	No	940785	9/11/2013	562920	43
NA	General Industry - Other	Maintenance	401	1.100	0.0	5.000	0.21	<12	No	940785	9/11/2013	562920	41
NA	General Industry - Other	Manager	412	2.000	17.0	0.526	3.79	340	No	715898	10/29/2012	326199	225
NA	General Industry - Other	Manager	375	0.220	0.0	5.000	0.04	<12	No	912649	6/17/2013	327310	313
NA	General Industry - Other	Manager	293	0.064	0.0	5.000	0.01	<12	No	704478	10/24/2012	327991	347
NA	General Industry - Other	Material Handler	469	0.048	0.0	5.000	0.01	<12	No	954407	1/9/2014	333131	101
NA	General Industry - Other	Mixer Operator	472	0.000	0.0	5.000	0.10	<12	No	329766	4/5/2012	325320	802
NA	General Industry - Other	Mixer Operator	480	0.830	5.7	1.299	0.64	47	No	914915	6/27/2013	333992	744
NA	General Industry - Other	Mixer Operator	271	3.100	0.0	5.000	0.62	<12	No	941626	9/17/2013	333992	875
NA	General Industry - Other	Mixer Operator	428	0.190	0.0	5.000	0.04	<12	No	898904	4/3/2013	325211	227
NA	General Industry - Other	Ocularist	49	0.000	0.0	5.000	0.00	<12	No	951884	12/11/2013	339115	78
NA	General Industry - Other	Ocularist	180	0.000	0.0	5.000	0.00	<12	No	951884	12/11/2013	339115	77
NA	General Industry - Other	Office Manager	370	0.000	0.0	5.000	0.00	<12	No	708318	10/18/2012	444190	142
NA	General Industry - Other	Operator	305	1.026	3.1	1.960	0.52	32	No	457413	6/6/2012	327331	558
NA	General Industry - Other	Operator	385	0.440	0.0	5.000	0.09	<12	No	910396	6/6/2013	326150	861

Table IV.A-2 OIS Health Sampling Data for Respirable Crystalline Silica 2011-2014 (Document ID 3958)													
Sec.	**Section Name**	**Job Category**	**Sample Duration (min.)**	**Resp. Dust (mg/m^3)**	**Pct. Silica**	**PEL (mg/m^3)**	**Severity**	**Resp. Silica ($\mu g/m^3$)**	**Included in Profile**	**Inspec. ID**	**Opening Date**	**NAICS**	**Docket File Row #**
NA	General Industry - Other	Operator	371	0.450	0.0	5.000	0.09	<12	No	910396	6/6/2013	326150	862
NA	General Industry - Other	Operator	411	0.207	0.0	5.000	0.00	<12	No	191861	2/21/2012	238340	69
NA	General Industry - Other	Operator	399	2.600	5.1	1.408	1.82	133	No	392122	4/19/2012	327390	842
NA	General Industry - Other	Operator	352	0.480	0.0	5.000	0.10	<12	No	910396	6/6/2013	326150	863
NA	General Industry - Other	Operator	47	1.000	0.0	5.000	0.20	<12	No	940750	9/10/2013	213111	89
NA	General Industry - Other	Operator	333	1.100	2.0	2.500	0.46	22	No	850764	1/28/2013	327124	823
NA	General Industry - Other	Operator	406	0.520	7.8	1.017	0.51	41	No	583278	8/16/2012	327122	619
NA	General Industry - Other	Optical Line Technician	379	2.000	0.0	5.000	0.41	<12	No	940785	9/11/2013	562920	49
NA	General Industry - Other	Optical Line Technician	379	0.000	0.0	5.000	0.00	<12	No	940785	9/11/2013	562920	51
NA	General Industry - Other	Other	480	1.100	2.0	2.500	0.44	22	No	110849	1/4/2012	331513	706
NA	General Industry - Other	Other	480	0.160	0.0	5.000	0.03	<12	No	422283	5/8/2012	331222	460
NA	General Industry - Other	Other	425	0.740	7.7	1.031	0.72	57	No	940732	9/10/2013	331511	423
NA	General Industry - Other	Other	388	1.035	4.1	1.639	0.63	42	No	110406	12/15/2011	331511	440
NA	General Industry - Other	Other	459	0.780	0.0	5.000	0.16	<12	No	422283	5/8/2012	331222	459
NA	General Industry - Other	Painter	429	0.000	0.0	5.000	0.00	<12	No	893576	3/5/2013	811121	387
NA	General Industry - Other	Painter	36	1.200	38.0	0.250	4.79	456	No	922315	7/18/2013	333911	160
NA	General Industry - Other	Painter	282	0.300	0.0	5.000	0.06	<12	No	616939	9/6/2012	541850	728
NA	General Industry - Other	Painter	120	0.038	0.0	5.000	0.01	<12	No	949729	11/14/2013	811111	132
NA	General Industry - Other	Painter	386	0.190	0.0	5.000	0.04	<12	No	892952	3/1/2013	336411	84
NA	General Industry - Other	Parking Attendant	160	0.093	0.0	5.000	0.02	<12	No	898514	4/1/2013	812930	524
NA	General Industry - Other	Powder Coating Technician	15	0.000	0.0	5.000	0.00	<12	No	924714	8/2/2013	331521	245

Table IV.A-2 OIS Health Sampling Data for Respirable Crystalline Silica 2011-2014 (Document ID 3958)													
Sec.	**Section Name**	**Job Category**	**Sample Duration (min.)**	**Resp. Dust (mg/m^3)**	**Pct. Silica**	**PEL (mg/m^3)**	**Severity**	**Resp. Silica ($\mu g/m^3$)**	**Included in Profile**	**Inspec. ID**	**Opening Date**	**NAICS**	**Docket File Row #**
NA	General Industry - Other	Press Operator	436	0.250	0.0	5.000	0.05	<12	No	908418	5/22/2013	325520	916
NA	General Industry - Other	Press Operator	428	0.270	6.0	1.250	0.22	16	No	951724	12/11/2013	326299	72
NA	General Industry - Other	Pro-Edge Operator	326	0.012	0.0	5.000	0.00	<12	No	189867	1/23/2012	337127	1010
NA	General Industry - Other	Puller	66	0.230	0.0	5.000	0.05	<12	No	956713	1/28/2014	327991	337
NA	General Industry - Other	Puller	60	0.650	0.0	5.000	0.13	<12	No	956713	1/28/2014	327991	336
NA	General Industry - Other	Rig Operator	80	0.000		5.000	0.00	<12	No	739901	11/15/2012	211111	218
NA	General Industry - Other	Rural Carrier	263	0.082	26.0	0.357	0.23	21	No	907718	5/20/2013	491110	682
NA	General Industry - Other	Rural Carrier	235	0.036	45.0	0.213	0.17	16	No	907718	5/20/2013	491110	684
NA	General Industry - Other	Rural Carrier	173	0.190	15.0	0.588	0.32	29	No	907718	5/20/2013	491110	683
NA	General Industry - Other	Sand Conveyor	435	0.320	35.0	0.270	1.17	112	No	868003	2/5/2013	238290	638
NA	General Industry - Other	Sand Conveyor	467	0.430	22.0	0.417	1.03	95	No	868003	2/5/2013	238290	642
NA	General Industry - Other	Sand Conveyor	455	0.056	63.0	0.154	0.37	35	No	868003	2/5/2013	238290	643
NA	General Industry - Other	Sand Conveyor	420	0.160	22.0	0.417	0.38	35	No	868003	2/5/2013	238290	640
NA	General Industry - Other	Sand Conveyor	435	0.084	0.0	5.000	0.02	<12	No	868003	2/5/2013	238290	639
NA	General Industry - Other	Sand Conveyor	431	0.350	26.0	0.357	0.99	91	No	868003	2/5/2013	238290	641
NA	General Industry - Other	Sander Operator	454	0.042	0.0	5.000	0.01	<12	No	907569	5/20/2013	327215	94
NA	General Industry - Other	Saw Operator	330	0.032	0.0	5.000	0.01	<12	No	189867	1/23/2012	337127	1009
NA	General Industry - Other	Saw Operator	365	0.068	0.0	5.000	0.01	<12	No	910396	6/6/2013	326150	864
NA	General Industry - Other	Shakeout	128	0.270	0.0	5.000	0.05	<12	No	843825	1/24/2013	333243	858
NA	General Industry - Other	Solidifier	420	2.200	0.0	5.000	0.44	<12	No	790741	12/18/2012	562211	579
NA	General Industry - Other	Sorter	249	0.610	5.1	1.408	0.44	31	No	950510	12/3/2013	212319	537

Table IV.A-2 OIS Health Sampling Data for Respirable Crystalline Silica 2011-2014 (Document ID 3958)

Sec.	Section Name	Job Category	Sample Duration (min.)	Resp. Dust (mg/m³)	Pct. Silica	PEL (mg/m³)	Severity	Resp. Silica (μg/m³)	Included in Profile	Inspec. ID	Opening Date	NAICS	Docket File Row #
NA	General Industry - Other	Stone cutter	363	0.160	0.0	5.000	0.03	<12	No	943377	10/30/2013	327991	236
NA	General Industry - Other	Stone Tech - cuts and polishes	220	0.740	26.0	0.357	2.06	192	No	956858	1/29/2014	326199	1092
NA	General Industry - Other	Supervisor	406	0.330	0.0	5.000	0.07	<12	No	951568	12/11/2013	327112	588
NA	General Industry - Other	Supervisor	312	0.000	0.0	5.000	0.00	<12	No	896647	3/20/2013	337110	66
NA	General Industry - Other	Supervisor	385	0.096	0.0	5.000	0.02	<12	No	898904	4/3/2013	325211	228
NA	General Industry - Other	Supervisor	270	0.220	0.0	5.000	0.04	<12	No	424395	5/2/2012	332991	462
NA	General Industry - Other	Supervisor	270	0.123	0.0	5.000	0.02	<12	No	424395	5/2/2012	332991	463
NA	General Industry - Other	Supervisor	140	0.000	0.0	5.000	0.00	<12	No	190899	2/7/2012	331525	542
NA	General Industry - Other	Transloader Operator	455	0.436	52.9	0.182	2.40	231	No	526620	7/16/2012	423840	942
NA	General Industry - Other	Trimmer	463	0.082	0.0	5.000	0.02	<12	No	950175	11/25/2013	336412	331
NA	General Industry - Other	Trimmer	463	0.120	0.0	5.000	0.02	<12	No	950175	11/25/2013	336412	330
NA	General Industry - Other	Tripper Floor Operator	403	0.150	51.6	0.187	0.79	77	No	909015	5/30/2013	212322	1047
5.1	Abrasive Blasters	Abrasive Blaster's Helper (Assisting with dry blasting, uncontrolled, no blasting booth)	447	1.000	2.8	2.083	0.50	28	Yes	907767	5/22/2013	237310	677
5.1	Abrasive Blasters	Abrasive Blasting Operator (Dry blasting, uncontrolled, no blasting booth or cabinet)	461	0.840	2.1	2.448	0.34	18	Yes	907767	5/22/2013	237310	676
5.1	Abrasive Blasters	Abrasive Blasting Operator (Dry blasting, uncontrolled, no blasting booth or cabinet)	278	0.950	12.0	0.714	1.32	114	Yes	959510	2/21/2014	238390	361
5.1	Abrasive Blasters	Abrasive Blasting Operator (Dry blasting, uncontrolled, no blasting booth or cabinet)	118	32.000	40.6	0.235	135.79	12983	Yes	915995	7/3/2013	238320	318

Table IV.A-2 OIS Health Sampling Data for Respirable Crystalline Silica 2011-2014 (Document ID 3958)													
Sec.	**Section Name**	**Job Category**	**Sample Duration (min.)**	**Resp. Dust (mg/m^3)**	**Pct. Silica**	**PEL (mg/m^3)**	**Severity**	**Resp. Silica ($\mu g/m^3$)**	**Included in Profile**	**Inspec. ID**	**Opening Date**	**NAICS**	**Docket File Row #**
5.1	Abrasive Blasters	Abrasive Blasting Operator (Dry blasting, uncontrolled, no blasting booth or cabinet)	183	0.570	0.0	5.000	0.11	<12	Yes	896187	3/18/2013	238390	912
5.1	Abrasive Blasters	Abrasive Blasting Operator (Dry blasting, uncontrolled, no blasting booth or cabinet)	118	17.000	3.3	1.887	8.95	561	Yes	959025	2/13/2014	238990	897
5.1	Abrasive Blasters	Abrasive Blasting Operator (Dry blasting, uncontrolled, no blasting booth or cabinet)	512	0.000	0.0	5.000	0.00	<12	Yes	896187	3/18/2013	238390	911
5.1	Abrasive Blasters	Abrasive Blasting Operator (Dry blasting, uncontrolled, no blasting booth or cabinet)	117	25.000	35.0	0.270	91.71	8749	Yes	915995	7/3/2013	238320	320
5.1	Abrasive Blasters	Abrasive Blasting Operator (Dry blasting, uncontrolled, no blasting booth or cabinet)	156	3.300	14.9	0.590		493	Yes	92153	7/6/2011	238990	403
5.1	Abrasive Blasters	Abrasive Blasting Operator (Dry blasting, uncontrolled, no blasting booth or cabinet)	186	11.000	3.4	1.852	6.20	374	Yes	899547	4/5/2013	238990	144
5.1	Abrasive Blasters	Abrasive Blasting Operator (Dry blasting, uncontrolled, no blasting booth or cabinet)	167	1.600	4.3	1.587	1.03	69	Yes	899547	4/5/2013	238990	145
5.1	Abrasive Blasters	Abrasive Blasting Operator (Dry blasting, uncontrolled, no blasting booth or cabinet)	118	16.000	2.4	2.273	6.85	384	Yes	959025	2/13/2014	238990	898
5.3	Heavy Equipment Operators	Demolition/Abrading/Fracturing Equipment Operator	460	0.300	16.4	0.543	0.55	49	Yes	902143	4/8/2013	238910	16
5.3	Heavy Equipment Operators	Demolition/Abrading/Fracturing Equipment Operator	188	0.676	6.4	1.190	0.57	43	Yes	556859	8/1/2012	238910	5
5.3	Heavy Equipment Operators	Excavating/Grading/Load Transfer Equipment Operator	129	0.380	0.0	5.000	0.08	<12	Yes	959859	2/21/2014	238910	954
5.4	Hole Drillers Using Hand-Held Drills	Other mixed conditions	124	0.240	0.0	5.000	0.05	<12	Yes	938231	9/3/2013	236220	828
5.4	Hole Drillers Using Hand-Held Drills	Other mixed conditions	237	0.730	0.0	5.000	0.15	<12	Yes	403982	4/26/2012	237310	806

Table IV.A-2 OIS Health Sampling Data for Respirable Crystalline Silica 2011-2014 (Document ID 3958)													
Sec.	**Section Name**	**Job Category**	**Sample Duration (min.)**	**Resp. Dust (mg/m^3)**	**Pct. Silica**	**PEL (mg/m^3)**	**Severity**	**Resp. Silica ($\mu g/m^3$)**	**Included in Profile**	**Inspec. ID**	**Opening Date**	**NAICS**	**Docket File Row #**
5.4	Hole Drillers Using Hand-Held Drills	Other mixed conditions	203	3.200	4.0	1.667	1.93	128	Yes	403982	4/26/2012	237310	808
5.4	Hole Drillers Using Hand-Held Drills	Indoors, concrete substrate, no controls	72	0.200	0.0	5.000	0.04	<12	Yes	896810	3/20/2013	238220	825
5.5	Demolition Workers Using Jackhammers and Handheld Power Chipping Tools	Outdoor - baseline	49	3.000	11.0	0.769	3.86	330	Yes	704518	10/24/2012	236220	694
5.5	Demolition Workers Using Jackhammers and Handheld Power Chipping Tools	Outdoor - baseline	126	0.670	0.0	5.000	0.13	<12	Yes	331823	4/12/2012	238110	803
5.5	Demolition Workers Using Jackhammers and Handheld Power Chipping Tools	Outdoor - baseline	200	1.167	18.0	0.500	2.33	210	Yes	557798	8/6/2012	237310	167
5.5	Demolition Workers Using Jackhammers and Handheld Power Chipping Tools	Outdoor - baseline	200	1.875	23.0	0.400	4.69	431	Yes	557798	8/6/2012	237310	166
5.5	Demolition Workers Using Jackhammers and Handheld Power Chipping Tools	Indoor - baseline	374	0.140	0.0	5.000	0.03	<12	Yes	959859	2/21/2014	238910	950
5.5	Demolition Workers Using Jackhammers and Handheld Power Chipping Tools	Indoor - baseline	382	0.300	0.0	5.000	0.06	<12	Yes	959859	2/21/2014	238910	951
5.5	Demolition Workers Using Jackhammers and Handheld Power Chipping Tools	Indoor - baseline	453	1.700	9.2	0.896	1.90	156	Yes	959859	2/21/2014	238910	959
5.5	Demolition Workers Using Jackhammers and Handheld Power Chipping Tools	Indoor - baseline	368	0.960	8.5	0.956	1.01	81	Yes	959859	2/21/2014	238910	952
5.5	Demolition Workers Using Jackhammers and Handheld Power Chipping Tools	Indoor - baseline	315	0.329	28.3	0.330	0.00	93	Yes	513799	7/9/2012	236220	90

Table IV.A-2 OIS Health Sampling Data for Respirable Crystalline Silica 2011-2014 (Document ID 3958)														
Sec.	**Section Name**	**Job Category**	**Sample Duration (min.)**	**Resp. Dust (mg/m³)**	**Pct. Silica**	**PEL (mg/m³)**	**Severity**	**Resp. Silica (μg/m³)**	**Included in Profile**	**Inspec. ID**	**Opening Date**	**NAICS**	**Docket File Row #**
5.5	Demolition Workers Using Jackhammers and Handheld Power Chipping Tools	Indoor - baseline	475	1.100	7.6	1.041	1.03	84	Yes	959859	2/21/2014	238910	956
5.5	Demolition Workers Using Jackhammers and Handheld Power Chipping Tools	Indoor - baseline	469	1.900	7.7	1.028	1.88	147	Yes	959859	2/21/2014	238910	955
5.5	Demolition Workers Using Jackhammers and Handheld Power Chipping Tools	Indoor - baseline	449	1.200	12.2	0.703	1.74	147	Yes	959859	2/21/2014	238910	958
5.5	Demolition Workers Using Jackhammers and Handheld Power Chipping Tools	Indoor - baseline	90	0.860	13.0	0.667	1.28	112	Yes	824782	1/14/2013	236220	351
5.5	Demolition Workers Using Jackhammers and Handheld Power Chipping Tools	Indoor - baseline	368	0.310	7.4	1.060	0.29	23	Yes	959859	2/21/2014	238910	949
5.5	Demolition Workers Using Jackhammers and Handheld Power Chipping Tools	Indoor with water applied	335	9.900	7.0	1.111	8.89	693	Yes	891471	2/20/2013	238910	8
5.5	Demolition Workers Using Jackhammers and Handheld Power Chipping Tools	Indoor with water applied	379	3.900	16.0	0.556	7.06	624	Yes	934746	8/21/2013	238990	1066
5.5	Demolition Workers Using Jackhammers and Handheld Power Chipping Tools	Indoor with water applied	420	5.500	4.7	1.488	3.72	260	Yes	896800	3/20/2013	238990	522
5.5	Demolition Workers Using Jackhammers and Handheld Power Chipping Tools	Indoor with water applied	472	1.200	7.2	1.083	1.15	87	Yes	586818	8/22/2012	237110	723
5.5	Demolition Workers Using Jackhammers and Handheld Power Chipping Tools	Indoor with water applied	470	0.330	0.0	5.000	0.07	<12	Yes	586818	8/22/2012	237110	724

Table IV.A-2 OIS Health Sampling Data for Respirable Crystalline Silica 2011-2014 (Document ID 3958)

Sec.	Section Name	Job Category	Sample Duration (min.)	Resp. Dust (mg/m³)	Pct. Silica	PEL (mg/m³)	Severity	Resp. Silica (μg/m³)	Included in Profile	Inspec. ID	Opening Date	NAICS	Docket File Row #
5.5	Demolition Workers Using Jackhammers and Handheld Power Chipping Tools	Indoor with water applied	415	6.300	4.5	1.536	4.12	284	Yes	896800	3/20/2013	238990	523
5.5	Demolition Workers Using Jackhammers and Handheld Power Chipping Tools	Indoor with water applied	242	0.430	5.8	1.282	0.34	25	Yes	586818	8/22/2012	237110	725
5.5	Demolition Workers Using Jackhammers and Handheld Power Chipping Tools	Indoor with water applied	381	5.500	16.0	0.556	9.93	880	Yes	934746	8/21/2013	238990	1065
5.5	Demolition Workers Using Jackhammers and Handheld Power Chipping Tools	Indoor with water applied	379	3.800	16.0	0.556	6.85	608	Yes	934746	8/21/2013	238990	1064
5.5	Demolition Workers Using Jackhammers and Handheld Power Chipping Tools	Indoor with water applied	453	0.320	4.6	1.515	0.21	15	Yes	906848	5/13/2013	236220	735
5.5	Demolition Workers Using Jackhammers and Handheld Power Chipping Tools	Other	224	0.170	0.0	5.000	0.03	<12	Yes	639698	9/18/2012	238110	852
5.5	Demolition Workers Using Jackhammers and Handheld Power Chipping Tools	Other	224	8.800	13.0	0.667	13.24	1144	Yes	943253	10/15/2013	238110	748
5.5	Demolition Workers Using Jackhammers and Handheld Power Chipping Tools	Other	160	11.000	6.9	1.124	9.40	759	Yes	943055	10/8/2013	238110	696
5.5	Demolition Workers Using Jackhammers and Handheld Power Chipping Tools	Other	227	2.900	12.0	0.714	4.12	348	Yes	943253	10/15/2013	238110	749
5.5	Demolition Workers Using Jackhammers and Handheld Power Chipping Tools	Other	80	0.630	15.0	0.588	1.08	95	Yes	824782	1/14/2013	236220	352

Table IV.A-2 OIS Health Sampling Data for Respirable Crystalline Silica 2011-2014 (Document ID 3958)														
Sec.	**Section Name**	**Job Category**	**Sample Duration (min.)**	**Resp. Dust (mg/m^3)**	**Pct. Silica**	**PEL (mg/m^3)**	**Severity**	**Resp. Silica ($\mu g/m^3$)**	**Included in Profile**	**Inspec. ID**	**Opening Date**	**NAICS**	**Docket File Row #**
5.5	Demolition Workers Using Jackhammers and Handheld Power Chipping Tools	Other	446	0.260	0.0	5.000	0.05	<12	Yes	681678	10/11/2012	238140	343
5.5	Demolition Workers Using Jackhammers and Handheld Power Chipping Tools	Other	449	0.250	0.0	5.000	0.05	<12	Yes	681678	10/11/2012	238140	345
5.5	Demolition Workers Using Jackhammers and Handheld Power Chipping Tools	Other	456	0.220	0.0	5.000	0.05	<12	Yes	681678	10/11/2012	238140	346
5.5	Demolition Workers Using Jackhammers and Handheld Power Chipping Tools	Other	450	0.370	0.0	5.000	0.07	<12	Yes	681678	10/11/2012	238140	342
5.5	Demolition Workers Using Jackhammers and Handheld Power Chipping Tools	Other	195	0.230	0.0	5.000	0.05	<12	Yes	681678	10/11/2012	238140	344
5.5	Demolition Workers Using Jackhammers and Handheld Power Chipping Tools	Other	82	0.004	0.0	5.000	0.00	<12	Yes	586818	8/22/2012	237110	722
5.6	Masonry Cutters Using Portable Saws	Handheld Saw Operator (Outdoors, dry cutting)	296	1.482	6.5	1.176	1.26	96	Yes	957492	2/5/2014	237990	360
5.6	Masonry Cutters Using Portable Saws	Handheld Saw Operator (Outdoors, dry cutting)	428	1.400	6.1	1.235	1.17	85	Yes	917916	7/11/2013	238110	489
5.6	Masonry Cutters Using Portable Saws	Handheld Saw Operator (Outdoors, dry cutting)	203	2.800	0.0	5.000	0.55	<12	Yes	748661	11/20/2012	238140	730
5.6	Masonry Cutters Using Portable Saws	Handheld Saw Operator (Outdoors, dry cutting)	200	1.417	0.0	5.000		<12	Yes	748661	11/20/2012	238140	729
5.6	Masonry Cutters Using Portable Saws	Handheld Saw Operator (Outdoors, dry cutting)	425	0.501	9.8	0.850	0.59	49	Yes	92385	7/12/2011	237310	25
5.6	Masonry Cutters Using Portable Saws	Handheld Saw Operator (Outdoors, dry cutting)	291	0.480	7.3	1.075	0.44	35	Yes	652758	9/20/2012	238140	259
5.6	Masonry Cutters Using Portable Saws	Handheld Saw Operator (Outdoors, dry cutting)	307	2.495	4.0	1.667	1.50	100	Yes	957492	2/5/2014	237990	358

Table IV.A-2 OIS Health Sampling Data for Respirable Crystalline Silica 2011-2014 (Document ID 3958)													
Sec.	**Section Name**	**Job Category**	**Sample Duration (min.)**	**Resp. Dust (mg/m^3)**	**Pct. Silica**	**PEL (mg/m^3)**	**Severity**	**Resp. Silica ($\mu g/m^3$)**	**Included in Profile**	**Inspec. ID**	**Opening Date**	**NAICS**	**Docket File Row #**
5.6	Masonry Cutters Using Portable Saws	Handheld Saw Operator (Outdoors, dry cutting)	431	0.820	4.7	1.493	0.55	39	Yes	917916	7/11/2013	238110	488
5.6	Masonry Cutters Using Portable Saws	Handheld Saw Operator (Outdoors, dry cutting)	319	0.347	11.0	0.770	0.45	38	Yes	92385	7/12/2011	237310	26
5.6	Masonry Cutters Using Portable Saws	Handheld Saw Operator (Outdoors, dry cutting)	275	4.800	0.0	5.000	0.96	<12	Yes	652758	9/20/2012	238140	260
5.6	Masonry Cutters Using Portable Saws	Handheld Saw Operator (Outdoors, dry cutting)	233	0.175 (mppcf)	3.6	29.060 (mppcf)	0.06	6	Yes	109939	12/7/2011	238910	840
5.6	Masonry Cutters Using Portable Saws	Handheld Saw Operator (Indoors, dry cutting)	65	0.099	0.0	5.000	0.02	<12	Yes	538638	7/24/2012	236220	791
5.7	Masonry Cutters Using Stationary Saws	Masonry Cutter Using Stationary Saw (dry cutting, no engineering controls)	413	0.230	10.0	0.833	0.27	23	Yes	899044	4/1/2013	423320	1041
5.7	Masonry Cutters Using Stationary Saws	Masonry Cutter Using Stationary Saw (Wet cutting methods)	415	0.210	17.0	0.526	0.40	36	Yes	899044	4/1/2013	423320	1042
5.8	Millers Using Portable or Mobile Machines	Operator/Helper - Small Driven Milling Machine (less than half lane)	100	0.258 (mppcf)	8.1	19.080 (mppcf)	0.14	21	Yes	476798	6/20/2012	237310	1020
5.8	Millers Using Portable or Mobile Machines	Operator/Helper - Small Driven Milling Machine (less than half lane)	100	0.575 (mppcf)	11.0	15.630 (mppcf)	0.37	63	Yes	476798	6/20/2012	237310	1019
5.8	Millers Using Portable or Mobile Machines	Workers Using Walk-Behind Milling Machine	400	0.000	0.0	5.000	0.00	<12	Yes	951235	12/5/2013	238190	211
5.8	Millers Using Portable or Mobile Machines	Workers Using Walk-Behind Milling Machine	5	0.000	0.0	5.000	0.00	<12	Yes	951235	12/5/2013	238190	210
5.8	Millers Using Portable or Mobile Machines	Workers Using Walk-Behind Milling Machine	393	0.000	0.0	5.000	0.00	<12	Yes	951235	12/5/2013	238190	214
5.8	Millers Using Portable or Mobile Machines	Workers Using Walk-Behind Milling Machine	411	0.000	0.0	5.000	0.00	<12	Yes	951235	12/5/2013	238190	209
5.8	Millers Using Portable or Mobile Machines	Workers Using Walk-Behind Milling Machine	117	1.400	36.0	0.263	5.16	504	Yes	955786	1/17/2014	238110	74

Table IV.A-2 OIS Health Sampling Data for Respirable Crystalline Silica 2011-2014 (Document ID 3958)													
Sec.	**Section Name**	**Job Category**	**Sample Duration (min.)**	**Resp. Dust (mg/m^3)**	**Pct. Silica**	**PEL (mg/m^3)**	**Severity**	**Resp. Silica ($\mu g/m^3$)**	**Included in Profile**	**Inspec. ID**	**Opening Date**	**NAICS**	**Docket File Row #**
5.8	Millers Using Portable or Mobile Machines	Workers Using Walk-Behind Milling Machine	399	0.000	0.0	5.000	0.00	<12	Yes	951235	12/5/2013	238190	215
5.9	Rock and Concrete Drillers	Other	240	0.110	0.0	5.000	0.02	<12	Yes	408422	4/30/2012	237310	809
5.11	Tuckpointers and Grinders	Tuckpointers (Outdoors, uncontrolled)	120	21.000	13.0	0.667	31.12	2730	Yes	909807	6/4/2013	238140	827
5.11	Tuckpointers and Grinders	Tuckpointers (Outdoors, uncontrolled)	96	1.000 (mppcf)	2.7	32.470 (mppcf)	0.31	27	Yes	77004	6/22/2011	236220	839
5.11	Tuckpointers and Grinders	Tuckpointers (Outdoors, uncontrolled)	52	0.027	0.0	5.000	0.01	<12	Yes	456893	6/6/2012	238140	720
5.11	Tuckpointers and Grinders	Tuckpointers (Outdoors, uncontrolled)	45	23.000	8.2	0.980	23.29	1886	Yes	936328	8/29/2013	236220	874
5.11	Tuckpointers and Grinders	Tuckpointers (Outdoors, uncontrolled)	315	8.800	9.8	0.848	10.33	862	Yes	906969	5/16/2013	238140	831
5.11	Tuckpointers and Grinders	Tuckpointers (Outdoors, uncontrolled)	120	0.150	0.0	5.000	0.03	<12	Yes	918808	6/25/2013	236220	87
5.11	Tuckpointers and Grinders	Tuckpointers (Outdoors, uncontrolled)	297	2.487 (mppcf)	4.2	27.170 (mppcf)	0.92	105	Yes	77004	6/22/2011	236220	838
5.11	Tuckpointers and Grinders	Tuckpointers (Outdoors, uncontrolled)	282	2.700	10.5	0.803	3.41	282	Yes	782870	12/13/2012	238140	81
5.11	Tuckpointers and Grinders	Tuckpointers (Outdoors, uncontrolled)	14	0.000	0.0	5.000		<12	Yes	450433	5/31/2012	238140	202
5.11	Tuckpointers and Grinders	Tuckpointers (Outdoors, uncontrolled)	310	18.000	8.4	0.962	18.37	1512	Yes	906969	5/16/2013	238140	832
5.11	Tuckpointers and Grinders	Tuckpointers (Outdoors, uncontrolled)	287	3.900	12.5	0.689	5.70	488	Yes	782870	12/13/2012	238140	82
5.11	Tuckpointers and Grinders	Tuckpointers (Outdoors, LEV)	265	1.630 (mppcf)	11.0	15.600 (mppcf)		180	Yes	476239	6/19/2012	238140	79
5.11	Tuckpointers and Grinders	Tuckpointers (Outdoors, LEV)	98	0.450	0.0	5.000	0.09	<12	Yes	943112	10/10/2013	238140	816
5.11	Tuckpointers and Grinders	Tuckpointers (Outdoors, LEV)	118	0.710 (mppcf)	10.0	16.700 (mppcf)		71	Yes	476239	6/19/2012	238140	80
5.11	Tuckpointers and Grinders	Tuckpointers (Outdoors, LEV)	98	0.300	0.0	5.000	0.06	<12	Yes	943112	10/10/2013	238140	817
5.11	Tuckpointers and Grinders	Grinders (Outdoors, with controls)	283	0.310	24.0	0.385	0.82	74	Yes	870683	2/6/2013	238990	380

Table IV.A-2 OIS Health Sampling Data for Respirable Crystalline Silica 2011-2014 (Document ID 3958)

Sec.	Section Name	Job Category	Sample Duration (min.)	Resp. Dust (mg/m^3)	Pct. Silica	PEL (mg/m^3)	Severity	Resp. Silica ($\mu g/m^3$)	Included in Profile	Inspec. ID	Opening Date	NAICS	Docket File Row #
5.11	Tuckpointers and Grinders	Grinders (Outdoors, no controls)	426	0.933	12.0	0.714	1.31	112	Yes	63013	6/6/2011	237310	23
5.11	Tuckpointers and Grinders	Grinders (Outdoors, no controls)	302	0.230	30.0	0.313	0.74	69	Yes	870683	2/6/2013	238990	381
5.11	Tuckpointers and Grinders	Grinders (Outdoors, no controls)	364	0.099	0.0	5.000	0.02	<12	Yes	941642	9/16/2013	236220	398
5.11	Tuckpointers and Grinders	Grinders (Outdoors, with controls)	485	0.640 (mppcf)	15.0	12.500 (mppcf)	1.34	96	Yes	546878	7/30/2012	238190	206
5.11	Tuckpointers and Grinders	Grinders (Outdoors, with controls)	227	0.069	50.0	0.192	0.36	35	Yes	843303	1/23/2013	238160	1030
5.11	Tuckpointers and Grinders	Grinders (Outdoors, with controls)	224	0.210	14.0	0.625	0.33	29	Yes	843303	1/23/2013	238160	1031
5.11	Tuckpointers and Grinders	Grinders (Indoors, no or general ventilation)	431	1.407 (mppcf)	16.0	11.900 (mppcf)	2.62	225	Yes	546878	7/30/2012	238190	205
5.11	Tuckpointers and Grinders	Grinders (Indoor with LEV)	235	0.940	24.0	0.385	2.46	226	Yes	955786	1/17/2014	238110	73
5.11	Tuckpointers and Grinders	Grinders (Indoor, overhead grinding, no controls)	366	1.300	3.7	1.742	0.74	49	Yes	913803	6/25/2013	236220	742
5.11	Tuckpointers and Grinders	Grinders (Indoor, overhead grinding, no controls)	361	0.990	7.1	1.104	0.90	70	Yes	913803	6/25/2013	236220	743
5.11	Tuckpointers and Grinders	Grinders (Indoor, overhead grinding, no controls)	370	3.300	6.0	1.254	2.67	197	Yes	913803	6/25/2013	236220	741
5.11	Tuckpointers and Grinders	Grinders (Outdoors, no controls)	120	0.210	0.0	5.000	0.04	<12	Yes	918808	6/25/2013	236220	85
5.11	Tuckpointers and Grinders	Grinders (Indoors, with water)	216	0.170	0.0	5.000	0.04	<12	Yes	903770	5/2/2013	238340	662
5.11	Tuckpointers and Grinders	Grinders (Indoors, with water)	221	0.200	0.0	5.000	0.04	<12	Yes	903770	5/2/2013	238340	660
NA	Construction - Other	Carpenter	131	0.080	0.0	5.000	0.02	<12	No	614918	8/20/2012	238310	216
NA	Construction - Other	Floor Cleaner	60	0.440	0.0	5.000	0.09	<12	No	956233	1/24/2014	236220	201
NA	Construction - Other	Foreman	190	0.658	11.0	0.769	0.86	72	No	63013	6/6/2011	237310	21
NA	Construction - Other	Laborer	117	0.500	0.0	5.000	0.10	<12	No	331823	4/12/2012	238110	805
NA	Construction - Other	Laborer	226	0.330	0.0	5.000	0.07	<12	No	639698	9/18/2012	238110	853
NA	Construction - Other	Laborer	385	0.055	0.0	5.000	0.01	<12	No	845903	1/24/2013	238120	354
NA	Construction - Other	Laborer	475	0.150	0.0	5.000	0.03	<12	No	910558	5/15/2013	238220	311

Table IV.A-2 OIS Health Sampling Data for Respirable Crystalline Silica 2011-2014 (Document ID 3958)													
Sec.	**Section Name**	**Job Category**	**Sample Duration (min.)**	**Resp. Dust (mg/m^3)**	**Pct. Silica**	**PEL (mg/m^3)**	**Severity**	**Resp. Silica ($\mu g/m^3$)**	**Included in Profile**	**Inspec. ID**	**Opening Date**	**NAICS**	**Docket File Row #**
NA	Construction - Other	Laborer	480	0.570	0.0	5.000	0.11	<12	No	534058	9/18/2012	237990	566
NA	Construction - Other	Laborer	176	0.160	0.0	5.000	0.03	<12	No	63013	6/6/2011	237310	22
NA	Construction - Other	Laborer	183	0.038	0.0	5.000	0.01	<12	No	950017	11/25/2013	237310	535
NA	Construction - Other	Laborer	239	0.092	0.0	5.000	0.02	<12	No	408422	4/30/2012	237310	810
NA	Construction - Other	Laborer	480	0.590	2.4	2.293	0.26	14	No	534058	9/18/2012	237990	567
NA	Construction - Other	Laborer	183	0.260	0.0	5.000	0.05	<12	No	950017	11/25/2013	237310	536
NA	Construction - Other	Laborer	231	3.500	4.2	1.613	2.18	147	No	403982	4/26/2012	237310	807
NA	Construction - Other	Laborer	119	0.170	0.0	5.000	0.03	<12	No	577478	8/16/2012	236220	515
NA	Construction - Other	Laborer	414	0.067	0.0	5.000	0.01	<12	No	63013	6/6/2011	237310	24
NA	Construction - Other	Laborer - cutting	231	0.000	0.0	5.000	0.00	<12	No	843303	1/23/2013	238160	1028
NA	Construction - Other	Laborer - cutting	443	0.470	11.0	0.769	0.61	52	No	891772	2/22/2013	238140	383
NA	Construction - Other	Laborer - cutting	106	1.800	9.1	0.901	2.05	164	No	732761	11/13/2012	237310	83
NA	Construction - Other	Laborer - cutting	229	0.000	0.0	5.000	0.00	<12	No	843303	1/23/2013	238160	1029
NA	Construction - Other	Laborer - cutting	375	1.600	12.0	0.714	2.21	192	No	963110	3/11/2014	238910	17
NA	Construction - Other	Laborer - cutting	50	0.310	0.0	5.000	0.06	<12	No	573939	8/15/2012	238140	692
NA	Construction - Other	Laborer - cutting	13	0.000	0.0	5.000	0.00	<12	No	891772	2/22/2013	238140	385
NA	Construction - Other	Laborer - demolition	385	6.500	2.6	2.164	3.02	170	No	953584	1/2/2014	236220	836
NA	Construction - Other	Laborer - demolition	355	1.800	3.6	1.786	1.04	65	No	953584	1/2/2014	236220	837
NA	Construction - Other	Laborer - demolition	186	0.693	0.0	5.000	0.14	<12	No	556859	8/1/2012	238910	4
NA	Construction - Other	Laborer - mixing mortar	384	10.000	0.0	5.000	2.05	<12	No	878223	2/5/2013	238990	516
NA	Construction - Other	Laborer - mixing mortar	455	5.900	0.0	5.000	1.18	<12	No	895995	3/13/2013	238140	518
NA	Construction - Other	Laborer - mixing mortar	453	0.210	4.6	1.515	0.14	10	No	955403	1/14/2014	238140	224
NA	Construction - Other	Laborer - mixing mortar	447	15.000	0.0	5.000	2.94	<12	No	895995	3/13/2013	238140	517
NA	Construction - Other	Laborer - mixing mortar	403	3.900	0.0	5.000	0.78	<12	No	895995	3/13/2013	238140	519
NA	Construction - Other	Mason	116	0.000	0.0	5.000	0.00	<12	No	577478	8/16/2012	236220	514
NA	Construction - Other	Mason	118	0.790	7.7	1.031	0.77	61	No	577478	8/16/2012	236220	513
NA	Construction - Other	Operator	375	0.053	0.0	5.000	0.01	<12	No	941642	9/16/2013	236220	396
NA	Construction - Other	Operator	160	0.440	0.0	5.000	0.09	<12	No	920329	7/17/2013	238990	834
NA	Construction - Other	Other	379	0.220	38.8	0.245	0.90	85	No	822081	1/11/2013	238340	1095
NA	Construction - Other	Other	347	0.029	0.0	5.000	0.01	<12	No	941642	9/16/2013	236220	397
NA	Construction - Other	Other	494	0.047	0.0	5.000	0.01	<12	No	799822	12/19/2012	238310	304
NA	Construction - Other	Other	432	0.250	0.0	5.000	0.05	<12	No	799822	12/19/2012	238310	303
NA	Construction - Other	Other	467	0.050	0.0	5.000	0.01	<12	No	799822	12/19/2012	238310	302
NA	Construction - Other	Other	233	0.056	0.0	5.000		<12	No	191861	2/21/2012	238340	70

Table IV.A-2 OIS Health Sampling Data for Respirable Crystalline Silica 2011-2014 (Document ID 3958)													
Sec.	**Section Name**	**Job Category**	**Sample Duration (min.)**	**Resp. Dust (mg/m^3)**	**Pct. Silica**	**PEL (mg/m^3)**	**Severity**	**Resp. Silica ($\mu g/m^3$)**	**Included in Profile**	**Inspec. ID**	**Opening Date**	**NAICS**	**Docket File Row #**
NA	Construction - Other	Other	449	0.130	13.0	0.667	0.20	17	No	799822	12/19/2012	238310	305
NA	Construction - Other	Painter	200	0.033	0.0	5.000	0.01	<12	No	915995	7/3/2013	238320	316
NA	Construction - Other	Pipefitter	483	1.900	2.0	2.500	0.76	38	No	910558	5/15/2013	238220	312
NA	Construction - Other	Pipefitter	401	0.330	8.0	1.000	0.33	26	No	963134	3/11/2014	238220	18
NA	Construction - Other	Supervisor	89	16.000	8.5	0.952	17.26	1360	No	909807	6/4/2013	238140	826
NA	Construction - Other	Supervisor	47	2.900	9.6	0.862	3.38	278	No	704518	10/24/2012	236220	693
NA	Construction - Other	Supervisor	67	0.594	10.0	0.833	0.00	59	No	668120	10/3/2012	238140	208
NA	Construction - Other	Supervisor	378	0.200	9.9	0.840	0.24	20	No	845903	1/24/2013	238120	353
NA	Construction - Other	Supervisor	318	0.059	0.0	5.000	0.01	<12	No	906671	5/14/2013	236118	734
NA	Construction - Other	Supervisor	256	0.071	0.0	5.000	0.01	<12	No	904969	5/7/2013	236118	733
NA	Construction - Other	Tender	463	0.990	5.3	1.370	0.72	52	No	541720	7/26/2012	236220	688
NA	Construction - Other	Tender	459	0.850	7.6	1.042	0.82	65	No	541720	7/26/2012	236220	689
NA	Construction - Other	Tender	456	0.930	5.9	1.266	0.73	55	No	541720	7/26/2012	236220	690
NA	Construction - Other	Tile Setter	340	0.090	0.0	5.000	0.02	<12	No	192165	2/23/2012	238350	800
NA	Construction - Other	Welder	487	1.900	0.0	5.000	0.37	<12	No	910558	5/15/2013	238220	310

CHAPTER V: COSTS OF COMPLIANCE

INTRODUCTION

This chapter assesses the costs to establishments in all affected industry sectors of reducing worker exposures to silica to an eight-hour time-weighted average (TWA) permissible exposure limit (PEL) of 50 μg/m^3—or, alternatively, for employers in construction to meet the Table 1 requirements—and of complying with the standard's ancillary requirements. This cost assessment is based on OSHA's technological feasibility analysis presented in Chapter IV of this FEA; analyses of the costs of the standard conducted by OSHA's contractor, Eastern Research Group; testimony during the hearings; and the comments submitted to the docket as part of the rulemaking process.

OSHA estimates that the standard will have a total cost of $1,029.8 million per year in 2012 dollars. Of that total, $370.8 million will be borne by the general industry and maritime sectors, and $659.0 million will be borne by the construction sector. Costs originally estimated for earlier years in the PEA were adjusted to 2012 dollars using the appropriate price indices. In general, all employee and supervisor wages (loaded) were from the 2012 BLS OES;[1] medical costs were inflated to 2012 dollars using the medical services component of the Consumer Price Index; and, unless otherwise specified, all other costs were inflated using the GDP Implicit Price Deflator[2].

All costs were annualized using a discount rate of 3 percent, which—along with 7 percent[3]—is one of the discount rates recommended by OMB.[4] Annualization periods

[1] Bureau of Labor Statistics (BLS) Occupational Employment Statistics (OES) (BLS, 2012b). Fringe markup is from the following BLS release: Employer Costs for Employee Compensation news release text; For release 10:00 AM (EDT) Wednesday, March 11, 2015; USDL-15-0386; Employer Costs for Employee Compensation – December 2014; Fringe markup equals 1.462693.

[2] Gross Domestic Product (GDP): Implicit Price Deflator; Series ID: GDPDEF; U.S. Bureau of Economic Analysis (BEA); seasonally adjusted; annual frequency; aggregation method: average; Index 2009 = 100; date range: 1947-01-01 to 2014-10-01; last updated: 2015-03-27 8:01 AM CDT; BEA Account Code: A191RD3.

[3] Appendix V-D of this FEA presents costs by NAICS industry and establishment size category using, as alternatives, both a 7 percent discount rate and a 0 percent discount rate. In the sensitivity analysis presented in Chapter VII of this FEA, OSHA compares the estimated cost of the rule using the 3 percent discount rate to the estimated cost using these alternative discount rates.

[4] The annualized cost of the final rule is derived by converting the discount present value (PV) of costs by year into an equivalent uniform annual stream of costs. So, $PV = \Sigma\, C_i/(1+r)^i$ where i = the ith year and r = the discount rate and C_i is the cost in the ith year. The annualization factor is $a = (r * (1+r)^i) / ((1+r)^i$

for expenditures on equipment are based on equipment life, while there is a 10-year annualization period for one-time costs. Note that the benefits of the standard, discussed in Chapter VII of this FEA, were annualized over a 60-year period to reflect the time needed for benefits to reach steady-state values. Therefore, the time horizon of OSHA's complete analysis of this rule is 60 years. Employment and production in affected industries are being held constant over this time horizon for purposes of the analysis. All non-annual costs are estimated to repeat every ten years over the 60-year time horizon, including one-time costs that recur because of changes in operations over time or because of new entrants that must comply with the standard.[5] Table V-1 shows, by affected industry in the sectors of general industry and maritime, annualized compliance costs for all establishments, all small entities (as defined by the Small Business Act and the Small Business Administration's (SBA's) implementing regulations; see 15 U.S.C. 632 and 13 CFR 121.201), and for all very small entities (those with fewer than 20 employees).

Table V-2 similarly shows, by affected industry in construction, annualized compliance costs for all entities, all small entities, and all very small entities. Note that the totals in these tables and all other tables in this chapter, as well as totals summarized in the text, may not precisely sum from underlying elements due to rounding.

OSHA's exposure profile, presented in Chapter III of this FEA, represents the Agency's best estimate of current exposures (i.e., baseline exposures). Except for compliance with Table 1 in construction, OSHA did not attempt to determine the extent to which current exposures in compliance with the new silica PEL are the result of baseline engineering controls or the result of other circumstances leading to low exposures. This information is not needed to estimate the costs of (additional) engineering controls needed to comply with the new PEL, but it is relevant to estimate the costs of complying with Table 1 in construction.

For both construction and general industry/maritime, the estimated costs for the silica rule represent the additional costs necessary for employers to achieve full compliance with the new standard, assuming that all firms are compliant with the previous standard. Thus, the estimated costs do not include any costs necessary to achieve compliance with previous silica requirements, to the extent that some employers may not be fully complying with previously-applicable regulatory requirements. OSHA almost never assigns costs for reaching compliance with an already existing standard to a new standard

– 1). Thus, the annualized cost equals a*PV, where r = .03 in the primary case, and i is summed over a 10-year period.

[5] To the extent one-time costs do not recur, OSHA's cost estimates, when expressed as an annualization over a 10-year period, will overstate the cost of the standard.

addressing the same health issues. Nor are any costs associated with previously-existing compliance with the new requirements that has already been achieved included.

Because of the severe health hazards involved, as well as current OSHA regulation, the Agency expects that the estimated 11,640 abrasive blasters in the construction sector and the estimated 3,038 abrasive blasters in the maritime sector are currently wearing respirators as required by OSHA's abrasive blasting provisions (29 CFR 1915.154 (referencing 29 CFR 1910.134)). Furthermore, an estimated 264,761 workers, including abrasive blasters, will need to use respirators at least once during a year to achieve compliance with the new silica rule, and, based on a respirator use survey jointly administered by the National Institute for Occupational Safety and Health (NIOSH) and the Bureau of Labor Statistics (BLS) (NIOSH/BLS, 2003), an estimated 56 percent of construction employees whose exposures are high enough that they will need respirators under the new rule currently use such respirators. OSHA therefore estimates that 56 percent of affected construction employees already use respirators in compliance with the respirator requirements of the final silica rule.

Other than respiratory protection, OSHA did not assume baseline compliance with any other ancillary provision, even though some employers have reported that they currently monitor silica exposure, provide silica training, and conduct medical surveillance.

The remainder of this chapter is organized as follows. First, unit and total costs by provision are presented for general industry and maritime. Second, unit and total costs by provision are presented for construction. The chapter concludes with a summary of the estimated costs of the rule for all affected industries.

Table V-1: Annualized Costs, by Industry, for All General Industry and Maritime Entities Affected by the Silica Standard

NAICS	Industry	All Establishments	Small Entities (SBA-Defined)	Very Small Entities (<20 Employees)
213112	Support Activities for Oil and Gas Operations	$97,927,752	$24,247,594	$11,907,226
324121	Asphalt Paving Mixture and Block Manufacturing	$513,042	$257,611	$57,921
324122	Asphalt Shingle and Coating Materials Manufacturing	$3,811,893	$1,272,241	$267,935
325510	Paint and Coating Manufacturing	$1,008,627	$572,603	$96,372
327110	Pottery, Ceramics, and Plumbing Fixture Manufacturing	$8,788,336	$5,059,640	$2,389,156
327120	Clay Building Material and Refractories Manufacturing	$21,252,204	$13,647,591	$1,765,486
327211	Flat Glass Manufacturing	$725,452	$129,486	$11,319
327212	Other Pressed and Blown Glass and Glassware Manufacturing	$2,208,578	$970,207	$276,747
327213	Glass Container Manufacturing	$2,212,672	$2,113,092	$23,711
327320	Ready-Mix Concrete Manufacturing	$30,004,503	$20,250,184	$5,616,970
327331	Concrete Block and Brick Manufacturing	$7,020,737	$4,550,565	$1,383,138
327332	Concrete Pipe Manufacturing	$3,810,088	$1,900,067	$336,697
327390	Other Concrete Product Manufacturing	$20,878,235	$14,539,705	$4,568,859
327991	Cut Stone and Stone Product Manufacturing	$14,628,182	$13,106,845	$5,664,898
327992	Ground or Treated Mineral and Earth Manufacturing	$4,288,421	$2,075,935	$426,975
327993	Mineral Wool Manufacturing	$2,615,391	$990,251	$140,721
327999	All Other Miscellaneous Nonmetallic Mineral Product Manufacturing	$11,597,806	$5,872,264	$2,430,981
331110	Iron and Steel Mills and Ferroalloy Manufacturing	$646,402	$146,290	$0
331210	Iron and Steel Pipe and Tube Manufacturing from Purchased Steel	$163,038	$83,666	$0
331221	Rolled Steel Shape Manufacturing	$51,060	$42,989	$0
331222	Steel Wire Drawing	$92,206	$67,130	$0
331314	Secondary Smelting and Alloying of Aluminum	$35,312	$19,590	$0
331420	Copper Rolling, Drawing, Extruding, and Alloying	$135,310	$68,335	$0
331492	Secondary Smelting, Refining, and Alloying of Nonferrous Metal (except Copper and Aluminum)	$70,791	$37,734	$0
331511	Iron Foundries	$23,362,955	$12,442,276	$967,507
331512	Steel Investment Foundries	$5,450,435	$2,672,675	$124,895
331513	Steel Foundries (except Investment)	$11,118,366	$5,503,027	$559,542
331524	Aluminum Foundries (except Die-Casting)	$4,120,657	$3,130,109	$842,096
331529	Other Nonferrous Metal Foundries (except Die-Casting)	$2,569,518	$1,693,459	$816,991
332111	Iron and Steel Forging	$154,626	$79,975	$0
332112	Nonferrous Forging	$40,101	$13,664	$0
332117	Powder Metallurgy Part Manufacturing	$52,988	$29,903	$0
332119	Metal Crown, Closure, and Other Metal Stamping (except Automotive)	$340,536	$266,352	$0
332215	Metal Kitchen Cookware, Utensil, Cutlery, and Flatware (except Precious) Manufacturing	$48,090	$27,196	$0
332216	Saw Blade and Handtool Manufacturing	$179,774	$120,315	$0
332323	Ornamental and Architectural Metal Work Manufacturing	$44,015	$35,067	$13,862

Table V-1: Annualized Costs, by Industry, for All General Industry and Maritime Entities Affected by the Silica Standard (continued)

NAICS	Industry	All Establishments	Small Entities (SBA-Defined)	Very Small Entities (<20 Employees)
332439	Other Metal Container Manufacturing	$76,117	$42,327	$0
332510	Hardware Manufacturing	$171,563	$91,570	$0
332613	Spring Manufacturing	$96,006	$63,105	$0
332618	Other Fabricated Wire Product Manufacturing	$158,941	$126,762	$0
332710	Machine Shops	$1,580,507	$1,463,233	$0
332812	Metal Coating, Engraving (except Jewelry and Silverware), and Allied Services to Manufacturers	$3,443,786	$2,755,111	$949,586
332911	Industrial Valve Manufacturing	$229,195	$100,135	$0
332912	Fluid Power Valve and Hose Fitting Manufacturing	$219,774	$88,050	$0
332913	Plumbing Fixture Fitting and Trim Manufacturing	$49,483	$29,537	$0
332919	Other Metal Valve and Pipe Fitting Manufacturing	$92,474	$48,163	$0
332991	Ball and Roller Bearing Manufacturing	$145,507	$28,037	$0
332996	Fabricated Pipe and Pipe Fitting Manufacturing	$192,491	$116,327	$0
332999	All Other Miscellaneous Fabricated Metal Product Manufacturing	$460,336	$398,663	$0
333318	Other Commercial and Service Industry Machinery Manufacturing	$348,809	$220,586	$0
333413	Industrial and Commercial Fan and Blower and Air Purification Equipment Manufacturing	$156,056	$75,552	$0
333414	Heating Equipment (except Warm Air Furnaces) Manufacturing	$116,177	$76,185	$0
333511	Industrial Mold Manufacturing	$226,974	$196,365	$0
333514	Special Die and Tool, Die Set, Jig, and Fixture Manufacturing	$275,889	$239,261	$0
333515	Cutting Tool and Machine Tool Accessory Manufacturing	$183,291	$148,284	$0
333517	Machine Tool Manufacturing	$156,698	$120,338	$0
333519	Rolling Mill and Other Metalworking Machinery Manufacturing	$75,852	$52,800	$0
333612	Speed Changer, Industrial High-Speed Drive, and Gear Manufacturing	$102,884	$48,595	$0
333613	Mechanical Power Transmission Equipment Manufacturing	$100,450	$43,878	$0
333911	Pump and Pumping Equipment Manufacturing	$217,882	$79,486	$0
333912	Air and Gas Compressor Manufacturing	$135,840	$61,295	$0
333991	Power-Driven Handtool Manufacturing	$56,450	$16,285	$0
333992	Welding and Soldering Equipment Manufacturing	$98,775	$48,996	$0
333993	Packaging Machinery Manufacturing	$129,107	$82,146	$0
333994	Industrial Process Furnace and Oven Manufacturing	$71,404	$52,056	$0
333995	Fluid Power Cylinder and Actuator Manufacturing	$153,238	$64,620	$0
333996	Fluid Power Pump and Motor Manufacturing	$68,340	$22,056	$0
333997	Scale and Balance Manufacturing	$24,516	$11,603	$0
333999	All Other Miscellaneous General Purpose Machinery Manufacturing	$329,237	$197,602	$0
334519	Other Measuring and Controlling Device Manufacturing	$221,763	$115,924	$0
335210	Small Electrical Appliance Manufacturing	$24,524	$17,998	$1,302
335221	Household Cooking Appliance Manufacturing	$28,748	$13,297	$0
335222	Household Refrigerator and Home Freezer Manufacturing	$26,111	$4,707	$0

Table V-1: Annualized Costs, by Industry, for All General Industry and Maritime Entities Affected by the Silica Standard (continued)

NAICS	Industry	All Establishments	Small Entities (SBA-Defined)	Very Small Entities (<20 Employees)
335224	Household Laundry Equipment Manufacturing	$12,403	$157	$0
335228	Other Major Household Appliance Manufacturing	$26,829	$3,765	$0
336111	Automobile Manufacturing	$362,562	$20,482	$0
336112	Light Truck and Utility Vehicle Manufacturing	$324,735	$7,727	$0
336120	Heavy Duty Truck Manufacturing	$183,916	$36,819	$0
336211	Motor Vehicle Body Manufacturing	$260,377	$164,332	$0
336212	Truck Trailer Manufacturing	$180,129	$97,653	$0
336213	Motor Home Manufacturing	$45,680	$10,810	$0
336310	Motor Vehicle Gasoline Engine and Engine Parts Manufacturing	$334,051	$116,317	$0
336320	Motor Vehicle Electrical and Electronic Equipment Manufacturing	$315,816	$157,980	$0
336330	Motor Vehicle Steering and Suspension Components (except Spring) Manufacturing	$180,676	$58,720	$0
336340	Motor Vehicle Brake System Manufacturing	$140,620	$60,248	$0
336350	Motor Vehicle Transmission and Power Train Parts Manufacturing	$364,252	$129,753	$0
336370	Motor Vehicle Metal Stamping	$516,924	$310,283	$0
336390	Other Motor Vehicle Parts Manufacturing	$778,085	$366,093	$0
336611	Ship Building and Repairing	$9,586,384	$2,404,761	$110,154
336612	Boat Building	$2,566,768	$1,969,321	$156,109
336992	Military Armored Vehicle, Tank, and Tank Component Manufacturing	$69,849	$23,894	$0
337110	Wood Kitchen Cabinet and Countertop Manufacturing	$204,454	$155,433	$64,773
337215	Showcase, Partition, Shelving, and Locker Manufacturing	$215,675	$156,085	$0
339114	Dental Equipment and Supplies Manufacturing	$5,930,743	$4,331,589	$1,716,366
339116	Dental Laboratories	$6,857,347	$5,719,685	$4,641,195
339910	Jewelry and Silverware Manufacturing	$2,690,864	$2,065,825	$993,578
339950	Sign Manufacturing	$408,620	$354,823	$140,698
423840	Industrial Supplies Merchant Wholesalers	$2,292,917	$1,287,104	$528,996
444110	Home Centers	$110,386	$6,043	$1,681
482110	Rail transportation	$16,562,059	$0	$0
561730	Landscaping Services	$24,481,907	$18,249,100	$15,602,766
621210	Offices of Dentists	$2,592,207	$2,432,481	$2,094,401
	Totals	**$370,810,530**	**$186,093,853**	**$67,691,610**

[a] Not available. This estimate excludes NAICS 482110 (Railroad transportation) because the Census data did not include information sufficient for OSHA to identify the number of railroad establishments that are small firms and very small entities.
Source: OSHA, Directorate of Standards and Guidance, Office of Regulatory Analysis, based on OSHA (2016).

Table V-2: Annualized Costs, by Industry, for All Construction Entities Affected by the Silica Standard

NAICS	Industry	All Establishments	Small Entities (SBA-Defined)	Very Small Entities (<20 Employees)
236100	Residential Building Construction	$54,944,997	$49,798,948	$41,976,835
236200	Nonresidential Building Construction	$52,733,126	$34,357,970	$19,584,315
237100	Utility System Construction	$83,397,297	$30,262,348	$14,713,621
237200	Land Subdivision	$1,960,835	$966,584	$670,956
237300	Highway, Street, and Bridge Construction	$48,314,733	$21,399,925	$8,185,695
237900	Other Heavy and Civil Engineering Construction	$13,342,117	$5,415,610	$2,958,952
238100	Foundation, Structure, and Building Exterior Contractors	$139,227,106	$110,212,308	$65,772,437
238200	Building Equipment Contractors	$60,058,912	$41,087,873	$28,091,857
238300	Building Finishing Contractors	$55,340,177	$44,499,467	$32,007,884
238900	Other Specialty Trade Contractors	$101,830,889	$76,873,828	$48,852,375
221100	Electric Utilities	$3,203,249	$0	$199,861
999200	State Governments	$8,620,645	$0	$0
999300	Local Governments	$35,997,165	$0	$0
	Totals	**$658,971,248**	**$414,874,862**	**$263,014,788**

Source: OSHA, Directorate of Standards and Guidance, Office of Regulatory Analysis, based on OSHA (2016).

COSTS FOR GENERAL INDUSTRY AND MARITIME

Estimation of the costs of the final rule for general industry and maritime is broken out in this section for three categories of costs: (1) control costs to comply with the PEL of 50 μg/m^3; (2) respirator costs, in those cases where engineering controls are not sufficient to reduce worker exposures to the PEL; and (3) "program" and familiarization costs to comply with the ancillary provisions of the rule.

As discussed in Chapter III (and summarized in Table III-12) of this FEA, OSHA judged that there was no baseline compliance in the general industry or maritime sectors with any of the ancillary provisions (but 100 percent baseline compliance with the existing Hazard Communication training program); 50 percent baseline compliance with the respirator program requirements but no baseline compliance with the respirator use requirements; and 100 percent baseline compliance with the engineering control requirements for workers currently below the new PEL.

Engineering Control Costs

This section of the chapter covers OSHA's estimates of engineering control costs for general industry and maritime sectors. Oil and natural gas fracturing operations are addressed separately because OSHA used a different methodology to estimate engineering control costs for this application group. This section will address OSHA's overall methodology, the methodology for each category of costs (such as ventilation, housekeeping, conveyors), issues specific to small entities, and issues specific to the hydraulic fracturing industry. Within each of these discussions, this section summarizes the methodology used in the PEA to estimate engineering control costs, summarizes and responds to the comments on the PEA, and summarizes the changes made to the methodology used in the PEA for this FEA. Finally, the chapter presents OSHA's final estimates of engineering control costs.

Introduction

The PEA's technological feasibility analysis identified the types of engineering controls that affected industries or sectors would need in order to control worker exposures to at or below the proposed PEL of 50 μg/m^3. Through its contractor, Eastern Research Group (ERG), OSHA generated cost estimates for those controls using product and technical literature, equipment vendors, industrial engineers, industrial hygienists, and other sources, as relevant to each item. Wherever possible, objective cost estimates from recognized technical sources were used. Specific sources for each estimate were presented with the cost estimates.

Table V-4 of the PEA provided a list of possible controls on an industry-by-industry basis and included details on control specifications and costs. The basic information for the types of controls needed was taken from the PEA's technological feasibility analysis. The following discussion explains how OSHA developed and used these estimates to prepare the aggregate costs of engineering controls presented in the PEA.

In developing engineering control cost estimates for the PEA, OSHA made a variety of estimates about the size or scope of the engineering or work practice changes necessary to reduce silica exposures in accordance with the proposed rule. In some cases, OSHA estimated that employers would need to install all new engineering controls. In other cases, though, employers were expected to only need to add additional ventilation capacity or improve maintenance for existing equipment. In these cases, the costs were based on judgments of the amount of incremental change (either additional capacity or additional maintenance work) required per year. These estimates of the size or scope of the necessary engineering or work practice changes reflected representative conditions for the affected workers based on technical literature (including NIOSH Health Hazard Evaluations), judgments of knowledgeable consultants and industry observers, and site visits. A detailed list of the specific costing assumptions and information sources for each control, grouped by job category or industry sector, was shown in PEA Appendix V-A, Table V-A-1.

In order to estimate costs in a consistent manner, OSHA, in the PEA, estimated all costs on an annualized basis. For capital costs, OSHA calculated the annualized capital cost, using a three percent discount rate over the expected lifetime of the capital item. The capital costs for long-lasting capital items (such as ventilation system improvements) were annualized over ten years. OSHA estimated that, in the general industry and maritime sectors, any capital expenditure would also entail maintenance costs equal to ten percent of the value of the capital investment annually.

General Methodology

General Methodology: Per-Worker Basis and Treatment of Overexposures for Cost Calculations

PEA estimates

OSHA, in the PEA, estimated control costs on a per-worker basis. Costs were related directly to the estimates of the number of workers needing controls (i.e., workers exposed over 50 μg/m^3). OSHA divided engineering control costs into two categories: 1) those only needed by establishments with employees exposed to levels of silica that exceeded the preceding general industry PEL of 100 μg/m^3; and 2) those applicable to all establishments where workers were exposed to levels of silica above the proposed PEL (whether just above 50 μg/m^3 or also above 100 μg/m^3). It should be noted that the maritime sector has been subject to a different preceding PEL of 250 μg/m^3. The PEA estimates were presented in the PEA cost analysis tables. The overwhelming majority of the costs (90 percent of all engineering control costs and 85 percent of costs associated with meeting the preceding PEL of 100 μg/m^3) were associated with the second category (controls applicable to all establishments with exposures above the proposed or preceding PEL). Because OSHA is not accounting for the costs of controls necessary to reach the preceding PEL, the PEA focused on controls that may be needed to meet the new PEL. OSHA derived per-worker costs by examining the controls needed for each job category in each industry and dividing the cost of that control by the number of workers whose exposures would be reduced by that control. OSHA then multiplied the estimated per-worker control cost by the number of workers exposed between the proposed (new) PEL of 50 μg/m^3 and the preceding PEL of 100 μg/m^3. The numbers of workers in this category were based on the exposure profiles for at-risk occupations developed in the technological feasibility analysis in Chapter IV of the PEA and the estimates of the number of workers employed in these occupations developed in the industry profile in Chapter III of the PEA. The exposure profile information was determined to be the best available data for estimating the need for incremental controls on a per-worker basis.

In general, in the PEA, OSHA inferred the extent to which exposure controls were already in place from the distribution of overexposures among the affected workers. Thus, if most exposures in a facility were above the preceding PEL, OSHA broadly interpreted this as a sign of limited or no controls, and if most exposures were below the proposed (new) PEL of 50 μg/m^3, this would be indicative of having adequate controls in place. OSHA calculated the costs of controls per exposed worker in each job category and assigned this cost to the total number of employees exposed between the proposed (new) PEL and the preceding PEL. For example, if a control cost $1,000 per year and covered 4 employees, the cost per employee would be $250 per year. If 100 employees in the job category were exposed between the preceding and proposed (new) PEL, then the total costs would be $250 times 100 employees or $25,000. No costs were estimated for employees currently exposed above the preceding PEL or below the proposed (new) PEL.

OSHA determined that multiple controls would be needed for almost all jobs in general industry in order reduce exposures from baseline conditions to meeting the proposed (new) PEL of 50 μg/m^3. Some of these controls cover a group of workers, while others might be individualized (such as daily housekeeping by each individual worker).

Comments on the Per-Worker Basis and Proportionality of Costs

URS, speaking for the American Chemistry Council (ACC), argued that OSHA's approach underestimated the costs of controls because it based costs on controls per worker instead of controls per facility (Document ID 2307, Attachment 8, p. 4). Since OSHA did not provide a distribution of exposures by facility or provide facility-specific information, URS used data in the record to create its own models to account for facility size. URS described its approach as follows:

> URS created three statistical binomial distributions of overexposed workers, one for each of the three facility sizes, using OSHA's estimate of the percentage of over-exposed workers for that job. The result was a binomial distribution curve indicating the percentage of overexposed workers for each job category for each size-specific "model facility." For each binomial distribution, the peak of the distribution curve centers on the average number of overexposed workers per facility for that job description according to OSHA's estimate (Document ID 2307, Attachment 8, p. 7).

In taking this approach, URS erroneously assumed that the distribution of overexposed workers per facility was random, as evidenced by its use of a binomial distribution to approximate overexposures per facility within each of three facility sizes (Document ID 2307, Attachment 8, p. 7). Examination of the spreadsheet URS provided shows that this approach approximately doubles the number of controls needed and, and for this reason, doubles the total cost of engineering controls (Document ID 2307, Attachment 26, Table 2A, URS Summary Worksheet).

OSHA disagrees with URS's implicit conclusion that overexposures are random across facilities. It is not reasonable to assume that controls have no relation to exposure level as this approach assumes. As will be discussed later in the context of OSHA's treatment of the preceding PEL, the data underlying the exposure profile show that establishments with low exposures are much more likely to have controls in place than those with very high exposures.

URS then assumed that if one worker in a job category is overexposed, then all controls listed by OSHA will be needed (Document ID 2307, Attachment 25, Engineering Costs). URS did not dispute that multiple controls would be needed for almost all jobs in general industry in order reduce exposures from baseline conditions to meeting the proposed (new) PEL of 50 μg/m^3. The existence of multiple controls weakens the theory suggested by URS--that all controls are needed if even one worker is exposed at levels above the

PEL--because as explained above, some controls are individualized while some protect groups of workers.

The best possible approach to what engineering controls are needed might differ based on whether 1) there are no controls for a job category in place at all and most workers are overexposed by a large margin; or 2) only some workers in a job category are overexposed by a small margin (i.e., a set of controls is already in place).

In the first case, the most common approach would be to apply a relatively full set of controls, as explained in OSHA's technological feasibility analysis. This might start with enclosures and local exhaust ventilation (LEV), but, if exposures are high and the establishment is very dusty, it might also include initial cleaning or the introduction of ongoing routine housekeeping. In these situations, in which most employees are overexposed, OSHA estimated that the full set of controls listed in the technological feasibility analysis would be applied and, in these cases, there would be little difference in the results obtained using OSHA's approach and the results obtained using the approach suggested by URS.

However, the approach to controlling silica exposures that OSHA believes to be typical when establishments are faced with the second situation would be quite different, and therefore different from what URS expected. Commenters from both labor (Document ID 4204, p. 40) and industry (Document ID 1992, p. 6) pointed out that when there are controls in place or only some workers are overexposed, the first step is to examine work practices. The AFL-CIO noted that exposures can be controlled through work practices, repositioning ventilation systems, and controlling fugitive emissions (carryover from adjacent silica emitting processes) (Document ID 4204, p. 40). Implementing these types of changes can be inexpensive. The principal cost of improving work practices may only be training or retraining workers in appropriate work practices. OSHA's proportional cost approach in the PEA may therefore overestimate costs for situations in which overexposures can be corrected with work practice changes because the Agency will have included costs for engineering controls when, in fact, none will be needed. The URS approach will always include the costs of all controls for a job category in any facility where anyone in a job category is overexposed, and will thus yield even higher estimates.

As described in Chapter IV, Technological Feasibility, and summarized below, in situations in which there are LEV systems in place but the PEL is still not being met, employers would typically try many things short of removing the entire system and replacing it with a system with greater air flow velocities (and thus greater capacity and cost). The incremental solutions to controlling silica exposures include minor design modification of existing controls, better repair and maintenance of existing controls, adding additional LEV capacity to existing systems, improving housekeeping, modifying tools or machinery causing high levels of emissions, and reducing cross contamination. Some worksites might require a slightly different and readily modified design. For example, an OSHA special emphasis program inspection of a facility in the Concrete Products industry discovered that installing a more powerful fan motor, installing a new filter bag for the bag-filling machine LEV, and moving hoods closer to the packing operator's position reduced respirable dust exposure by 92 percent, to 11 $\mu g/m^3$ (Document ID 0126, pp. 7-8). In an assessment of the Asphalt Roofing industry, NIOSH recommended repair and servicing of existing process enclosures and ventilation systems to eliminate leaks and poor hood capture but did not indicate that entirely new systems would need to be installed (Document ID 0889, pp. 12-13; 0891, pp. 3 and 11; 0890, p. 14; 0893, p. 12).

In other cases, better equipment repair and maintenance procedures can be the key to meeting the PEL when there are already controls in place. For example, as described in Chapter IV of this FEA, in the Concrete Products industry, OSHA obtained a sample of 116 $\mu g/m^3$ for a material handler who operated a forklift to transport product between stations. The inspector noted that there were leaks in the silo bin chute and that some controls were not fully utilized. The report indicated that dust generated by various other processes in the facility was a contributing factor to the forklift operator's high level of exposure. In this case, the first course of action for the employer would be to correct the deficiencies in the existing systems. Similarly, at a site visit in the Paint and Coating industry, ERG monitored mixer operators' exposures and obtained results below the limit of detection while workers emptied 50-pound bags of powder into hoppers when dust control systems were working properly. These values are 95 percent lower than the 263 $\mu g/m^3$ obtained during another shift, at the same plant, when the dust control systems malfunctioned (Document ID 0199, p. 9).

In other cases, as pointed out by a foundry commenter, adding LEV capacity to existing systems for silica emissions not yet subject to any LEV control can be a good strategy for lowering exposures (Document ID 1992, p. 6). In one foundry, NIOSH investigators recommended installation of LEV over the coater and press areas, enclosure of the coating process, and/or repair and servicing of existing process enclosures and ventilation systems to eliminate leaks and poor hood capture (Document ID 0889, pp. 12-13; 0891, pp. 3 and 11; 0890, p. 14; 0893, p. 12).

Various combinations of improved housekeeping, initial cleaning, and switching to High-Efficiency Particulate Air (HEPA) vacuums can also help employers meet the PEL. In the Structural Clay industry, professional cleaning in a brick manufacturing facility removed "several inches" of dust from floors, structural surfaces and equipment (Document ID

1365, pp. 3-19-3-20; 0571). These changes alone led to a dramatic decrease in exposures, by as much as 90 percent, to below 50 μg/m^3, for materials handlers. Similar results were observed for grinding operators (Document ID 0571). In one NIOSH evaluation, operators in a grinding area where good housekeeping practices were being implemented had substantially lower exposures than operators in a grinding room where the housekeeping practices were poor. The grinding room referred to as the “C plant” had 2 to 3 inches of settled dust on the floor and had an exposure result of 144 μg/m^3. Grinding operators at the grinding room referred to as the “B plant,” where dust had been cleaned up, had substantially lower exposures (24 μg/m^3) (Document ID 0235, pp. 6-7).

Good housekeeping also increases the useful life of equipment. As discussed in Chapter IV of this FEA, dust clogs machines and reduces their useful life. As an example, regulating cotton dust was acknowledged to increase productivity by reducing down time. It also increased the useful life of looms (Document ID 2256, Attachment 4, p. 11). The Agency predicts that this is likely to be the case with silica controls as well. Dust being properly captured at the source can also result in cost savings in housekeeping activities because less dust needs to be cleaned up when it is captured at the source and not allowed to spread (Document ID 2256, Attachment 4, p. 11).

In specific situations, there are a variety of other controls that may be useful. As discussed in the technological feasibility chapter of this FEA, Simcox et al. (1999) (Document ID 1146) found that Fabricators in the Cut Stone industry had a mean exposure of 490 μg/m^3, which was reduced 88 percent to 60 μg/m^3 when dry grinding tools used on granite were replaced or modified to be water-fed. Similar reductions were found at other facilities when wet grinding, polishing, and cutting methods were adopted (Document ID 1365, p. 11-20; 1146, p. 579). In the technological feasibility chapter, OSHA examined the work practices of cut stone splitters and chippers and found that a combination of wetting the floor at appropriate times, modifying ventilation directly from the top of the saws, and retrofitting splitting stations with LEV reduced exposures from a mean of 117 μg/m^3 to a mean of 18 μg/m^3, an 85 percent reduction (Document ID 1365, p. 11-22; 0180).

Finally, in situations where there is cross contamination, employers may achieve the PEL for some workers without implementing any controls specific to that job category. As pointed out by the AFL-CIO, when this occurs, OSHA’s costs may be overestimated (Document ID 4204, Attachment 1, p. 105).

These examples show that in many situations, where there are already controls in place, or where exposures are only slightly above the PEL, the PEL can be met by a variety of mechanisms short of installing an entirely new set of controls. Since the record shows that, frequently, exposures can be controlled without installing new engineering controls, OSHA's approach of estimating costs based on the proportion of the workers exposed above the PEL is much more likely to be accurate than estimates based on URS's suggestion that all controls are needed whenever one worker is exposed above the PEL.

The URS facility-based approach would require taking the costs of newly installing a full set of controls even if only one worker is exposed above the PEL. This approach assumes that (1) the existing exposure levels in a given facility have been achieved without the use of any controls; and (2) existing controls cannot be improved upon for less than the cost of installing an entirely new system of controls. These assumptions are unsupported by the URS comments and the nature of exposure control, as discussed above.
OSHA therefore rejects URS's approach and is maintaining its per-worker basis for calculating costs for this FEA. Based on the evidence presented in this section, the Agency concludes that OSHA's proportional approach of assigning control costs to each worker based on the cost per worker of a complete set of controls is a better approach to commonly encountered exposure situations than to assume that any reading above the PEL triggers the need for a complete set of controls.

The AFL-CIO argued that OSHA's proportional approach resulted in an over-estimation of costs because it involved adding costs for the exposed occupation wherever there was an overexposure, even when the overexposure was primarily or solely the result of cross contamination. The AFL-CIO recommended that OSHA "identify operations which are unlikely to [generate] silica emissions, or background and bystander exposure measurements, and subtract those measured exposure levels from those operations which do emit silica" (Document ID 4204, Attachment 1, pp. 31-32). OSHA has routinely included the elimination of cross contamination as a component of the controls needed for some job categories. However, as discussed in Chapter IV of this FEA, OSHA also believes that other controls will still be needed for many job categories and as long as these additional controls are needed, overall costs will not decline as a result of controlling cross contamination.

General Methodological Issues—Comments on Costs Associated with Exposures Over the Preceding PEL

Many commenters argued that OSHA should have attributed the costs of reaching the preceding PEL of 100 μg/m^3 to this standard (Document ID 2307, Attachment 8b, p. 16; 2195, p. 33; 1819, p. 2; 2375, Attachment 2, p. 65; 2307, Attachment 1, p. 2; 2379, Attachment 2, p. 9). For example, Stuart Sessions of Environomics, Inc., (Environomics) commenting on behalf of the ACC, stated that of the workers currently exposed over 50 μg/m^3, two-thirds are exposed over 100 μg/m^3, and that OSHA erred in excluding the costs of reducing those exposures to 100 μg/m^3 (Document ID 2307, Attachment C, pp. 2-3).[6]

OSHA's preliminary initial regulatory flexibility analysis (PIRFA) for the 2003 Small Business Advocacy Review (SBAR) panel included benefits and costs associated with future compliance with existing silica requirements on the basis that the rule would help improve compliance with the existing silica rules (OSHA, 2003a and 2003b). Upon further consideration, OSHA determined that a more fair and accurate measure of the benefits and costs of the proposed rule was to begin the analysis with a baseline of full compliance with existing requirements; OSHA has retained this approach for the final rule. The Agency offers three reasons in support of this approach. First, the obligation to comply with the preceding silica PEL is independent of OSHA's actions in this rulemaking. The benefits and costs associated with achieving compliance with the preceding silica rules are a function of those rules and do not affect the choice of PEL. The question before the Agency was whether to adopt new rules, and its analysis focused on the benefits and costs of those new rules. Second, the Agency's longstanding policy is to assume 100 percent compliance for purposes of estimating the costs and benefits of new rules, and to assume less than full compliance with the existing OSHA rules would be inconsistent with that policy. Finally, assuming full compliance with the existing rules is in keeping with standard OSHA practice in measuring the incremental effects of a new rule against pre-existing legal obligations. Reliance on costs that assume full compliance with both the preceding and proposed (new) OSHA rules makes it easier to compare the two regulatory schemes.

Some commenters also disagreed with the way OSHA attributed costs to employers whose workers were being exposed to silica at levels greater than the preceding PEL of 100 μg/m^3 (Document ID 3251, p. 2; 3296, p. 2; 3333, p. 2; 3373, p. 2; 2503, p. 2; 2291, p. 16; 4209, p. 111). These commenters argued that OSHA did not attribute any costs of reaching 50 μg/m^3 to employers whose employees were exposed above 100 μg/m^3. They argued that OSHA instead assumed that the costs and controls necessary to reach 100 μg/m^3 would also be sufficient to reach a level of 50 μg/m^3 and, as discussed above, that OSHA did not account for those costs because reducing exposures to the preceding PEL of 100 μg/m^3 was already required before this rulemaking. The American Foundry Society (AFS) argued that OSHA reduced costs by two-thirds "under the logic that employers must comply with the current PEL and the proposal does not add any existing

[6] As this commenter pointed out, this is largely an issue with respect to engineering and respiratory protection costs. As the preceding PEL for silica has no required ancillary provisions, all employers affected by this rule—whether exposures in their facility are above the preceding PEL or above the new PEL—will be newly required to comply with the rule's ancillary provisions and OSHA has fully accounted for these costs.

obligation" (Document ID 2379, Appendix 1, p. 10). AFS added that OSHA's underestimation of costs in this manner was particularly severe because OSHA used outdated data that showed more employees with exposures over 100 μg/m^3, whereas more recent data would show fewer employees with exposures above 100 μg/m^3 and more with exposures between 50 and 100 μg/m^3. Had OSHA used these updated data, in AFS's estimation, the Agency would have identified more employers needing to install additional engineering controls and thus there would be additional costs that were not accounted for in the PEA (Document ID 2379, Attachment 3, pp. 9-10). ACC made a similar point, saying that, as a result of OSHA's methodology, "the exposure reduction costs for the estimated 81,000 workers now exposed above 100 μg/m^3 are not taken into account by OSHA on either a full cost basis or an incremental cost basis" (Document ID 2308, Attachment 9, pp. 2-3).

In addition, URS, among others, argued that "OSHA fails to account for the non-linear costs associated with each incremental reduction in silica concentrations," meaning that URS believed that it is more costly to achieve additional reductions in exposure as exposures are lowered. For example, according to URS's contention, it would be more costly to reduce exposures from 75 μg/m^3 to 50 μg/m^3 than from 125 μg/m^3 to 100 μg/m^3 (Document ID 2308, Attachment 8, p. 11; 2291, p. 16; 4209, p. 11; 2307, Attachment 2, pp. 181-182; 2379, Attachment 2, p. 9; 3487, p. 13).

OSHA has several responses to these criticisms. In response to the criticism that OSHA overestimated the number of workers with exposure levels above 100 μg/m^3 as a result of using outdated data, the Agency has updated the exposure profile used to develop the final analysis of costs. This update is described previously in Chapters III and IV of this FEA. As a result of this update, OSHA found that, in the aggregate, the percentage of workers in general industry exposed to silica levels between 50 μg/m^3 and 100 μg/m^3 rose from 33 percent as estimated in the PEA to 42 percent. And, as the commenters noted would be the case, the percentage exposed at levels above 100 μg/m^3 fell from 67 percent to 58 percent. OSHA has updated this analysis to incorporate these data and has estimated costs for these additional workers whose exposures fall between 50 μg/m^3 and 100 μg/m^3. The revised distribution also shows that of those workers with exposures above the new PEL, 41 percent are exposed between the new PEL and the preceding general industry PEL with an average exposure level of 70 μg/m^3, 29 percent are exposed between the preceding PEL and 250 μg/m^3 with an average exposure level of 156 μg/m^3, and 30 percent are exposed above 250 μg/m^3 with an average exposure level of 485 μg/m^3. Where an industry submitted more recent exposure data or information about exposure distributions within their industry, OSHA was able to show that its final exposure distribution was roughly equivalent (see Chapter IV of this FEA).

The technological feasibility analysis (presented in Chapter IV of this FEA) describes the controls necessary for reducing exposures from the highest levels observed in an industry's exposure profile to the new PEL. In all application groups except two (asphalt paving products and dental laboratories), the highest observed exposures were above the preceding PEL. With the exception of hydraulic fracturing,[7] the technological feasibility analysis did not distinguish between the controls necessary to meet the preceding general industry PEL of 100 μg/m^3 and those necessary to meet the new general industry PEL of 50 μg/m^3. Instead, the technological feasibility analysis simply listed the controls necessary for those employers whose employees had the highest baseline exposures to significantly reduce exposures and, in most operations, meet the new PEL.

It was not necessary for OSHA to distinguish between controls necessary to achieve the preceding PEL and those necessary to achieve the new PEL in order to demonstrate the technological feasibility of achieving a PEL of 50 μg/m^3. Such a distinction would have been difficult because, from a baseline of uncontrolled exposures, the controls necessary to meet the preceding and new PELs are difficult to distinguish. For example, if there are two different controls necessary to fully meet the new PEL, then it is logically possible that two different establishments may achieve an exposure level at or below the preceding PEL in different ways. One establishment may have excellent housekeeping but poorly maintained LEV. Another may have well maintained LEV but poor housekeeping. For individual cases, there is not a simple demarcation of which controls of the total set of controls are necessary to achieve the new PEL when only the exposure level and not the controls already in place are known. Nor, as discussed above, is it the case that a control, once installed, will always provide identical protection. Two otherwise equal facilities may have the same installed controls but different exposure levels because of the quality of the maintenance of the system.

For the purposes of costing engineering controls for general industry and maritime in the PEA, OSHA assigned all of the costs for meeting a PEL of 50 μg/m^3 – including the costs of controls necessary to meet the preceding PEL of 100 μg/m^3 – to all workers with exposure levels between 50 μg/m^3 and 100 μg/m^3. However, OSHA assigned no costs in the PEA to employees whose exposures exceeded the preceding PEL. This approach would be accurate for both those above and below the preceding PEL only if the exact same controls would be needed to control exposures in both situations and these controls would always yield an exposure level below the preceding PEL. However, as discussed in the previous section on proportionality of costs, OSHA has determined that this is not typically the case. There exist multiple kinds of controls and the actual application and

[7] Due to an unusually rich data set, and the great similarity of different fracturing operations, both with respect to the equipment used and the current levels of control, OSHA was able to estimate which controls are necessary to go from an uncontrolled situation to the preceding PEL and which are necessary to get from the preceding PEL to the new PEL in the hydraulic fracturing industry.

operation of the control can differ. The approach applied in the PEA applied more controls than will typically be needed where exposures are below the preceding PEL and thus overestimates costs in these situations, but then assigns no costs for achieving the new PEL where exposures are above the preceding PEL. In the latter situation, it can reasonably be expected that, in most cases, some costs would be incurred to meet the new PEL even after the preceding PEL is met and therefore the PEA methodology underestimated costs in those situations. Although these over- and under-estimates are partially offsetting, OSHA acknowledges that any over-estimates of cost do not necessarily offset the potential under-estimates of costs.

OSHA has therefore decided to adopt an approach to the estimation of costs different from that adopted in the PEA. In this FEA, OSHA relied on data available in the rulemaking record to both correct the overestimate of costs for those below the preceding PEL and, as many industry commenters urged, estimate the costs necessary to meet the preceding PEL as well as the new PEL for those above the preceding PEL.

To be clear, these data still do not enable OSHA to distinguish between the exact controls needed to get from uncontrolled exposures to the preceding PEL and those needed to get from the preceding PEL to the new PEL on an industry-by-industry and occupation-by-occupation basis. However, the data do enable OSHA to show that the majority of the costs of controlling silica exposures are incurred in order to reduce exposures from uncontrolled levels to the preceding PEL. OSHA will then assume that 50 percent of the costs incurred will be to implement the controls necessary to get from the uncontrolled situation to the preceding PEL and 50 percent to implement the controls necessary to go from the preceding PEL to meeting the new PEL. If, in fact, a majority of the costs are incurred in order to reduce exposures to the preceding PEL, the assumption that attributes 50 percent of costs to going from the preceding PEL to the new PEL will overestimate the true costs for establishments with exposures at the preceding PEL or between the preceding PEL and the new PEL.

In order to assess whether the majority of the costs are necessary to meet the preceding PEL, OSHA first examined what kinds of exposures are associated with the uncontrolled situations that served as the starting point for the estimates of needed controls in the technological feasibility analysis. The average level of exposure across all of general industry for employees with exposure exceeding the preceding PEL is over 300 $\mu g/m^3$. Thus, on average, across all industries the uncontrolled situation involves high levels of exposure, commonly more than 3 times the preceding PEL.[8]

[8] To check that this was not the result of a very high exposures for a small number of employees or industries, OSHA examined the exposure profile presented in Table III-9 and found that in only 4 industries

In general, to reduce exposures from over 2.5 times the preceding PEL to the preceding PEL, employers would have to implement some measure or measures and those measures would be the ones that provide the greatest reduction in silica exposures and therefore control most of the silica exposures in the facility. In most cases this will be a working LEV system or some form of worker isolation. Measures like improved housekeeping cannot reduce exposures from the levels observed in uncontrolled exposure situations to the preceding PEL. OSHA reviewed industry-by-industry and occupation-by-occupation cost estimates for engineering controls and found that, on average 63 percent of the costs were for LEV, 23 percent were for housekeeping, and 16 percent were for other controls, most commonly wet methods (based on OSHA, 2016). In many cases, where wet methods were applicable, wet methods represented the majority of the costs and there were not significant LEV costs. As a result, 79 percent of the costs of controls, on average, are attributable to either wet methods or LEV. The combination of LEV or wet methods with some improvement in housekeeping (though not the improvements necessary to meet the new PEL) will constitute the majority of costs for virtually all occupational categories. Some improvement in housekeeping will typically also be required to meet even the preceding PEL.[9] While employers can probably meet the preceding PEL with less than ideally maintained LEV systems, improvements in maintenance will not reverse the conclusion that the majority of the costs are incurred to meet the preceding PEL. This is the case because on average 63 percent of engineering control costs are necessary to reach the preceding PEL and some housekeeping costs will also be necessary, leaving a significant percentage of expenditures above 50 percent of the costs available for improved maintenance.

To confirm the findings of this cost-spreadsheet- based analysis of where the majority of the costs are incurred, OSHA reviewed industries where good data are available on controls in both uncontrolled situations and situations with exposures between the new and the preceding PEL. OSHA examined the exposures and controls in eight ferrous sand casting foundry facilities. In these eight facilities, four had relatively few workers exposed above 50 μg/m^3, and the other four had many exposures over 100 μg/m^3. OSHA found that those facilities with most exposures over 100 μg/m^3 generally had little or no

(with 1.1 percent of all employees exposed above the preceding PEL) were there no exposures above 250 μg/m^3.

[9] For example, in several industry sectors where workers are currently manually dumping silica-containing materials, the use of automated and ventilated dumping stations is needed to reduce exposures from over 250 μg/m^3 to below the preceding PEL. However, once these controls are installed and in use, final exposures are often below the limit of detection or less than 12 μg/m^3 -- well below the new PEL (see technological feasibility chapter for paint and coatings). However, to maintain these exposures below the new PEL, these industry sectors will need to ensure that ventilation systems are properly maintained and will need sufficient housekeeping to ensure against build-ups of dust.

LEV (relying instead on general ventilation), poor housekeeping, no enclosures for workers, and poor maintenance. The foundries where silica dust was better controlled generally had working LEV systems, good housekeeping that kept surfaces free of silica dust, and good maintenance practices. This indicates that LEV and some housekeeping are essential to meeting the preceding PEL. OSHA also examined data on all exposures with control descriptions. These data showed that exposures above 250 $\mu g/m^3$ occurred in uncontrolled situations or situations in which controls, though installed, were not in use. In situations where exposures were between the preceding and new PELs, most exposures showed some controls in place, normally LEV, but not all controls recommended. In some cases there were no controls in place. These generally represented situations in which exposures were much lower than the typical uncontrolled situations and such facilities would not normally need the full controls necessary to go from very high levels of exposure to the new PEL. (See Exhibit: Descriptions of Controls (2016).)

Based on these findings, OSHA determined that the majority of costs are incurred in order to implement controls necessary to get from an uncontrolled situation to the preceding PEL. However, OSHA developed cost estimates for engineering controls based on the conservative assumption that 50 percent of the total costs of going from an uncontrolled situation to the new PEL are incurred in order to reach the preceding PEL and the remaining 50 percent are incurred to reach the new PEL.[10] For example, in the cut stone industry 63 percent of those exposed above the new PEL are also above the preceding PEL, and 37 percent are below the preceding PEL but above the new PEL. Total cost to the cut stone industry of going from uncontrolled exposure to the new PEL is estimated, using the spreadsheets mentioned above, to be $17.7 million. With OSHA's assumption that half of the costs of going from an uncontrolled situation to the new PEL are incurred in order to reach the preceding PEL, then the cost for those employers with employees exposed above the preceding PEL would be 63 percent of $17.5 million times 0.5, which equals $5.5 million. The cost for those below the preceding PEL would be 37 percent of $17.7 million times 0.5, which equal $3.3 million. The total cost of going from the preceding PEL to the new PEL in the cut stone industry is therefore the sum of these two calculations: $8.9 million.) This will overestimate the costs of reaching the new PEL, given the majority of the costs are incurred to implement controls necessary to reach the preceding PEL.[11]

[10] This approach was not applied to the two industries, dental laboratories and asphalt paving materials, where the exposure profile showed that there were no exposures above the preceding PEL.

[11] OSHA also notes that this approach shows rising incremental costs of control, which is consistent with some comments. This is because 50 percent of the costs are estimated to be incurred to go from levels of over 250 $\mu g/m^3$ to 100 $\mu g/m^3$ and equal costs are estimated to be incurred to go from 100 $\mu g/m^3$ to 50 $\mu g/m^3$.

As presented in more detail below, this approach results in a total annualized cost estimate for general industry and maritime engineering controls of $225 million. Fortunately, this cost estimate is not highly sensitive to the percentage chosen. Each decrement of 5 percentage points changes the engineering control costs by approximately 5.5 percent. Thus, for example, if 65 percent of the costs are necessary to go from the preceding PEL to the new PEL, then the annualized cost estimate for engineering controls would rise to $261 million per year.[12]

Accounting for Costs of Downtime

Some commenters suggested that OSHA failed to account for the downtime that installing engineering controls or performing an initial through cleaning would require (e.g., Document ID 2368, p. 13 for engineering controls; Document ID 2379, Attachment 2, p. 16 for initial thorough cleaning).

Almost all firms need downtime occasionally in order to perform general maintenance, inventory, or other tasks. In the final rule, OSHA has extended the compliance date for general industry from one year to two years. This will allow almost all employers to schedule work that might require downtime to install, improve, or maintain controls that they determine are necessary to meet the new PEL or to perform the initial thorough cleaning at times when they would already need scheduled downtime for other purposes. Therefore, OSHA has determined that there will be no additional costs incurred for downtime in order for employers to install engineering controls or to perform the initial thorough cleaning.

Technological Change

One commenter, Dr. Ruth Ruttenberg, testifying for the AFL-CIO, argued that OSHA had overestimated costs by failing to consider technological change:

> Technological improvements – both engineering and scientific – are constantly occurring, especially when the pressure of a pending or existing regulation provide a strong incentive to find a way to comply at a lower cost. … These improvements are well-documented following the

[12] A value of 100 percent would be totally implausible as it would imply that all establishments currently far above the preceding PEL could achieve that PEL without cost. Put another way, this would be equivalent to saying that, if OSHA had decided to adopt the alternative PEL of 100 μg/m^3 (i.e., the same as the preceding general industry PEL), as some employer groups recommended, any employers currently above that PEL – regardless of how far above the PEL they were - would be able to meet a PEL of 100 μg/m^3 without implementing any new engineering controls.

> promulgation of rules for vinyl chloride, coke ovens, lead, asbestos, lock-out/tag-out, ethylene oxide, and a host of others (Document ID 2256, Attachment 4, p. 2).

She recognized that OSHA, in the PEA, already predicted some "technological and cost-saving advances with silica," such as expanding the use of automated processes and developing more effective bag seals, but criticized OSHA for not accounting for those cost savings in its analysis:

> Technological improvements are as sure a reality – based on past experience and academic research – as overestimation of cost and underestimate of benefits are in an OSHA regulatory analysis. More than 40 years of OSHA history bear this out (Document ID 2256, Attachment 4, p. 3).

When promulgating health standards, OSHA generally takes an approach in which cost estimates and economic feasibility analyses are based on the technologies specified in the technological feasibility analysis. This is a conservative approach to satisfying OSHA's legal obligations to show economic and technological feasibility. As a result, the Agency does not account for some factors that may reduce costs, such as technological changes that reduce the costs of controls over time and improvements in production that reduce the number of employees exposed. As pointed out in the PEA and from the examples described in the "Total Cost Summary" at the end of this chapter, some past experience suggests that these factors tend to result in OSHA's costs being overestimated.[13] OSHA considers the primary purpose of the cost estimate to be to provide a basis for evaluating the economic feasibility of the rule, and OSHA has determined that for this rulemaking, feasibility is most accurately demonstrated by using an approach that does not account for the potential impacts of future technological changes.

General Methodological Issues: Number of Workers Covered by a Control

<u>*PEA estimates*</u>

The cost calculations in the PEA included estimates of the number of workers whose exposures are controlled by each engineering control. Because working arrangements vary within occupations and across facilities of different sizes, there are no definitive data on how many workers are likely to be covered by a given set of controls. In many small facilities, especially those that might operate only one shift per day, some controls will

[13] On the other hand, there is supplemental evidence from Harrington et al. (2000) that OSHA does not systematically overestimate costs on a per-unit basis, and that the reason for overestimation of costs at the aggregate level has been a combination of difficulty with establishing baseline conditions and noncompliance. Nevertheless, several examples of OSHA's overestimation of costs reported in the article are due to technological improvements.

limit exposures for only a single worker. Also, small facilities might have only one worker in certain affected job categories. More commonly, however, and especially in the principal production operations, several workers are likely to derive exposure reductions from each engineering control.

The PEA relied on case-specific judgments of the number of workers whose exposures are controlled by each engineering control (see Table 3-3 in ERG, 2007b). The majority of controls were estimated to benefit four workers, based on the judgment that there is often multi-shift work and that many work stations are shared by at least two workers per shift. The costs of some types of equipment that protect multiple employees, such as HEPA vacuums, were spread over larger groups of employees (e.g., six to eight workers). In the PEA, the average number of workers affected represented an average across all establishments, large and small.

Comments and responses

Some commenters questioned OSHA's estimate of the number of workers whose exposures could be controlled per newly added or enhanced control. OSHA's PEA most commonly estimated that four workers would have their exposures reduced for each new or enhanced engineering control. Dr. Ronald Bird, testifying for the Chamber of Commerce, argued that OSHA's estimates were simply arbitrary assumptions (Document ID 2368, p. 14). Stuart Sessions, testifying for the ACC, argued that the use of a single standard crew size of four led OSHA to underestimate costs and economic impacts for smaller establishments, at which, he argued, "there are virtually never as many as four overexposed workers in any job category, and it is simply impossible that one application of a package of controls in this situation could protect as many as 4 overexposed workers on average" (Document ID 4231, Attachment 1, p. 6).

The approach OSHA used was intended to represent the average number of employees affected by a given set of controls. Larger establishments may have more than four workers whose exposures are reduced by a single control, and smaller establishments may have fewer than four. However, OSHA agrees that this approach may result in an underestimate of costs for the smallest establishments. Because it is particularly important to consider the costs to the smallest establishments, OSHA has reduced the number of employees whose exposures are reduced per control by half for establishments with fewer than twenty employees, so that in those small establishments a given control is assumed to reduce exposures for two workers instead of four as assumed in the PEA. Because larger establishments may have greater numbers of employees whose exposures are reduced per control, this change may result in an overall overestimation of costs. (In the PEA, the overestimation of costs for larger facilities was partially offset by the underestimation of costs for smaller establishments. This is no longer the case in this

FEA.) OSHA nevertheless believes the revised approach used in this FEA is better than the approach used in the PEA for purposes of capturing economic impacts on smaller establishments, even though it may result in aggregate costs being overestimated.

Variability

Some commenters argued that both OSHA's technological feasibility and cost analyses were flawed because OSHA neglected to address the day-to-day variability of exposure measurements. By failing to address the issue of variability, these commenters argued, OSHA grossly underestimated the costs of engineering controls. These commenters reported that silica exposures would have to be controlled to levels considerably lower than the proposed (new) PEL in order to account for the variation in exposures across jobs and from day to day (e.g., Document ID 2307, Attachment 2, p. 202; 2308, Attachment 7, p. 2; 2308, Attachment 8, p. 6; 2379, Attachment 4, p. 1; 2291, p. 11; 2195, pp. 26-27; 2503, p. 2; 2222, Attachment 1, p. 1). For example, in response to a written question about the activities in which employers were able to achieve the proposed (new) PEL "most of the time," AFS objected to the premise of the question, noting that "[s]everal foundries have received citations for exposures above the current PEL on operations or tasks for which the proposed PEL is achieved most of the time" (Document ID 2379, Appendix 1, p. 18). AFS argued that OSHA's non-compliance model of enforcement requires employers to reduce average exposures to half the PEL in order to have confidence that exposures will never exceed the PEL (Document ID 2379, Appendix 2, p. 29). The Asphalt Roofing Manufacturing Association (ARMA) made a similar point and said that the majority of asphalt roofing plants operated by its members have some exposures over the PEL of 50 $\mu g/m^3$, even if it's a "relatively small incidence" (Document ID 2291, p. 11).

Both AFS and ARMA offered estimates of the magnitude of this variability by measuring the statistical variance of exposures. AFS stated that to assure 84 percent confidence in compliance with the preceding PEL, the mean exposures in some specific jobs in specific foundries would need to be below half that PEL, and that the "mean level necessary to achieve the 95 percent confidence of compliance could not be determined but is significantly below one half the PEL" (Document ID 2379, Appendix 1, p. 23). ARMA examined the distribution of silica exposures in over 1,300 samples from 57 asphalt roofing facilities. These data showed that even though the median exposures for all jobs were below the new action level of 25 $\mu g/m^3$, a total of 9 percent of all samples were above the new PEL of 50 $\mu g/m^3$ (Document ID 2291, p. 5, Table 1). ARMA also provided an estimate of the "lowest strictly achievable level" (meaning a level not to be exceeded more than 5 percent of the time) which varied by job classification from 67 to 310 $\mu g/m^3$ (Document ID 2291, p. 9, Table 2).

One serious problem with the ARMA analysis is that the discussions of variability and the estimates of mathematical variance are based on results either from different facilities with potentially different levels of controls or from all job categories within one facility. The key issue for assessing the importance of variability is the variance within a given job category in a specific establishment with specific controls. The methodology employed is such that even if individual job categories or individual facilities had no variance, pooling data across facilities would create variance.

ARMA estimated that sufficiently controlling variation would require investment in capture vents, duct work, and dust collection systems costing up to $2.1 million each in initial costs per manufacturing line (Document ID 2291, p. 12). AFS did not provide a cost estimate solely for sufficiently controlling variation.

The AFL-CIO disagreed with industry's arguments and instead argued that the best way to reduce variance was not simply to add additional engineering controls because, as explained earlier in the discussion of URS's comments on the per-worker cost basis, overexposures are not random:

> The worker-to-worker variation is explainable and controllable: workers use different methods, they may take different positions relative to ventilation systems, they may use different work practices, and they may be subject to fugitive emissions (carryover from adjacent silica emitting processes). These differences in conditions can be observed by the industrial hygienist collecting the air sample, compared to exposure levels, and changed. Day-to-day variation for the same worker is caused by variation in materials, ventilation systems, production rate, and adjacent sources showing such variation. Sometimes these variations can be large, based on breakdowns of ventilation, process upsets and blowouts (Document ID 4204, p. 40).

OSHA's enforcement policies are discussed in Chapter IV of this FEA and in the preamble. Variability of exposures is potentially a cost issue when there are technologically feasible controls that have costs not otherwise accounted for that could further reduce environmental variability. If it is not technologically feasible to reduce variability then there will be no further costs. For example, if an employer has installed all feasible controls, there are no additional costs for engineering controls because there are no additional controls to purchase, regardless of variability. On the other hand, an employer who has a median exposure level of 80 percent of the PEL with frequent excursions above and who could feasibly reduce variability would be required to do so. As noted above, those (AFS, ARMA) who argued that OSHA had underestimated costs by failing to account for exposure variability, in general, assumed that the best approach to reducing variability would be to increase the levels of LEV to reduce the average exposure level to half of the PEL or less, without examining the origin of the variability.

OSHA agrees with the AFL-CIO that variability in exposure is likely controllable by examining the origins of the variability. One origin is poor work practices. To improve work practices, employers could observe work practices when monitoring takes place; determine which work practices are associated with high exposures; and modify those work practices found to lead to high exposures. Variability can also be the result of controls not functioning properly, either resulting from sudden failures or from gradual deterioration of performance over time. The latter can be prevented by good maintenance.

Both in its cost assessment for the proposal and in the modifications made for this final rule, OSHA has taken account of the costs necessary to reduce unusual and exceptionally high exposure levels and thus reduce some sources of variation. As discussed in the cost of ancillary provisions, OSHA has estimated costs for exposure monitoring that include the time for observation of the worker. OSHA has also estimated costs for training to assure good work practices, and has increased the estimated length of training in general industry to ensure that the time is sufficient for training on work practices. In this section, OSHA has costed LEV, LEV maintenance, and the need for replacement LEV to assure that the LEV will function properly. OSHA has therefore already accounted for a variety of costs associated with steps that can be taken to reduce variability in exposures.

Substitution of Low- or Non-Silica Inputs

PEA estimate

For several industries, employers might lower silica exposures by substituting low- or non-silica inputs for existing inputs. While this option can be an extremely effective method for controlling silica exposures in many industries, OSHA did not cost this option in the PEA. OSHA determined that there were often complicating factors that restricted the potential for broad substitution of non-silica-containing inputs for silica-containing inputs throughout the affected industries. It is possible that the same product quality cannot be maintained without using silica. Some products made with substitute ingredients were judged to be inferior in quality and potentially not viable in the market. In addition, a substitute silica ingredient might introduce adverse health risks of its own. Further, in several instances, the availability of reasonably inexpensive alternative non-silica ingredients was well known but the alternative was not selected as a control option by most firms. In light of these concerns, OSHA decided not to include the option of non-silica substitutes in estimating the cost of the proposed rule.[14]

Comments and Responses on Substitution

Some commenters complained that OSHA's analysis did not account for the costs of substitution (Document ID 2264, Attachment 1, p. 27; 2379, Attachment 2, p. 6; 3485, p. 25; 3487, p. 17).

OSHA considered the comments on the issue but has decided to adhere to the approach taken in the PEA. OSHA did not take account of the costs of substituting other substances for silica, because, while such substitution might have substantial benefits and avoid the need for engineering controls, OSHA determined that, in most situations, substitution is not the least costly method of achieving the proposed or new PEL (Document ID 2379, Attachment 2, p. 6). As a result, OSHA's final cost analyses do not account for the possibility that firms would choose to substitute for substances other than silica. To the extent that substitutes are the least costly solution in some situations, OSHA has overestimated the costs.

Cost of Air Quality Permit Notification

The Agency received comments suggesting that foundries and other manufacturing plants would be required by the Environmental Protection Agency (EPA), or other federal or state environmental authorities, to incur an administrative cost to ensure their systems are compliant with relevant EPA regulations. Commenters expressed concern that the permitting process itself could be a major undertaking, made worse by difficult compliance deadlines. Given that the final rule provides extra time for planning and permitting, OSHA has examined the potential impacts of the new rule and finds that the commenters are overstating the potential for such costs. The argument for significant permitting costs was typically combined (e.g., Document ID 2379, Appendix 3) with an argument that the Agency underestimated the amount of ventilation required to comply with the final rule; comments on ventilation requirements are dealt with in great detail elsewhere in this chapter.

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[14] OSHA's analysis in the PEA recognized that some silica-free substitutes were already being used for some industrial activities. To the extent that the rule induces some firms that can easily switch to silica substitutes that may be less costly for them rather than undertaking more expensive control methods, OSHA will have overestimated the costs of the rule. Offsetting OSHA's potential overestimate of costs in this regard would be any negative adverse health effects associated with silica substitutes. Thus, affected firms switching to substitutes could potentially lower both the costs and the benefits of the rule.

Upon investigation, while OSHA agrees that it would be appropriate to recognize an administrative burden with respect to the interfacing environmental regulations, the Agency believes that many of the commenters' concerns were overstated. First, many control methods needed to comply with the final rule will not require alterations to existing ventilation systems. As discussed earlier in this chapter, work practices, housekeeping and maintenance are important components in controlling exposures; in many cases existing ventilation, as designed and permitted with the environmental authority, is adequate, but needs to be maintained better. In addition, most establishments, particularly smaller ones, will continue to have particulate emissions levels that fall below the level of EPA permit requirements. In the case of large facilities that do not, the changes will be on a sufficiently small scale that they will not require elaborate re-permitting, but will only require minor incremental costs for notifying the environmental authorities, or in some cases, submitting a "minor" permit. (*See* http://www2.epa.gov/nsr and http://www2.epa.gov/title-v-operating-permits.) Taking into account the preceding silica PEL and the estimate that baghouses will capture 99 percent of silica emissions (Document ID 3641, p. VII-19), OSHA concludes that it is unlikely that facilities will encounter a need for significant air permit modifications.

The Agency recognizes, however, that there will be minor incremental costs for notifying environmental authorities. While many establishments in the United States may have no requirement to do so, the Agency has conservatively assumed that all establishments with twenty or more employees in most industries will need to dedicate a certain amount of time to preparing a one-time notification to environmental authorities to ensure that their air permits accurately reflect current operating conditions. OSHA has determined that small establishments would generally lack the large scale industrial facilities requiring permits, and that the few that might require such permits would be balanced out by the likely inclusion of medium establishments that do not actually require permits for their emissions. The industries excluded were those that generally lack large scale industrial facilities or that do not produce a concentrated, as opposed to diverse or unconsolidated, emission source. The excluded industries were hydraulic fracturing, shipyards, dental equipment and labs, jewelry, railroads, and landscaping.

To allow for adequate administrative time for creating and submitting the notification, at those facilities that could potentially incur costs, OSHA allocated 20 hours to establishments with 20 to 499 employees and 40 hours to establishments with 500 or more employees. A manager's loaded hourly wage rate of $74.97 was applied to estimate the cost to employers (BLS, 2012b). The costs per establishment were estimated at approximately $1,500 per medium establishment and $3,000 per large establishment. Because both new permit applications and permit modifications are minor administrative chores, OSHA's cost estimates are sufficient to cover either case.

Costs for Specific Engineering Controls

Ventilation Costs

PEA estimates

In the PEA, OSHA determined that at many workstations, employers needed to improve ventilation to reduce silica exposures. The cost of ventilation enhancements estimated in the PEA generally reflected the expense of ductwork and other equipment for the immediate workstation or individual location and, potentially, the cost of incremental capacity system-wide enhancements and increased operating costs for the heating, ventilation, and air conditioning (HVAC) system for the facility.

In considering the specific ventilation enhancements for given job categories the PEA estimated the type of LEV and the approximate quantity in cubic feet per minute (cfm) of air flow required to reduce worker exposures.

To develop generally applicable ventilation cost estimates for the PEA, a set of workstation-specific and facility-wide ventilation estimates were defined using suggested ventilation approaches described in the American Conference of Governmental Industrial Hygienists (ACGIH) Industrial Ventilation Manual, 24th edition, 2001 (Document ID 1607). With the assistance of industrial hygienists and plant ventilation engineering specialists, workstation estimates of cfm were derived from the ACGIH Ventilation Manual, and where not covered in that source, from expert judgements for the purpose of costing LEV enhancements (Document ID 1608, p. 29).

Over a wide range of circumstances, ventilation enhancement costs, which included a cost factor for HEPA filters and baghouses, where needed, varied from roughly $9 per cfm to approximately $18 per cfm (Document ID 1608, p. 29). Because of a lack of detailed data to estimate the specific ventilation installation costs for a given facility, an estimate of the likely average capital cost per cfm was used and applied to all ventilation enhancements. Based on discussions with ventilation specialists, $12.83 per cfm was judged to be a reasonable overall estimate of the likely capital costs of ventilation enhancements (Document ID 3983, p. 1).[15]

OSHA applied the per-cfm capital cost estimate to estimated cfm requirements for each workstation. By using the unit value of $12.83 per cfm, the cost estimates for each ventilation enhancement included both the cost of the LEV enhancement at the

[15] This unit value ($12.83 per cfm) was derived by inflating ERG's 2003 estimate of $11 to 2009 dollars using the implicit price deflator of 1.167.

workstation and the contribution of the enhancement to the overall facility ventilation system requirements. That is, each ventilation enhancement at a workstation was expected to generate costs to the building's general ventilation system either by requiring increased capacity to make up for the air removed by the LEV system or to filter the air before returning it to the workplace.

For operating costs, engineering consultants analyzed the costs of heating and cooling system operation for 12 geographically (and therefore, climatologically) diverse U.S. cities. The analysis, presented in Table 3-2 in the ERG report (Document ID 1608, p. 30), showed the heating and cooling British Thermal Unit (BTU) requirements for 60-hours-a-week operation (12 hours a day, Monday through Friday) or for a continuous 24-hour-a-day, year-round operation, with and without recirculation of plant air. Facilities that recirculate air have much lower ventilation system operating costs because they do not need to heat or cool outside air to comfortable inside temperatures.

In the PEA, ventilation operating costs were based on a weighted average of the costs of four operating scenarios: 1) no recirculated air, continuous operation; 2) no recirculated air, operating 60 hours per week; 3) recirculated HEPA filtered air, continuous operation; and 4) recirculated HEPA filtered air, operating 60 hours per week. These scenarios were chosen to reflect the various types of operating system characteristics likely to be found among affected facilities. The weights (representing the share of total facilities falling into each category) and operating costs per cfm for each of these scenarios are shown below in Table V-3:

Table V-3: Ventilation Operating Cost Averaging Assumptions in the PEA

Type of system	Average Cost per CFM	Share of Total
No recirculated air, continuous operation	$15.55	5.0%
No recirculated air, operating 60 hours per week	$5.78	15.0%
Recirculated HEPA filtered air, continuous operation	$1.40	20.0%
Recirculated HEPA filtered air, operating 60 hours per week (cost proportional to the number of hours operated)	$0.50	60.0%
Weighted average operating cost per CFM	**$2.22**	

Source: Document ID 1781, Workbook #6 - GI Unit Costs_Active, Vent op costs

The national average annual operating cost per cfm was estimated to be $2.22. This estimate was a weighted average of the operating costs for facilities that recirculate air and those that require make-up air. The operating costs for HEPA-filter recirculated air were estimated at $0.50 per cfm for facilities operating 60 hours per week and $1.40 per cfm for those continuously operating 24 hours per day. The operating costs for facilities that do not recirculate air were $5.78 per cfm for those operating 60 hours per week and $15.55 per cfm for those operating continuously. In generating these estimates, it was judged that 80 percent of facilities would recirculate airflow and 20 percent would not, and that 75 percent within each group operate for 12 hours per day on weekdays, with the remainder operating continuously, year-round, for 24 hours a day.

OSHA also added a maintenance factor to the operating cost estimates, which was 10 percent of the capital cost investments of $12.83 per cfm for ventilation systems. As a result, the total annual costs per cfm, excluding annualized capital costs, were estimated to be $3.50 (weighted average operating costs of $2.22 plus annual maintenance costs of 10 percent of $12.83.)

Underlying the cost results was the assumption that, over the course of the proposed one-year compliance period for engineering controls, employers would schedule installation of ventilation to minimize disruption of production, just as they would with any modification to their plants.

Comments and responses on Local Exhaust Ventilation Issues: Need for a Complete New System

Local exhaust ventilation represents one of the major costs associated with engineering controls in both the PEA and in this FEA. Commenters raised issues both about OSHA's PEA estimates of the unit costs of LEV and about the adequacy of OSHA's estimates of the volume of LEV that would be needed to adequately control silica exposures.

URS, testifying on behalf of ACC, argued that any firm that would be utilizing LEV to meet a PEL of 50 μg/m^3 would need to remove any existing LEV and install an entirely new LEV system. Thus, in URS's estimation, there would be no incremental addition of LEV. In a discussion of the URS approach during OSHA's informal public hearings, OSHA asked the URS representative to confirm that his organization commented that when a majority of workers are exposed over the PEL, the existing controls must be replaced instead of enhanced:

> MR. BURT: I want to be sure I understand what that's saying. Let's say you encountered a situation in which there were four workers. Two were exposed at 35, two at 60. You would scrap all of the controls and start over again. That's what it seems to be saying.
>
> […]
>
> MR. WAGGENER: [Y]es, that they would need to be replaced with a more adequate system (Document ID 3582, Tr. 2109-2110).

OSHA's examination of the spreadsheets URS provided documenting its independently developed cost estimates shows that, in all cases where any employee in an establishment was exposed above 50 μg/m^3, URS assumed that the employer would need to install a complete new LEV system and included the costs for installing and operating this entirely new system (Document ID 2308, Attachment 8, pp. 13-14).

John Burke from OSCO Industries took a different approach to the question that better illustrates the options that OSHA believed to be available when it developed the PEA estimates:

> A single large dust collector is probably already handling the exhausting of the entire sand conditioning system. Most likely all the pick-up points referenced in the economic analysis already have suction being applied and yet there is still an overexposure. What do you do and how much is that going to cost? If the sand system operator is overexposed then you could first evaluate work practices controls. If work practice controls are unsuccessful and additional suction is needed, that suction is going to be very expensive! If your environmental operating permit allows it you may be able to tweak the performance of the dust collector. There may be some things you can do to tweak the capacity of your existing dust collector to bring it up to exactly its permitted air volume or you might have to enlarge your dust collector (Document ID 1992, p. 6).

OSHA agrees with Mr. Burke. As discussed above, there are usually a wide variety of ways to improve existing controls before removing and reinstalling an LEV system. As a result, OSHA finds the URS approach unrealistic and likely to significantly overestimate costs.

Comments and Responses on the Volume of Controls Needed

One commenter, URS, questioned OSHA's estimates of the volume of additional LEV that would be needed to comply with the standard. URS, testifying for ACC, reported that OSHA's estimates in the PEA were too low as compared to the recommendations in Table 6-2 of the ACGIH Ventilation Manual (28th Edition) (ACGIH, 2013). They criticized OSHA's estimates saying that OSHA routinely underestimated required capture velocities by at least a factor of two for particles with high (conveyor loading, crushing) or very high (grinding, abrasive blasting, tumbling) energies of dispersion (Document ID 2308, Attachment 8, pp. 12 and 14). URS said that "the capture velocities for LEV systems in OSHA's models were often based on the minimum recommended velocity," that OSHA's estimated additional LEV was too low because "the ACGIH capture velocity values used by OSHA were first developed and published many years ago" and were not sufficient to control dust to the levels OSHA is now proposing, and that "the velocity values used in OSHA's cost model are most likely undersized by a factor of 2 or more" (Document ID 2308, pp. 11-12). Other than its own supposition, URS did not identify an alternative source for OSHA to use as the basis for estimates of ventilation capacity necessary to control silica exposures.

In response to these comments, and in order to determine whether ACGIH recommendations had changed between the 24th edition (which OSHA used to develop estimates in the PEA) and the more recent 28th edition, OSHA checked its estimated volumes against those in the more recent ACGIH Ventilation Manual (Chapter 13 in the 28th edition (Document ID 3883)). In the 24th edition of the Manual, ACGIH provided a single recommendation for ventilation capacity rather than a range. In the PEA, OSHA adopted this recommendation and did not choose a value from within a range of values. The 28th edition of the Manual provides more flexibility in system design and specification and incorporates a recommended range. However, OSHA determined that the ventilation capacity estimates did not change between the 24th edition of the Manual and the 28th edition. In most cases, OSHA's estimated volumes were identical to those recommended by ACGIH. The exceptions were situations in which ACGIH provided no recommendation (in which case OSHA relied on recommendations of industrial hygienists), and situations in which the technological feasibility analysis recommended additional volumes of LEV capacity above what employers were typically using. In the latter situations, OSHA estimated that an additional 25 percent of the ACGIH specification would be necessary to adequately control silica exposures. (See Exhibit: Comparison of OSHA CFM Volumes to ACGIH Values (2016).)
URS argued that silica was different from other substances LEV might be applied to in ways that would call for higher volumes of ventilation (Document ID 2308, Attachment 8, p. 14). However, at least some of the volumes criticized by URS are listed in the ACGIH manual as being appropriate for situations that clearly involve silica, such as shake-out stations.

OSHA's estimates of the ventilation capacity necessary to control silica exposures relied on a detailed set of recommendations provided by ACGIH while URS simply asserted that these values are "most likely undersized by a factor of 2 or more" without providing additional evidence to support this (Document ID 2308, Attachment 8, p. 12). Based on these findings, OSHA has determined that the ACGIH recommendations constitute the best available evidence and has maintained the estimates of ventilation capacity from the PEA for this FEA.

Comments providing alternative ventilation system cost estimates

Other commenters provided much higher costs than OSHA's estimates but without providing any background to allow OSHA to put those costs in context. It is difficult for OSHA to evaluate a cost estimate without information on the size of the facility, the estimated volume of air, and the exposure levels before and after the LEV was installed.

The Interlocking Concrete Pavement Institute (ICPI) commented that OSHA underestimated compliance costs because "[o]ne ICP manufacturer reported that it could cost $150,000 to acquire and install highly efficient vacuum and water dust-control systems" and other manufacturers reported similarly high costs (Document ID 2246, p. 11). At the public hearings, OSHA sought clarification on the assumptions underlying the ICPI cost estimate, and the ICPI representative stated that $150,000 was a mid-range estimate. The representative also confirmed that this was the cost of an entirely new system:

> MR. BLICKSILVER: [D]oes this actually represent the incremental cost associated with complying with OSHA's proposed rule? … Or is this an overall cost for dust control in these manufacturing plants?
> MR. SMITH: The latter. (Document ID 3589, Tr. 4407-4409)

In a follow-up verbal exchange, OSHA requested that ICPI analyze their survey data to produce median values for the range of cost estimates and submit their analysis as a post-hearing comment (Document ID 3589, Tr. 4409). However, no ICPI comments appeared in the record following the Institute's testimony at the hearings.

Similarly, OSHA asked Mr. Tom Slavin, testifying for AFS, for additional information from AFS on the many cost estimates for individual foundries that they had included in their comments:

> MR. BURT: You provide many examples of cost to specific foundries of specific activities. I would like to suggest that those can be most useful if we have data on the size of the firm in question, the type of foundry if that's appropriate, and what they were trying to accomplish with this effort.
>
> Were they at 400 and trying to get to 100, at 100 trying to get lower? Something that puts it in context would again make these many, many helpful quotes much more useful.
>
> Size is just critical, just because of the fact that when we don't know whether we're talking about 20 or 200 people in a foundry really affects what you want to do with those cost estimates. And that one's relatively simple, size of firm, type of foundry if you have it, what they were trying to do with that effort. (Document ID 3584, Tr. 2773-2774)

Later in the exchange, OSHA requested information on "the components of [AFS's estimated cost per cfm of additional ventilation] that would be capital cost, installation cost, and then any other operating costs you have" (Document ID 3584, Tr. 2784). OSHA received no response to this request.

Unfortunately, it is almost impossible for OSHA to make use of commenters' estimates of costs or volume of LEV systems without information on the size of the facility and on what the resulting system accomplished in terms of reducing exposure levels. OSHA consistently requested this kind of information, but did not receive it. As shown in the discussion of alternative estimates of costs by small entity representatives during the SBAR Panel (discussed below), even estimates that appear higher than OSHA's average costs can be consistent with those costs when the full context for the estimates is examined.

Comments and Responses on Unit Cost per CFM

Many commenters thought that OSHA's unit costs for ventilation were too low. With respect to the annualized value of the capital costs plus operating and maintenance costs of $5.33 that OSHA used in the PEA, AFS stated:

> The PEA uses an annual cost factor of $5.33 for ventilation, including ducting and bag house operation [. . .] is far below foundry experience. A group of foundry ventilation managers and ventilation experts estimated the annual cost per CFM at $20 for exhaust alone and another $6-10 for makeup air critical to achieving the lower PEL. The cost to meet the new U.S. Environmental Protection Agency (EPA) dust loading criteria increases the exhaust annual cost to $25 per CFM. Any new installation would be expected to design to the new criteria even if not yet required to do so for that specific jurisdiction (Document ID 2379, Appendix 3, p. 9).

URS, commenting on behalf of ACC, estimated the annualized cost of LEV to be $27 per cfm, and increased OSHA's estimate of capital costs from $12.83 to $22 per cfm for the purpose of URS's cost estimate (Document ID 2308, Attachment 8, pp. 13-14).
Many other commenters from industry suggested unit costs for additional LEV. For example, AFS provided independent estimates of annualized costs of $20 to $25 per cfm and URS estimated $22 to $27 capital costs per cfm (Document ID 2379, Appendix 1, p. 45; 2308, Attachment 8, p. 14; 2379, Appendix 2, p. 13; 2503, p. 2; 2119, Attachment 3, p. 4; 2248, p. 8; 3490, p. 3; 3584, Tr. 2779).

OSHA agrees that there can be a wide range of both capital and operating costs associated with LEV. Capital costs will vary according to such factors as the exact nature of the ventilation (including the design of the slot, hood, or bagging station), the volume of materials to be handled by the ventilation, and the length of the ductwork necessary. OSHA also would like to clarify that, as shown in OSHA's spreadsheets (OSHA, 2016), where there are major structural changes associated with a control, such as automation, a new bagging station, or conveyor closure, these costs are estimated over and above the basic capital costs of LEV. Annual operating costs vary according to climate, hours of operation, and the extent to which air is recirculated. To examine these possible costs, OSHA reviewed the thoroughly documented LEV costs presented in its Final Economic Analysis for the Occupational Exposure to Hexavalent Chromium Standard (Document ID 3641). In that FEA, OSHA's estimates of the capital costs for LEV (updated to 2012 dollars) averaged more than $20 per cfm when major work station changes, such as automated bag slitting stations, were included in the cost of LEV. Ordinary additional LEV without major workstation changes was estimated to have an average capital cost of $9 per cfm in 2012 dollars. Operating costs in that rulemaking were estimated to be somewhat higher than estimated here, but combined annualized costs (capital plus operating costs) were approximately the same. (See Exhibit: Analysis of LEV Costs from Hex Chrome (2016).) OSHA agrees that the capital costs of some kinds of LEV that involve significant workstation modifications or even automation can exceed $20 per cfm, but finds an average of $12.83 per cfm in capital costs to be reasonable given that some kinds of LEV installation can cost as little as $3 to $5 per cfm. OSHA also finds the operating cost estimates used in this FEA to be a reasonable average across a very wide variety of circumstances.

Housekeeping and Dust Suppression Costs

PEA costs

For a number of occupations, the technological feasibility analysis in the PEA indicated that improved housekeeping practices were needed to reduce silica exposures. The degree of incremental housekeeping depended upon how dusty the operations were and the appropriate equipment for addressing the dust problem. The incremental costs for most such occupations reflected labor associated with additional housekeeping efforts. Because incremental housekeeping labor was required on virtually every work shift by most of the affected occupations, the costs of housekeeping in the PEA were significant. The PEA also estimated that employers would need to purchase HEPA vacuums and to incur the ongoing costs of HEPA vacuum filters. The time needed for such housekeeping varied from five to twenty minutes per affected worker per day. Appendix V-A in the PEA provided detailed specifications on the application of housekeeping and other dust-suppression controls in each occupational category and the sources of OSHA's unit cost data for such controls.

For some indoor dust suppression tasks, it was assumed that dust suppression mixes - often sawdust-based with oil or other material that adheres to dust and allows it to be swept up without becoming airborne - were spread over the areas to be swept. For these products, estimates were made of usage rates and the incremental times necessary to employ them in housekeeping tasks.

For outdoor dust suppression, the PEA determined that workers must often spray water over storage piles and raw material receiving areas. The methods by which water is provided for these tasks can vary widely, from water trucks to available hoses. It was judged that most facilities would make hoses available for spraying and that spraying requires a materials-handling worker to devote part of the workday to lightly spray the area for dust control.

The PEA did not include any costs for thorough cleaning designed to remove accumulated dust, either as a one-time cost or as an annual cost.

Comments and Responses on Costs of Routine Housekeeping and Initial Cleaning

Commenters had a number of issues with respect to how OSHA treated the costs of housekeeping, including the time and equipment needed for vacuuming, the need for professional floor to ceiling cleaning, and the costs of the ban on dry sweeping.

Comments and Responses on Costs of Routine Housekeeping

With respect to the use of HEPA vacuums, AFS commented that due to the volume of sand involved, foundries often use vacuums that cost $45,000 instead of the $3,500 estimated by OSHA in the PEA (Document ID 4229, Attachment 1, p. 23). Several commenters reported that HEPA semi-mobile central vacuum systems cost more than $40,000 to purchase and cost approximately $4,000 per year to maintain, and that sweeping compound costs approximately $4,000 per year (Document ID 2384, p. 7; 2114, Attachment 1, p. 4). Several others noted that acquiring HEPA vacuums and employee time for vacuuming would be expensive (Document ID 2301, Attachment 1, p. 74; 3300, pp. 4-5; 2114, Attachment 1, p. 4).

OSHA’s costs are for improved housekeeping, beyond the necessary tasks related to dealing with the large volumes of sand used in foundries. For this final rule, OSHA estimates the costs of additional housekeeping as those necessary for overexposed worker to spend ten minutes vacuuming their immediate work areas with a fifteen-gallon HEPA vacuum. It is possible that a large firm may find a dust handling system or a semi-mobile central vacuum system less expensive than having individual workers equipped with smaller capacity HEPA vacuums spend additional time performing housekeeping on each shift.

With respect to the shipbuilding sector, OSHA found that it had not accounted for the costs of HEPA vacuums for abrasive blasting helpers. OSHA has added costs for the vacuums, but not for the time spent performing housekeeping as the vacuums replace dry sweeping.

As to the possible costs of the ban on dry sweeping, OSHA has modified this prohibition in ways that should avoid significant costs in situations where dry sweeping is the only effective method of housekeeping.

Comments and Responses on Costs of Initial Cleaning

URS, testifying for ACC, questioned OSHA's omission of "professional cleaning" from its cost models for some industries, noting that professional cleaning was identified in the PEA as necessary for some industries to achieve the PEL (Document ID 2308, Attachment 8, p. 12). URS also provided estimates of the cost of professional cleaning:

> Based on communications with several industries, URS estimates that a thorough annual professional cleaning will cost about $1.00 per square foot of the facility process operations area.
> … A professional cleaning can take several days to accomplish […] For square footage, URS assumed 20,000 square feet for very small facilities, 50,000 square feet for small facilities, and 200,000 square feet for large facilities (Document ID 2308, Attachment 8, p. 24).

Initial thorough facility cleaning and rigorous housekeeping are supplemental controls and work practices addressed in the technological feasibility analysis for the following application groups: Concrete Products, Pottery, Structural Clay, Mineral Processing, Iron Foundries, Nonferrous Sand Foundries, and Captive Foundries. OSHA failed to include the costs of a thorough initial cleaning in the PEA, but has developed estimates of these costs for the FEA in response to the URS comment. The final standard sets the performance objective of achieving the PEL using engineering controls, work practices, and where necessary, respiratory protection, and, with respect to facility cleaning and housekeeping, the rule does not mandate that firms hire outside specialists. To estimate the final costs for initial thorough facility cleaning, OSHA first developed an analysis of average production floor space in square feet for two plant sizes based on data on plant floor space and employment for individual facilities reported in various NIOSH control technology and exposure assessment field studies (OSHA examined Document ID 215; 216; 268; 1373; 1383; 3786; 3996; and 4114. The analysis is in Exhibit: Analysis of Plant Floor Space (2016)). For the purpose of estimating cleaning costs, OSHA characterized establishments with fewer than twenty employees as very small establishments, and characterized establishments with twenty or more employees as larger establishments.

OSHA determined, based on a review of the data in the NIOSH field studies, that production floor space averages 725 square feet per employee (see Exhibit: Analysis of Plant Floor Space (2016)). For very small establishments with fewer than 20 employees, OSHA used an average of 7 employees per establishment. For larger establishments, OSHA used an average of 80 employees. (These estimates of the number of employees are based on OSHA (2016), which shows that the average number of employees for establishments with fewer than 20 employees is 7 employees and that the average number of employees for establishments with more than 20 employees is 80 employees.) Based on these parameters, OSHA's floor space model found that the typical floor space for very small establishments is 5,075 square feet and for larger establishments is 58,000 square feet.

ERG spoke with a representative of an upper-Midwestern firm specializing in the industrial cleaning of foundries and related facilities (Document ID 3817, p. 2). According to that representative, cleaning costs depend on numerous factors, such as the distance to the facility that needs to be cleaned, the size and number of machines and pieces of equipment present, the types of required cleaning activities, and the presence of confined spaces. The representative described one of his company's clients as a sand-casting foundry that produces 42,000 tons of gray and ductile iron castings per year in a 210,000 square foot facility. According to the representative, a crew of two technicians cleans the facility every 2 to 3 weeks at a cost of $2,200 to $3,500 per cleaning, which requires one day, or roughly $0.01 to $0.02 per square foot in 2014 dollars.

For the FEA, OSHA is estimating, based on data from the ERG field interviews, that it will take 4 to 5 days to perform a one-time initial cleaning (remove all visible silica dust) and that if the same facility is cleaned every 2 to 3 weeks it will take 1 day to clean it. At a cost of $0.02 per day per square foot, and using a cleaning duration of five days, OSHA calculated a cost of $0.15 per square foot in 2012 dollars for an initial thorough cleaning. This value is derived from inflating the 2003 estimate of $0.10 per square foot ($0.02 per day per square foot over 5 days) to 2012 dollars, which raised the cost to $0.12 per square foot. OSHA also allowed for an additional allotment of 25 percent of the estimated cost of $0.12 per square foot (in 2012 dollars) to ensure that the cleaning was sufficiently thorough to achieve compliance, increasing the total from $0.12 to $0.15. OSHA judges that this is a reasonable average for the range of facilities to be covered, especially given that some annual cleaning is probably already occurring at most facilities and therefore the full cost of cleaning would not be attributable to this rule. The costs here are applied to represent an incremental cleaning beyond that employed for normal business purposes.

As discussed earlier in this chapter, URS, an engineering consultant to ACC, estimated that a thorough annual professional cleaning will cost about $1.00 per square foot of a facility's process operations area. URS provided no specific reference for that unit estimate other than that it communicated with industry representatives (Document ID 2308, Attachment 8, p. 24). The data OSHA used to develop its cost estimates are based on interviews with companies that provide housekeeping services rather than companies that may or may not have purchased such services. OSHA's estimated costs for a thorough initial cleaning are over five times the costs of a thorough cleaning where there is just few weeks' worth of accumulated dust. Greater accumulations during an initial cleaning do not mean that the initial cleaning will cost 50 times the cost of a more basic/regular cleaning, as much of the cost of the initial cleaning will be due to the time spent going over the entire facility with the appropriate cleaning devices—a cost that is fixed by area and not by accumulation. OSHA therefore rejects the URS unit estimate of $1.00 per square foot as not representative of a typical cost for initial thorough facility cleaning, particularly for firms that choose to use in-house resources. Nonetheless, OSHA acknowledges that unique circumstances may create higher unit costs than the value OSHA is using in this FEA. OSHA also acknowledges that the cost of cleaning per square foot probably declines as facility size increases (Document ID 4231, p. 4). The paucity of data on square footage for the affected facilities, however, did not allow for further modeling of cleaning costs.

For this final analysis of costs for initial thorough facility cleaning, OSHA estimated that an upfront, one-time, extensive servicing (using vacuum and wash equipment) to rid the production area of respirable crystalline silica during plant turnaround or other downtime would cost $0.15 per square foot (including the additional allowance to ensure a sufficiently thorough cleaning) or $0.02 when annualized at 3 percent for 10 years, and OSHA applied that unit cost along with the average production floor space discussed above in OSHA's cost model (725 square feet per employee) to derive final costs for facility cleaning by application group. For the seven affected application groups, OSHA estimates that annualized initial thorough facility cleaning costs will range from just under $45,000 for Nonferrous Sand Foundries to $488,000 for Concrete Products. Across all seven affected application groups, OSHA estimates that annualized costs for initial thorough facility cleaning will total $2.8 million.

Conveyor Covers

The technological feasibility analysis in the PEA recommended reducing silica exposures by enclosing process equipment, such as conveyors, particularly where silica-containing materials were transferred (and notable quantities of dust can become airborne), or where dust is generated, such as in sawing or grinding operations. For the PEA, OSHA estimated the capital costs of conveyor covers as $20.73 (updated to 2012 dollars) per linear foot, based on Iandola (2003) (as summarized in footnote a in Table V-3 of the PEA). OSHA estimated that each work crew of four affected workers would require 100 linear feet of conveyors. OSHA, based on ERG's estimates, calculated maintenance costs as 10 percent of capital costs. Based on the technological feasibility analysis, OSHA also included the cost of LEV on the vents of the conveyors for the structural clay, foundry, asphalt roofing, and mineral processing application groups, but not for the glass and mineral wool application groups.

URS commented that OSHA underestimated the length of conveyors by using 100 linear feet in its estimate, and suggested that the estimate of 200 feet that it used as the basis for its estimates was still an underestimation for some foundries (Document ID 2307, Attachment 26, Control Basis and Control Changes tabs). URS maintained OSHA's estimate of $20.73 per linear foot in its own calculations. However, it appears that URS did not understand that OSHA estimated 100 linear feet of conveyors for every four workers, not 100 linear feet of conveyors for an entire affected establishment. Further, the URS comment indicated that 100 linear feet was an underestimate for "medium and large foundries." But because OSHA's estimate of 100 linear feet is for every four workers, OSHA actually estimated much longer conveyor lengths for larger facilities with more workers. OSHA has determined that its estimate of 100 linear feet for every four workers at a cost of $20.73 per linear foot is a reasonable approach for estimating the costs of conveyor covers.

Selected Control Options That Are Not Costed

Consistent with ERG's cost model, in the PEA OSHA chose not to estimate costs for some control options mentioned in the accompanying technological feasibility analysis in Chapter IV of the PEA. In these cases, OSHA judged that other control options for a specific at-risk occupation were sufficient to meet the PEL. AFS identified several control options for which OSHA did not estimate costs:

- Substitution of non-silica sand (V-A-51)
- Pneumatic sand handling systems (V-A-51)
- Didion drum to clean scrap for furnace operators (V-A-52)
- Non-silica cores and core coatings (V-A-52)
- Professional cleaning costs and associated downtime (V-A-52)
- Physical isolation of pouring areas (V-A-52)
- Modify ventilation system to reduce airflow from other areas (V-A-52)
- Automation of a knockout process (V-A-53)
- Automated abrasive blast pre-cleaning of castings for finishing operators (V-A-54)
- Wet methods (V-A-54)
- Low silica refractory (V-A-55) (Document ID 2379, p. 16)

Just because a control is mentioned in the technological feasibility analysis does not mean that OSHA has determined that its use is required – only that it represents a technologically feasible method for controlling exposures. The Agency developed cost estimates based on the lowest cost combination of controls that allows employers to move from an uncontrolled situation to meeting the new PEL. OSHA did not include the costs for possible controls that were either more expensive or were not necessary to achieve the PEL. OSHA (2016) describes in detail which controls were considered necessary to achieve the PEL. OSHA continues in this FEA to exclude costs for these kinds of more expensive possible controls.

Railroads

In its preliminary estimates, OSHA inadvertently applied the preceding general industry PEL of 100 μg/m^3 in its analysis of the railroad industry. Silica exposures among railroad employees, however, result from ballast dumping, which is track work that is generally subject to OSHA's construction standard and covered by the preceding construction PEL of 250 μg/m^3 (see discussion of railroads in Chapter III, Industry Profile). As a result, OSHA has changed its conclusion that there would be no incremental costs for railroads to meet the new PEL. OSHA has reassigned all costs previously assigned to meeting the preceding PEL to being incremental costs of meeting the new PEL. Although the railroad activities affected by the new silica rule will typically constitute construction work, OSHA has categorized all compliance costs for railroads with general industry costs under NAICS 482110 because the railroad industry is predominately engaged in non-construction work and its NAICs code is not typically classified as a construction code..

Costs of Engineering Controls for Hydraulic Fracturing in the PEA

Both in the PEA and in this FEA, OSHA presented the methods of estimating the costs of controlling silica exposures during hydraulic fracturing separately from the engineering control costs for all other portions of general industry because there are some fundamental differences in the methodology OSHA used, and thus in the comments OSHA received on that methodology. In the PEA, OSHA began its analysis of hydraulic fracturing in the standard way of examining the set of engineering controls available to control employee exposures to silica. Unlike the way OSHA handled the rest of general industry, however, for hydraulic fracturing OSHA identified precisely which controls were necessary to go from current levels of exposure to the preceding general industry PEL of 100 μg/m^3 and then what further controls would be necessary to go from the preceding general industry PEL of 100 μg/m^3 to the new PEL of 50 μg/m^3. OSHA took a different approach for this sector because the data available for this industry, as a result of an extensive set of site visits, were adequate to make this kind of determination. OSHA determined that a combination of wet methods, partial enclosure, and LEV controls would be sufficient to meet a PEL of 100 μg/m^3 for hydraulic fracturing. OSHA then determined that LEV controls at thief hatches and operator enclosures would be sufficient to reduce exposures during hydraulic fracturing from 100 μg/m^3 to 50 μg/m^3. The costs of these additional engineering controls were shown in Tables A-14, A-15, and A-16 for large, medium, and small fleets, respectively, in the PEA (the full derivation of the results in these tables can be found in ERG, 2013, Document ID 1712).

As discussed in the Industry Profile section of this FEA (Chapter III), the basic unit for analysis for this industry is the fleet rather than the establishment. Rather than allocating costs according to the proportion of workers above a given exposure level, as was done for the rest of general industry, for hydraulic fracturing the controls applied per fleet were judged to reduce the exposures of all workers associated with the fleet.

Public Comments on OSHA's Preliminary Cost Estimates for Engineering Controls in Hydraulic Fracturing

General methodology

Though there were extensive comments on OSHA's estimates of engineering control costs for hydraulic fracturing, no commenter objected to the differences in methodology compared to OSHA's treatment of the other general industry sectors (as outlined above). Halliburton Energy Services, Inc. commented that OSHA's analysis "lacks data" (Document ID 4211, p. 5). As discussed in Chapter IV Technological Feasibility, OSHA agrees that there is limited experience with many possible controls. For this reason, OSHA has allowed this industry an extended compliance deadline of five years before they have to meet the new PEL with engineering controls. However, OSHA does not agree that that this adds significant uncertainty to the costs analysis. The costs of the controls OSHA has examined, and especially those needed to go from the preceding general industry PEL to the new PEL can readily be ascertained. It is possible that the cost of some controls that have not yet been tested and that OSHA has not costed could be much lower than the costs OSHA estimated in the PEA and in this FEA.

<u>Compliance rate</u>

In the joint comments submitted by the American Petroleum Institute and the Independent Petroleum Association of America (API/IPAA or "the Associations"), the Associations disagreed with OSHA's estimated current compliance rate for the use of engineering controls. In the PEA, OSHA estimated a compliance rate of ten percent for engineering controls in this industry. In their comments the Associations said that "ERG assumed that 10% of all hydraulic fracturing firms already utilize: (1) baghouse controls; (2) caps on fill ports; (3) dust curtains; (4) wetting methods; and (5) conveyor skirting systems" (Document ID 2301, p. 40, fn. 148).

While OSHA used a compliance rate of ten percent for all of these controls, it is not meant to represent that all prescribed controls are used in ten percent of firms. OSHA's compliance rates take into account that some well sites, as documented in Chapter IV of the PEA, were observed to be using a variety of controls that reduce dust levels, and as a result, those firms will not need to implement as many additional controls in order to achieve the new PEL. Further, as noted in Chapter IV of the FEA, the industry is constantly installing additional controls to reduce silica exposures. Thus the Agency sees no reason to change its estimate of current compliance. In any case, removing the assumption would make only a ten percent difference to the cost estimates, which would not be a change of large enough magnitude to threaten OSHA's conclusion that compliance with the final rule is economically feasible for the hydraulic fracturing industry.

Maintenance costs

In the PEA, OSHA estimated that the life of most capital equipment would be ten years, and that maintenance and operating costs would range from ten to thirty percent of capital costs per year (ten percent being most common).

API/IPAA argued that the hostile, sandy environment of the well site shortens the useful life of equipment and increases maintenance costs. The Associations estimated that the useful life of equipment ranges from 5 years to 7.5 years and that annual operating and maintenance costs range from 10 percent to 25 percent of capital costs. While OSHA agrees that the oilfield environment is challenging and dusty, there is no evidence in the record that these environments are more challenging than other industrial settings where equipment lives of 10 years and operating and maintenance costs of 10 to 30 percent have been used as reasonable estimates.

Cost of Specific Controls

Dust Booths

In the PEA, OSHA estimated that there would need to be one dust booth for each sand moving machine, and that this would result in one dust booth for small fleets, three for medium fleets, and five for large fleets. In critiquing OSHA's cost analysis for hydraulic fracturing, API/IPAA disagreed with OSHA's estimates that only sand mover operators would need to utilize dust control booths in order to achieve the new PEL (Document ID 2301, p. 69). API/IPAA suggested that instead there would need to be one booth per affected worker and that only one worker could utilize a given booth. In the Associations' estimate this would mean that there would need to be 3, 8 and 12 booths for small, medium, and large fleets, respectively (Document ID 2301, Attachment 4, Dust Booths, row 9).

As discussed in the technological feasibility chapter of this FEA, OSHA agrees that workers other than sand mover operators will need to use dust booths. However, OSHA does not agree that a booth can only accommodate a single person. These booths are places of refuge and are not assigned to specific individuals. The technological feasibility chapter (Chapter IV) in this FEA determined that dust booths can accommodate more than one person per booth. Because OSHA agrees that more employees than sand mover operators will need booths, OSHA has raised its estimates of booths needed by size class from 1, 4, and 5 booths to 3, 6, and 8 booths. While this estimate of the number of booths is lower than that recommended by API/IPAA, OSHA finds that these booths can accommodate 2 persons per booth and thus can accommodate more workers than API/IPAA suggested.

In the PEA, OSHA estimated the transportation costs for booths as $37.25 per booth. API/IPAA disagreed. The Associations argued that a cost of $513 for a small fleet, which would have only one booth, would be more appropriate (Document ID 2301, p. 69). Most of the difference between API/IPAA's cost estimate for deploying dust control booths and OSHA's estimate is attributable to the fact that the Associations presented their cost per fleet and OSHA presented its cost per booth. API/IPAA applied their estimate of the number of booths necessary at these worksites when deriving their estimate and they estimated about six times as many booths being necessary as OSHA did. However, after further examination of this cost, OSHA determined that the standard per-mile shipping rate that it used to estimate transportation costs in the PEA was applied incorrectly. This resulted in an estimate of transportation costs for booths in the PEA that was too low. OSHA has determined that the cost to transport dust booths presented by the Associations more completely captured the costs associated with transporting these booths. For this FEA, OSHA has accepted the Associations' per-fleet transportation cost of $513 for each booth and applied the cost to the Agency's estimate of the number of booths necessary to control silica exposures on well sites.

Water misting

In the PEA, OSHA estimated that water misting system would be needed to control residual emissions from some releases from sand moving systems. These water misting systems were estimated to cost $60,000 per fleet to purchase and an additional 20 percent of the purchase cost for installation. API/IPAA incorrectly assumed that these water misting systems were intended to control all dust emission from truck traffic and other sources (Document ID 2301, pp. 69-70). This was not the case—dust suppression for truck and other traffic was costed at a much higher rate separately from water misting. OSHA's cost estimates for misting systems were based on conversations with a mining dust control specialist who indicated the price and efficacy of available water misting systems (Document ID 1571). While API/IPAA disagreed with OSHA's costs, they did not offer any data to show an alternative cost, instead simply carrying OSHA's estimate for water misting systems forward in their analysis to arrive at their cost estimate (Document ID 2301, Attachment 3, Water Misting, cells K:O6 and J8). OSHA has determined that the equipment that formed the basis for its cost estimates in the PEA may not be durable enough to stand up to the wear from frequent loading, unloading, and transportation. Therefore, the Agency, based on its own judgment, has increased the estimated cost of a water misting system by 33 percent in order to account for the need for a more durable system. Based on this, OSHA's final cost analysis for hydraulic fracturing includes costs of $79,800 per fleet to purchase the equipment plus installation costs of $15,960 for installation (20 percent of the purchase price) for water misting equipment to control residual dust emissions from sand moving systems.

Costs of Transportation

In developing the costs for hydraulic fracturing firms to comply with this rule in the PEA, it was determined that the baghouse controls that are commercially available are integrated into sandmover units and therefore should not present any logistical difficulties for transportation purposes. However, in examining the costs to transport, assemble, and disassemble the control equipment, API/IPAA noted potential difficulties in adding baghouse controls to sandmovers, which are often nearly at weight limits for road movement (Document ID 2301, p. 71).

OSHA's determination about integrated units has not changed since the PEA. The existence of integrated units is further discussed in Chapter IV of this FEA, Technological Feasibility. OSHA notes that sandmover units are not the heaviest items transported by hydraulic fracturing firms, so the additional weight associated with baghouse controls would be insignificant in this context. These firms are highly experienced in moving the heavy, bulky equipment needed on well sites and including additional controls on this equipment is not expected to create a situation that exceeds the capabilities of these firms.

Containerized systems

Commenting on OSHA's analysis of the cost of controls for hydraulic fracturing, API/IPAA expressed concern that OSHA was considering requiring the use of containerized systems. The Associations stated that these systems would be economically infeasible for small fleets and raised questions about whether these systems would be sufficient to allow fleets using them to achieve the PEL (Document ID 4222, p. 7). Neither in the PEA nor the FEA has OSHA's cost analysis reflected the use of containerized systems, nor does OSHA require their use. Instead, containerized systems represent a possible technological change that could potentially reduce the costs of silica control. OSHA has in no way quantitatively tried to estimate the effects of this possible reduction.

Conveyor skirting

In the PEA, OSHA found that conveyor skirting systems with appropriate LEV would be needed to meet the new PEL, and included the cost of such controls in the incremental costs associated with the new PEL. As discussed in Chapter IV of this FEA, Technological Feasibility, however, OSHA now finds that these conveyor skirting systems will be needed to meet the preceding PEL, but not to further lower exposures to the new PEL, so OSHA is not including costs for these controls as incremental costs associated with achieving the new PEL. As a result, this FEA does not include costs for conveyor skirting systems and LEV.

Dust Suppression – control of dust generated from traffic

On the other hand, dust suppression to control silica emissions generated by truck traffic, estimated in the PEA as necessary only to meet the preceding PEL, has now been determined to be necessary to meet the new PEL (See Chapter IV, Technological Feasibility). As a result, in this FEA OSHA added the costs of dust suppression to control silica dust generated by truck traffic to the estimated incremental costs of meeting the new PEL. OSHA estimates that dust suppression is more expensive in the aggregate than conveyor skirting systems with appropriate LEV.

OSHA made two additional changes to the costs of dust suppression from the PEA to the FEA. First, OSHA accepted the unit costs for dust suppression application provided by API/IPAA (Document ID 2301, Attachment 3, Dust Suppression). This unit cost is somewhat lower than the original estimate that OSHA adopted in the PEA (Document ID 1712). This seems reasonable to OSHA based on the costs of the most commonly used dust suppression materials. Second, OSHA has determined that these controls will be utilized to reduce exposures for ancillary support workers and remote/intermittent workers, 50 percent of whom work in situations that currently have exposures below the new PEL (as shown in the exposure profile in the section on hydraulic fracturing in Chapter IV, Technological Feasibility). As a result, instead of assigning dust suppression costs for all wells (as in the PEA), OSHA determined in the FEA that dust suppression costs would be incurred by 50 percent of wells. This aligns with a view that, in many cases, natural conditions (silica content of soils, dustiness, wetness and/or climate) are such that dust suppression is not needed.

Small Business Considerations

Small Business Regulatory Enforcement Fairness Act (SBREFA) Comments on Compliance Costs in General Industry and Maritime

Before publishing the NPRM, OSHA received comment on the accuracy of its unit costs through the Small Business Advocacy Review (SBAR) Panel process.
The Small Entity Representatives (SERs) who participated in the 2003 SBAR Panel process on OSHA's draft standards for silica provided many comments on the estimated compliance costs OSHA presented in the Preliminary Initial Regulatory Flexibility Analysis (PIRFA) for general industry and maritime (Document ID 0938).

In response to the SERs' comments, OSHA carefully reviewed its cost estimates and evaluated the alternative estimates and methodologies suggested by the SERs. OSHA updated all unit costs presented in the PIRFA to reflect the most recent cost data available and inflated all costs to 2009 dollars prior to publication of the proposed rule. However, the Agency generally determined that the control cost estimates in the PIRFA were based on sound methods and reliable data sources.

For the PEA, OSHA reviewed the SERs' cost estimates for small entities in the foundry and structural clay industries. Given that those SERs did not report their own sizes, the Agency could not compare their estimates to the estimates in the PEA. OSHA concluded that the compliance costs reported by the SERs in general industry that did provide size data were not incompatible with OSHA's own estimates of the costs of engineering controls to comply with the PEL. As discussed above, for the FEA, OSHA has halved the number of workers assumed to be covered by each control for most controls in establishments with fewer than twenty employees, which results in a doubling of the engineering control costs for these establishments.

Comments and Responses on Costs for Small Establishments

Stuart Sessions, testifying on behalf of ACC, argued that OSHA had underestimated costs to small establishments for two reasons: 1) small establishments may have higher exposures and therefore many need to spend more money installing controls to reduce those exposures; and 2) costs to small establishments may involve diseconomies of scale—whereby smaller facilities would have to pay more per unit to procure and install systems—that OSHA had not accounted for (Document ID 4231, Attachment 1, pp. 2-4).

With respect to the issue about small establishments having higher exposures—the commenter simply asserted that this is the case without providing any evidence to support the claim. Mr. Sessions speculated that smaller businesses have a "lesser ability to afford compliance expenditures and lesser ability to devote management attention to compliance responsibilities" (Document ID 4231, Attachment 1, p. 2). While it is possible that very small establishments may not have the same controls already in place as large establishments, as asserted by the commenter, this does not necessarily mean that very small establishments will have higher exposures. Small and very small establishments typically only have one shift per day, so fewer shifts are being worked where there is a potential for exposure. They also may spend more time on activities not involving silica exposures. For example, a small art foundry that produces one or two castings a week will simply spend proportionally less time on activities that lead to silica exposure than a large production foundry.

With respect to the issue of diseconomies of scale, OSHA has taken this phenomenon into account in its cost estimates in the FEA. First, in order to provide a conservative estimate of costs for the purposes of determining the impacts on very small employers, OSHA has revised what Mr. Sessions called "the most inappropriate of OSHA's assumptions" (Document ID 4231, Attachment 1, p. 6). In the PEA, OSHA estimated that a single control would reduce the exposures of four workers. For this FEA, OSHA has revised its estimates so that the number of workers whose exposures are reduced by a control are half that used in the PEA for establishments with fewer than 20 employees—reducing the number of workers covered by a control from four to two. OSHA made this adjustment even though there are ways in which small establishments may have lower costs per cfm than larger establishments. For capital costs, a major element of cost per cfm is the length of ductwork. Within the same industry, the length of ductwork will be much shorter in smaller establishments. For operating costs per cfm, length of operating time is a key element of costs.

OSHA has continued to estimate that the exposures of four employees whose exposures would be reduced per control for establishments with more than twenty employees (even though it is likely that more than four workers have their exposures reduced per control in the largest establishments). This effectively means that very large establishments with hundreds of employees have been modeled as if their costs were equivalent to that of several 20-40 person establishments combined. Far from neglecting diseconomies of scale, in an effort to be conservative and adequately account for the challenges faced by smaller establishments, OSHA has instead neglected to account for economies of scale in larger establishments.

Mr. Sessions calculated some higher overall costs for smaller establishments (Document ID 4231, Attachment 1, pp. 6-10). However, these costs are critically dependent on the assumptions already addressed and rejected by OSHA, such as that exposures are random and that any exposures require that all possible controls be installed to control those exposures.

Final Control Costs

Unit Control Costs

Methodology

For this FEA, OSHA used unit costs developed in the PEA for specific respirable crystalline silica control measures from product and technical literature, equipment vendors, industrial engineers, industrial hygienists, and other sources, as relevant to each item. Some PEA estimates were modified for this FEA based on comments in the record, and all costs were updated to 2012 dollars. Specific sources for each estimate are presented with the cost estimates. Wherever possible, objective cost estimates from recognized technical sources were used. Table V-4 provides details on control specifications and data sources underlying OSHA's unit cost estimates.

Table V-4:

Source Materials for Costs of Compliance Estimates for General Industry and Maritime

Control	Description	CFM (for	Capital Cost [a]	Operating Cost	Annualized Capital Cost	Comment
Local exhaust ventilation (LEV)	Average capital and operating cost assumptions; per cfm	N/A	$13.34	$3.70	$1.56	Estimated by industrial ventilation consultants, capital cost of $12.83 per cfm [a]; operating costs reflect current energy prices
Conveyor covers (unventilated)	Conveyor covers (2 ft. bed, including all hardware); per linear foot	N/A	$20.73	NA	$2.43	$17.10 per linear foot for 100 ft. (Iandola, 2003) [a]
Maintenance percentage	Standard rate for maintenance of capital equipment	N/A	NA	NA	NA	10% - estimated as a percentage of capital cost
Dust suppressants	Kleen Products 50lb poly bag green sweeping compound	N/A	NA	$676.47	$0.00	$0.28/lb, 2 lbs/day; 5 minutes/day (www.fastenal.com).
HEPA vacuum for housekeeping	NILFISK VT60 wet/dry hepa vac, 15 gal	N/A	$3,632.58	$511.20	$793.19	Nilfisk, HEPA vacuum (http://www.sylvane.com/nilfisk.html)
HEPA vacuum for housekeeping	NILFISK, large capacity	N/A	$8,002.49	$988.90	$1,747.38	Nilfisk, HEPA vacuum (McCarthy, 2003)
Saw enclosure	8x8x8 wood/plastic	N/A	$526.90	$52.69	$115.05	Fabrication costs estimated by ERG, assuming in-plant work. Five-year life.
Cab enclosures	Enclosed cabs	N/A	$15,762	$5,517	$3,441.81	ERG estimate based on vendor interviews.
LEV for hand held grinders	Shrouds + vacuum	N/A	$1,737.51	$608.13	$379.39	Vacuum plus shroud adapter (http://www.proventilation.com/products/productDetail.asp?id=15); 35% for
Upgraded abrasive blast cabinet	Improved maintenance and purchases for some	N/A	$4,850	$1,000	$568.57	Assumes addit.maint. (of up to $2,000) or new cabinets ($8,000) (Norton, 2003) [a]
Yard dust suppression	100 ft, 1" contractor hose and nozzle	N/A	$212.19	$0.00	$110.89	Contactor hose and nozzle; 2 year life; (www.pwmall.com) [a]
Wet methods to clean concrete mixing equip.	10 mins per day per operator	N/A	$0.00	$1,024.04	$0.00	10 mins per day per mixer operator
HEPA vacuum substitute for compressed air	Incremental time to remove dust by vacuum	N/A	NA	$536.47	$0.00	5 min per day per affected worker
Spray system for wet concrete finishing	Shop-built sprayer system	N/A	$213.42	$21.34	$111.54	Assumes $100 in materials and 4 hours to fabricate. Also 10% for maint.
Improved spray booth for pottery	Maintenance time & materials	N/A	$121.25	$118.42	$239.67	Annual: $100 materials plus 4 hours maintenance time [a]
Improved LEV for ceramics spray booth	Increased air flow; per cfm	N/A	$3.33	$0.92	$3.33	25% of installed CFM price

Table V-4: (continued)

Source Materials for Costs of Compliance Estimates for General Industry and Maritime

Control	Description	CFM (for Ventilation)	Capital Cost [a]	Operating Cost	Annualized Capital Cost	Comment
Exhaust for saw, cut stone industry	Based on saw LEV (e.g., pg. 10-158, 159, 160, ACGIH, 2001)	645	$8,602.67	$2,385.88	$1,008.50	Includes 545 cfm for saw base and 100 cfm for blade guard; updated to ACGIH 2013; VS-65-02, pg. 13-79
LEV for hand chipping in cut stone	Granite cutting and finishing; (pg. 10-94, ACGIH, 2001)	600	$8,002.49	$2,219.43	$938.14	ERG estimate of CFM requirements
Exhaust trimming machine	Based on abrasive cut-off saw; (pg. 10-134) (ACGIH, 2001)	500	$6,668.74	$1,849.52	$781.78	Opening of 2 sq ft assumed, with 250 cfm/sq.ft
Bag opening	Bag opening station; (pg. 10-19, ACGIH, 2001)	1,513	$20,179.60	$5,596.66	$2,365.66	3.5'x1.5' opening; with ventilated bag crusher (200 cfm)
Conveyor ventilation	Conveyor belt ventilation; (pg. 10-70, ACGIH, 2001)	700	$9,336.23	$2,589.33	$1,094.49	Per take-off point, 2' wide belt.
Bucket elevator ventilation	Bucket elevator ventilation (pg. 10-68; ACGIH,2001)	1,600	$21,339.96	$5,918.47	$2,501.69	2'x3'x30' casing; 4 take-offs @250 cfm; 100 cfm per sq ft of cross section
Bin and hopper ventilation	Bin and hopper ventilation (pg. 10-69; ACGIH, 2001)	1,050	$14,004.35	$3,884.00	$1,641.74	350 cfm per ft^2; 3' belt width
Screen ventilation	Ventilated screen (pg. 10-173, ACGIH, 2001)	1,200	$16,004.97	$4,438.86	$1,876.27	4'x6' screen; 50 cfm per ft^2
Batch operator workstation	Bin & hopper ventilation for unvented mixers (pg. 10-69, ACGIH, 2001)	1,050	$14,004.35	$3,884.00	$1,641.74	ERG estimate of CFM requirements
LEV for hand grinding operator (pottery)	Hand grinding bench (pg. 10-135, ACGIH, 2001)	3,750	$50,015.54	$13,871.42	$5,863.35	ERG estimate of CFM requirements
LEV, mixer and muller hood	Mixer & muller hood (pg. 10-87, ACGIH, 2001)	1,050	$14,004.35	$3,884.00	$1,641.74	ERG estimate of CFM requirements
LEV for bag filling stations	Bag filling station (pg. 10-15, ACGIH, 2001)	1,500	$20,006.21	$5,548.57	$2,345.34	Includes costs for air shower
Installed manual spray mister	Manual controls, system covers 100 ft of conveyor	N/A	$10,609.36	$1,060.94	$1,243.74	National Environmental Services Company (Kestner, 2003). [a]
Install cleaning hoses, reslope floor, drainage	Plumbing for hose installations, floor resloping and troughs	N/A	$36,412.40	$3,323.52	$4,268.64	ERG estimate. Includes cost of water and labor time.
Substitute alt., non-silica, blasting media	Alternative media estimated to cost 22 percent more	N/A	$0.00	$5,156.25	$0.00	Based on 220,000 square feet of coverage per year per crew
Shakeout conveyor enclosure	Ventilated shakeout conveyor enclosure	10,000	$133,374.76	$36,990.46	$15,635.59	ERG estimate
Shakeout side-draft ventilation	Shakeout double side-draft table (pg. 10-23, ACGIH, 2001)	28,800	$384,119.32	$106,532.52	$45,030.50	ERG estimate of CFM requirements
Shakeout enclosing hood	Ventilated enclosing hood (pg. 10-23, ACGIGH, 2001); 4'x4' openings	7,040	$93,895.83	$26,041.28	$11,007.46	ERG estimate of opening size required

Table V-4: (continued)

Source Materials for Costs of Compliance Estimates for General Industry and Maritime

Control	Description	CFM (for Ventilation)	Capital Cost [a]	Operating Cost	Annualized Capital Cost	Comment
Small knockout table	Portable grinding table pg. 10-136), ACGIH, 2001), 3'x3' opening	1,350	$18,005.59	$4,993.71	$2,110.80	ERG estimate of opening size required
Large knockout table	Hand grinding table (pg. 10-135), ACGIH, 2001), 4'x6' surface	4,800	$64,019.89	$17,755.42	$7,505.08	ERG estimate of bench surface area
Ventilated abrasive cutoff saw	Ventilated cut-off saw (pg. 10-134, ACGIH, 2001, 2'x3' opening	1,500	$20,006.21	$5,548.57	$2,345.34	ERG estimate of opening size required
Hand grinding bench (foundry)	Bench with LEV (pg. 10-135, ACGIH, 2001); 3'x5'	3,750	$50,016	$13,871.42	$5,863.35	ERG estimate of CFM requirements; 250 cfm/sq. ft.
Forming operator bench (pottery)	Bench with LEV (pg. 10-149, ACGIH, 2001), 3'x4'	1,400	$18,672	$5,178.66	$2,188.98	ERG estimate of CFM requirements; 125 cfm per linear foot
Hand grinding bench (pottery)	Bench with LEV (pg. 10-135, ACGIH, 2001); 3'x4'	2,400	$32,010	$8,877.71	$3,752.54	ERG estimate of CFM requirements; 200 cfm/sq. ft.
Hand tool hardware	Retrofit suction attachment	200	$464	$739.81	$54.42	ERG estimate of CFM requirements [a]
Clean air island	Clean air supplied directly to worker	2,500	$33,343.69	$9,247.61	$3,908.90	ERG estimate of CFM requirements; 125 cfm/sq. ft. for 20 square feet
Water fed chipping equipment drum cleaning	Shop-built water feed equipment	N/A	$242.50	$0.00	$242.50	ERG estimate. $200 in annual costs [a]
Ventilation for drum cleaning	Ventilation blower and ducting	N/A	$823.98	$205.99	$179.92	Electric blower (1,277 cfm) and 25 ft. of duct. Northern Safety Co. (p. 193) [a]
Control room	10'x10' ventilated control room with HEPA filter	200	$20,327.53	$739.81	$2,383.01	ERG estimate based on Means, 2003, ACGIH, 2001
Control room improvement	Repair and improve control room enclosure	N/A	$2,240	NA	$262.60	ERG estimate. Assumes repairs are 20% of new control room cost.
Improved bag valves	Bags with extended polyethylene valve, incremental cost per bag	N/A	$0.01	NA	NA	Cecala et al., 1986 [a]
Respirator	Half-mask respirator	N/A	NA	NA	$520.32	ERG, 2003 [Economic Analysis of APF rule], Updated to 2012
Improved maintenance on process equipment enclosures (concrete II)	Maintenance time & materials	N/A	$303.12	$250.59	$553.71	Annual: $250 materials plus 8 hours maintenance time [a]
Improved maintenance on process equipment enclosures (Mineral Proc)	Maintenance time & materials	N/A	$303.12	$257.08	$560.21	Annual: $250 materials plus 8 hours maintenance time [a]
Initial cleaning	Thorough initial cleaning, per square foot	N/A	$0.00	$0.15	$0.15	ERG estimate
Self-contained dust collection system			$800.00	$80.00	$93.78	Self-contained dust collection system. Darby Dental Lab Supply, 2005 (www.darbylab.com)

Control sources: Indicated in table.

N/A = Not applicable.

Table V-4: (continued)

Source Materials for Costs of Compliance Estimates for General Industry and Maritime

Control	Description	CFM (for Ventilation)	Capital Cost [a]	Operating Cost	Annualized Capital Cost	Comment

[a] Adjusted from 2003 price levels using an inflation factor of 1.212 based on GDP Implicit price deflator for 2003 and 2012.

Source: OSHA, Directorate of Standards and Guidance, Office of Regulatory Analysis, based on OSHA (2016).

Summary of Control Costs

Table V-5 summarizes the estimated number of at-risk workers and the annualized silica control costs for each application group. Control costs in general industry and maritime for firms to achieve the PEL of 50 μg/m^3 level are expected to total $238.1 million annually. As shown, application group-level costs exceed $15.0 million annually for concrete products, hydraulic fracturing, iron foundries, railroads, and structural clay.

Table V-6 shows aggregate annual control costs in general industry and maritime by NAICS industry. These costs reflect the disaggregation of application group costs among the industries that comprise each group. (See Table III-1 in Chapter III of this FEA on the profile of affected industries.)

Table V-5: Annualized Control Costs in General Industry and Maritime Associated with the Final Silica Standard, PEL=50 μg/m³, by Application Group

Application Group	Total	Employees Exposed Above PEL=50 μg/m³		Control Costs [a]
		Number	Percent	
Asphalt Paving Products	14,353	48	0.3%	**$199,831**
Asphalt Roofing Materials	9,074	1,410	15.5%	**$1,789,474**
Captive Foundries	2,069,329	1,821	0.1%	**$9,159,118**
Captive Stone Cutting	685,238	127	0.0%	**$140,483**
Concrete Products	76,503	10,750	14.1%	**$27,020,020**
Cut Stone	24,537	5,243	21.4%	**$8,913,357**
Dental Equipment	15,835	1,983	12.5%	**$4,355,009**
Dental Laboratories	917,269	1,101	0.1%	**$1,428,977**
Flat Glass	8,990	126	1.4%	**$557,199**
Hydraulic Fracturing	272,357	11,207	4.1%	**$84,432,467**
Iron Foundries	56,522	10,151	18.0%	**$23,819,024**
Jewelry	23,733	2,412	10.2%	**$317,348**
Landscaping	548,662	12,612	2.3%	**$1,276,327**
Mineral Processing	9,153	1,479	16.2%	**$2,947,577**
Mineral Wool	13,925	457	3.3%	**$2,005,181**
Nonferrous Sand Casting Foundries	24,968	1,060	4.2%	**$4,494,065**
Non-Sand Casting Foundries	15,190	962	6.3%	**$4,034,862**
Other Glass Products	27,118	780	2.9%	**$3,387,164**
Paint	35,328	386	1.1%	**$512,668**
Porcelain Enameling	191,638	1,888	1.0%	**$1,901,938**
Pottery	13,096	2,496	19.1%	**$5,955,772**
Railroads	N/A	5,340	N/A	**$16,220,542**
Ready-Mix Concrete	66,196	19,941	30.1%	**$6,171,957**
Refractories	6,567	361	5.5%	**$612,564**
Refractory Repair	82,871	591	0.7%	**$550,862**
Shipyards	136,365	2,805	2.1%	**$10,079,555**
Structural Clay	14,418	2,837	19.7%	**$15,810,712**
Totals	**5,359,235**	**100,375**	**1.9%**	**$238,094,052**

[a] Incremental costs of complying with the new PEL from the preceding PEL

[b] Costs and impact to rail transportation were estimated separately. See the discussions presented in Chapter VI for more information.

Source: OSHA, Directorate of Standards and Guidance, Office of Regulatory Analysis, based on OSHA (2016).

Table V-6:
Annualized Control Costs in General Industry and Maritime Associated with the Final Silica Standard, PEL=50 μg/m³, by Industry

NAICS	Industry	Total Employees	Employees Exposed Above PEL=50 μg/m³		Control Costs [a]
			Number	Percent	
213112	Support Activities for Oil and Gas Operations	272,357	11,207	4.1%	**$84,432,467**
324121	Asphalt Paving Mixture and Block Manufacturing	14,353	48	0.3%	**$199,831**
324122	Asphalt Shingle and Coating Materials Manufacturing	9,074	1,410	15.5%	**$1,789,474**
325510	Paint and Coating Manufacturing	35,328	386	1.1%	**$512,668**
327110	Pottery, Ceramics, and Plumbing Fixture Manufacturing	13,096	2,496	19.1%	**$5,955,772**
327120	Clay Building Material and Refractories Manufacturing	20,985	3,198	15.2%	**$16,423,275**
327211	Flat Glass Manufacturing	8,990	126	1.4%	**$557,199**
327212	Other Pressed and Blown Glass and Glassware Manufacturing	13,434	386	2.9%	**$1,677,938**
327213	Glass Container Manufacturing	13,684	394	2.9%	**$1,709,226**
327320	Ready-Mix Concrete Manufacturing	66,196	19,941	30.1%	**$6,171,957**
327331	Concrete Block and Brick Manufacturing	14,896	2,045	13.7%	**$4,153,422**
327332	Concrete Pipe Manufacturing	8,229	1,130	13.7%	**$2,294,454**
327390	Other Concrete Product Manufacturing	45,284	6,216	13.7%	**$12,626,461**
327991	Cut Stone and Stone Product Manufacturing	24,537	5,243	21.4%	**$8,913,357**
327992	Ground or Treated Mineral and Earth Manufacturing	7,129	1,152	16.2%	**$2,295,864**
327993	Mineral Wool Manufacturing	13,925	457	3.3%	**$2,005,181**
327999	All Other Miscellaneous Nonmetallic Mineral Product Manufacturing	10,118	1,687	16.7%	**$8,597,395**
331110	Iron and Steel Mills and Ferroalloy Manufacturing	105,309	93	0.1%	**$465,771**
331210	Iron and Steel Pipe and Tube Manufacturing from Purchased Steel	25,592	23	0.1%	**$113,363**
331221	Rolled Steel Shape Manufacturing	7,836	7	0.1%	**$34,766**
331222	Steel Wire Drawing	14,241	13	0.1%	**$63,076**
331314	Secondary Smelting and Alloying of Aluminum	5,415	5	0.1%	**$23,872**
331420	Copper Rolling, Drawing, Extruding, and Alloying	21,408	19	0.1%	**$93,284**

Table V-6: (continued)

Annualized Control Costs in General Industry and Maritime Associated with the Final Silica Standard, PEL=50 μg/m³, by Industry

NAICS	Industry	Total Employees	Employees Exposed Above PEL=50 μg/m³		Control Costs [a]
			Number	Percent	
331492	Secondary Smelting, Refining, and Alloying of Nonferrous Metal (except Copper and	10,913	10	0.1%	**$48,440**
331511	Iron Foundries	38,286	6,876	18.0%	**$16,134,210**
331512	Steel Investment Foundries	15,190	962	6.3%	**$4,034,862**
331513	Steel Foundries (except Investment)	18,236	3,275	18.0%	**$7,684,814**
331524	Aluminum Foundries (except Die-Casting)	15,446	656	4.2%	**$2,780,798**
331529	Other Nonferrous Metal Foundries (except Die-Casting)	9,522	404	4.2%	**$1,713,267**
332111	Iron and Steel Forging	24,030	21	0.1%	**$106,434**
332112	Nonferrous Forging	6,182	5	0.1%	**$27,279**
332117	Powder Metallurgy Part Manufacturing	8,160	7	0.1%	**$36,052**
332119	Metal Crown, Closure, and Other Metal Stamping (except Automotive)	53,018	47	0.1%	**$234,189**
332215	Metal Kitchen Cookware, Utensil, Cutlery, and Flatware (except Precious) Manufacturing	7,374	6	0.1%	**$32,655**
332216	Saw Blade and Handtool Manufacturing	27,852	25	0.1%	**$123,396**
332323	Ornamental and Architectural Metal Work Manufacturing	29,694	16	0.1%	**$20,424**
332439	Other Metal Container Manufacturing	11,749	10	0.1%	**$51,863**
332510	Hardware Manufacturing	26,540	23	0.1%	**$117,483**
332613	Spring Manufacturing	14,829	13	0.1%	**$65,599**
332618	Other Fabricated Wire Product Manufacturing	24,626	22	0.1%	**$109,036**
332710	Machine Shops	245,538	216	0.1%	**$1,086,755**
332812	Metal Coating, Engraving (except Jewelry and Silverware), and Allied Services to	49,911	1,654	3.3%	**$1,625,192**
332911	Industrial Valve Manufacturing	35,657	31	0.1%	**$157,784**
332912	Fluid Power Valve and Hose Fitting Manufacturing	34,663	31	0.1%	**$153,500**
332913	Plumbing Fixture Fitting and Trim Manufacturing	7,567	7	0.1%	**$33,527**
332919	Other Metal Valve and Pipe Fitting Manufacturing	14,260	13	0.1%	**$63,022**
332991	Ball and Roller Bearing Manufacturing	22,522	20	0.1%	**$99,714**
332996	Fabricated Pipe and Pipe Fitting Manufacturing	29,914	26	0.1%	**$132,275**

Table V-6: (continued)

Annualized Control Costs in General Industry and Maritime Associated with the Final Silica Standard, PEL=50 μg/m^3, by Industry

NAICS	Industry	Total Employees	Employees Exposed Above PEL=50 μg/m^3		Control Costs [a]
			Number	Percent	
332999	All Other Miscellaneous Fabricated Metal Product Manufacturing	70,118	68	0.1%	**$312,979**
333318	Other Commercial and Service Industry Machinery Manufacturing	54,518	48	0.1%	**$241,287**
333413	Industrial and Commercial Fan and Blower and Air Purification Equipment Manufacturing	24,138	21	0.1%	**$106,821**
333414	Heating Equipment (except Warm Air Furnaces) Manufacturing	17,959	16	0.1%	**$79,591**
333511	Industrial Mold Manufacturing	35,194	31	0.1%	**$155,856**
333514	Special Die and Tool, Die Set, Jig, and Fixture Manufacturing	42,810	38	0.1%	**$189,400**
333515	Cutting Tool and Machine Tool Accessory Manufacturing	28,451	25	0.1%	**$125,835**
333517	Machine Tool Manufacturing	24,322	21	0.1%	**$107,566**
333519	Rolling Mill and Other Metalworking Machinery Manufacturing	11,582	10	0.1%	**$51,625**
333612	Speed Changer, Industrial High-Speed Drive, and Gear Manufacturing	16,072	14	0.1%	**$71,161**
333613	Mechanical Power Transmission Equipment Manufacturing	15,545	14	0.1%	**$68,757**
333911	Pump and Pumping Equipment Manufacturing	33,772	30	0.1%	**$149,614**
333912	Air and Gas Compressor Manufacturing	21,225	19	0.1%	**$93,972**
333991	Power-Driven Handtool Manufacturing	8,859	8	0.1%	**$39,303**
333992	Welding and Soldering Equipment Manufacturing	15,781	14	0.1%	**$69,967**
333993	Packaging Machinery Manufacturing	20,010	18	0.1%	**$88,491**
333994	Industrial Process Furnace and Oven Manufacturing	11,009	10	0.1%	**$48,741**
333995	Fluid Power Cylinder and Actuator Manufacturing	24,208	21	0.1%	**$107,135**
333996	Fluid Power Pump and Motor Manufacturing	10,554	9	0.1%	**$46,708**
333997	Scale and Balance Manufacturing	3,725	3	0.1%	**$16,433**
333999	All Other Miscellaneous General Purpose Machinery Manufacturing	51,495	45	0.1%	**$227,996**
334519	Other Measuring and Controlling Device Manufacturing	34,604	31	0.1%	**$153,947**
335210	Small Electrical Appliance Manufacturing	8,216	10	0.1%	**$11,066**
335221	Household Cooking Appliance Manufacturing	10,408	12	0.1%	**$14,018**
335222	Household Refrigerator and Home Freezer Manufacturing	9,374	11	0.1%	**$12,626**

Table V-6: (continued)

Annualized Control Costs in General Industry and Maritime Associated with the Final Silica Standard, PEL=50 μg/m³, by Industry

NAICS	Industry	Total Employees	Employees Exposed Above PEL=50 μg/m³		Control Costs [a]
			Number	Percent	
335224	Household Laundry Equipment Manufacturing	4,438	5	0.1%	**$5,977**
335228	Other Major Household Appliance Manufacturing	9,059	11	0.1%	**$12,201**
336111	Automobile Manufacturing	62,686	55	0.1%	**$277,561**
336112	Light Truck and Utility Vehicle Manufacturing	56,524	50	0.1%	**$250,233**
336120	Heavy Duty Truck Manufacturing	30,756	27	0.1%	**$135,990**
336211	Motor Vehicle Body Manufacturing	40,544	36	0.1%	**$179,484**
336212	Truck Trailer Manufacturing	28,304	25	0.1%	**$125,352**
336213	Motor Home Manufacturing	7,395	7	0.1%	**$32,725**
336310	Motor Vehicle Gasoline Engine and Engine Parts Manufacturing	52,752	46	0.1%	**$233,483**
336320	Motor Vehicle Electrical and Electronic Equipment Manufacturing	50,017	44	0.1%	**$221,367**
336330	Motor Vehicle Steering and Suspension Components (except Spring) Manufacturing	28,663	25	0.1%	**$126,884**
336340	Motor Vehicle Brake System Manufacturing	21,859	19	0.1%	**$96,722**
336350	Motor Vehicle Transmission and Power Train Parts Manufacturing	58,248	51	0.1%	**$257,824**
336370	Motor Vehicle Metal Stamping	81,018	71	0.1%	**$358,513**
336390	Other Motor Vehicle Parts Manufacturing	122,041	107	0.1%	**$540,116**
336611	Ship Building and Repairing	108,311	2,228	2.1%	**$8,005,888**
336612	Boat Building	28,054	577	2.1%	**$2,073,668**
336992	Military Armored Vehicle, Tank, and Tank Component Manufacturing	10,990	10	0.1%	**$48,772**
337110	Wood Kitchen Cabinet and Countertop Manufacturing	76,052	86	0.1%	**$81,270**
337215	Showcase, Partition, Shelving, and Locker Manufacturing	33,437	29	0.1%	**$147,925**
339114	Dental Equipment and Supplies Manufacturing	15,835	1,983	12.5%	**$4,355,009**
339116	Dental Laboratories	44,097	864	2.0%	**$1,121,590**
339910	Jewelry and Silverware Manufacturing	48,169	2,434	5.1%	**$425,899**
339950	Sign Manufacturing	69,051	163	0.2%	**$191,729**
423840	Industrial Supplies Merchant Wholesalers	82,871	591	0.7%	**$550,862**

Table V-6: (continued)

Annualized Control Costs in General Industry and Maritime Associated with the Final Silica Standard, PEL=50 μg/m³, by Industry

NAICS	Industry	Total Employees	Employees Exposed Above PEL=50 μg/m³		Control Costs [a]
			Number	Percent	
444110	Home Centers	609,186	41	0.0%	**$59,213**
482110	Rail transportation [b]	NA	5,340	NA	**$16,220,542**
561730	Landscaping Services	548,662	12,612	2.3%	**$1,276,327**
621210	Offices of Dentists	873,172	237	0.0%	**$307,387**
	Totals	**5,359,235**	**100,375**	**1.9%**	**$238,094,052**

[a] Incremental costs of complying with the new PEL from the preceding PEL.

[b] Costs and impact to rail transportation were estimated separately. See the discussion in Chapter VI for more information.

Source: OSHA, Directorate of Standards and Guidance, Office of Regulatory Analysis, based on OSHA (2016).

Respiratory Protection Costs

This section presents OSHA's estimate of the costs for general industry and maritime employers to comply with the respiratory protection requirements of the final rule. Contained below is an overview of the estimated costs associated with respirator use presented in the PEA, comments received on the preliminary estimates and OSHA's response to those comments, the changes made in this FEA, and finally the estimated costs associated with respirator use as required by the final rule.

PEA Estimate of Respiratory Protection Costs

In the PEA, OSHA's cost estimates assumed that implementation of the recommended controls prevented workers in general industry and maritime from being exposed over the proposed PEL in most cases. OSHA expected, based on the preliminary technological feasibility analysis, that engineering controls would be adequate to keep exposures at or below the alternative PEL of 100 $\mu g/m^3$ (examined for analytical purposes) and the proposed PEL of 50 $\mu g/m^3$ for most operations most of the time, but that these controls might not be adequate in all cases to ensure that worker exposures in all affected job categories are at or below 50 $\mu g/m^3$. OSHA's preliminary analysis determined that, with the exception of workers authorized to enter regulated areas, reusable respirators would be more cost-effective than disposable respirators. For workers in maritime, the preliminary exposure determination identified abrasive blasting as the only activity with silica exposures above 50 $\mu g/m^3$, and OSHA preliminarily determined that maritime workers engaged in abrasive blasting are already required to use respirators under existing OSHA standards. Therefore, OSHA estimated no additional costs for maritime workers to use respirators as a result of the proposed silica rule.

In the PEA, respirator cost information from a 2003 OSHA respirator study was used to estimate the annual, per-worker cost of $570.13 (in 2009 dollars) for a non-disposable half-mask, non-powered, air-purifying respirator (ERG, 2003). This unit cost includes expenses for accessories, training, fit testing, and cleaning. In the PEA, OSHA estimated that 10 percent of the workers in general industry and maritime with current silica exposures above 50 $\mu g/m^3$ would require respirators, at least occasionally, after the implementation of engineering controls, to achieve the proposed PEL. This translated into 11,992 workers needing respirators. Applying the annual unit cost of $570.13 to the workers required to wear a respirator under the proposed rule resulted in total costs for respirator use (not including programmatic costs) of $6.8 million annually.[16]

[16] Note that these respirator costs did not include the costs of disposable respirators used in regulated areas. Costs for these disposable respirators were estimated as part of regulated area costs.

The PEA also estimated the burden to employers to establish a respiratory protection program. OSHA projected that this expense would involve an initial 8 hours for establishments with 500 or more employees and 4 hours for all other establishments. After the first year, OSHA estimated that 20 percent of employers would revise the program in any given year, with the largest establishments (500 or more employees) expending 4 hours for program revision, and all other employers expending 2 hours for program revision. OSHA preliminarily estimated that, of the establishments that would require respirator use to achieve compliance, half of the establishments in general industry and all of the establishments in maritime already have a respiratory protection program. OSHA estimated that the combined costs of the respiratory protection program and the costs for respirator provision and use totaled $6.9 million annually in general industry and maritime.

Comments and Responses on PEA Estimate of Respiratory Protection Costs

OSHA received limited comment on the issue of respirator use and associated costs. A few commenters provided estimates of the costs for respiratory protection under the proposed rule. The Precast/Prestressed Concrete Institute (PCI)—in providing estimates of the costs for the types of controls and ancillary measures necessary to comply with the proposed standard, including respirators—noted, "[a] powered air-purifying respirator (PAPR) is expensive […]" (Document ID 2276, p. 10). A PAPR is not required by the standard, and OSHA expects that silica exposures can be controlled using disposable N95 respirators or reusable half-face elastomeric respirators, both of which have an assigned protection factor (APF) of 10.

The Society for Protective Coatings estimated annual costs for respirators ranging from $100 to $150 per worker (Document ID 2120, p. 2). However, this range did not include a detailed breakdown of how that cost was estimated, so OSHA cannot compare this range to OSHA's own estimates for per-worker annual respirator costs presented later in this section. In addition, in their post-hearing comments, PCI estimated that "[f]it testing and associated medical clearance for one worker costs between $75 and $400" (Document ID 4029, Attachment 1, p. 3). While OSHA included the cost of medical clearance to wear a respirator as part of the medical surveillance required by this standard, OSHA's estimated cost of fit testing alone appears to be in line with the estimate that PCI presented.

OSHA also received comment regarding the productivity impact of wearing respirators. For example, Peter Soyka, representing James Hardie Building Products, developed a model that included a productivity impact for "wearing respirators to account for fatigue and adverse impacts on employee-to-employee communication" (Document ID 2322, Appendix G, p. 32). OSHA does not believe it is appropriate to assign a productivity impact for respirator wear for the final silica rule. This is consistent with decades of OSHA rulemaking. To establish a relevant productivity effect for respirators, it needs to be compared against its prospective baseline, which in this case would involve inhaling substantial amounts of silica. As outlined also in the discussion of the productivity effects of engineering controls, there was ample comment to suggest the productivity loss from inhaling silica over an extended period of time, both physiologically and psychologically, is at least as problematic as wearing a respirator.

For example, Deven Johnson, testified about the human effect of controlling silica:

> Another thing is, an individual who is working in an environment where […] he or she is constantly bombarded with concrete dust all day long, your productivity drops as you get more and more miserable as the day goes on. Commonsense would dictate, if you're not blasting me in the face with dust and sand and silica for eight hours a day, that I'm going to feel physically better and I'm not going to be as tired and exhausted and pissed off as I normally would be at the end of the day. Your productivity goes up […]. (Document ID 3581, Tr. 1594-1595)

Further, Mr. Javier Garcia Hernandez, from National Council for Occupational Safety and Health/Equality State Policy Center/Laborsafe, testified on the cognitive factors that affect productivity and why engineering controls should aid productivity:

> …as a construction worker, I highly believe that we're more productive when we are protected […]. We spend less energy focusing on how to protect ourselves. Just imagine you're working in a roomful of dust and you're just trying to either close your eyes or cover your mouth so the less you breathe. So you're constantly thinking about how to breathe less dust but if you have the respirator or the wet, the controlled area, whether it is water or respiratory protection, you're much more productive because our mind is less occupied in how to protect ourselves and we spend that time that we would have spent protecting ourselves working (Document ID 3586, Tr. 3248-49).

Todd Ward, a bricklayer, testified that workers have some awareness of the hazards of dry cutting blocks and that:

> . . . when [workers] on the job [are] dry cutting they know – it affects morale as well when they know […] they have some safeguards and they're protecting their lungs. So there is an increased productivity when you have a good morale then on the job (Document ID 3585, Tr. 3057).

Based on these comments and reasoning, OSHA is not including a productivity cost for wearing respirators. This same reasoning applies for general industry and maritime as well as construction. Thus, OSHA has chosen not to repeat this discussion in the construction respirator cost section.

Some commenters disagreed with the number of workers that OSHA estimated would need respirators as a result of this rule. Alexandra Persichetti, representing Morgan Advanced Materials, North America, commented that this rule would greatly expand respirator use due to "the creation of a regulated area or implementation of an access control plan" (Document ID 2337, p. 2). In addition, the American Foundry Society disagreed with OSHA's estimate of the number of workers in respiratory protection programs as a result of the regulated area provision (Document ID 4035, Attachment 1, p. 9). OSHA discusses the relationship between respirator use and regulated areas in the regulated area cost section presented later in this chapter. The respiratory protection costs incurred only for entry into a regulated area (for a person not otherwise required to wear a respirator to comply with the PEL requirements of the final rule) are not included in the respiratory protection costs presented in this section; those respiratory protection costs are estimated as part of regulated area costs.

URS disagreed with OSHA's derivation of the number of workers who would require respirators:

> URS estimates that the percentage of silica-exposed workers likely to be exposed above the proposed 50 μg/m³ PEL following the installation of controls will be one-half the percentage of silica-exposed workers that OSHA estimates are now exposed above the current 100 μg/m³ PEL (Document ID 2308, Attachment 8, p. 22).

Two key analytical assumptions account for the difference between OSHA's estimate of the number of workers who will need respirators and the estimate presented by URS. First, OSHA does not consider the overexposures under the preceding PEL to be indicative of the exposures that employers will be able to achieve under the new PEL. OSHA's technological feasibility analysis determined that engineering controls are sufficient to achieve the new PEL for most operations most of the time. The residual 10 percent (or more, depending on the technological feasibility analysis for each particular industry) that OSHA estimated to need respirators in the PEA represented situations that are outside the norm.[17] Second, OSHA assumes that all employers are attempting to comply with the rule for the purpose of estimating costs, so OSHA's cost analysis does

[17] For this FEA, OSHA increased its estimate of the number of respirators needed in general industry and maritime in part by modifying its approach for estimating the number of needed respirators, as discussed later in this section.

not take potential non-compliance into account. OSHA's estimates recognize, however, that despite employers' best efforts, exposures may remain high in some workplaces if engineering controls are improperly used or maintained (and the residual 10 percent respirator use would account for these employees).

Mark de Bernardo, representing Halliburton, argued that OSHA did not "take account of ubiquitous respirator use" and therefore "inflated the number of workers at exposure levels above the proposed PEL and artificially inflated the number of avoided fatalities" (Document ID 2302, p. 10). OSHA discusses the estimates of workers exposed above the PEL in Chapter III of this FEA, but notes that, while overestimating baseline overexposures would, indeed, result in an overestimate of benefits, it would also mean that OSHA had overestimated the cost of respirator use necessary to comply with the new PEL.

Estimates of Respiratory Protection Costs for the Final Rule

The methodology OSHA used to estimate the costs to employers of respiratory protection in this FEA is largely similar to the methodology it employed in the PEA. OSHA has updated to 2012 the profile numbers that serve as input to the model (i.e., the number of employees, the number of establishments, and wage rates) and has updated all costs to reflect 2012 dollars. However, whereas the PEA estimated that, with the exception of workers who are entering regulated areas,[18] all workers in general industry who need respirators with an APF of 10 would use non-disposable, half-face respirators, the FEA estimates that half of the workers who need respirators will use half-face elastomeric respirators and half will use disposable N95 respirators. This is because, as clarified in the final rule,[19] both disposable and non-disposable respirators are available with an APF of 10, and, with each type of respirator offering certain advantages, OSHA accordingly estimates that about half of the employees in general industry and maritime will prefer the ease of use of disposable respirators while the other half will prefer the durability of non-disposable respirators. Similar to the PEA, this FEA identified abrasive blasting as the only maritime activity with silica exposures above the PEL of 50 $\mu g/m^3$. In the PEA, OSHA concluded that all maritime workers engaged in abrasive blasting were already required to use respirators under existing OSHA standards and, therefore, maritime

[18] In both the PEA and the FEA, OSHA estimated that any person entering a regulated area would use a disposable N95 respirator. For further discussion, see the regulated area cost section later in this chapter.

[19] The clarification is clearest in Table 1 for the construction rule, where in the proposal the stated requirement was for a "half-mask (10)" and "(10)" referred to the APF while in the final rule the stated requirement is simply for an "APF 10." As a result, in the PEA in support of the proposal, the OSHA economists erroneously assumed that disposable N95 respirators would not satisfy the "half-mask (10)" requirement and only estimated costs for non-disposable half-mask respirators.

establishments would incur no additional costs for maritime workers to use respirators as a result of this final rule. However, for this FEA, OSHA has determined from its earlier technological feasibility analysis that only abrasive blasting operators, but not abrasive blasting helpers, are already required to use respirators under existing OSHA standards. The Agency, therefore, has added respirator costs for abrasive blaster helpers in maritime (half of all the abrasive blaster workers) as a result of this final rule.

Paragraph (g) of this rule requires that, where respiratory protection is required, employers provide each employee with an appropriate respirator that complies with the requirements of paragraph (g) and also with 29 CFR 1910.134. This final rule requires respiratory protection during the installation or implementation of engineering and work practice controls when employees are exposed above the PEL; during tasks, such as certain maintenance and repair tasks, for which engineering and work practice controls are not feasible and employees are exposed above the PEL; in situations where all feasible engineering and work practice controls have been installed and such controls are not sufficient to reduce exposures to or below the PEL; and during periods when the employee is in a regulated area. The rule also requires, where respirator use is required, that the employer institute a respiratory protection program in accordance with 29 CFR 1910.134.

According to OSHA's Respiratory Protection standard, employers whose workers are required to wear respirators during the course of their job duties must establish a written respiratory protection program. A respiratory protection program must contain the following elements:

- Procedures for selecting respirators;
- Medical evaluations of employees required to use respirators;
- Fit testing procedures;
- Procedures for proper use of respirators in routine and reasonably foreseeable emergency situations;
- Procedures and schedules for cleaning, disinfecting, storing, inspecting, repairing, discarding, and otherwise maintaining respirators;
- Procedures to ensure adequate air quality, quantity, and flow of breathing air for atmosphere-supplying respirators;
- Training of employees in respiratory hazards and proper use of respirators; and
- Procedures for regularly evaluating the effectiveness of the program.

For this FEA, OSHA estimated the costs for developing a respiratory protection program, annual fit testing, the costs for equipment (which includes the cost for respirators, any necessary accessories, and cleaning (when non-disposable respirators are used)), and annual training. Costs for medical clearance are included as part of medical surveillance costs, and recordkeeping costs are included in the respirator program costs.

OSHA estimated that a human resources manager, or equivalent, with an hourly wage rate of $74.97, will be responsible for developing the respiratory protection program (BLS, 2012b). As in the PEA, the Agency estimated that it will take 4 hours for small employers (those with fewer than 20 employees) and medium employers (those with between 20 and 499 employees) and 8 hours for large employers (those with 500 or more employees) to develop the respiratory protection program and provide the appropriate recordkeeping. In addition, as in the PEA, OSHA estimated that it will take half as much time (2 hours for small and medium employers and 4 hours for large employers) to review and update the respiratory protection plan (including appropriate recordkeeping), and that 20 percent of establishments will do so in any given year. The unit costs for respiratory protection program development and updating in general industry and maritime is displayed in Table V-7 below. The table also shows the estimated baseline compliance rates in general industry and maritime, with separate, higher rates for hydraulic fracturing. These are the same baseline compliance rates that were used to estimate respiratory protection program costs in the PEA.

Table V-7: Respiratory Protection Program Unit Costs in General Industry and Maritime

	Establishment Size		
	Small (<20)	**Medium (20-499)**	**Large (500+)**
Respirator users per establishment with respirators	2	4	6
Program development			
Hours	4	4	8
Labor value	$300	$300	$600
Program Updates			
Hours	2	2	4
Labor value	$150	$150	$300
Establishments updating program			
Per year	20.0%	20.0%	20.0%
Compliance rate (GI & Maritime)	50.0%	50.0%	50.0%
Compliance rate (Hydraulic Fracturing)	70.0%	80.0%	95.0%

Source: OSHA, Directorate of Standards and Guidance, Office of Regulatory Analysis, based on OSHA (2016) and BLS (2012b).

The Respiratory Protection Standard requires that, before a worker is required to use a respirator with a negative or positive pressure tight-fitting facepiece, the employee must be fit tested with the same make, model, style, and size of respirator that will be used (29

CFR 1910.134(f)). OSHA estimates that qualitative fit testing will be performed by a supervisor on groups of four employees simultaneously. This fit testing is estimated to take a total of one hour for each employee and fifteen minutes of a supervisor's time per-employee (one hour divided by the four employees in the group). The total cost per-employee for fit testing in general industry or maritime is shown below in Table V-8.

Table V-8: Cost of Qualitative Fit Testing in General Industry and Maritime	
Testing group size	4
Employee hours	1
Supervisor hours	0.25
Loaded employee hourly wage	$24.75
Loaded supervisor hourly wage	$40.38
Cost per employee	$34.85
Source: OSHA, Directorate of Standards and Guidance, Office of Regulatory Analysis, based on OSHA (2016) and BLS (2012b).	

As previously discussed, OSHA reevaluated the assumption used in the PEA that all workers in general industry and maritime needing respirators would use reusable half-face elastomeric respirators. The Agency determined that N95 disposable filtering facepiece respirators would be adequate to protect workers from respirable silica hazards and that these respirators could be used to comply with the requirements of the final rule when an APF of 10 is specified. For this FEA, OSHA has judged that half of workers in general industry and maritime who need respirators with an APF of 10 would use a disposable N95 respirator and that half would use an elastomeric reusable half-face respirator.

The unit equipment costs for each type of respirator are presented in Table V-9 below. OSHA estimates that, in general industry or maritime, an employee who needs respiratory protection will need such protection every workday. The employer could choose to supply disposable N95 respirators, which the employee would replace every day but which would need no cleaning or additional accessories, or reusable elastomeric half-mask respirators, which can be used for two years but which will require weekly cleaning and additional accessories[20] that will need to be replaced regularly.

[20] OSHA's respirator costs are based on estimates of the annual costs of respirator use derived in an earlier study (ERG, 2003). These costs include not only the purchase cost of the respirator itself, but the ancillary costs of accessories (e.g., filters) and other costs associated with respirator cleaning and required training and fit testing. The 2003 estimates were based on a unit cost of $3.57 for a replacement pair of filters for half-mask negative-pressure air-purifying respirators. These were extrapolated to an annual cost

Table V-9: Respirator Unit and Annualized Costs in General Industry and Maritime

Equipment	Disposable Filtering Face-Piece	Elastomeric Half-Mask Respirator	Elastomeric Full-Face Respirator
Equipment Cost (each)	$1.05	$32.74	$269.78
Equipment Service Life (years)	1	2	2
Annualized Equipment Cost	$1.05	$17.11	$140.99
Accessory Cost	0	$295.52	$295.52
Accessory Service Life (years)	1	1	1
Annualized Accessory Cost	$0.00	$295.52	$295.52
Total Annualized Equipment	$1.05	$312.63	$436.51
No. per year	250	1	1
Total Annualized Cost	**$262.92**	**$312.63**	**$436.51**

Source: OSHA, Directorate of Standards and Guidance, Office of Regulatory Analysis, based on OSHA (2016).

Workers who are provided with reusable respirators will need to clean those respirators. OSHA estimates that this will happen weekly and take five minutes (0.08 hours) of the worker's time. On a yearly basis this will cost $103.14 for a worker in general industry or maritime who uses a non-disposable respirator. These costs are shown below in Table V-10.

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of $285.52 per year, assuming that the filters would be changed 80 times a year.

In the PEA cost analysis, respirator costs from the 2003 study were used, but inflated from 2003 to 2009 dollars using the implicit price deflator for this period. For this FEA, those costs have again been adjusted for inflation to 2012 dollars resulting in an annual cost for filters of $295.52. Research conducted for the PEA showed that filter prices have not, in fact, increased since 2003, and might well have declined, at least for the N95 particulate filters used for silica protection. Thus, it is possible that OSHA has overestimated the cost for accessories for reusable respirators in this FEA.

Table V-10: Respirator Cleaning Costs in General Industry and Maritime（non-disposable

Cleaning Frequency per year	50
Time (hours)	0.08
Loaded employee wage	$24.75
Yearly cost	$103.14

Source: OSHA, Directorate of Standards and Guidance, Office of Regulatory Analysis, based on OSHA (2016) and BLS (2012b).

The final cost component of a respiratory protection program is training workers in respiratory hazards and in the proper use of respiratory protection. OSHA estimates that this training will take two hours and that it will be provided by a supervisor to a group of four employees at a time. The total per-employee cost for training on respiratory hazards and respirator use will be equal to two hours of the worker's wage plus one half hour of the supervisor's wage (two hours of supervisor time total divided among four workers). The unit costs for this training are shown below in Table V-11.

Table V-11: Respirator Training Costs in General Industry and Maritime

Class size	4
Training hours	2
Loaded employee wage	$24.75
Loaded supervisor wage	$40.38
Cost per employee	**$69.70**

Source: OSHA, Directorate of Standards and Guidance, Office of Regulatory Analysis, based on OSHA (2016) and BLS (2012b).

The total annualized costs for respirators in general industry are shown below in Table V-12.

Table V-12: Total Annualized Costs for Respirators (Excluding Programmatic Costs)
in General Industry and Maritime

	Disposable Filtering Facepiece	Elastomeric Half-Mask Respirator	Elastomeric Full-Face Respirator
Equipment	$262.92	$312.63	$436.51
Fit testing, training, & cleaning [a]	$104.55	$207.69	$207.69
Total	**$367.46**	**$520.32**	**$644.20**

[a] Cleaning applies to reusable elastomeric respirators only

Source: OSHA, Directorate of Standards and Guidance, Office of Regulatory Analysis, based on OSHA (2016) and BLS (2012b).

For this FEA, OSHA estimates that respirators will be required: (1) for all workers that the Agency's technological feasibility analysis has determined will require respirator use; and (2) for ten percent of the remaining workers currently exposed above 50 μg/m^3 at covered workplaces.[21]

This is a change in methodology from the PEA, where OSHA estimated the percentage of workers requiring respirators in an industry as either (1) or (2), whichever was larger. The Agency believes that the FEA formula, which results in higher estimates of respirator usage, is more accurate in that it reflects the combined effects of (1) and (2) whereas the earlier methodology did not. The number of workers that this FEA estimates will need respirators is presented below in Table V-13.[22]

Table V-13 below also aggregates unit costs and the number of workers estimated to be wearing respirators and calculates the costs for providing equipment, the programmatic costs associated with respirator use, and the total costs to each industry for the respiratory protection requirements. The total cost for respiratory protection increased from about $6.9 million in the PEA to about $10.5 million in the FEA. While the number of workers estimated to be exposed over the PEL of 50 μg/m^3 decreased from the PEA to the FEA,

[21] This additional 10 percent is designed to cover circumstances in which engineering controls do not reduce exposure levels to the extent anticipated by the technological feasibility analysis (e.g., because controls are not selected, used, or maintained properly).

[22] Table V-13 denotes, in the "Required by Tech. Feas." column, the number of workers requiring respirators as indicated by the technological feasibility analysis and, in the "Others" column, the remaining workers OSHA estimates will need respirators (10 percent of remaining workers with exposures currently above the PEL of 50 μg/m^3). For example, if an industry has 100 at-risk workers, and the technological feasibility analysis indicates that 20 workers will require respirators, OSHA would estimate that 10 percent of the remaining 80 workers (or 8) would also require respirators, for a total of 28. The row for that industry would display 20 in the "Required by Tech. Feas." column and 8 in the "Others" column.

the number of workers estimated to be wearing respirators increased from about 12,000 to about 31,000 workers. This is due to the changes in the way OSHA estimated the extent of respirator use, as previously described. In fact, much of the increase in respirator use from the PEA to the FEA can be explained by an increase in OSHA's estimate of the number of employees using respirators in NAICS 327320 Ready-mix Concrete Manufacturing (as a result of longer-duration exposures estimated in the technological feasibility analysis).

Table V-13: Annualized Respirator and Program Costs for Employers in General Industry and Maritime Affected by OSHA's Silica Standard

NAICS	Industry	No. of Respirator Users: Currently Exposed Above 50 μg/m³	Required by Tech. Feas.	Others	Total	Annualized Respirator Costs [a]	Annualized Program Costs	Total Cost
213112	Support Activities for Oil and Gas Operations	11,207	11,207	0	11,207	$236,240	$143,503	**$379,743**
324121	Asphalt Paving Mixture and Block Manufacturing	48	0	5	5	$2,112	$67	**$2,179**
324122	Asphalt Shingle and Coating Materials Manufacturing	1,410	0	141	141	$62,602	$1,437	**$64,039**
325510	Paint and Coating Manufacturing	386	0	39	39	$17,151	$424	**$17,575**
327110	Pottery, Ceramics, and Plumbing Fixture Manufacturing	2,496	0	250	250	$110,785	$2,814	**$113,598**
327120	Clay Building Material and Refractories Manufacturing	3,198	1,607	159	1,766	$906,855	$18,296	**$925,152**
327211	Flat Glass Manufacturing	126	87	4	91	$46,980	$864	**$47,844**
327212	Other Pressed and Blown Glass and Glassware Manufacturing	386	263	12	275	$142,214	$2,974	**$145,188**
327213	Glass Container Manufacturing	394	268	13	280	$144,866	$2,638	**$147,503**
327320	Ready-Mix Concrete Manufacturing	19,941	5,377	1,456	6,833	$3,444,238	$96,334	**$3,540,572**
327331	Concrete Block and Brick Manufacturing	2,045	481	156	638	$319,875	$7,886	**$327,761**
327332	Concrete Pipe Manufacturing	1,130	266	86	352	$176,707	$4,098	**$180,805**
327390	Other Concrete Product Manufacturing	6,216	1,463	475	1,939	$972,426	$22,298	**$994,723**
327991	Cut Stone and Stone Product Manufacturing	5,243	0	524	524	$232,750	$7,028	**$239,778**
327992	Ground or Treated Mineral and Earth Manufacturing	1,152	0	115	115	$51,147	$1,281	**$52,428**
327993	Mineral Wool Manufacturing	457	301	16	316	$163,401	$3,239	**$166,640**
327999	All Other Miscellaneous Nonmetallic Mineral Product Manufacturing	1,687	0	169	169	$74,875	$1,910	**$76,785**
331110	Iron and Steel Mills and Ferroalloy Manufacturing	93	6	9	14	$6,758	$144	**$6,902**
331210	Iron and Steel Pipe and Tube Manufacturing from Purchased Steel	23	1	2	3	$1,645	$33	**$1,678**

Table V-13: Annualized Respirator and Program Costs for Employers in General Industry and Maritime Affected by OSHA's Silica Standard (continued)

NAICS	Industry	No. of Respirator Users: Currently Exposed Above 50 μg/m³	Required by Tech. Feas.	Others	Total	Annualized Respirator Costs [a]	Annualized Program Costs	Total Cost
331221	Rolled Steel Shape Manufacturing	7	0	1	1	$504	$10	**$514**
331222	Steel Wire Drawing	13	1	1	2	$915	$18	**$933**
331314	Secondary Smelting and Alloying of Aluminum	5	0	0	1	$346	$7	**$353**
331420	Copper Rolling, Drawing, Extruding, and Alloying	19	1	2	3	$1,354	$27	**$1,380**
331492	Secondary Smelting, Refining, and Alloying of Nonferrous Metal (except Copper and Aluminum)	10	1	1	1	$703	$14	**$717**
331511	Iron Foundries	6,876	1,128	575	1,702	$841,876	$16,723	**$858,599**
331512	Steel Investment Foundries	962	333	63	396	$201,119	$3,905	**$205,024**
331513	Steel Foundries (except Investment)	3,275	537	274	811	$400,990	$8,077	**$409,068**
331524	Aluminum Foundries (except Die-Casting)	656	94	56	150	$73,692	$1,555	**$75,247**
331529	Other Nonferrous Metal Foundries (except Die-Casting)	404	58	35	92	$45,402	$1,017	**$46,419**
332111	Iron and Steel Forging	21	1	2	3	$1,544	$31	**$1,575**
332112	Nonferrous Forging	5	0	1	1	$396	$8	**$404**
332117	Powder Metallurgy Part Manufacturing	7	0	1	1	$523	$10	**$533**
332119	Metal Crown, Closure, and Other Metal Stamping (except Automotive)	47	3	4	7	$3,398	$67	**$3,465**
332215	Metal Kitchen Cookware, Utensil, Cutlery, and Flatware (except Precious) Manufacturing	6	0	1	1	$474	$9	**$483**
332216	Saw Blade and Handtool Manufacturing	25	1	2	4	$1,790	$35	**$1,826**
332323	Ornamental and Architectural Metal Work Manufacturing	16	0	2	2	$714	$21	**$735**
332439	Other Metal Container Manufacturing	10	1	1	2	$753	$15	**$767**
332510	Hardware Manufacturing	23	1	2	4	$1,705	$34	**$1,739**
332613	Spring Manufacturing	13	1	1	2	$952	$19	**$970**
332618	Other Fabricated Wire Product Manufacturing	22	1	2	3	$1,582	$31	**$1,613**
332710	Machine Shops	216	13	20	33	$15,768	$308	**$16,077**

Table V-13: Annualized Respirator and Program Costs for Employers in General Industry and Maritime Affected by OSHA's Silica Standard (continued)

NAICS	Industry	No. of Respirator Users: Currently Exposed Above 50 μg/m³	Required by Tech. Feas.	Others	Total	Annualized Respirator Costs [a]	Annualized Program Costs	Total Cost
332812	Metal Coating, Engraving (except Jewelry and Silverware), and Allied Services to Manufacturers	1,654	0	165	165	$73,413	$1,930	**$75,344**
332911	Industrial Valve Manufacturing	31	2	3	5	$2,289	$46	**$2,335**
332912	Fluid Power Valve and Hose Fitting Manufacturing	31	2	3	5	$2,227	$46	**$2,273**
332913	Plumbing Fixture Fitting and Trim Manufacturing	7	0	1	1	$486	$10	**$496**
332919	Other Metal Valve and Pipe Fitting Manufacturing	13	1	1	2	$914	$18	**$933**
332991	Ball and Roller Bearing Manufacturing	20	1	2	3	$1,447	$30	**$1,476**
332996	Fabricated Pipe and Pipe Fitting Manufacturing	26	2	2	4	$1,919	$38	**$1,957**
332999	All Other Miscellaneous Fabricated Metal Product Manufacturing	68	4	6	10	$4,730	$94	**$4,825**
333318	Other Commercial and Service Industry Machinery Manufacturing	48	3	5	7	$3,501	$70	**$3,571**
333413	Industrial and Commercial Fan and Blower and Air Purification Equipment Manufacturing	21	1	2	3	$1,550	$31	**$1,580**
333414	Heating Equipment (except Warm Air Furnaces) Manufacturing	16	1	1	2	$1,155	$23	**$1,177**
333511	Industrial Mold Manufacturing	31	2	3	5	$2,261	$44	**$2,306**
333514	Special Die and Tool, Die Set, Jig, and Fixture Manufacturing	38	2	4	6	$2,748	$54	**$2,802**
333515	Cutting Tool and Machine Tool Accessory Manufacturing	25	2	2	4	$1,826	$36	**$1,861**
333517	Machine Tool Manufacturing	21	1	2	3	$1,561	$31	**$1,592**
333519	Rolling Mill and Other Metalworking Machinery Manufacturing	10	1	1	2	$749	$15	**$764**
333612	Speed Changer, Industrial High-Speed Drive, and Gear Manufacturing	14	1	1	2	$1,033	$21	**$1,053**
333613	Mechanical Power Transmission Equipment	14	1	1	2	$998	$20	**$1,017**

Table V-13: Annualized Respirator and Program Costs for Employers in General Industry and Maritime Affected by OSHA's Silica Standard (continued)

NAICS	Industry	No. of Respirator Users: Currently Exposed Above 50 μg/m³	No. of Respirator Users: Required by Tech. Feas.	No. of Respirator Users: Others	No. of Respirator Users: Total	Annualized Respirator Costs [a]	Annualized Program Costs	Total Cost
333911	Pump and Pumping Equipment Manufacturing	30	2	3	5	$2,171	$44	**$2,214**
333912	Air and Gas Compressor Manufacturing	19	1	2	3	$1,363	$27	**$1,391**
333991	Power-Driven Handtool Manufacturing	8	0	1	1	$570	$12	**$582**
333992	Welding and Soldering Equipment Manufacturing	14	1	1	2	$1,015	$21	**$1,036**
333993	Packaging Machinery Manufacturing	18	1	2	3	$1,284	$25	**$1,309**
333994	Industrial Process Furnace and Oven Manufacturing	10	1	1	1	$707	$14	**$721**
333995	Fluid Power Cylinder and Actuator Manufacturing	21	1	2	3	$1,554	$32	**$1,586**
333996	Fluid Power Pump and Motor Manufacturing	9	1	1	1	$678	$14	**$691**
333997	Scale and Balance Manufacturing	3	0	0	1	$238	$5	**$243**
333999	All Other Miscellaneous General Purpose Machinery Manufacturing	45	3	4	7	$3,308	$66	**$3,374**
334519	Other Measuring and Controlling Device Manufacturing	31	2	3	5	$2,234	$45	**$2,279**
335210	Small Electrical Appliance Manufacturing	10	0	1	1	$425	$10	**$435**
335221	Household Cooking Appliance Manufacturing	12	0	1	1	$539	$13	**$552**
335222	Household Refrigerator and Home Freezer Manufacturing	11	0	1	1	$485	$11	**$497**
335224	Household Laundry Equipment Manufacturing	5	0	1	1	$230	$6	**$235**
335228	Other Major Household Appliance Manufacturing	11	0	1	1	$469	$11	**$480**
336111	Automobile Manufacturing	55	3	5	9	$4,027	$89	**$4,117**
336112	Light Truck and Utility Vehicle Manufacturing	50	3	5	8	$3,631	$81	**$3,712**
336120	Heavy Duty Truck Manufacturing	27	2	3	4	$1,973	$43	**$2,017**
336211	Motor Vehicle Body Manufacturing	36	2	3	5	$2,604	$53	**$2,657**
336212	Truck Trailer Manufacturing	25	1	2	4	$1,819	$37	**$1,856**
336213	Motor Home Manufacturing	7	0	1	1	$475	$10	**$485**
336310	Motor Vehicle Gasoline Engine and Engine Parts Manufacturing	46	3	4	7	$3,388	$70	**$3,458**
336320	Motor Vehicle Electrical and Electronic Equipment Manufacturing	44	3	4	7	$3,212	$66	**$3,278**

Table V-13: Annualized Respirator and Program Costs for Employers in General Industry and Maritime Affected by OSHA's Silica Standard (continued)

NAICS	Industry	No. of Respirator Users: Currently Exposed Above 50 μg/m³	Required by Tech. Feas.	Others	Total	Annualized Respirator Costs [a]	Annualized Program Costs	Total Cost
336330	Motor Vehicle Steering and Suspension Components (except Spring) Manufacturing	25	2	2	4	$1,841	$38	**$1,879**
336340	Motor Vehicle Brake System Manufacturing	19	1	2	3	$1,403	$28	**$1,432**
336350	Motor Vehicle Transmission and Power Train Parts Manufacturing	51	3	5	8	$3,741	$78	**$3,819**
336370	Motor Vehicle Metal Stamping	71	4	7	11	$5,202	$106	**$5,308**
336390	Other Motor Vehicle Parts Manufacturing	107	6	10	17	$7,837	$160	**$7,997**
336611	Ship Building and Repairing	1,823	0	182	182	$80,914	$1,909	**$82,823**
336612	Boat Building	472	0	47	47	$20,958	$506	**$21,464**
336992	Military Armored Vehicle, Tank, and Tank Component Manufacturing	10	1	1	1	$708	$15	**$723**
337110	Wood Kitchen Cabinet and Countertop Manufacturing	86	0	9	9	$3,806	$115	**$3,921**
337215	Showcase, Partition, Shelving, and Locker Manufacturing	29	2	3	5	$2,146	$42	**$2,189**
339114	Dental Equipment and Supplies Manufacturing	1,983	0	198	198	$88,005	$2,279	**$90,284**
339116	Dental Laboratories	864	0	86	86	$38,353	$1,306	**$39,658**
339910	Jewelry and Silverware Manufacturing	2,434	1	243	245	$108,645	$3,077	**$111,723**
339950	Sign Manufacturing	163	0	16	16	$7,230	$208	**$7,438**
423840	Industrial Supplies Merchant Wholesalers	591	591	0	591	$307,575	$8,417	**$315,992**
444110	Home Centers	41	0	4	4	$1,827	$39	**$1,867**
482110	Rail transportation	0	0	0	0	$0	$0	**$0**
561730	Landscaping Services	12,612	0	1,261	1,261	$559,849	$18,481	**$578,330**
621210	Offices of Dentists	237	0	24	24	$10,511	$446	**$10,958**
	Totals	**94,526**	**24,170**	**7,036**	**31,206**	**$10,103,887**	**$389,819**	**$10,493,706**

[a] Includes equipment, training, fit testing, and cleaning costs.

Source: OSHA, Directorate of Standards and Guidance, Office of Regulatory Analysis, based on OSHA (2016).

Exposure Assessment Costs

Overview of regulatory requirement

Section 1910.1053 of the final standard applies to employers engaged in general industry or maritime activities, and paragraph (d) requires those employers to assess the exposure of each employee who "is or may reasonably be expected to be exposed to respirable crystalline silica at or above the action level." Employers may either follow a performance option (as specified in paragraph (d)(2)) or a scheduled monitoring option (as specified in paragraph (d)(3)). For the performance option, the employer must assess the 8-hour TWA exposure for each employee on the basis of any combination of air monitoring data or objective data sufficient to accurately characterize employee exposures to respirable crystalline silica. For the scheduled monitoring option (termed the "periodic" monitoring option in the proposal), the employer must perform initial monitoring to assess the 8-hour TWA exposure for each employee on the basis of one or more personal breathing zone (PBZ) air samples that reflect the exposures of employees on each shift, for each job classification, in each work area. Where several employees perform the same job tasks on the same shift and in the same work area, the employer may sample a representative fraction of these employees in order to meet this requirement. In representative sampling, the employer must sample the employee(s) who are expected to have the highest exposure to respirable crystalline silica.

Under the scheduled monitoring option, requirements for periodic monitoring depend on the results of initial monitoring. If the initial monitoring indicates that employee exposures are below the action level, no further monitoring is required. If the most recent exposure monitoring reveals employee exposures to be at or above the action level but at or below the PEL, the employer must repeat monitoring within six months of the most recent monitoring. If the most recent exposure monitoring reveals employee exposures to be above the PEL, the employer must repeat monitoring within three months of the most recent monitoring.

Under paragraph (d)(4), employers must reassess exposures whenever a change in the production, process, control equipment, personnel, or work practices may reasonably be expected to result in new or additional exposures at or above the action level, or when the employer has any reason to believe that new or additional exposures at or above the action level have occurred. Also, paragraph (d)(5) requires employers to ensure that samples taken are evaluated in accordance with the procedures in Appendix A of the final standard.

In addition, paragraph (d)(6) requires the employer to individually notify each affected employee in writing of the results of an exposure assessment conducted in accordance with paragraph (d) of this section or post the results in an appropriate location accessible to all affected employees. Paragraph (d)(7) provides for the right of an employee-designated representative to observe any exposure monitoring.

PEA cost estimates

In the PEA, OSHA estimated that establishments performing exposure monitoring would require the assistance of an outside consulting industrial hygienist (IH) to obtain accurate results because the testing protocols were judged to be too challenging for firms to adequately perform using their own staff. OSHA also estimated in the PEA that, on average, there are four workers per work area.

In the PEA, OSHA conservatively estimated exposure monitoring costs by assuming all employers would follow the scheduled monitoring option, rather than the performance option, to comply with proposed paragraph (d). While this likely resulted in an overestimation of costs because the scheduled monitoring option has more stringent requirements than the performance option, OSHA chose to be conservative because of insufficient data about how many employers would choose the performance option. OSHA's initial cost estimates in the PEA were based on the employer selecting the regularly scheduled exposure monitoring option and conducting the initial exposure assessment by testing one worker in each distinct job classification within each work area, who is, or may reasonably be expected to be, exposed to airborne concentrations of respirable crystalline silica at or above the action level.

In addition to the initial exposure monitoring, OSHA estimated, for costing purposes, that exposure monitoring would be conducted (a) twice a year where initial or subsequent exposure monitoring reveals that employee exposures are at or above the action level but at or below the PEL, and (b) four times a year where initial or subsequent exposure monitoring reveals that employee exposures are above the PEL. For the PEA, OSHA judged that approximately 15 percent of workers whose initial exposure or subsequent monitoring was at or above the action level would require resampling due to a change in production, process, control equipment, personnel, or work practices that may reasonably be expected to result in new or additional exposures at or above the action level.

Further, OSHA estimated in the PEA that an IH would spend one day, at a cost of $500, to obtain the following number of PBZ samples: 2 for establishments with fewer than 20 employees; 6 for establishments with 20-499 employees; and 8 for establishments with 500 or more employees. In addition, OSHA estimated that analysis of each sample would cost $133.38 in lab fees and shipping costs. When combined with the IH fee, the cost per PBZ sample was projected to range from $195.88 to $383.38 (depending on establishment size).

In the PEA, the Agency indicated that it was not aware of any published studies presenting data on the frequency with which employee-designated representatives observe exposure monitoring but stated its belief that in some cases union officials are given the opportunity to observe monitoring at no direct cost to the employer. For these reasons, in the PEA, OSHA included no additional cost for this provision.

Other costs taken in the PEA were unit costs stemming from lost productivity during exposure sampling. OSHA estimated a 30-minute loss in employee time while attaching the pump and a 15-minute loss for the time required for recordkeeping, which includes recording the sampling results and notifying the employee of the sampling results. The loss in employee time was multiplied by an average employee hourly wage rate, including fringe benefits, to estimate the associated cost. The recordkeeping time was multiplied by a manager's hourly wage rate, including fringe benefits, to estimate the associated costs. Overall, in the PEA, OSHA estimated that unit costs would range from approximately $224.94 to $412.44 per sample. The Agency also conservatively estimated that no establishments in general industry or maritime were currently conducting exposure monitoring and assumed no current compliance with the proposed exposure monitoring requirements, as OSHA had no data about the number of establishments in general industry or maritime currently conducting exposure monitoring for respirable crystalline silica.

Comments and responses on exposure monitoring

General Methodology

OSHA received a number of comments on the costs of exposure monitoring, with some commenters stating that OSHA had underestimated costs in the PEA and others stating that OSHA had overestimated costs.

Commenters disagreed with OSHA's estimate of 15 percent of workers requiring reassessment. In particular, in his testimony, Jack Waggener, speaking for URS, testified that:

> For the periodic monitoring, OSHA, who we believe is unrealistically low, assumed that 15 percent of the workers would be over the action level and that no worker would be over the PEL. We expect many

> people to be over the PEL and many more people to be over the action level (Document ID 3582, Tr. 2019).

OSHA believes that Mr. Waggener simply misunderstood the Agency's methodology here. OSHA estimated that there would be an additional 15 percent of those at or over the action level performing additional testing due to a change in production, process, control equipment, personnel, or work practices that may reasonably be expected to result in new or additional exposures at or above the action level. OSHA was not suggesting that only 15 percent of worker exposures would be over the action level and none over the PEL.

Additionally, the American Foundry Society (AFS) asserted that the percentage of exposure sampling should be increased by 25 percent for reassessment based on experience (Document ID 2379, Attachment 3, p. 35). OSHA does not have strong evidence to dispute the AFS estimate, so the Agency has adopted AFS's 25 percent estimate for this FEA.

Under paragraph (d)(7) of the final rule, the employer must provide any required PPE at no cost to the observer. One commenter, the Korte Company, asserted that OSHA had omitted the cost of PPE for an employee's designated representative during observation of monitoring "without regards to whether or not the representative is trained or qualified to be wearing the required PPE" (Document ID 3230, p.1). While the Korte Company is in construction, the Agency believes this issue could also arise in general industry and maritime and therefore will address it here as well as in the construction section of this chapter. In response, OSHA would like to make several points. The final rule contains requirements for regulated areas in general industry and maritime, and these requirements include the provision of an appropriate respirator to authorized persons—including persons present to observe monitoring—in a regulated area.

Therefore, OSHA has already included respirator costs for observation of monitoring as part of regulated area costs. In most cases, observation of monitoring is expected to occur during the set-up and at the end of the exposure monitoring—outside of the regulated area, where a respirator is not required. Furthermore, in most cases, designated representatives have experience in observing monitoring—often in the presence of chemicals for which respirators would be required; therefore, the designated representatives would be expected to be trained and qualified to wear a respirator. For these reasons, OSHA has not included additional exposure monitoring costs for PPE during observation of monitoring.

Alternatives to hiring an industrial hygienist

In the PEA, OSHA estimated that employers would incur the cost of hiring an industrial hygienist to perform all necessary sampling. However, some commenters noted that there were less costly alternatives to hiring an outside IH consultant to conduct exposure monitoring.

A number of commenters suggested that the silica sampling could instead be conducted by in-house personnel. Kellie Vazquez, from Holes, Incorporated (a construction contractor), testified that the company she represented has done exposure monitoring using in-house personnel for some tasks its workers perform (Document ID 3580, Tr. 1411), while Andrew O'Brien from the National Industrial Sand Association (NISA) reported that "many NISA member companies [have] found that it is more cost-effective for them to train particular staff, and acquire the relevant equipment, than it is to hire consultants" (Document ID 3414, p. 10-11). Dr. Franklin Mirer, from the AFL-CIO, reported that General Motors has "a union rep who does all the air sampling," that at Johnson Controls hourly workers are performing exposure monitoring, and that, in his opinion, "the regular kind of facility management safety rep can do [exposure monitoring] as well" (Document ID 3578, Tr. 985-986). Dr. Mirer noted that while OSHA's exposure monitoring costs are "correctly derived from estimates of traditional consultant IH measurements, paying professional wages," employers could reduce costs by having "trained production or maintenance personnel, employed at the production facility, collect the samples" (Document ID 2256, Attachment 3, p. 12).

NISA urged OSHA to model costs for firms that choose to perform exposure monitoring using in-house personnel (Document ID 2195, p. 24), noting that the cost of doing so was not significant:

> …even the two largest companies [that NISA surveyed on this issue], one of which is publicly-held, regard these costs as sufficiently minor that the companies, which rigorously track all elements of their operating costs, do not bother to track the employee costs associated with dust exposure monitoring (Document ID 2195, p. 23).

Mr. O'Brien stated that "some percentage of OSHA-regulated establishments can and will internalize the function [of air monitoring]" and that the ability of firms to perform monitoring in-house is not an issue of business or establishment size. Mr. O'Brien directed OSHA to a document on the NISA website that could assist firms in performing air monitoring in-house[23] (Document ID 3414, pp. 10-11). Mr. O'Brien also testified that NISA has a three-day program to train workers to become qualified to do exposure sampling (not restricted to silica sampling) (Document ID 3577, Tr. 609).

Some commenters also suggested that when conducting the sampling in-house, employers could further reduce costs by utilizing less-expensive dust monitoring, as opposed to exposure monitoring specifically for respirable crystalline silica. Under this approach, if the content of dust in the air was less than the action level, an employer could then conclude that the respirable crystalline silica content would also be below the action level. Dr. Mirer suggested that "real-time aerosol monitor[ing] combined with area samples for silica would enable source identification, real-time results, knowing the overexposure within minutes of when it happened rather than waiting for the lab results to come back" and that "rather than do full shift sampling at each station," employers can "take area samples for silica, and then … use a dust monitor at each position to look at what the mass [of dust] is, apply the silica content, and you've got [the content of respirable crystalline silica]" (Document ID 3578, Tr. 941-942, 1004).

Robert Scholz, from TRC Consulting, testified that respirable dust monitors are commercially available and that if the silica content of the dust was known, then one could calculate exposures. Mr. Scholz also noted that these methods have been used by the foundry industry for twenty years and have become more widely used in the last ten years (Document ID 3584, Tr. 2738-9), while Scott Schneider, from the Laborers' Health and Safety Fund of North America, testified that respirable dust monitors are "becoming more useful, easier, and less expensive, and could be used" for defining a regulated area or on a job site. (Document ID 3589, Tr. 4264).

OSHA acknowledges that it might be more cost effective for firms to comply with the exposure monitoring requirement by using in-house personnel or by following the performance option and using less expensive general respirable dust monitoring, and that the Agency's assumption that all affected firms will comply by following the scheduled monitoring option and hiring consulting industrial hygienists will likely result in an overestimation of the cost of compliance.[24] However, OSHA does not have sufficient data in the rulemaking record regarding how many employers may choose to perform

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[23] The document referenced is "Occupational Health Program for Exposure to Crystalline Silica in the Industrial Sand Industry", submitted as Document ID 2195, Appendix B. The document was accessed by OSHA staff on April 21, 2015 and does contain instructions for collection of exposure samples.

[24] Employers may comply with the exposure monitoring requirements of the standard by utilizing dust monitoring instead of silica monitoring only if they are following the performance option under section (d)(2) and treating the result as objective data. If employers are following the scheduled monitoring option, as this cost section assumes, then under section (d)(5), they must follow Appendix A and utilize a method that tests for respirable crystalline silica content.

monitoring in-house, with or without the use of commercially available dust monitoring, or how much those alternatives would cost. For example, even if a significant number of employers attempted in-house monitoring, it is not clear how many of those would need to provide additional training to their employees who would conduct the sampling, or how often those conducting the less expensive dust monitoring would need to incur additional costs when the silica content of the dust was not already known. Thus, OSHA was not able to make an accurate determination regarding the share of firms that would comply using other methods, or the cost involved in doing so. Because of this, OSHA is taking the more conservative approach and assuming that employers will follow the scheduled monitoring option for exposure monitoring. It should be noted, however, that the final standard does not preclude employers from utilizing other methods in order to comply with this provision when following the performance option under paragraph (d)(2).

Cost of an industrial hygienist

Having concluded that the final estimates will be based on the use of an industrial hygienist, the Agency turns now to the cost of that service. OSHA received a large number of comments on its estimate in the PEA that an IH would spend one day, at a cost of $500, to set up and collect up to eight PBZ samples. Many of the commenters critical of OSHA's cost estimates provided alternative estimates of their own, but these estimates ranged widely, as did the assumptions underlying them. Most of the comments discussed below are from general industry, but relevant comments from construction have been included as well.

First of all, some commenters took issue with the assumption of establishments hiring outside IH consultants to conduct the exposure assessments. Andrew O'Brien, from the NISA, stated that "NISA's member companies conduct exposure assessments using in-house personnel" (Document ID 3414, p. 10). OSHA recognizes that establishments may employ an in-house IH or an in-house IH technician to conduct the monitoring. However, there will be other establishments that do not, and OSHA is attempting to estimate an average cost across all establishments while erring on the side of overestimating rather than underestimating costs. Kellie Vazquez, from Holes Incorporated, stated that OSHA's costs were too low and that she would need to hire an industrial hygienist and provide a company vehicle at a total cost over $100,000 per year (Document ID 2338, p. 4). OSHA notes that the final rule does not specify that the exposure monitoring be performed by employees of a regulated employer. An employer could choose the less expensive option between hiring an IH employee and contracting with an IH consultant.

In terms of using an IH consultant, Franklin Mirer of the AFL-CIO stated that "the monitoring costs are correctly derived from estimates of traditional consultant IH measurements, paying professional wages" (Document ID 2256, Attachment 3, p. 8). The Precast/Prestressed Concrete Institute (PCI), estimated:

> the cost of a single one-day monitoring visit by an industrial hygienist, assuming 8 hours on site, 3 hours for preparation, 5 hours for report writing, and 4 hours for travel, would be at least $1,000 plus $100-$150 for the laboratory costs[25] (Document ID 2276, p. 9).

The American Foundry Society (AFS) commented that "[t]he industrial hygienist cost is closer to $1700 per day rather than $500 as estimated by OSHA in the PEA" (Document ID 2379, Appendix 3, p. 22). The AFS included consultant fees, travel time, and pump rental in its estimate. Christopher Norch, from Denison Industries and testifying on behalf of the AFS, noted that it cost one foundry $3,000 for one day of sampling by a consultant (Document ID 3584, Tr. 2678).

The American Subcontractors Association, a national trade association representing subcontractors, specialty trade contractors, and suppliers in the construction industry, reported that "retaining an industrial hygienist to conduct such monitoring would cost between $1,500 and $2,500 per day (Document ID 2187, p. 5).

The Asphalt Roofing Manufacturers Association asserted that OSHA's estimate of the costs to comply with this provision was unreasonably low because, among other things:

- The estimate includes only the cost of a base level IH technician to collect the samples. It does not take into account oversight costs and project planning or project management by a consultant CIH [certified industrial hygienist].
- The costs for travel and other reasonable project expenses are not included.
- The costs for IH consultant reports are not included.
- The costs for developing IH employee letters for those who participated in sampling were not included (Document ID 2291, p. 19).

Dr. Ronald Bird, on behalf of the Chamber of Commerce, similarly commented that OSHA omitted:

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[25] OSHA notes that laboratory costs have been separately estimated, so they should not be included in estimates of IH costs.

> . . . costs of preparation for sampling, including research regarding past monitoring results, if any, and qualitative inspection of the facility, processes and materials used to identify work areas susceptible to exposure, analyzing workers task similarities and other factors relevant to grouping workers for air sampling purposes . . . (Document ID 2368, p. 12).

These criticisms of OSHA's estimates were echoed by the Independent Petroleum Association of America, which estimated a cost of $2,500 per day for a visit by an IH to conduct sampling, including the IH's travel, salary, equipment, and report-preparation costs. These estimates were based on "[average] survey response by hydraulic fracturing companies for per day cost of IH visit to [hydraulic fracturing] site (remoteness premium)" (Document ID 2301, Attachment 3, tab Exposure Assessment Factors and Exposure Assessment Costs). The IPAA further noted that:

> Where a static industry may be expected to be located within reasonable proximity to infrastructure and services required to comply with the ancillary provisions, hydraulic fracturing operations typically are not. Members of the Associations have reported that hiring an industrial hygienist to conduct exposure monitoring at a hydraulic fracturing site has four to six times as much per day [$2,000 to $3,000] as OSHA has estimated [$500] would be required for a stationary industry within a reasonable distance to a metropolitan area (Document ID 2301, p. 73).[26]

URS Corporation, on behalf of ACC, commented that OSHA underestimated costs of a CIH because the Agency omitted additional time "for the CIH to draw conclusions based on the sampling and to write reports," which URS Corporation estimated would take an additional day (Document ID 2307, Attachment 8, p. 20).

OSHA has interpreted URS's cost model to yield an IH exposure monitoring cost of $3,200, consisting of two days at $1,600 a day (including $100 a day for travel). Relatedly, in post-hearing comments on behalf of the ACC, Environomics reported that it had

> increased the estimated costs for exposure assessment by increasing the unit cost estimate for an industrial hygienist to visit a site for exposure sampling, and by reducing the average number of overexposed employees that would likely be sampled during a single site sampling visit (thus projecting more sampling visits as necessary to assess exposure for all

[26] The bracketed costs were added by OSHA for clarity.

> General Industry employees suspected of being exposed above the PEL) (Document ID 4015, p. 52).

To summarize, the Agency received IH cost estimates from commenters of $500 or less (AFL-CIO and NISA), $1,000 (PCI), $1,700 (AFS, with $3,000 reported by one foundry), $2,000 (an average calculated for ASA-reported range), $2,500 (an average calculated for IPAA), and $3,200 (URS/ACC). These various cost estimates reflect important differences in assumptions concerning IH qualifications and expertise (from an IH technician to an IH to a CIH); the duration of IH exposure monitoring to obtain up to eight samples, including report writing (1 day versus more than 1 day); and possible related IH expenses (particularly travel-related costs).

In addition, during the comment period, OSHA had its contractor, ERG, conduct telephone interviews with seven industrial hygiene consultants to obtain better estimates of the costs associated with exposure monitoring.[27] In a memorandum from ERG to OSHA, dated May 28, 2014, summarizing the interview results, ERG concluded from the interviewee comments that written reports may be needed to identify potential sources of exposure, that IH labor costs would apply to the preparation of sampling reports, and that it is common practice for a single IH (or field technician) to collect up to 8 full-shift samples and prepare a report in a single day (Document ID 3767). Averaging over the seven IH consultant interviewees, ERG reported that they estimated a minimum labor cost of $1,813 and a maximum labor cost of $2,411—or an average labor cost of $2,112 per day of sampling, including report writing. In addition to these summary costs, OSHA found two statements in the ERG report to be critical:

> One of the consultants stated that sampling costs are typically highest during the "discovery phase," such as characterization of a new site or facility or compliance with a new rulemaking, and that sampling costs are generally lower for routine periodic monitoring (Document ID 3767, p. 2).

Along the same lines, ERG also reported that an IH technician is often used "to perform routine sampling at well characterized sites; however, for new or complex operations, a certified industrial hygienist (CIH) might be needed" (Document ID 3767, p. 2).

These two statements help explain the wide variation in cost estimates submitted by commenters. In effect, commenters appear to be estimating costs for exposure

[27] Interview questions included the price range for a typical sampling project and report, labor costs for sample collection and report, other costs such as sample analysis and equipment rental, and regional differences in costs, for example for firms with office locations in different parts of the country, among others.

monitoring under two entirely different sets of circumstances: (1) initial monitoring during the "discovery phase" or for sites that have not previously been well characterized (in terms of being evaluated for purposes of exposure monitoring); and (2) routine periodic monitoring at sites that have previously been well characterized. Accordingly, OSHA has concluded that the best way to categorize the estimates provided in the comments is to provide two estimates of exposure monitoring costs in this FEA: one for initial monitoring and one for periodic monitoring.

Based on the comments received in the record, and recognizing that the highest estimate may be worst case estimates and not representative of average costs, OSHA has decided to significantly increase its estimate from $500 (in the PEA) to $2,500 for an IH consultant to perform initial exposure monitoring or to perform at sites that have not previously been well characterized. OSHA derived this cost estimate by taking ERG's estimate (developed from its interviews) of approximately $2,100 for sampling and report-writing and adding to it approximately $400 to cover IH travel time and travel expenses. To estimate travel time, because this was not accounted for in the PEA, OSHA obtained supplemental information on the General Service Administration (GSA) government-consulting hourly rate schedule for CIHs and other IH professionals.[28] The GSA hourly consulting rate for CIHs in 2012 was $144.20, and GSA mileage and lodging reimbursement rates in 2012 were $0.56 per mile and $77 per night.[29] Assuming two hours of travel time at $288.40, $56 for 100 miles of travel, and one night in a hotel at $77, these travel costs amount to approximately $421. This is likely an overestimate because many CIHs will not have to travel as far as 100 miles roundtrip or stay in a hotel, so OSHA rounded down from $421 to $400 for travel costs. To corroborate the $2,100 amount for sampling and report-writing, OSHA divided $2,100 by the CIH hourly rate of $144.20, resulting in approximately 14.5 hours, which OSHA judges to be a reasonable estimate of the time a CIH would spend on these activities. Thus, this estimated IH cost would include necessary IH travel time, travel expenses, and report preparation and would cover 2, 6, and 8 PBZ samples per day for small, medium, and large establishments, respectively. This estimate is broadly within the range of estimates from commenters when the lowest ones have been excluded. Again, this cost represents an average, and the Agency expects that some establishments' costs will be higher, but others lower (including those employers that have IH staff).

[28] Values reported here are for 2012 and are loaded for IH compensation and overhead. https://www.gsaadvantage.gov/ref_text/GS10F0091T/0K3PG4.2DOSEL_GS-10F-0091T_GSAWEBDOC12262011UPDATEFINAL.PDF

[29] Values reported here are for 2012 and available at http://www.gsa.gov/portal/content/103969 and http://www.gsa.gov/portal/category/100120.

To estimate the cost of routine periodic monitoring at sites that have previously been well characterized, OSHA judged that the IH labor time required would be approximately 75 percent of the time required for initial monitoring, or approximately 11 hours, since the sampling protocol would have already been established and that the daily rate for an IH or IH technician would be approximately 2/3 of the CIH hourly rate.[30] Based on these judgments, OSHA estimates that the IH periodic exposure monitoring costs would be approximately $1,250, or half of the $2,500 estimate.[31] This cost would cover 2, 6, and 8 PBZ samples per day for small, medium, and large establishments, respectively. This estimate is broadly within the range of estimates from commenters when the highest ones have been excluded.

OSHA notes that the cost estimates per sample under both circumstances reflect the fact that there are some economies of scale in obtaining exposure samples.

For purposes of estimating exposure monitoring unit costs in general industry and maritime, OSHA has applied the $2,500 cost estimate for IH services to all exposure monitoring at hydraulic fracturing sites (where the worksite is not fixed and has not been previously characterized) and to all initial monitoring. OSHA has applied the $1,250 cost estimate for IH services to scheduled or repeated exposure monitoring at fixed sites in general industry and maritime (thus, excluding hydraulic fracturing sites). In the construction sector, the $2,500 cost estimate for IH services applies to all exposure monitoring since the worksite is not fixed and has not been previously characterized.

Laboratory fees

Based on the 2000 EMSL Laboratory Testing Catalog, which was the source used for the PEA, OSHA estimated that analysis of each sample will cost $140.27 (adjusted to 2012 dollars by OSHA (2016)) in lab fees and shipping costs. This is roughly consistent with the laboratory costs estimate of $100-$150 offered by the Precast/Prestressed Concrete Institute (Document ID 2276, p. 9). NISA also submitted cost estimates from five NISA member companies that showed a cost per sample ranging from $49 to $129 for "analytics," which is lower than OSHA's estimate (Document ID 4008, Attachment 3, p. 1). Given these fairly consistent ranges of cost, OSHA is again using the same cost in

[30] This latter judgment is buttressed by the supplemental information on GSA rates that OSHA obtained. The GSA hourly rates in 2012 for an IH and for an IH technician II are 74 percent and 48 percent, respectively, of the corresponding rate for a CIH. https://www.gsaadvantage.gov/ref_text/GS10F0091T/0K3PG4.2DOSEL_GS-10F-0091T_GSAWEBDOC12262011UPDATEFINAL.PDF

[31] This is based on 75 percent of the time, or 3/4, times 2/3 of the hourly rate. (3/4)*(2/3) = 1/2.

constant dollars that it did in the PEA because the EMSL catalog represents a published cost from a widely used laboratory.[32]

OSHA also again notes the comments promoting the use of commercially available dust-monitoring equipment discussed above. While the use of this equipment in practice would likely reduce the number of samples that would be sent to laboratories, meaning that OSHA's estimate of the laboratory fee costs is an overestimate, any cost reductions would result from a combination of factors such as whether the silica content of the dust is known and how many employers would use these devices. OSHA did not find sufficient information in the record to determine what the reduction in laboratory expenses would be if some employers used dust-monitoring equipment. Furthermore, under the scheduled monitoring option, employers would need to comply with the laboratory requirements in Appendix A. OSHA is therefore, for cost purposes, taking a conservative approach and assuming that employers would follow the scheduled monitoring option instead of the performance option and pay the laboratory fee for each sample.

When the laboratory fee is combined with the IH fee, the direct cost per PBZ sample in general industry and maritime is projected to range from $296.52 to $1,390.27—depending on establishment size, purpose of exposure monitoring (initial or periodic), and industry type (hydraulic fracturing or not). This is an increase from the range of $195.88 to $383.38 estimated in the PEA.

Other unit costs

OSHA did not receive comment on the other exposure monitoring unit costs in the PEA and has retained them in the FEA. These include the costs to reflect a 30-minute loss in employee time while attaching the pump and the 15 minutes required for recordkeeping, including recording the sampling results and notifying the employee of the sampling results. The only difference was that these costs were updated to 2012 dollars. The loss in employee time was multiplied by the employee's hourly wage rate, including fringe benefits, to estimate the associated cost. The recordkeeping time was multiplied by a manager's hourly wage rate, including fringe benefits, to estimate the associated costs.

Summary of updated unit costs

[32] Because of the age of the original data source, ERG obtained supplemental information by contacting EMSL Laboratory, Galson Labs, and Analytics Corporation (all AIHA-accredited). ERG found the current cost estimates to average close to the original estimates in constant dollars, while noting that shipping costs per sample will vary with the number of samples and with the urgency of delivery.

For this FEA, OSHA developed separate cost estimates for (1) initial monitoring or any exposure monitoring at hydraulic fracturing sites and (2) scheduled monitoring at fixed sites (which excludes hydraulic fracturing). Costs under (2) were estimated to be lower because the exposure monitoring is expected to be of shorter duration (possibly obviating an overnight stay) and could be conducted by a lower-cost IH or IH technician rather than by a CIH. For initial monitoring or any exposure monitoring at hydraulic fracturing sites, the total unit cost of an exposure sample is estimated to range from $483.89 to $1,421.39 (depending on establishment size). For periodic monitoring in general industry and maritime, excluding hydraulic fracturing sites, the total unit cost of an exposure sample is estimated to range from $327.64 to $796.39 (depending on establishment size).

Overall, in the FEA, OSHA estimated that the total unit costs[33] of an exposure sample in general industry and maritime would range from approximately $327.64 to $1,421.39—depending on establishment size, purpose of exposure monitoring (initial or periodic), and industry type (hydraulic fracturing or not). This is an increase from the range of $224.94 to $412.44 estimated in the PEA.

Aside from updating the costs to reflect 2012 dollars, the only changes to the unit costs of exposure monitoring in general industry and maritime are due to the increased unit cost of a PBZ sample based on the increased cost to hire an IH consultant, as explained above. Table V-14 shows the unit costs and associated assumptions used to estimate the cost of an exposure assessment in general industry and maritime.

Table V-14
Exposure Assessment - General Industry and Maritime
Assumptions and Unit Costs
Coverage: All employees exposed above action level

Costs and Parameters	Comments/Assumptions

[33] Total unit costs include the direct costs (lab fee plus industrial hygienist fee) plus recordkeeping costs and worker productivity loss.

Direct Costs by Establishment Size	Small (<20)	Medium (20-499)	Large (500+)	
Initial Monitoring				
IH fees/PBZ sample	$1,250.00	$416.67	$312.50	Consulting CIH - cost per sample. Assumes IH fee of $2,500 for 2, 6, and 8 samples for small, medium, and large
Scheduled Monitoring - HF sites (also construction)				
	$1,250.00	$416.67	$312.50	Consulting CIH - cost per sample. Assumes IH fee of $2,500 for 2, 6, and 8 samples for small, medium, and large
Scheduled Monitoring - Fixed sites: General Industry & Maritime (HF excluded)				
	$625.00	$208.33	$156.25	Fee per sample. Assumes IH charges for periodic monitoring at fixed sites of one-half of the cost for initial monitoring ($1,250); for 2, 6, and 8 samples for small, medium, and large
Lab Fees and shipping cost	$140.27	$140.27	$140.27	Lab fees per sample (EMSL Laboratory, 2000) and OSHA estimates. Inflated to 2012 values.
Total - per PBZ sample - Initial	$1,390.27	$556.94	$452.77	
Total - per PBZ sample - HF	$1,390.27	$556.94	$452.77	
Total - per PBZ sample - Scheduled, fixed sites (Gen Ind and Maritime, except	$765.27	$348.60	$296.52	
Requirements				
Number of workers per work area	4			ERG assumption
Initial Monitoring	1			Based on requirements in standard

Table V-14 (continued)
Exposure Assessment - General Industry and Maritime
Assumptions and Unit Costs
Coverage: All employees exposed above action level

Costs and Parameters				**Comments/Assumptions**
Scheduled Monitoring Frequency (per year)				
Exposed < Action Level	0			Based on requirements in standard
Exposed <PEL and >AL	2			Based on requirements in standard
Exposed >PEL	4			Based on requirements in standard
Percentage of workers requiring reassessment	25.0%			Revised estimate based on comments
Time Requirements				
Lost production time while pump Is attached to worker	30			ERG assumption
Recordkeeping by a manager per sample	15			Includes employee notification of monitoring results
Unit Costs by				
	Small (<20)	Medium (20-499)	Large (500+)	
Cost per sample (PBZ) - Initial Monitoring for Gen Ind and Maritime and All Monitoring for HF				
Direct Costs	$1,390.27	$556.94	$452.77	
Productivity Loss	$12.38	$12.38	$12.38	Based on average production worker wage, adjusted for benefits (BLS, 2012b)
Recordkeeping	$18.74	$18.74	$18.74	Based on HR manager's wage rate, adjusted for benefits (BLS, 2012b)
Total	$1,421.39	$588.06	$483.89	

Table V-14 (continued)
Exposure Assessment - General Industry and Maritime
Assumptions and Unit Costs
Coverage: All employees exposed above action level

Costs and Parameters				Comments/Assumptions
Cost per sample (PBZ) - Scheduled Monitoring, General Industry & Maritime, except HF				
Direct Costs	$765.27	$348.60	$296.52	
Productivity Loss	$12.38	$12.38	$12.38	Based on average production worker wage, adjusted for benefits (BLS, 2012b)
Recordkeeping	$18.74	$18.74	$18.74	Based on HR manager's wage rate, adjusted for benefits (BLS, 2012b)
Total	$796.39	$379.72	$327.64	
Cost per sample (PBZ) - Scheduled Monitoring, Hydraulic Fracturing				
Direct Costs	$1,390.27	$556.94	$452.77	
Productivity Loss	$12.38	$12.38	$12.38	Based on average production worker wage, adjusted for benefits (BLS, 2012b)
Recordkeeping	$18.74	$18.74	$18.74	Based on HR manager's wage rate, adjusted for benefits (BLS, 2012b)
Total	$1,421.39	$588.06	$483.89	

Source: OSHA, Directorate of Standards and Guidance, Office of Regulatory Analysis, based on OSHA (2016).

Number of Exposure Samples Taken Annually

For costing purposes, based on OSHA (2016) and as estimated in the PEA, OSHA estimated that, on average, there are four workers per work area. OSHA interpreted the initial exposure assessment as requiring initial testing of at least one worker in each distinct job classification and work area who is, or may reasonably be expected to be, exposed to airborne concentrations of respirable crystalline silica. In the FEA, as in the PEA, OSHA used the scheduled monitoring option under the exposure monitoring requirements to estimate, for costing purposes, that exposure monitoring will be conducted (a) twice a year where initial or subsequent exposure monitoring reveals that employee exposures are at or above the action level but at or below the PEL, and (b) four times a year where initial or subsequent exposure monitoring reveals that employee exposures are above the PEL.

As required under paragraph (d)(4) of the rule, whenever there is a change in the production, process, control equipment, personnel, or work practices that may result in new or additional exposures at or above the action level or when the employer has any reason to suspect that a change may result in new or additional exposures at or above the action level, the employer must conduct additional monitoring. As previously addressed in this section, OSHA has estimated in this FEA that for workers whose initial exposure or subsequent monitoring was at or above the action level, 25 percent annually would require an additional sample under section (d)(4) because of a change in work conditions.

To summarize OSHA's estimate of exposure monitoring frequency in general industry and maritime, each "representative" worker will receive initial monitoring. If the initial sampling results are below the action level, then no more exposure monitoring for that representative worker is estimated to take place in the initial year or in subsequent years. If the initial sampling results are not below the action level or above the PEL, then the representative worker will receive exposure monitoring an average of 2 times every year starting with the initial year, and 25 percent of these workers, on average, will require an additional sample be taken annually because of changing work conditions. If the initial sampling results are above the PEL, then the representative worker will receive exposure monitoring an average of 4 times every year starting with the initial year, and 25 percent of these workers, on average, will require an additional sample be taken annually because of changing work conditions.[34]

[34] This may be an overestimate in that, under the performance option, an employer may decide that continued monitoring does not serve to better characterize employee exposure. In these cases, as long as the air monitoring data continues to accurately characterize employee exposure, employers can use the existing data to meet their exposure assessment obligations without collecting more recent data.

OSHA notes that the National Association of Manufacturers (NAM) argued that in order to "demonstrate results meeting the 95 percent confidence limit […] it would be necessary to take 20 or more samples under substantially identical conditions" (Document ID 2380, Attachment 2, p. 17). OSHA disagrees with NAM's justification for the extensive sampling and has discussed the 95-percent-confidence-interval issue in greater detail in the Summary and Explanation section of the preamble concerning general industry and maritime compliance with the PEL. OSHA therefore retained its determination from the PEA that employers would not need to repeat sampling in order to achieve any particular confidence level.

Current Compliance

The AFL-CIO commented that OSHA's costs for exposure monitoring assumed that employers are not already conducting exposure monitoring, and contended that OSHA thus overestimated the costs of compliance because those employers would not need to spend the estimated amount to comply with the new exposure monitoring requirements (Document ID 2256, Attachment 4, pp. 1 and 5). Dr. Ruth Ruttenberg, speaking on behalf of the AFL-CIO, noted that the preliminary initial regulatory flexibility analysis (PIRFA) included an existing compliance assumption of 32.6 percent that was removed in the PEA (Document ID 2256, Attachment 4, p. 5). The PIRFA compliance assumption was based on 1988 National Occupational Exposure Survey (NOES) data, which presented a wide range of percentages and which OSHA concluded were somewhat unreliable. After weighing comment from the SBAR panel, OSHA determined it was prudent not to include baseline compliance estimates in the PEA based on NOES data and instead to await evidence to be submitted on this issue. Unfortunately, such evidence was not submitted to the record. The Agency agrees that it is very likely that some employers already conduct exposure monitoring, but concludes that there is not sufficient evidence in the record as to how many establishments currently conduct exposure monitoring. Therefore, for costing purposes for the FEA, as in the PEA, OSHA has conservatively assumed no current compliance with the exposure monitoring requirements.

Conclusion

Based on the unit costs of exposure monitoring presented in Table V-14, OSHA provides, in Table V-15, the estimated annual exposure monitoring costs for general industry and maritime, by NAICS industry and size of establishment, for the final rule. As shown, the combined costs of the exposure monitoring requirements for general industry and maritime are an estimated $79.8 million annually.

Table V-15: Annual Exposure Monitoring Costs: General Industry and Maritime

NAICS	Industry	At-Risk Employees Total	At-Risk Employees ≥25 μg/m³	At-Risk Employees > 50 μg/m³ (respirator `	Initial Assessment	Scheduled Assessment	Total Assessment Costs
213112	Support Activities for Oil and Gas Operations	16,960	13,819	11,207	$324,079	$8,721,562	**$9,045,642**
324121	Asphalt Paving Mixture and Block Manufacturing	4,737	48	5	$132,976	$26,745	**$159,722**
324122	Asphalt Shingle and Coating Materials Manufacturing	3,158	3,158	141	$60,973	$1,168,605	**$1,229,578**
325510	Paint and Coating Manufacturing	2,511	515	39	$51,648	$208,385	**$260,034**
327110	Pottery, Ceramics, and Plumbing Fixture Manufacturing	6,269	3,989	250	$130,511	$1,615,153	**$1,745,664**
327120	Clay Building Material and Refractories Manufacturing	7,893	4,915	1,766	$155,347	$2,373,115	**$2,528,462**
327211	Flat Glass Manufacturing	221	134	91	$3,854	$70,129	**$73,983**
327212	Other Pressed and Blown Glass and Glassware Manufacturing	674	411	275	$13,020	$236,865	**$249,885**
327213	Glass Container Manufacturing	686	419	280	$11,883	$216,410	**$228,292**
327320	Ready-Mix Concrete Manufacturing	27,123	20,690	6,833	$758,718	$13,863,007	**$14,621,725**
327331	Concrete Block and Brick Manufacturing	7,182	2,902	638	$173,306	$1,547,382	**$1,720,688**
327332	Concrete Pipe Manufacturing	3,967	1,603	352	$89,285	$797,772	**$887,058**
327390	Other Concrete Product Manufacturing	21,832	8,821	1,939	$485,014	$4,334,250	**$4,819,265**
327991	Cut Stone and Stone Product Manufacturing	9,429	6,794	524	$247,637	$3,505,876	**$3,753,513**
327992	Ground or Treated Mineral and Earth Manufacturing	5,432	2,798	115	$116,024	$1,140,409	**$1,256,434**
327993	Mineral Wool Manufacturing	789	489	316	$14,879	$271,321	**$286,200**
327999	All Other Miscellaneous Nonmetallic Mineral Product Manufacturing	7,952	4,096	169	$173,500	$1,704,871	**$1,878,371**
331110	Iron and Steel Mills and Ferroalloy Manufacturing	594	186	14	$9,139	$56,456	**$65,595**

Table V-15: Annual Exposure Monitoring Costs: General Industry and Maritime (continued)

NAICS	Industry	At-Risk Employees Total	At-Risk Employees ≥ 25 $\mu g/m^3$	At-Risk Employees > 50 $\mu g/m^3$ (respirators users)	Initial Assessment	Scheduled Assessment	Total Assessment Costs
331210	Iron and Steel Pipe and Tube Manufacturing from Purchased Steel	145	45	3	$2,365	$14,592	**$16,956**
331221	Rolled Steel Shape	44	14	1	$752	$4,640	**$5,393**
331222	Steel Wire Drawing	81	25	2	$1,376	$8,486	**$9,863**
331314	Secondary Smelting and Alloying of Aluminum	30	10	1	$525	$3,238	**$3,763**
331420	Copper Rolling, Drawing, Extruding, and Alloying	119	37	3	$2,005	$12,365	**$14,370**
331492	Secondary Smelting, Refining, and Alloying of Nonferrous Metal (except Copper and [illegible]	62	19	1	$1,051	$6,482	**$7,533**
331511	Iron Foundries	13,583	10,089	1,702	$233,669	$3,699,754	**$3,933,423**
331512	Steel Investment Foundries	5,487	1,729	396	$91,640	$645,574	**$737,214**
331513	Steel Foundries (except Investment)	6,469	4,805	811	$110,727	$1,753,311	**$1,864,039**
331524	Aluminum Foundries (except Die-Casting)	5,601	1,727	150	$110,439	$676,957	**$787,396**
331529	Other Nonferrous Metal Foundries (except Die-Casting)	3,451	1,064	92	$71,774	$439,640	**$511,414**
332111	Iron and Steel Forging	136	42	3	$2,298	$14,175	**$16,473**
332112	Nonferrous Forging	35	11	1	$575	$3,547	**$4,122**
332117	Powder Metallurgy Part Manufacturing	46	14	1	$793	$4,889	**$5,682**
332119	Metal Crown, Closure, and Other Metal Stamping (except Automotive)	299	93	7	$5,106	$31,489	**$36,595**
332215	Metal Kitchen Cookware, Utensil, Cutlery, and Flatware (except Precious)	42	13	1	$697	$4,297	**$4,993**
332216	Saw Blade and Handtool Manufacturing	157	49	4	$2,670	$16,467	**$19,137**
332323	Ornamental and Architectural Metal Work Manufacturing	40	21	2	$988	$10,380	**$11,368**
332439	Other Metal Container Manufacturing	66	21	2	$1,122	$6,919	**$8,040**

Table V-15: Annual Exposure Monitoring Costs: General Industry and Maritime (continued)

NAICS	Industry	At-Risk Employees Total	At-Risk Employees ≥ 25 μg/m^3	At-Risk Employees > 50 μg/m^3 (respirators users)	Initial Assessment	Scheduled Assessment	Total Assessment Costs
332510	Hardware Manufacturing	150	47	4	$2,513	$15,503	**$18,017**
332613	Spring Manufacturing	84	26	2	$1,434	$8,844	**$10,278**
332618	Other Fabricated Wire Product Manufacturing	139	43	3	$2,388	$14,723	**$17,111**
332710	Machine Shops	1,387	433	33	$23,892	$147,316	**$171,208**
332812	Metal Coating, Engraving (except Jewelry and Silverware), and Allied Services	4,113	2,205	165	$92,930	$978,702	**$1,071,632**
332911	Industrial Valve Manufacturing	201	63	5	$3,373	$20,805	**$24,178**
332912	Fluid Power Valve and Hose Fitting Manufacturing	196	61	5	$3,164	$19,527	**$22,691**
332913	Plumbing Fixture Fitting and Trim Manufacturing	43	13	1	$707	$4,362	**$5,069**
332919	Other Metal Valve and Pipe Fitting Manufacturing	80	25	2	$1,359	$8,382	**$9,742**
332991	Ball and Roller Bearing Manufacturing	127	40	3	$2,073	$12,793	**$14,866**
332996	Fabricated Pipe and Pipe Fitting Manufacturing	169	53	4	$2,873	$17,720	**$20,593**
332999	All Other Miscellaneous Fabricated Metal Product	405	131	10	$7,032	$44,788	**$51,820**
333318	Other Commercial and Service Industry Machinery	308	96	7	$5,113	$31,548	**$36,661**
333413	Industrial and Commercial Fan and Blower and Air Purification Equipment Manufacturing	136	43	3	$2,323	$14,324	**$16,647**
333414	Heating Equipment (except Warm Air Furnaces)	102	32	2	$1,751	$10,794	**$12,545**
333511	Industrial Mold Manufacturing	199	62	5	$3,408	$21,015	**$24,423**
333514	Special Die and Tool, Die Set, Jig, and Fixture Manufacturing	242	75	6	$4,139	$25,522	**$29,661**
333515	Cutting Tool and Machine Tool Accessory Manufacturing	161	50	4	$2,768	$17,066	**$19,834**
333517	Machine Tool Manufacturing	137	43	3	$2,331	$14,376	**$16,707**

Table V-15: Annual Exposure Monitoring Costs: General Industry and Maritime (continued)

NAICS	Industry	At-Risk Employees Total	At-Risk Employees ≥ 25 μg/m³	At-Risk Employees > 50 μg/m³ (respirators users)	Initial Assessment	Scheduled Assessment	Total Assessment Costs
333519	Rolling Mill and Other Metalworking Machinery Manufacturing	66	21	2	$1,118	$6,895	**$8,013**
333612	Speed Changer, Industrial High-Speed Drive, and Gear Manufacturing	91	28	2	$1,512	$9,329	**$10,842**
333613	Mechanical Power Transmission Equipment	88	27	2	$1,490	$9,189	**$10,679**
333911	Pump and Pumping Equipment Manufacturing	191	60	5	$3,181	$19,623	**$22,804**
333912	Air and Gas Compressor Manufacturing	120	37	3	$1,989	$12,271	**$14,260**
333991	Power-Driven Handtool Manufacturing	50	16	1	$819	$5,054	**$5,873**
333992	Welding and Soldering Equipment Manufacturing	89	28	2	$1,431	$8,833	**$10,264**
333993	Packaging Machinery Manufacturing	113	35	3	$1,924	$11,867	**$13,792**
333994	Industrial Process Furnace and Oven Manufacturing	62	19	1	$1,072	$6,610	**$7,682**
333995	Fluid Power Cylinder and Actuator Manufacturing	137	43	3	$2,247	$13,865	**$16,112**
333996	Fluid Power Pump and Motor Manufacturing	60	19	1	$992	$6,119	**$7,111**
333997	Scale and Balance	21	7	1	$361	$2,229	**$2,590**
333999	All Other Miscellaneous General Purpose Machinery	291	91	7	$4,905	$30,255	**$35,160**
334519	Other Measuring and Controlling Device	196	61	5	$3,265	$20,144	**$23,409**
335210	Small Electrical Appliance	24	13	1	$418	$4,395	**$4,813**
335221	Household Cooking Appliance Manufacturing	30	16	1	$479	$5,042	**$5,521**
335222	Household Refrigerator and Home Freezer Manufacturing	27	15	1	$408	$4,302	**$4,710**
335224	Household Laundry Equipment Manufacturing	13	7	1	$186	$1,959	**$2,145**

Table V-15: Annual Exposure Monitoring Costs: General Industry and Maritime (continued)

NAICS	Industry	At-Risk Employees Total	At-Risk Employees ≥ 25 μg/m³	At-Risk Employees > 50 μg/m³ (respirator users)	Initial Assessment	Scheduled Assessment	Total Assessment Costs
335228	Other Major Household Appliance Manufacturing	26	14	1	$389	$4,106	**$4,496**
336111	Automobile Manufacturing	354	111	9	$5,070	$31,359	**$36,428**
336112	Light Truck and Utility Vehicle Manufacturing	319	100	8	$4,548	$28,135	**$32,683**
336120	Heavy Duty Truck	174	54	4	$2,530	$15,643	**$18,173**
336211	Motor Vehicle Body	229	72	5	$3,789	$23,375	**$27,163**
336212	Truck Trailer Manufacturing	160	50	4	$2,611	$16,115	**$18,727**
336213	Motor Home Manufacturing	42	13	1	$629	$3,890	**$4,519**
336310	Motor Vehicle Gasoline Engine and Engine Parts	298	93	7	$4,745	$29,292	**$34,037**
336320	Motor Vehicle Electrical and Electronic Equipment Manufacturing	283	88	7	$4,566	$28,185	**$32,752**
336330	Motor Vehicle Steering and Suspension Components (except Spring) Manufacturing	162	51	4	$2,592	$16,000	**$18,592**
336340	Motor Vehicle Brake System Manufacturing	123	39	3	$2,030	$12,529	**$14,559**
336350	Motor Vehicle Transmission and Power Train Parts	329	103	8	$5,185	$32,019	**$37,205**
336370	Motor Vehicle Metal Stamping	458	143	11	$7,486	$46,198	**$53,684**
336390	Other Motor Vehicle Parts Manufacturing	689	215	17	$11,179	$68,994	**$80,172**
336611	Ship Building and Repairing	3,038	2,633	182	$47,275	$805,170	**$852,445**
336612	Boat Building	787	682	47	$15,459	$262,331	**$277,790**
336992	Military Armored Vehicle, Tank, and Tank Component Manufacturing	62	19	1	$954	$5,894	**$6,848**
337110	Wood Kitchen Cabinet and Countertop Manufacturing	223	114	9	$5,672	$56,882	**$62,553**
337215	Showcase, Partition, Shelving, and Locker Manufacturing	189	59	5	$3,204	$19,760	**$22,964**
339114	Dental Equipment and Supplies Manufacturing	4,956	1,983	198	$104,688	$841,119	**$945,808**
339116	Dental Laboratories	31,105	5,184	86	$928,104	$2,875,655	**$3,803,758**

Table V-15: Annual Exposure Monitoring Costs: General Industry and Maritime (continued)

NAICS	Industry	At-Risk Employees Total	At-Risk Employees ≥ 25 µg/m³	At-Risk Employees > 50 µg/m³ (respirators users)	Initial Assessment	Scheduled Assessment	Total Assessment Costs
339910	Jewelry and Silverware Manufacturing	6,772	2,455	245	$162,920	$1,184,301	**$1,347,221**
339950	Sign Manufacturing	384	217	16	$9,451	$105,001	**$114,453**
423840	Industrial Supplies Merchant Wholesalers	1,773	1,182	591	$49,584	$887,509	**$937,093**
444110	Home Centers	107	55	4	$1,907	$19,215	**$21,122**
482110	Rail transportation	0	0	0	$0	$0	**$0**
561730	Landscaping Services	43,033	24,747	1,261	$1,246,347	$13,748,117	**$14,994,46**
621210	Offices of Dentists	8,525	1,421	24	$328,394	$1,015,287	**$1,343,680**
	Totals	**277,949**	**141,594**	**31,206**	**$6,747,042**	**$73,003,69**	**$79,750,73**

Source: OSHA, Directorate of Standards and Guidance, Office of Regulatory Analysis, based on OSHA (2016).

Medical Surveillance Costs

OSHA requested comments on the estimated costs in the PEA, but the comments, which are addressed in the following discussion, did not provide a persuasive argument that the Agency should use alternative costs in its final estimates. Accordingly, based on the rationale provided in the PEA and consideration of the issues identified in the following discussion and the record as a whole, OSHA has decided to maintain the same unit cost structure and time requirements used in the PEA. The only change from the PEA to the FEA was to update unit costs from 2009 to 2012 dollars.

Explanation of Medical Surveillance Provision

Paragraph (i) of the final standard requires the employer to make medical surveillance available for each employee occupationally exposed to respirable crystalline silica at or above the action level of 25 $\mu g/m^3$ for 30 days or more per year. This is a change from the proposed standard, which required that employers make medical surveillance available only for workers exposed to respirable crystalline silica above the PEL of 50 $\mu g/m^3$. The Summary and Explanation section of the preamble on medical surveillance provides a discussion of the rationale for this change.

Medical surveillance will include an initial (baseline) medical examination and periodic examinations. The initial medical examination must be made available to the employee within 30 days after initial assignment, unless the employee has received an equivalent medical examination within the last three years. The periodic medical examination must be made available to the employee at least every three years, or more frequently if recommended by the physician or licensed health care professional (PLHCP).

In accordance with paragraph (i)(2) of the final standard, the initial medical examination will consist of (1) a medical and work history, (2) a physical examination with special emphasis on the respiratory system, (3) a chest x-ray interpreted and classified according to the International Labour Office (ILO) International Classification of Radiographs of Pneumoconioses by a NIOSH-certified B Reader, (4) a pulmonary function test administered by a spirometry technician with a current certificate from a NIOSH-approved course, (5) testing for latent tuberculosis (TB) infection, and (6) any other tests deemed appropriate by the PLHCP. In accordance with paragraph (i)(3) of the final standard, the contents of the periodic medical examinations are the same as those for the initial examination, with the exception that testing for latent tuberculosis infection is not required. However, consistent with what was done in the PEA (without subsequent comment), OSHA medical experts in the Office of Occupational Medicine and Nursing estimated that the PLHCP will recommend testing for latent tuberculosis during the periodic medical examination for 15 percent of workers in general industry and maritime (Document ID 1720, p. V-54).

Note that the relevant language in both the proposed and final rule requires "the employer to make medical surveillance available to each employee…" For costing purposes, in both the PEA and FEA, OSHA assumed that all eligible employees would take advantage of the medical surveillance made available by the employer. In fact, to the extent that this is not true, OSHA will have overestimated the cost to employers of the medical surveillance provision. As evidence illustrating less than 100 percent employee participation, the record includes a study of miner participation rates in medical surveillance programs indicating that participation over the time span of the study ranged from 25 percent to 41.7 percent (Document ID 3998, Attachment 15; see also Document ID 3587, Tr. 3616-3617).

PEA Estimates

As presented in the PEA (and shown in Table V-10 in the PEA), OSHA's medical experts in its Office of Occupational Medicine and Nursing provided estimates (in 2009 dollars) of the following medical costs: a complete medical and work history, a triennial review and updating of health history, a physical examination by a PLHCP, a chest x-ray, the classification of a chest x-ray by a NIOSH-certified B Reader, a pulmonary function test, an examination by a specialist (defined in the standard as an American Board Certified Pulmonary Disease or Occupational Medicine Specialist), other necessary tests (the medical experts estimated that these would likely be required by 10 percent of examined workers), and a latent TB test (Document ID 1720, p. V-51). OSHA also used the research and expertise of staff from its Office of Occupational Medicine and Nursing and from OSHA's contractor, ERG, to provide preliminary estimates in the PEA of how much time each medical activity would take. These estimates included, for the employee, 120 minutes for the health history survey and exam, including x-ray; 30 minutes to review and update the health history; 60 minutes for the physical exam and tests (including pulmonary function but excluding x-ray); 30 minutes for the chest x-ray; 5 minutes for the reading of the latent TB test (return visit to receive results); and 60 minutes for an examination by a specialist (Document ID 1720, pp. V-51-V-54).

The PEA also accounted for round-trip travel costs necessary to see an off-site physician. Off-site travel time for a worker in general industry or maritime was estimated to be 60 minutes for medical surveillance at any off-site location. OSHA further enumerated in the PEA the percentage of employees seeing an off-site physician by establishment size. For the initial examination, it was estimated that 80 percent of employees in small establishments (with fewer than 20 employees), 25 percent in medium-sized establishments (with 20 – 499 employees), and 0 percent in large establishments (with 500 or more employees) would see an off-site physician. For new hires, the percentages increase slightly to 90 percent of employees in small establishments, 50 percent in medium establishments, and 10 percent in large establishments. For general industry and maritime, OSHA also estimated a hiring rate[35] of 27.2 percent (utilizing 2008 data from the Bureau of Labor Statistics Job Openings and Labor Turnover Survey) and judged that 75 percent of new hires would require an initial health screening (the other 25 percent of new hires would have previous job experience covered by either silica standard such they would have had a compliant health screening within the prior three years). OSHA did not receive comment on this 75 percent estimate, other than from commenters questioning whether it accounted for persons who would not need to be re-screened, which it does). The initial screening for current employees was estimated to range in cost from $389.38 to $424.94 per employee, depending on establishment size, and the initial screening for new hires was estimated to range in cost from $393.82 to $429.38 per employee, again, depending on establishment size. The slightly higher initial screening costs for new hires relative to current employees is due, in the former case, to the larger percentage of off-site physician visits, which has associated added costs for travel time.

Comments and Responses on Medical Surveillance

Underestimation of Costs

A frequent criticism expressed by commenters was that OSHA had underestimated the costs associated with the medical surveillance provision. Some commenters, such as the National Precast Concrete Association, only asserted that OSHA's cost estimates for various provisions, including medical surveillance, were underestimated, without specifying any particular element of those costs or providing any alternative cost estimates (Document ID 2067, p. 4). Some commenters were more specific. John Burke, from OSCO Industries, Inc., commented that the "local cost of the required medical surveillance procedures [at] $185/annually is approximately one-half of the cost required to conduct the medical surveillance on one employee" (Document ID 1992, p. 7). The cost Mr. Burke was referring to was for a single worker (per small entity in NAICS 331511) in Table IX-1 of the PEA, but that was the *annualized* medical surveillance cost *for 2.2 workers* in a small foundry, not the unit cost for a single worker. The comparable OSHA cost estimate for an initial medical screening for a single current employee in a small (20-499 employee) establishment, as shown in Table V-10 (page V-53) of the PEA, was $384—which is larger than Mr. Burke's estimate of $370 (since $185 is one-half of

[35] In the PEA, OSHA in some cases referred to this rate as the separations rate, but in fact the Agency was using the hiring rate reported by BLS. Because the regulatory analysis is based on steady-state economic conditions, the separations rate, the hiring rate, and the turnover rate are effectively identical.

the required cost, according to Mr. Burke). George Kennedy, from the National Utility Contractors Association, commented that "the cost of a medical evaluation that meets the NPRM requirements ranges from $300 to $500 per employee plus hourly wages and travel costs" (Document ID 2171, p. 5).

The Portland Cement Association (PCA) provided detailed cost information on the components of the medical exam:

> The total minimum cost for the four medical tests is more than twice the estimated cost in the proposal; the average national cost to comply with the medical testing provisions for employees in a medical surveillance program contained in the proposed rule is more than five times the estimate provided to OSHA (Document ID 2284, p. 7).

The PCA utilized http://health.costhelper.com and www.newchoicehealth.com to source its estimates. Both sites appear to be privately-held information providers and not necessarily subject to public data standards for validity. OSHA disagrees with PCA's estimates based on a review of these sites by ERG, an OSHA contractor, which produced significantly different results, with low-end costs substantially less than the low end cited by PCA (ERG, 2015). Furthermore, the PCA comment seems to have drawn many of its cost estimates not from the "typical" costs given by the CostHelper website but from site user-submitted comments about what they had been billed for similar procedures. Characterizing these as if they capture nationally-representative ranges of costs is inaccurate.[36] It is noteworthy that PCA's estimates for medical surveillance were above the range put forward by all other commenters in both general industry (as discussed above) and in construction (as discussed in the construction medical surveillance cost section later in this chapter). Also, while a number of commenters argued that costs within a certain range were typical of their members or employees, PCA did not make that claim.

[36] From ERG (May 1, 2015): For example, the page for "X-Ray Cost" gives two different ranges for those without insurance and 19 different costs, including one for a chest x-ray. The costs that are cited are drawn from NewChoiceHealth.com, Berger Health System in Ohio, Baptist Memorial Health Care in Memphis, as well as user-submitted comments regarding what the user paid for a foot/hip/ankle X-ray and "CT abdomen with contrast." The estimate given by PCA as an "average national cost" ($370) appears to be the cost from NewChoiceHealth.com for a chest x-ray; it is not clear how the "minimum national cost" ($190) was derived, as this figure is not currently listed on the site. The "maximum national cost" ($5,300) might be based on the $5,200 cost submitted by user "Budde in Booneville, MS" for a CT abdomen with contrast, which is a significantly different (and more expensive) test than a chest x-ray.

For a pulmonary function test, CostHelper estimates the cost as "$40-$800 total," whereas the PCA comment gives the minimum as $490 and maximum as $4,500. The "maximum national cost" listed by PCA appears to have been derived from a comment by the user "SecondBreath in Boston, MA," who estimated the costs at $4,445.00, and went on to say "Gross charges before insurance discount. Same tests two months ago were $2,155. At an affiliated regional hospital same tests were around $800."

The Asphalt Roof Manufacturers Association (ARMA) commented that OSHA's costs in the PEA substantially underestimated the full cost for:

> (i) the exam, (ii) the time away from work for the employee to have the exam performed, (iii) backfill of the job position while the exam is performed, and (iv) recordkeeping. The cost for just the exam may approach as much as $500 to $700 per exam, depending on the region of the country. Of course, larger employers may be able to negotiate lower costs based on volume of exams needed [footnote reference added by OSHA] (Document ID 2291, p. 26).[37]

Similarly, Stephanie Salmon, from the American Foundry Society (AFS), submitted a table comparing the estimates presented in the PEA for medical surveillance to estimates from the AFS, stating that "[t]hose [medical surveillance costs] estimated by AFS are higher than those estimated by OSHA in the PEA" (Document ID 2379 Appendix 3, p. 23). OSHA is unable to comment on the individual ARMA and AFS estimates as they did not contain source or reference material. While OSHA cannot address the validity of the ARMA and AFS estimates, OSHA recognizes that there is a wide range of costs and fees per service. The cost estimates included in this FEA represent a midpoint in the range, as derived from a national database of Medicare reimbursement, plus 30 percent to compensate for the effect of Medicare discounts that are unlikely to apply to occupational medicine environments. While it is possible that costs in particular geographic areas (or as ARMA notes, for different-sized employers) may run higher or lower than the national average, no evidence was presented to suggest that OSHA's methodology for deriving a national estimate for workers and industries affected by the silica rule as a whole was flawed.

In addition, the National Rural Electric Cooperative Association (NRECA) submitted a cost estimate for initial health screenings for its members, arguing that "in the absence of objective air monitoring data, all employees may be subject to the establishment of an initial baseline examination" (Document ID 2365, p. 17). OSHA acknowledges that there will be many workers who meet the trigger for medical surveillance and will need initial medical examinations in the first year. However, employers in general industry or maritime excluded from the scope of the final rule based on objective data or whose employees' exposures will not meet or exceed the action level of 25 μg/m^3 for 30 or more days a year will not be subject to the medical surveillance requirements at all.

<u>Travel Time Estimates</u>

[37] OSHA notes that ARMA provided no cost information for the items (ii) through (iv) and that item (iii) is already reflected in item (ii). To see this latter point, consider that without the medical surveillance the employer would pay one employee for the work to be completed; with medical surveillance, the result is the same except that one more worker would have to be paid (not two more).

OSHA included an estimate in the PEA of 60 minutes of worker time for off-site travel to have a medical examination when required by the general industry and maritime standard. NRECA commented that:

> "[g]iven the rural nature of our members, the range used in OSHA's estimate is likely understated. More travel time and fewer medical personnel in rural area will increase this estimate in the case of rural electric cooperatives" (Document ID 2365, pp. 3 and 17).

The Agency's analysis examines the economic impact on all affected industries. The NRECA represents employers who comprise only a fraction of the energy generation and supply industry. While the Agency recognizes that there will be instances where the travel time for a particular worker at a rural worksite will be greater than the 60 minutes that OSHA has estimated in its unit costs, this estimate represents a national average for workers in general industry or maritime. Logically, more rural, geographically dispersed jobs are likely to require more travel time; this additional travel time is already offset in the average by the concentration of jobs in other areas with nearby medical services available where the travel time would be significantly less than 60 minutes. The commenter did not identify any other deficiencies in the estimate. Additionally, OSHA compared the travel estimate to that in previous rules. For example, OSHA's chromium rule did not have the travel component broken out but an initial medical exam was estimated at 3 hours which includes the exam, written opinion, and travel time. For silica, the estimate is 2 hours for the exam and 15 minutes for recordkeeping. Applying the same breakdown to chromium would leave 45 minutes for travel time. Given this review of the chromium rulemaking, OSHA concludes that it is likely being conservative and overestimating the amount of travel time necessary and will revisit the issue in future rulemakings. However, because the record was not further developed in this rulemaking, OSHA is not now reducing its estimate from the PEA.

OSHA also notes that one commenter, the National Federation of Independent Business (NFIB), said that one member reported that "his company requires workers to go to the doctor in pairs" (Document ID 2210, p. 8), which would increase lost worktime costs. However, the Agency believes this example is so unusual and unrepresentative of most business practices that lost worktime costs have not been revised to reflect this single example.

Current Compliance and Overlap with Respiratory Protection

Although OSHA believes that some affected establishments currently provide some medical testing to their silica-exposed employees (as evidenced by the comments from firms and industry associations on their current medical surveillance costs), the Agency doubts that many provide the comprehensive health screening required under the rule. For example, Dal-Tile commented that:

> Other OSHA regulations already require the facility to implement and maintain a Respiratory Protection Program (RPP). One component of an RPP is the requirement for every person who uses a respirator at any time during the year to ensure that they are physically capable of safely wearing the respirator. This is accomplished by requiring the employee to complete OSHA's Medical Questionnaire and submit it to a Doctor or other qualified occupational health care provider (Document ID 2147, p. 3).

The Dal-Tile comment notes the potential overlap of the respirator fitness evaluation required by OSHA's existing RPP requirement with the medical surveillance requirements of the final rule. In fact, the medical and work history required by the medical surveillance provisions of the final rule would also satisfy the respirator medical clearance required by the RPP, and a PLHCP report to the employer of the worker's fitness to wear a respirator. However, the Agency has conservatively ignored, in both the PEA and the FEA, any cost reduction for medical surveillance in the final rule arising from baseline compliance with the medical clearance requirement for respirator use.

Employee Turnover

In the PEA, OSHA estimated a hiring rate of 27.2 percent (utilizing 2008 data from the Bureau of Labor Statistics Job Openings and Labor Turnover Survey) and judged that 75 percent of new hires would require an initial health screening. As specified in paragraph (i)(2) of the rule, employees who had received a medical examination that meets the requirements of the rule within the previous three years will be exempt from the initial medical examination, so not all new hires will require initial medical testing. As noted earlier, OSHA estimated that 25 percent of new hires in general industry and maritime will be exempt from the initial medical examination.

A number of commenters noted that job turnover would affect the costs attributable to the medical surveillance requirement, because the final rule states that employees will not need an initial exam within 30 days of initial assignment if they have received a medical examination that meets the requirements of the rule within the last three years. For example, Dr. Ruth Ruttenberg, on behalf of the AFL-CIO, suggested that if no portability of medical records is assumed, "then there is an overestimation of cost for …medical surveillance" (Document ID 2256, Attachment 4, p. 5). Dr. Ruttenberg continued by stating that "when individuals leave their jobs, it does not mean that they leave their industry…Portability of training and medical surveillance will help avoid duplication of services" and reduce compliance costs to employers (Document ID 2256, Attachment 4,

p. 6). OSHA agrees that if an employee receives the required medical screening at one job, and then moves to a second job at which the employee would be covered by an OSHA silica standard, the second employer would not need to incur expenses for re-screening if it is within the time period specified in the standard. OSHA's cost estimates for medical surveillance in the FEA (and previously in the PEA) do avoid "duplication of services," consistent with the final rule. As noted earlier, OSHA did not receive comment on the accuracy of the 75 percent estimate. Hence, the Agency is retaining its estimate that 100 percent of current affected employees and 75 percent of new hires (based on the share of turnover associated with new hires to the industry) who meet the criteria for receiving medical surveillance, will be tested in the initial year after promulgation of this final rule.

Updated Unit Costs for FEA

Based on the preceding comments and the Agency's responses, OSHA has decided to maintain the same unit cost structure and time requirements used in the PEA, with the only changes being to update unit costs from 2009 to 2012 dollars.

With the assistance of its contractor, ERG, the Agency updated the information on representative unit costs of initial and periodic medical surveillance to 2012 dollars. Separate costs were estimated for current employees and for new hires as a function of employment size (i.e., 1-19, 20-499, or 500+) of affected establishments. Table V-16 presents the unit cost data and modeling assumptions used by OSHA to estimate medical surveillance costs.

As shown in Table V-16, the estimated unit cost of the initial health screening for current employees in general industry and maritime ranges from $414.97 to $434.78 and includes direct medical costs, the opportunity cost of worker time (i.e., lost work time, evaluated at the worker's 2012 hourly wage, including fringe benefits) for offsite travel and for the initial health screening itself, and recordkeeping costs. The variation in the unit cost of the initial health screening by establishment size is due entirely to differences in the percentage of workers expected to travel offsite for the health screening. In OSHA's experience, the larger the establishment, the more likely it is that the selected PLHCP would provide the health screening services at the establishment's worksite. As was done in the PEA, OSHA estimates that, on average, 20 percent of establishments with fewer than 20 employees, 75 percent of establishments with 20-499 employees, and 100 percent of establishments with 500 or more employees will have the initial health screening for current employees conducted onsite.

The unit cost components of the initial health screening for new hires in general industry and maritime are identical to those for existing employees with the exception that the percentage of workers expected to travel offsite for the health screening will be somewhat larger (due to fewer workers being screened annually, in the case of new hires, and therefore yielding fewer economies of onsite screening). OSHA estimates, on average, that 10 percent of establishments with fewer than 20 employees, 50 percent of establishments with 20-499 employees, and 90 percent of establishments with 500 or more employees will have the initial health screening for new hires conducted onsite. As shown in Table V-16, the estimated unit cost of the initial health screening for new hires in general industry and maritime ranges from $417.45 to $437.25.

Table V-16:
Medical Surveillance and TB Testing - General Industry
Assumptions and Unit Costs
Coverage: All employees exposed above action level

Screening Tool	Cost	Initial Screening	Periodic Screening	Comments/Assumptions
Direct Costs				
Complete medical and work history	$36.94	Yes	Yes	Assumed one third of physical exam cost
Periodic review and updating of health history	$36.94	NA	NA	Assumed one third of physical exam cost
Physical examination by knowledgeable PLHCP [a]	$110.83	Yes	Yes	Evaluation and office consultation including detailed examination ($100, inflated to 2012).
Chest X-ray [a]	$88.24	Yes	Triennial	Radiologic examination (a single posteroanterior radiographic projection) ($62.97; inflated to 2012). Costs include consultation and written report
Chest X-ray classified by a NIOSH-certified B Reader [a]	$43.44	Yes	Triennial	Average of three estimates made by B Readers to ERG, inflated to 2012
Pulmonary function test [a]	$60.62	Yes	Triennial	Spirometry, including reports showing graphical displays and numerical results for measurements of Forced Vital Capacity (FVC), Forced Expiratory Volume in One Second (FEV1), and FEV1/FVC ($43.26; inflated to 2012)
Examination by a specialist [b]	$210.89	Yes	NA	Office consultation and evaluation by a specialist ($158.07; inflated to 2012)
Other necessary tests	$66.50	Yes	Yes	Assumed required by 10 percent of workers ($60; inflated to 2012)

Table V-16: (continued)
Medical Surveillance and TB Testing - General Industry
Assumptions and Unit Costs
Coverage: All employees exposed above action level

Screening Tool	Cost	Initial Screening	Periodic Screening		Comments/ Assumptions
Latent TB Test [a]	$16.63				$15; inflated to 2012
Time Requirements for Medical Examinations (minutes)					
Travel time for off-site exam	60				
Complete medical and work history and exam, including x-ray	120				Per survey and exam
Health history review and update	30				Per review
Physical exam and tests (without x-ray)	60				Per exam
Chest x-ray	30				Per x-ray
Examination by a specialist	60				
Recordkeeping (initial and periodic screenings)	15				Average per screening
Recordkeeping (specialist referrals and recordkeeping)	60				Includes time for referrals
Percentage of employees seeing off-site physician by establishment size		-	-		
		Small (<20)	Medium (20-499)	Large (500+)	
Initial examination		80.0%	25.0%	0.0	
New hires		90.0%	50.0%	10.0	
Time requirements for TB Testing (minutes)					
Initial test	NA				Included in initial exam
Return for reading	5				
Travel Times (minutes) - off-site location					
Initial test	NA				Included in initial exam
Return for reading	60				

Table V-16: (continued)
Medical Surveillance and TB Testing - General Industry
Assumptions and Unit Costs
Coverage: All employees exposed above action level

Screening Tool	Cost	Initial Screening	Periodic Screening	Comments/ Assumptions
Hiring rate	25.0%			2012 annual hires rate for manufacturing industries. BLS, JOLTS
Share of turnover associated with new hires to the industry	75.0%			

Unit Costs	Establishment Size			
	Small (<20)	Medium (20-499)	Large (500+)	
Initial screening:				
Medical costs	$346.72	$346.72	$346.72	Including components specified above in "Direct Costs"
Lost work time - exam	$49.51	$49.51	$49.51	Based on average production worker wage, adjusted for benefits (BLS, 2012b)
Lost work time - travel	$19.80	$6.19	$0.00	Based on average production worker wage, adjusted for benefits (BLS, 2012b)
Record keeping	$18.74	$18.74	$18.74	Based on manager's wage rate, adjusted for benefits (BLS, 2012b)
Total	$434.78	$421.16	$414.97	
Initial screening: New hires				
Medical costs	$346.72	$346.72	$346.72	Including components specified above in "Direct Costs"
Lost work time - exam	$49.51	$49.51	$49.51	Based on average production worker wage, adjusted for benefits (BLS, 2012b)
Lost work time - travel	$22.28	$12.38	$2.48	Based on average production worker wage, adjusted for benefits (BLS, 2012b)

Table V-16: (continued)
Medical Surveillance and TB Testing - General Industry
Assumptions and Unit Costs
Coverage: All employees exposed above action level

Screening Tool	Cost	Initial Screening	Periodic Screening		Comments/ Assumptions
Record keeping		$18.74	$18.74	$18.74	Based on manager's wage rate, adjusted for benefits (BLS, 2012b)
Total		$437.25	$427.35	$417.45	
Triennial screening (with x-ray and pulmonary function test)					
Medical costs		$346.72	$346.72	$346.72	Including components specified above in "Direct Costs"
Lost work time - exam		$49.51	$49.51	$49.51	Based on average production worker wage adjusted for benefits (BLS, 2012b)
Lost work time - travel		$19.80	$6.19	$0.00	Based on average production worker wage, adjusted for benefits (BLS, 2012b)
Unit Costs		**Establishment Size**			
		Small (<20)	Medium (20-499)	Large (500+)	
Record keeping		$18.74	$18.74	$18.74	Based on manager's wage rate, adjusted for benefits (BLS, 2012b)
Total		$434.78	$421.16	$414.97	
Examination by pulmonary specialist					
Medical costs		$210.89	$210.89	$210.89	Including components specified above in "Direct Costs"
Lost work time – exam		$24.75	$24.75	$24.75	Based on average production worker wage adjusted for benefits (BLS, 2012b)
Lost work time – travel		$24.75	$24.75	$24.75	Based on average production worker

Table V-16: (continued)
Medical Surveillance and TB Testing - General Industry
Assumptions and Unit Costs
Coverage: All employees exposed above action level

Screening Tool	Cost	Initial Screening	Periodic Screening		Comments/ Assumptions
					wage adjusted for benefits (BLS, 2012b). All exams are off-site for all workers.
Record keeping		$74.97	$74.97	$74.97	Based on manager's wage rate, adjusted for benefits (BLS, 2012b)
Total		$335.37	$335.37	$335.37	
Initial TB testing					
Test cost		$16.63	$16.63	$16.63	
Lost work time - exam		$2.06	$2.06	$2.06	Based on average production worker wage, adjusted for benefits (BLS, 2012b).
Lost work time - travel		$19.80	$6.19	$0.00	Based on average production worker wage, adjusted for benefits (BLS, 2012b).
Total		$38.49	$24.88	$18.69	
New hire and subsequent TB testing					
Test cost		$16.63	$16.63	$16.63	
Lost work time - exam		$2.06	$2.06	$2.06	Based on average production worker wage, adjusted for benefits (BLS, 2012b).
Lost work time - travel		$22.28	$12.38	$2.48	Based on average production worker wage, adjusted for benefits (BLS, 2012b).
Total		$40.97	$31.06	$21.16	
Annualized costs - initial testing		$4.51	$2.92	$2.19	
Annualized costs - new hire and subsequent testing		$40.97	$31.06	$21.16	

Percentage of employees tested in initial year

Table V-16: (continued)
Medical Surveillance and TB Testing - General Industry
Assumptions and Unit Costs
Coverage: All employees exposed above action level

Screening Tool	Cost	Initial Screening	Periodic Screening	Comments/ Assumptions
Current Employees			100.0%	
New Hires			75.0%	
Percentage of employees recommended for periodic TB testing [c]			15.0%	

[a] Typical charge based on ERG contacts with occupational health providers.
[b] Mean expense per office-based physician visit to a specialist for diagnosis and treatment, based on data from the 2004 MEPS. Inflated to 2012 levels using the consumer price index.
[c] The corresponding table in the PEA erroneously referred to this as annual TB testing. This typographical error did not impact the costs in the PEA.
Source: OSHA, Directorate of Standards and Guidance, Office of Regulatory Analysis, based on OSHA (2016).

The periodic medical examination will occur at least every three years, or more frequently if recommended by the PLHCP. As previously noted, the contents of the periodic medical examination are identical to those for the initial examination, with the exception that testing for latent tuberculosis infection is not required.

The estimated unit cost of periodic health screening also includes direct medical costs, the opportunity cost of worker time, and recordkeeping costs. As shown in Table V-16, these unit costs vary from $414.97 to $434.78 every third year. The variation in the unit cost is due entirely to differences in the percentage of workers expected to travel offsite for the periodic health screening. OSHA estimated that the share of workers traveling offsite, as a function of establishment size, will be the same for the periodic health screening as for the initial health screening for existing employees.

For general industry, the key change from the PEA relates to the scope of medical surveillance coverage. For the final standard, medical surveillance is triggered when an employee is expected to be exposed at or above the action level for 30 or more days per year, while in the proposal it was triggered when an employee was expected to be exposed above the PEL for 30 or more days per year. This rule change has increased the number of workers who must be offered medical surveillance. The Summary and Explanation section of the preamble on medical surveillance contains a thorough discussion of the explanation for the change in the medical surveillance trigger.
The Agency applied the expanded scope (due to the new trigger) to the unit costs to estimate total health screening costs. Based on a ten-year time horizon, OSHA estimated the total annualized costs in general industry and maritime for health screenings, including initial health screenings for existing employees and new hires and periodic health screenings, required by the final rule. These estimates, disaggregated by affected NAICS industry, are presented in Table V-17.

Finally, as in the PEA, OSHA estimated the unit cost of a medical examination by a specialist for those employees with a chest x-ray classified as 1/0 or higher on the ILO scale or who are otherwise referred by the PLHCP. As shown in Table V-16, the estimated unit cost of a medical examination by a specialist is $335.37. This cost includes direct medical costs, the opportunity cost of worker time, and recordkeeping costs, including the cost of the employer’s time to make a referral to a specialist. In all cases regardless of establishment size, OSHA anticipates that the worker will travel offsite to receive the medical examination by a specialist and so has also included the standard 60 minutes in travel time costs for employees in general industry or maritime.

Based on Buchanan et al. (2003), OSHA estimated that, for those workers in general industry and maritime under medical surveillance (with exposures at or above the action level), there would be 544 new cases of silicosis a year (all expected to be identified by medical surveillance), based on x-rays of silica-exposed employees classified as 1/0 or higher. For the purpose of estimating costs, OSHA assumes that the PLHCP would refer the employee to a specialist only if the employee was diagnosed with silicosis. ERG distributed the cost of a specialist visit for these disease cases among industries in proportion to the number of workers exposed at or above the action level. Table V-18, which multiplies the unit cost by the number of referred workers, shows the total annualized cost in general industry and maritime of medical examinations by a specialist. Table V-19, which combines total health screening costs and the total costs of medical examinations by a specialist, shows aggregate annualized costs in general industry and maritime, by NAICS industry, for the medical surveillance requirements in the rule. For general industry and maritime, combined over all affected NAICS industries, the estimated cost of these medical surveillance requirements is $29.7 million annually.

Table V-17: Annualized Medical Surveillance Costs for General Industry and Maritime

NAICS	Industry	At-Risk (25 μg/m³)	Initial Screening	Screening for New	Triennial Screening	Total Examinations	Total TB Testing	Total
213112	Support Activities for Oil and Gas Operations	13,819	$683,962	$1,109,234	$991,503	$2,784,699	$66,627	$2,851,326
324121	Asphalt Paving Mixture and Block Manufacturing	48	$2,383	$3,852	$3,458	$9,694	$333	$10,026
324122	Asphalt Shingle and Coating Materials Manufacturing	3,158	$156,329	$253,512	$226,628	$636,468	$15,378	$651,846
325510	Paint and Coating Manufacturing	515	$25,527	$41,345	$37,003	$103,876	$2,727	$106,603
327110	Pottery, Ceramics, and Plumbing Fixture Manufacturing	3,989	$197,550	$319,720	$286,315	$803,584	$21,791	$825,375
327120	Clay Building Material and Refractories Manufacturing	4,915	$243,478	$394,783	$352,983	$991,245	$24,382	$1,015,627
327211	Flat Glass Manufacturing	134	$6,618	$10,733	$9,590	$26,941	$605	$27,546
327212	Other Pressed and Blown Glass and Glassware Manufacturing	411	$20,301	$32,849	$29,410	$82,560	$2,147	$84,706
327213	Glass Container Manufacturing	419	$20,664	$33,521	$29,945	$84,131	$1,866	$85,997
327320	Ready-Mix Concrete Manufacturing	20,690	$1,036,056	$1,674,756	$1,503,595	$4,214,407	$144,100	$4,358,507
327331	Concrete Block and Brick Manufacturing	2,902	$144,570	$234,024	$209,709	$588,303	$17,515	$605,817
327332	Concrete Pipe Manufacturing	1,603	$79,694	$129,082	$115,578	$324,354	$9,045	$333,399
327390	Other Concrete Product Manufacturing	8,821	$438,390	$710,150	$635,762	$1,784,303	$49,158	$1,833,460
327991	Cut Stone and Stone Product Manufacturing	6,794	$339,358	$548,757	$492,354	$1,380,468	$44,807	$1,425,275
327992	Ground or Treated Mineral and Earth Manufacturing	2,798	$138,915	$225,101	$201,436	$565,453	$15,015	$580,468
327993	Mineral Wool Manufacturing	489	$24,146	$39,128	$34,993	$98,267	$2,396	$100,663
327999	All Other Miscellaneous Nonmetallic Mineral Product Manufacturing	4,096	$203,483	$329,671	$295,080	$828,234	$22,435	$850,669
331110	Iron and Steel Mills and Ferroalloy Manufacturing	186	$9,081	$14,661	$13,134	$36,876	$901	$37,778
331210	Iron and Steel Pipe and Tube Manufacturing from Purchased Steel	45	$2,221	$3,595	$3,215	$9,031	$208	$9,239
331221	Rolled Steel Shape Manufacturing	14	$683	$1,108	$990	$2,780	$62	$2,842
331222	Steel Wire Drawing	25	$1,240	$2,012	$1,797	$5,049	$111	$5,160
331314	Secondary Smelting and Alloying of Aluminum	10	$470	$762	$681	$1,912	$42	$1,954
331420	Copper Rolling, Drawing, Extruding, and Alloying	37	$1,832	$2,969	$2,654	$7,455	$166	$7,621

Table V-17: Annualized Medical Surveillance Costs for General Industry and Maritime (continued)

NAICS	Industry	At-Risk (25 μg/m³)	Initial Screening	Screening for New Hires	Triennial Screening	Total Examinations	Total TB Testing	Total
331492	Secondary Smelting, Refining, and Alloying of Nonferrous Metal (except Copper and Aluminum)	19	$952	$1,544	$1,379	$3,875	$85	$3,960
331511	Iron Foundries	10,089	$496,943	$804,833	$719,761	$2,021,537	$47,331	$2,068,868
331512	Steel Investment Foundries	1,729	$85,030	$137,605	$123,111	$345,745	$8,167	$353,913
331513	Steel Foundries (except Investment)	4,805	$236,503	$382,800	$342,474	$961,777	$22,928	$984,705
331524	Aluminum Foundries (except Die-Casting)	1,727	$85,547	$138,707	$124,023	$348,276	$8,581	$356,858
331529	Other Nonferrous Metal Foundries (except Die-Casting)	1,064	$52,751	$85,453	$76,475	$214,679	$5,653	$220,332
332111	Iron and Steel Forging	42	$2,091	$3,390	$3,029	$8,510	$189	$8,699
332112	Nonferrous Forging	11	$535	$866	$774	$2,175	$50	$2,225
332117	Powder Metallurgy Part Manufacturing	14	$709	$1,151	$1,028	$2,888	$63	$2,951
332119	Metal Crown, Closure, and Other Metal Stamping (except Automotive)	93	$4,604	$7,469	$6,671	$18,744	$411	$19,155
332215	Metal Kitchen Cookware, Utensil, Cutlery, and Flatware (except Precious) Manufacturing	13	$641	$1,038	$928	$2,607	$59	$2,666
332216	Saw Blade and Handtool Manufacturing	49	$2,424	$3,931	$3,512	$9,868	$218	$10,087
332323	Ornamental and Architectural Metal Work Manufacturing	21	$1,069	$1,728	$1,550	$4,347	$135	$4,481
332439	Other Metal Container Manufacturing	21	$1,019	$1,652	$1,476	$4,147	$92	$4,239
332510	Hardware Manufacturing	47	$2,306	$3,738	$3,340	$9,384	$210	$9,594
332613	Spring Manufacturing	26	$1,290	$2,093	$1,869	$5,252	$115	$5,367
332618	Other Fabricated Wire Product Manufacturing	43	$2,144	$3,479	$3,107	$8,731	$191	$8,922
332710	Machine Shops	433	$21,379	$34,695	$30,984	$87,059	$1,893	$88,951
332812	Metal Coating, Engraving (except Jewelry and Silverware), and Allied Services to Manufacturers	2,205	$109,648	$177,594	$159,021	$446,262	$12,491	$458,752
332911	Industrial Valve Manufacturing	63	$3,097	$5,019	$4,486	$12,602	$283	$12,884
332912	Fluid Power Valve and Hose Fitting Manufacturing	61	$3,004	$4,861	$4,349	$12,213	$285	$12,498
332913	Plumbing Fixture Fitting and Trim Manufacturing	13	$657	$1,065	$952	$2,674	$61	$2,735

Table V-17: Annualized Medical Surveillance Costs for General Industry and Maritime (continued)

NAICS	Industry	At-Risk (25 μg/m³)	Initial Screening	Screening for New Hires	Triennial Screening	Total Examinations	Total TB Testing	Total
332919	Other Metal Valve and Pipe Fitting Manufacturing	25	$1,238	$2,007	$1,793	$5,038	$112	$5,150
332991	Ball and Roller Bearing Manufacturing	40	$1,953	$3,161	$2,827	$7,941	$183	$8,124
332996	Fabricated Pipe and Pipe Fitting Manufacturing	53	$2,600	$4,216	$3,767	$10,583	$233	$10,816
332999	All Other Miscellaneous Fabricated Metal Product Manufacturing	131	$6,453	$10,469	$9,351	$26,272	$581	$26,854
333318	Other Commercial and Service Industry Machinery Manufacturing	96	$4,732	$7,667	$6,854	$19,254	$436	$19,689
333413	Industrial and Commercial Fan and Blower and Air Purification Equipment Manufacturing	43	$2,100	$3,405	$3,042	$8,547	$188	$8,735
333414	Heating Equipment (except Warm Air Furnaces) Manufacturing	32	$1,566	$2,541	$2,269	$6,376	$139	$6,515
333511	Industrial Mold Manufacturing	62	$3,065	$4,972	$4,441	$12,478	$273	$12,751
333514	Special Die and Tool, Die Set, Jig, and Fixture Manufacturing	75	$3,724	$6,042	$5,397	$15,163	$332	$15,495
333515	Cutting Tool and Machine Tool Accessory Manufacturing	50	$2,476	$4,018	$3,588	$10,081	$219	$10,300
333517	Machine Tool Manufacturing	43	$2,114	$3,428	$3,062	$8,604	$190	$8,794
333519	Rolling Mill and Other Metalworking Machinery Manufacturing	21	$1,014	$1,645	$1,470	$4,129	$91	$4,220
333612	Speed Changer, Industrial High-Speed Drive, and Gear Manufacturing	28	$1,396	$2,262	$2,022	$5,680	$128	$5,808
333613	Mechanical Power Transmission Equipment Manufacturing	27	$1,351	$2,191	$1,957	$5,499	$122	$5,621
333911	Pump and Pumping Equipment Manufacturing	60	$2,935	$4,756	$4,251	$11,942	$269	$12,212
333912	Air and Gas Compressor Manufacturing	37	$1,843	$2,985	$2,669	$7,497	$170	$7,667
333991	Power-Driven Handtool Manufacturing	16	$770	$1,246	$1,115	$3,131	$72	$3,203
333992	Welding and Soldering Equipment Manufacturing	28	$1,368	$2,213	$1,981	$5,562	$131	$5,693
333993	Packaging Machinery Manufacturing	35	$1,739	$2,821	$2,520	$7,081	$156	$7,236
333994	Industrial Process Furnace and Oven Manufacturing	19	$959	$1,556	$1,390	$3,905	$85	$3,990
333995	Fluid Power Cylinder and Actuator Manufacturing	43	$2,100	$3,400	$3,040	$8,540	$195	$8,735

Table V-17: Annualized Medical Surveillance Costs for General Industry and Maritime (continued)

NAICS	Industry	At-Risk (25 μg/m³)	Initial Screening	Screening for New Hires	Triennial Screening	Total Examinations	Total TB Testing	Total
333996	Fluid Power Pump and Motor Manufacturing	19	$916	$1,485	$1,327	$3,728	$84	$3,812
333997	Scale and Balance Manufacturing	7	$323	$525	$469	$1,317	$29	$1,345
333999	All Other Miscellaneous General Purpose Machinery Manufacturing	91	$4,477	$7,259	$6,486	$18,222	$406	$18,628
334519	Other Measuring and Controlling Device Manufacturing	61	$3,020	$4,892	$4,373	$12,285	$278	$12,563
335210	Small Electrical Appliance Manufacturing	13	$629	$1,018	$911	$2,557	$63	$2,620
335221	Household Cooking Appliance Manufacturing	16	$792	$1,278	$1,145	$3,215	$82	$3,297
335222	Household Refrigerator and Home Freezer Manufacturing	15	$711	$1,146	$1,028	$2,886	$74	$2,960
335224	Household Laundry Equipment Manufacturing	7	$336	$541	$485	$1,362	$36	$1,398
335228	Other Major Household Appliance Manufacturing	14	$687	$1,106	$992	$2,785	$72	$2,858
336111	Automobile Manufacturing	111	$5,384	$8,665	$7,777	$21,826	$568	$22,394
336112	Light Truck and Utility Vehicle Manufacturing	100	$4,852	$7,808	$7,009	$19,668	$514	$20,182
336120	Heavy Duty Truck Manufacturing	54	$2,641	$4,254	$3,817	$10,712	$274	$10,986
336211	Motor Vehicle Body Manufacturing	72	$3,519	$5,700	$5,096	$14,316	$325	$14,641
336212	Truck Trailer Manufacturing	50	$2,455	$3,975	$3,555	$9,985	$230	$10,215
336213	Motor Home Manufacturing	13	$637	$1,028	$921	$2,586	$64	$2,650
336310	Motor Vehicle Gasoline Engine and Engine Parts Manufacturing	93	$4,564	$7,380	$6,606	$18,550	$438	$18,989
336320	Motor Vehicle Electrical and Electronic Equipment Manufacturing	88	$4,333	$7,010	$6,272	$17,615	$410	$18,025
336330	Motor Vehicle Steering and Suspension Components (except Spring) Manufacturing	51	$2,481	$4,013	$3,591	$10,086	$237	$10,323
336340	Motor Vehicle Brake System Manufacturing	39	$1,896	$3,070	$2,745	$7,710	$176	$7,887
336350	Motor Vehicle Transmission and Power Train Parts Manufacturing	103	$5,036	$8,140	$7,287	$20,463	$488	$20,951
336370	Motor Vehicle Metal Stamping	143	$7,023	$11,371	$10,169	$28,563	$657	$29,220
336390	Other Motor Vehicle Parts Manufacturing	215	$10,574	$17,112	$15,307	$42,993	$997	$43,990

Table V-17: Annualized Medical Surveillance Costs for General Industry and Maritime (continued)

NAICS	Industry	At-Risk (25 μg/m³)	Initial Screening	Screening for New Hires	Triennial Screening	Total Examinations	Total TB Testing	Total
336611	Ship Building and Repairing	2,633	$128,701	$207,524	$186,083	$522,309	$13,386	$535,695
336612	Boat Building	682	$33,730	$54,619	$48,880	$137,229	$3,521	$140,751
336992	Military Armored Vehicle, Tank, and Tank Component Manufacturing	19	$951	$1,535	$1,375	$3,860	$95	$3,955
337110	Wood Kitchen Cabinet and Countertop Manufacturing	114	$5,670	$9,161	$8,223	$23,054	$749	$23,803
337215	Showcase, Partition, Shelving, and Locker Manufacturing	59	$2,906	$4,713	$4,211	$11,831	$262	$12,093
339114	Dental Equipment and Supplies Manufacturing	1,983	$98,203	$158,868	$142,321	$399,392	$11,072	$410,463
339116	Dental Laboratories	5,184	$260,051	$419,823	$377,422	$1,057,296	$38,950	$1,096,246
339910	Jewelry and Silverware Manufacturing	2,455	$122,202	$197,644	$177,214	$497,060	$15,129	$512,189
339950	Sign Manufacturing	217	$10,820	$17,500	$15,693	$44,012	$1,359	$45,372
423840	Industrial Supplies Merchant Wholesalers	1,182	$59,167	$95,592	$85,853	$240,612	$8,329	$248,941
444110	Home Centers	55	$2,699	$4,380	$3,912	$10,991	$247	$11,238
482110	Rail transportation	0	0	0	0	0	0	0
561730	Landscaping Services	24,747	$1,240,287	$2,003,387	$1,800,001	$5,043,675	$179,821	$5,223,496
621210	Offices of Dentists	1,421	$72,124	$116,143	$104,808	$293,075	$13,519	$306,594
	Totals	**141,594**	**$7,043,585**	**$11,396,699**	**$10,214,287**	**$28,654,571**	**$848,550**	**$29,503,121**

Source: OSHA, Directorate of Standards and Guidance, Office of Regulatory Analysis, based on OSHA (2016).

Table V-18: Annualized Cost for Medical Examination by a Specialist for General Industry and

NAICS	Industry	≥AL	No. of Annual Referrals	Annual Costs
213112	Support Activities for Oil and Gas Operations	13,810	53	$17,808
324121	Asphalt Paving Mixture and Block Manufacturing	48	0	$61
324122	Asphalt Shingle and Coating Materials Manufacturing	3,158	12	$4,069
325510	Paint and Coating Manufacturing	515	2	$664
327110	Pottery, Ceramics, and Plumbing Fixture Manufacturing	3,989	15	$5,140
327120	Clay Building Material and Refractories Manufacturing	4,915	19	$6,334
327211	Flat Glass Manufacturing	134	1	$173
327212	Other Pressed and Blown Glass and Glassware Manufacturing	411	2	$530
327213	Glass Container Manufacturing	419	2	$540
327320	Ready-Mix Concrete Manufacturing	20,690	80	$26,663
327331	Concrete Block and Brick Manufacturing	2,902	11	$3,739
327332	Concrete Pipe Manufacturing	1,603	6	$2,066
327390	Other Concrete Product Manufacturing	8,821	34	$11,367
327991	Cut Stone and Stone Product Manufacturing	6,794	26	$8,755
327992	Ground or Treated Mineral and Earth Manufacturing	2,798	11	$3,606
327993	Mineral Wool Manufacturing	489	2	$630
327999	All Other Miscellaneous Nonmetallic Mineral Product Manufacturing	4,096	16	$5,279
331110	Iron and Steel Mills and Ferroalloy Manufacturing	186	1	$239
331210	Iron and Steel Pipe and Tube Manufacturing from Purchased Steel	45	0	$58
331221	Rolled Steel Shape Manufacturing	14	0	$18
331222	Steel Wire Drawing	25	0	$32
331314	Secondary Smelting and Alloying of Aluminum	10	0	$12
331420	Copper Rolling, Drawing, Extruding, and Alloying	37	0	$48

Table V-18: Annualized Cost for Medical Examination by a Specialist for General Industry and Maritime (continued)

NAICS	Industry	≥AL	No. of Annual Referrals	Annual Costs
331492	Secondary Smelting, Refining, and Alloying of Nonferrous Metal (except Copper and Aluminum)	19	0	$25
331511	Iron Foundries	10,089	39	$13,001
331512	Steel Investment Foundries	1,729	7	$2,228
331513	Steel Foundries (except Investment)	4,805	18	$6,192
331524	Aluminum Foundries (except Die-Casting)	1,727	7	$2,225
331529	Other Nonferrous Metal Foundries (except Die-Casting)	1,064	4	$1,371
332111	Iron and Steel Forging	42	0	$55
332112	Nonferrous Forging	11	0	$14
332117	Powder Metallurgy Part Manufacturing	14	0	$19
332119	Metal Crown, Closure, and Other Metal Stamping (except Automotive)	93	0	$120
332215	Metal Kitchen Cookware, Utensil, Cutlery, and Flatware (except Precious) Manufacturing	13	0	$17
332216	Saw Blade and Handtool Manufacturing	49	0	$63
332323	Ornamental and Architectural Metal Work Manufacturing	21	0	$28
332439	Other Metal Container Manufacturing	21	0	$27
332510	Hardware Manufacturing	47	0	$60
332613	Spring Manufacturing	26	0	$34
332618	Other Fabricated Wire Product Manufacturing	43	0	$56

Table V-18: Annualized Cost for Medical Examination by a Specialist for General Industry and Maritime (continued)

NAICS	Industry	≥AL	No. of Annual Referrals	Annual Costs
332710	Machine Shops	433	2	$558
332812	Metal Coating, Engraving (except Jewelry and Silverware), and Allied Services to Manufacturers	2,205	8	$2,842
332911	Industrial Valve Manufacturing	63	0	$81
332912	Fluid Power Valve and Hose Fitting Manufacturing	61	0	$79
332913	Plumbing Fixture Fitting and Trim Manufacturing	13	0	$17
332919	Other Metal Valve and Pipe Fitting Manufacturing	25	0	$32
332991	Ball and Roller Bearing Manufacturing	40	0	$51
332996	Fabricated Pipe and Pipe Fitting Manufacturing	53	0	$68
332999	All Other Miscellaneous Fabricated Metal Product Manufacturing	131	1	$168
333318	Other Commercial and Service Industry Machinery Manufacturing	96	0	$124
333413	Industrial and Commercial Fan and Blower and Air Purification Equipment Manufacturing	43	0	$55
333414	Heating Equipment (except Warm Air Furnaces) Manufacturing	32	0	$41
333511	Industrial Mold Manufacturing	62	0	$80
333514	Special Die and Tool, Die Set, Jig, and Fixture Manufacturing	75	0	$97
333515	Cutting Tool and Machine Tool Accessory Manufacturing	50	0	$65
333517	Machine Tool Manufacturing	43	0	$55
333519	Rolling Mill and Other Metalworking Machinery Manufacturing	21	0	$27

Table V-18: Annualized Cost for Medical Examination by a Specialist for General Industry and Maritime (continued)

NAICS	Industry	≥AL	No. of Annual Referrals	Annual Costs
333612	Speed Changer, Industrial High-Speed Drive, and Gear Manufacturing	28	0	$37
333613	Mechanical Power Transmission Equipment Manufacturing	27	0	$35
333911	Pump and Pumping Equipment Manufacturing	60	0	$77
333912	Air and Gas Compressor Manufacturing	37	0	$48
333991	Power-Driven Handtool Manufacturing	16	0	$20
333992	Welding and Soldering Equipment Manufacturing	28	0	$36
333993	Packaging Machinery Manufacturing	35	0	$45
333994	Industrial Process Furnace and Oven Manufacturing	19	0	$25
333995	Fluid Power Cylinder and Actuator Manufacturing	43	0	$55
333996	Fluid Power Pump and Motor Manufacturing	19	0	$24
333997	Scale and Balance Manufacturing	7	0	$8
333999	All Other Miscellaneous General Purpose Machinery Manufacturing	91	0	$117
334519	Other Measuring and Controlling Device Manufacturing	61	0	$79
335210	Small Electrical Appliance Manufacturing	13	0	$16
335221	Household Cooking Appliance Manufacturing	16	0	$21
335222	Household Refrigerator and Home Freezer Manufacturing	15	0	$19
335224	Household Laundry Equipment Manufacturing	7	0	$9
335228	Other Major Household Appliance Manufacturing	14	0	$18

Table V-18: Annualized Cost for Medical Examination by a Specialist for General Industry and Maritime (continued)

NAICS	Industry	≥AL	No. of Annual Referrals	Annual Costs
336111	Automobile Manufacturing	111	0	$143
336112	Light Truck and Utility Vehicle Manufacturing	100	0	$128
336120	Heavy Duty Truck Manufacturing	54	0	$70
336211	Motor Vehicle Body Manufacturing	72	0	$92
336212	Truck Trailer Manufacturing	50	0	$64
336213	Motor Home Manufacturing	13	0	$17
336310	Motor Vehicle Gasoline Engine and Engine Parts Manufacturing	93	0	$120
336320	Motor Vehicle Electrical and Electronic Equipment Manufacturing	88	0	$114
336330	Motor Vehicle Steering and Suspension Components (except Spring) Manufacturing	51	0	$65
336340	Motor Vehicle Brake System Manufacturing	39	0	$50
336350	Motor Vehicle Transmission and Power Train Parts Manufacturing	103	0	$132
336370	Motor Vehicle Metal Stamping	143	1	$184
336390	Other Motor Vehicle Parts Manufacturing	215	1	$277
336611	Ship Building and Repairing	2,633	10	$3,393
336612	Boat Building	682	3	$879
336992	Military Armored Vehicle, Tank, and Tank Component Manufacturing	19	0	$25
337110	Wood Kitchen Cabinet and Countertop Manufacturing	114	0	$147
337215	Showcase, Partition, Shelving, and Locker Manufacturing	59	0	$76

Table V-18: Annualized Cost for Medical Examination by a Specialist for General Industry and Maritime (continued)

NAICS	Industry	≥AL	No. of Annual Referrals	Annual Costs
339114	Dental Equipment and Supplies Manufacturing	1,983	8	$2,555
339116	Dental Laboratories	5,184	20	$6,681
339910	Jewelry and Silverware Manufacturing	2,455	9	$3,164
339950	Sign Manufacturing	217	1	$280
423840	Industrial Supplies Merchant Wholesalers	1,182	5	$1,524
444110	Home Centers	55	0	$70
482110	Rail transportation	0	0	$0
561730	Landscaping Services	24,747	95	$31,891
621210	Offices of Dentists	1,421	5	$1,831
	Totals	141,594	544	$182,466

Source: OSHA, Directorate of Standards and Guidance, Office of Regulatory Analysis, based on OSHA (2016).

Table V-19: Total Annualized Medical Surveillance Costs for General Industry and Maritime

NAICS	Industry	Total Examinations	Specialist Examinations	Total
General Industry				
213112	Support Activities for Oil and Gas Operations	$2,851,326	$17,808	$2,869,133
324121	Asphalt Paving Mixture and Block Manufacturing	$10,026	$61	$10,087
324122	Asphalt Shingle and Coating Materials Manufacturing	$651,846	$4,069	$655,915
325510	Paint and Coating Manufacturing	$106,603	$664	$107,267
327110	Pottery, Ceramics, and Plumbing Fixture Manufacturing	$825,375	$5,140	$830,515
327120	Clay Building Material and Refractories Manufacturing	$1,015,627	$6,334	$1,021,961
327211	Flat Glass Manufacturing	$27,546	$173	$27,719
327212	Other Pressed and Blown Glass and Glassware Manufacturing	$84,706	$530	$85,236
327213	Glass Container Manufacturing	$85,997	$540	$86,536
327320	Ready-Mix Concrete Manufacturing	$4,358,507	$26,663	$4,385,169
327331	Concrete Block and Brick Manufacturing	$605,817	$3,739	$609,557
327332	Concrete Pipe Manufacturing	$333,399	$2,066	$335,464
327390	Other Concrete Product Manufacturing	$1,833,460	$11,367	$1,844,827
327991	Cut Stone and Stone Product Manufacturing	$1,425,275	$8,755	$1,434,031
327992	Ground or Treated Mineral and Earth Manufacturing	$580,468	$3,606	$584,074

Table V-19: Total Annualized Medical Surveillance Costs for General Industry and Maritime (continued)

NAICS	Industry	Total Examinations	Specialist Examinations	Total
327993	Mineral Wool Manufacturing	$100,663	$630	$101,292
327999	All Other Miscellaneous Nonmetallic Mineral Product Manufacturing	$850,669	$5,279	$855,948
331110	Iron and Steel Mills and Ferroalloy Manufacturing	$37,778	$239	$38,017
331210	Iron and Steel Pipe and Tube Manufacturing from Purchased Steel	$9,239	$58	$9,297
331221	Rolled Steel Shape Manufacturing	$2,842	$18	$2,860
331222	Steel Wire Drawing	$5,160	$32	$5,192
331314	Secondary Smelting and Alloying of Aluminum	$1,954	$12	$1,966
331420	Copper Rolling, Drawing, Extruding, and Alloying	$7,621	$48	$7,669
331492	Secondary Smelting, Refining, and Alloying of Nonferrous Metal (except Copper and Aluminum)	$3,960	$25	$3,985
331511	Iron Foundries	$2,068,868	$13,001	$2,081,869
331512	Steel Investment Foundries	$353,913	$2,228	$356,141
331513	Steel Foundries (except Investment)	$984,705	$6,192	$990,897
331524	Aluminum Foundries (except Die-Casting)	$356,858	$2,225	$359,083
331529	Other Nonferrous Metal Foundries (except Die-Casting)	$220,332	$1,371	$221,703
332111	Iron and Steel Forging	$8,699	$55	$8,753
332112	Nonferrous Forging	$2,225	$14	$2,239
332117	Powder Metallurgy Part Manufacturing	$2,951	$19	$2,969
332119	Metal Crown, Closure, and Other Metal Stamping (except Automotive)	$19,155	$120	$19,275

Table V-19: Total Annualized Medical Surveillance Costs for General Industry and Maritime (continued)

NAICS	Industry	Total Examinations	Specialist Examinations	Total
332215	Metal Kitchen Cookware, Utensil, Cutlery, and Flatware (except Precious) Manufacturing	$2,666	$17	$2,683
332216	Saw Blade and Handtool Manufacturing	$10,087	$63	$10,150
332323	Ornamental and Architectural Metal Work Manufacturing	$4,481	$28	$4,509
332439	Other Metal Container Manufacturing	$4,239	$27	$4,266
332510	Hardware Manufacturing	$9,594	$60	$9,654
332613	Spring Manufacturing	$5,367	$34	$5,400
332618	Other Fabricated Wire Product Manufacturing	$8,922	$56	$8,978
332710	Machine Shops	$88,951	$558	$89,509
332812	Metal Coating, Engraving (except Jewelry and Silverware), and Allied Services to Manufacturers	$458,752	$2,842	$461,594
332911	Industrial Valve Manufacturing	$12,884	$81	$12,965
332912	Fluid Power Valve and Hose Fitting Manufacturing	$12,498	$79	$12,577
332913	Plumbing Fixture Fitting and Trim Manufacturing	$2,735	$17	$2,752
332919	Other Metal Valve and Pipe Fitting Manufacturing	$5,150	$32	$5,182
332991	Ball and Roller Bearing Manufacturing	$8,124	$51	$8,175
332996	Fabricated Pipe and Pipe Fitting Manufacturing	$10,816	$68	$10,884
332999	All Other Miscellaneous Fabricated Metal Product Manufacturing	$26,854	$168	$27,022
333318	Other Commercial and Service Industry Machinery Manufacturing	$19,689	$124	$19,813
333413	Industrial and Commercial Fan and Blower and Air Purification Equipment Manufacturing	$8,735	$55	$8,790
333414	Heating Equipment (except Warm Air Furnaces) Manufacturing	$6,515	$41	$6,556

Table V-19: Total Annualized Medical Surveillance Costs for General Industry and Maritime (continued)

NAICS	Industry	Total Examinations	Specialist Examinations	Total
333511	Industrial Mold Manufacturing	$12,751	$80	$12,831
333514	Special Die and Tool, Die Set, Jig, and Fixture Manufacturing	$15,495	$97	$15,592
333515	Cutting Tool and Machine Tool Accessory Manufacturing	$10,300	$65	$10,365
333517	Machine Tool Manufacturing	$8,794	$55	$8,849
333519	Rolling Mill and Other Metalworking Machinery Manufacturing	$4,220	$27	$4,247
333612	Speed Changer, Industrial High-Speed Drive, and Gear Manufacturing	$5,808	$37	$5,845
333613	Mechanical Power Transmission Equipment Manufacturing	$5,621	$35	$5,656
333911	Pump and Pumping Equipment Manufacturing	$12,212	$77	$12,289
333912	Air and Gas Compressor Manufacturing	$7,667	$48	$7,716
333991	Power-Driven Handtool Manufacturing	$3,203	$20	$3,223
333992	Welding and Soldering Equipment Manufacturing	$5,693	$36	$5,729
333993	Packaging Machinery Manufacturing	$7,236	$45	$7,282
333994	Industrial Process Furnace and Oven Manufacturing	$3,990	$25	$4,015
333995	Fluid Power Cylinder and Actuator Manufacturing	$8,735	$55	$8,790
333996	Fluid Power Pump and Motor Manufacturing	$3,812	$24	$3,836
333997	Scale and Balance Manufacturing	$1,345	$8	$1,354
333999	All Other Miscellaneous General Purpose Machinery Manufacturing	$18,628	$117	$18,745
334519	Other Measuring and Controlling Device Manufacturing	$12,563	$79	$12,642
335210	Small Electrical Appliance Manufacturing	$2,620	$16	$2,637
335221	Household Cooking Appliance Manufacturing	$3,297	$21	$3,318

Table V-19: Total Annualized Medical Surveillance Costs for General Industry and Maritime (continued)

NAICS	Industry	Total Examinations	Specialist Examinations	Total
335222	Household Refrigerator and Home Freezer Manufacturing	$2,960	$19	$2,979
335224	Household Laundry Equipment Manufacturing	$1,398	$9	$1,406
335228	Other Major Household Appliance Manufacturing	$2,858	$18	$2,876
336111	Automobile Manufacturing	$22,394	$143	$22,537
336112	Light Truck and Utility Vehicle Manufacturing	$20,182	$128	$20,311
336120	Heavy Duty Truck Manufacturing	$10,986	$70	$11,056
336211	Motor Vehicle Body Manufacturing	$14,641	$92	$14,734
336212	Truck Trailer Manufacturing	$10,215	$64	$10,279
336213	Motor Home Manufacturing	$2,650	$17	$2,667
336310	Motor Vehicle Gasoline Engine and Engine Parts Manufacturing	$18,989	$120	$19,108
336320	Motor Vehicle Electrical and Electronic Equipment Manufacturing	$18,025	$114	$18,138
336330	Motor Vehicle Steering and Suspension Components (except Spring) Manufacturing	$10,323	$65	$10,389
336340	Motor Vehicle Brake System Manufacturing	$7,887	$50	$7,936
336350	Motor Vehicle Transmission and Power Train Parts Manufacturing	$20,951	$132	$21,084
336370	Motor Vehicle Metal Stamping	$29,220	$184	$29,404
336390	Other Motor Vehicle Parts Manufacturing	$43,990	$277	$44,267
336611	Ship Building and Repairing	$535,695	$3,393	$539,088
336612	Boat Building	$140,751	$879	$141,630
336992	Military Armored Vehicle, Tank, and Tank Component Manufacturing	$3,955	$25	$3,980
337110	Wood Kitchen Cabinet and Countertop Manufacturing	$23,803	$147	$23,950

Table V-19: Total Annualized Medical Surveillance Costs for General Industry and Maritime (continued)

NAICS	Industry	Total Examinations	Specialist Examinations	Total
337215	Showcase, Partition, Shelving, and Locker Manufacturing	$12,093	$76	$12,169
339114	Dental Equipment and Supplies Manufacturing	$410,463	$2,555	$413,018
339116	Dental Laboratories	$1,096,246	$6,681	$1,102,926
339910	Jewelry and Silverware Manufacturing	$512,189	$3,164	$515,353
339950	Sign Manufacturing	$45,372	$280	$45,652
423840	Industrial Supplies Merchant Wholesalers	$248,941	$1,524	$250,464
444110	Home Centers	$11,238	$70	$11,309
482110	Rail transportation	NA	NA	NA
561730	Landscaping Services	$5,223,496	$31,891	$5,255,387
621210	Offices of Dentists	$306,594	$1,831	$308,425
	Totals	$29,503,121	$182,466	$29,685,587

Source: OSHA, Directorate of Standards and Guidance, Office of Regulatory Analysis, based on OSHA (2016).

Familiarization Costs and Costs of Communication of Silica Hazards to Employees

In this section, OSHA presents its cost estimates for two employer information activities arising from the silica final rule: (1) employer familiarization with the final rule, and (2) communication of respirable crystalline silica hazards to employees as required by the final rule.

Familiarization Costs

OSHA did not estimate any employer familiarization costs in the PEA. OSHA's rationale for not including familiarization costs in the PEA was that there was already an existing silica standard in place and, therefore, the Agency expected that any familiarization costs for a revised silica standard would be negligible. However, several commenters on the proposed rule argued that employers will need to spend time to become familiar with the requirements of the final rule; that the employer time spent is the direct result of the final rule itself; and, therefore, that OSHA should include employer familiarization costs as part of the costs of the final rule.

For example, James Hardie Building Products, Inc. (Document ID 2322, p. 175) stated that:

> [T]he newly (or more extensively) regulated firm will almost certainly carry out the following activities, none of which have been accounted for or included in OSHA's analysis.
>
> - Obtaining, reviewing, and developing an understanding of rule provisions and how they apply to the affected business
> - Receiving review, analysis, and consultation by legal counsel (internal or outside) to identify the precise obligations imposed by the rule
> - Consultation with insurance carrier(s) and possible revisions to policies and terms
> - Developing or revising existing policies and procedures (e.g., code of conduct, EHS, employee development, training, performance evaluation, and procurement)
> - Making adjustments to job scheduling and employee deployment to job sites
> - Management monitoring of regulatory compliance and new/revised program success
> - Initiation/expansion of employee health tracking
> - Referrals to a pulmonologist, as required, and
> - Records management for all of the above.

Ronald Bird, on behalf of the United States Chamber of Commerce, also commented on familiarization costs:

> Familiarization covers at least the basic “initial” screening analysis to determine the likelihood that the regulation contains any applicable requirements or exposes the employer to any legal liabilities that merit further examination. For employers who are unable to conclude from an initial screening review whether a new or revised rule applies, there would be “extended familiarization” effort required to fully review the regulation to determine in detail what elements of the regulation apply and to plan organizational adjustments to comply with the rules (Document ID 2368, p. 9).

In addition, Stuart Sessions, of Environomics, Inc., in characterizing OSHA’s cost estimates as being too low in general, included the following as an example of such costs that OSHA had omitted from its cost analysis: “Cost to read the rule, become familiar with it and plan a compliance strategy for the facility or business” (Document ID 4231, Attachment 1, p. 11).

OSHA finds the comments in support of including *some* familiarization costs persuasive—along the lines recommended by Stuart Sessions above— and the Agency has now concluded that employers will need to spend some time to understand the ancillary provisions and the other new and revised components of the final rule and to determine what actions they must take in order to comply. OSHA notes that, in addition to its other purposes, the familiarization time will help supervisors to prepare/select training to provide to other supervisors and to other employees of the firm. The issue that remains is to estimate the magnitude of these familiarization costs.

To provide some context, the Agency notes that there is an existing OSHA PEL for respirable crystalline silica that covers the same group of employers, and an existing OSHA hazard communication standard that covers all workplace exposures, including respirable crystalline silica. Therefore, OSHA expects that the vast majority of employers will already know whether they are going to be covered by the final rule and will be familiar with the types of processes and controls available to reduce their employees’ exposure to silica.

The Agency further notes that it is offering various materials to assist employers in understanding and complying with the final rule. These include guidance materials such as fact sheets and other summary materials on the final rule; an OSHA dedicated silica webpage that will contain outreach and compliance assistance products; and, as required by Section 212 of the Small Business Regulatory Enforcement Fairness Act,[38] the release and dissemination of a small business compliance guide (not limited for use to small businesses) to provide additional guidance and ease familiarization and compliance with the final rule. In addition, OSHA has developed guidance to educate stakeholders on new Agency approaches taken in the respirable crystalline silica rule such as the requirements for the PLHCP's written medical opinion for the employer. Furthermore, OSHA expects that industry associations will be providing additional support materials and services to their members covered by the rule. For example, such materials are already provided by the Marble Industry of America (MIA) including "videos, handouts, and training guidelines on awareness and prevention to minimize the risk of silicosis" which are provided "free-of-charge to stone companies online" (Document ID 1722, p. 1). OSHA also intends to work with individual employers and industry groups to address specific compliance questions as necessary.

One commenter, Dr. Ronald Bird, on behalf of the United States Chamber of Commerce, offered an example of 8 hours as an amount of familiarization time that was a "composite of several persons' inputs" into Dr. Bird's review of OSHA's proposal, while adding: "It is difficult to imagine that the requisite review time would be much less, and for larger firms and complex operations the time could be much more" (Document ID 2368, p. 10). An 8-hour estimate is the same that OSHA used in its most recent estimate of familiarization time in its 2012 update to the Hazard Communication Standard (see 77 FR 17637-17638 (March 26, 2012)). OSHA believes that this is a reasonable estimate of familiarization time for a typical firm for this final silica rule.

For purposes of estimating familiarization costs associated with this final silica rule, OSHA expects that the employer will assign responsibility for investigating the details of the final rule, and for determining how to implement it, to one or more supervisors. How many supervisors will be assigned such responsibility and how the responsibility will be delegated among supervisors will presumably depend on a number of factors, such as the number of respirable crystalline silica-generating activities within the employer's facilities, which OSHA has estimated would be correlated with the size of the facility (as measured by the number of employees), and other employer-specific factors. OSHA's estimate of familiarization costs therefore reflects the total supervisor familiarization time (costed at a supervisory wage) for each covered employer, with the number of employees at each establishment also serving as a proxy to represent the diversity of silica activities. OSHA made a similar adjustment to distinguish different amounts of familiarization time for different entities when it conducted its analysis of its Hazard Communications Standard. In that analysis, OSHA distinguished between manufacturers and non-manufacturers to determine different amounts of time for familiarization, and used the

[38] P.L. 104-121, March 29, 1996 (as amended by P.L. 110-28, May 25, 2007)

presence or absence of safety directors in non-manufacturing firms as a proxy for the size of the establishment and the number of chemicals likely to be present (77 FR 17637-17638). For the silica rule, the requirements are not broken out separately for manufacturers and non-manufacturers, and the number of employees seems to be a more appropriate proxy for the level of familiarization that would be needed. Accordingly, OSHA has reduced the average of 8 hours of familiarization time for establishments with fewer employees and increased it significantly for establishments with a larger number of employees: 4 hours per covered employer with fewer than 20 employees; 8 hours per covered employer with 20 to 499 employees; and 40 hours per covered employer with 500 or more employees. These estimates represent average familiarization times; it is expected that some establishments will spend less time on familiarization than estimated here (e.g., if worker exposure never meets or exceeds the action level) and some will spend more time on familiarization than estimated here.

OSHA has not included any additional costs for legal expenses. OSHA crafted the rule to be clear to employers, and is providing additional materials explaining the requirements of the final rule and guidance from the Agency on how to comply with the final rule. The general industry requirements do not present any novel legal issues: the rule's structure and most of the included provisions are generally consistent with previous OSHA health standards, such as those protecting employees from exposure to lead (29 CFR 1910.1025) and hexavalent chromium (29 CFR 1910.1026). Thus, the Agency believes that employers would not choose to undertake review of the final rule by legal counsel or insurance providers and that such review would be unnecessary. OSHA has not previously included legal fees in other rulemakings, and the record does not include any persuasive argument for departing from this longstanding practice.

Table V-20 shows the unit cost by establishment size for employers to become familiar with the final rule. These costs will likely be one-time costs incurred during the first year in which the rule is effective, but the aggregate costs are annualized for consistency with the other cost estimates for the rule. Table V-21, which incorporates the unit familiarization costs in Table V-20, therefore displays OSHA's estimate of the annualized familiarization costs of the final rule for general industry and maritime, by NAICS industry. For general industry and maritime, the total annualized familiarization cost of the final rule is $2.1 million.

Table V-20:
Familiarization - General Industry and Maritime
Assumptions and Unit Costs

	Small (<20)	Medium (20-499)	Large (500+)	
Hours per establishment	4.0	8.0	40.0	
Total cost per establishment	$162	$323	$1,615	Based on supervisor wage of $40.38, inclusive of benefits (BLS, 2012b)
Annualized cost	$18.94	$37.87	$189.36	

Source: OSHA, Directorate of Standards and Guidance, Office of Regulatory Analysis, based on OSHA (2016).

Table V-21: Annualized Familiarization Costs for General Industry and Maritime

NAICS	Industry	Small (<20) Establishments	Small (<20) Costs	Medium (20-499) Establishments	Medium (20-499) Costs	Large (500+) Establishments	Large (500+) Costs	Total Establishments	Total Costs
213112	Support Activities for Oil and Gas	100	$1,894	344	$13,028	0	$0	444	$14,921
324121	Asphalt Paving Mixture and Block	1,222	$23,139	140	$5,302	0	$0	1,362	$28,441
324122	Asphalt Shingle and Coating Materials Manufacturing	110	$2,083	113	$4,279	0	$0	223	$6,362
325510	Paint and Coating Manufacturing	367	$6,951	401	$15,186	4	$757	772	$22,894
327110	Pottery, Ceramics, and Plumbing Fixture Manufacturing	539	$10,206	114	$4,317	2	$379	655	$14,902
327120	Clay Building Material and Refractories Manufacturing	540	$10,228	576	$21,814	0	$0	1,116	$32,042
327211	Flat Glass Manufacturing	4	$67	51	$1,931	1	$189	56	$2,188
327212	Other Pressed and Blown Glass and Glassware Manufacturing	77	$1,453	90	$3,408	4	$757	171	$5,619
327213	Glass Container Manufacturing	6	$114	55	$2,083	1	$189	62	$2,387
327320	Ready-Mix Concrete Manufacturing	4,372	$82,787	1,005	$38,061	0	$0	5,377	$120,847
327331	Concrete Block and Brick	574	$10,869	243	$9,203	0	$0	817	$20,072
327332	Concrete Pipe Manufacturing	202	$3,825	150	$5,681	0	$0	352	$9,506
327390	Other Concrete Product	1,382	$26,169	591	$22,382	0	$0	1,973	$48,551
327991	Cut Stone and Stone Product	1,537	$29,104	321	$12,157	1	$189	1,859	$41,450
327992	Ground or Treated Mineral and Earth Manufacturing	165	$3,124	84	$3,181	0	$0	249	$6,306
327993	Mineral Wool Manufacturing	62	$1,167	110	$4,166	2	$379	174	$5,711
327999	All Other Miscellaneous Nonmetallic Mineral Product Manufacturing	582	$11,028	318	$12,043	0	$0	900	$23,071
331110	Iron and Steel Mills and Ferroalloy	0	$0	232	$8,792	48	$9,089	280	$17,881
331210	Iron and Steel Pipe and Tube Manufacturing from Purchased Steel	0	$0	102	$3,879	8	$1,515	110	$5,394
331221	Rolled Steel Shape Manufacturing	0	$0	40	$1,528	1	$189	41	$1,717
331222	Steel Wire Drawing	0	$0	77	$2,910	1	$189	78	$3,099

Table V-21: Annualized Familiarization Costs for General Industry and Maritime (continued)

		Small (<20)		Medium (20-499)		Large (500+)		Total	
NAICS	Industry	Establishments	Costs	Establishments	Costs	Establishments	Costs	Establishments	Costs
331314	Secondary Smelting and Alloying of Aluminum	0	$0	30	$1,154	0	$0	30	$1,154
331420	Copper Rolling, Drawing, Extruding, and	0	$0	104	$3,924	3	$568	107	$4,492
331492	Secondary Smelting, Refining, and Alloying of Nonferrous Metal (except Copper and	0	$0	57	$2,163	1	$189	58	$2,352
331511	Iron Foundries	157	$2,973	239	$9,051	11	$2,083	407	$14,107
331512	Steel Investment	31	$587	91	$3,446	6	$1,136	128	$5,169
331513	Steel Foundries (except Investment)	93	$1,761	109	$4,128	6	$1,136	208	$7,025
331524	Aluminum Foundries (except Die-Casting)	240	$4,545	166	$6,287	0	$0	406	$10,831
331529	Other Nonferrous Metal Foundries (except Die-Casting)	191	$3,617	108	$4,090	1	$189	300	$7,896
332111	Iron and Steel Forging	0	$0	122	$4,613	3	$568	125	$5,181
332112	Nonferrous Forging	0	$0	27	$1,006	2	$379	29	$1,385
332117	Powder Metallurgy Part Manufacturing	0	$0	46	$1,743	0	$0	46	$1,743
332119	Metal Crown, Closure, and Other Metal Stamping (except	0	$0	284	$10,763	4	$757	288	$11,521
332215	Metal Kitchen Cookware, Utensil, Cutlery, and Flatware (except Precious)	0	$0	35	$1,309	2	$379	37	$1,688

Table V-21: Annualized Familiarization Costs for General Industry and Maritime (continued)

NAICS	Industry	Small (<20) Establishments	Small (<20) Costs	Medium (20-499) Establishments	Medium (20-499) Costs	Large (500+) Establishments	Large (500+) Costs	Total Establishments	Total Costs
332216	Saw Blade and Handtool Manufacturing	0	$0	143	$5,416	4	$757	147	$6,173
332323	Ornamental and Architectural Metal Work Manufacturing	13	$237	25	$935	3	$539	40	$1,711
332439	Other Metal Container Manufacturing	0	$0	60	$2,272	2	$379	62	$2,650
332510	Hardware	0	$0	127	$4,800	7	$1,325	134	$6,125
332613	Spring Manufacturing	0	$0	81	$3,063	1	$189	82	$3,253
332618	Other Fabricated Wire Product Manufacturing	0	$0	136	$5,138	1	$189	137	$5,328
332710	Machine Shops	0	$0	1,383	$52,380	1	$189	1,384	$52,570
332812	Metal Coating, Engraving (except Jewelry and Silverware), and Allied Services to Manufacturers	903	$17,091	717	$27,154	0	$0	1,620	$44,245
332911	Industrial Valve Manufacturing	0	$0	169	$6,413	8	$1,515	177	$7,928
332912	Fluid Power Valve and Hose Fitting	0	$0	126	$4,780	13	$2,462	139	$7,242
332913	Plumbing Fixture Fitting and Trim Manufacturing	0	$0	33	$1,242	3	$568	36	$1,810
332919	Other Metal Valve and Pipe Fitting	0	$0	72	$2,710	3	$568	75	$3,278
332991	Ball and Roller Bearing Manufacturing	0	$0	88	$3,326	11	$2,083	99	$5,409
332996	Fabricated Pipe and Pipe Fitting	0	$0	157	$5,945	3	$568	160	$6,513

Table V-21: Annualized Familiarization Costs for General Industry and Maritime (continued)

		Small (<20)		Medium (20-499)		Large (500+)		Total	
NAICS	Industry	Establishments	Costs	Establishments	Costs	Establishments	Costs	Establishments	Costs
332999	All Other Miscellaneous Fabricated Metal Product Manufacturing	4	$68	389	$14,722	4	$670	396	$15,459
333318	Other Commercial and Service Industry Machinery Manufacturing	0	$0	244	$9,258	14	$2,651	258	$11,909
333413	Industrial and Commercial Fan and Blower and Air Purification Equipment	0	$0	128	$4,830	3	$568	131	$5,398
333414	Heating Equipment (except Warm Air Furnaces)	0	$0	102	$3,847	0	$0	102	$3,847
333511	Industrial Mold Manufacturing	0	$0	192	$7,282	2	$379	194	$7,661
333514	Special Die and Tool, Die Set, Jig, and Fixture Manufacturing	0	$0	233	$8,818	3	$568	236	$9,386
333515	Cutting Tool and Machine Tool Accessory Manufacturing	0	$0	161	$6,082	0	$0	161	$6,082
333517	Machine Tool Manufacturing	0	$0	126	$4,766	3	$568	129	$5,334
333519	Rolling Mill and Other Metalworking Machinery	0	$0	60	$2,278	2	$379	62	$2,657
333612	Speed Changer, Industrial High-Speed Drive, and Gear	0	$0	73	$2,782	3	$568	76	$3,350

Table V-21: Annualized Familiarization Costs for General Industry and Maritime (continued)

		Small (<20)		Medium (20-499)		Large (500+)		Total	
NAICS	Industry	Establishments	Costs	Establishments	Costs	Establishments	Costs	Establishments	Costs
333613	Mechanical Power Transmission Equipment	0	$0	80	$3,046	2	$379	82	$3,424
333911	Pump and Pumping Equipment	0	$0	155	$5,866	10	$1,894	165	$7,759
333912	Air and Gas Compressor Manufacturing	0	$0	94	$3,573	5	$947	99	$4,520
333991	Power-Driven Handtool Manufacturing	0	$0	35	$1,335	2	$379	37	$1,714
333992	Welding and Soldering Equipment	0	$0	54	$2,042	4	$757	58	$2,799
333993	Packaging Machinery Manufacturing	0	$0	106	$4,003	2	$379	108	$4,382
333994	Industrial Process Furnace and Oven	0	$0	62	$2,356	0	$0	62	$2,356
333995	Fluid Power Cylinder and Actuator	0	$0	101	$3,819	5	$947	106	$4,766
333996	Fluid Power Pump and Motor Manufacturing	0	$0	48	$1,816	3	$568	51	$2,384
333997	Scale and Balance Manufacturing	0	$0	21	$794	0	$0	21	$794
333999	All Other Miscellaneous General Purpose Machinery	0	$0	255	$9,658	6	$1,136	261	$10,794
334519	Other Measuring and Controlling Device Manufacturing	0	$0	157	$5,939	7	$1,325	164	$7,265
335210	Small Electrical Appliance	1	$22	15	$574	4	$757	20	$1,354
335221	Household Cooking Appliance	1	$15	9	$338	5	$947	15	$1,299

Table V-21: Annualized Familiarization Costs for General Industry and Maritime (continued)

NAICS	Industry	Small (<20) Establishments	Costs	Medium (20-499) Establishments	Costs	Large (500+) Establishments	Costs	Total Establishments	Costs
335222	Household Refrigerator and Home Freezer Manufacturing	0	$4	5	$184	6	$1,136	11	$1,324
335224	Household Laundry Equipment	0	$1	0	$3	3	$568	3	$573
335228	Other Major Household Appliance	0	$5	3	$96	9	$1,704	12	$1,806
336111	Automobile	0	$0	15	$569	24	$4,545	39	$5,113
336112	Light Truck and Utility Vehicle Manufacturing	0	$0	6	$236	21	$3,976	27	$4,212
336120	Heavy Duty Truck Manufacturing	0	$0	22	$850	18	$3,408	40	$4,258
336211	Motor Vehicle Body Manufacturing	0	$0	177	$6,698	13	$2,462	190	$9,160
336212	Truck Trailer	0	$0	112	$4,249	9	$1,704	121	$5,954
336213	Motor Home	0	$0	12	$460	4	$757	16	$1,218
336310	Motor Vehicle Gasoline Engine and Engine Parts Manufacturing	0	$0	170	$6,434	26	$4,923	196	$11,357
336320	Motor Vehicle Electrical and Electronic Equipment	0	$0	183	$6,945	17	$3,219	200	$10,164
336330	Motor Vehicle Steering and Suspension Components (except Spring) Manufacturing	0	$0	97	$3,663	11	$2,083	108	$5,746
336340	Motor Vehicle Brake System Manufacturing	0	$0	92	$3,472	8	$1,515	100	$4,987
336350	Motor Vehicle Transmission and Power Train Parts	0	$0	170	$6,437	26	$4,923	196	$11,360

Table V-21: Annualized Familiarization Costs for General Industry and Maritime (continued)

		Small (<20)		Medium (20-499)		Large (500+)		Total	
NAICS	**Industry**	**Establishments**	**Costs**	**Establishments**	**Costs**	**Establishments**	**Costs**	**Establishments**	**Costs**
336370	Motor Vehicle Metal Stamping	0	$0	327	$12,372	28	$5,302	355	$17,674
336390	Other Motor Vehicle Parts Manufacturing	0	$0	460	$17,403	50	$9,468	510	$26,870
336611	Ship Building and Repairing	69	$1,300	257	$9,733	27	$5,113	353	$16,146
336612	Boat Building	91	$1,727	216	$8,180	6	$1,136	313	$11,044
336992	Military Armored Vehicle, Tank, and Tank Component	0	$0	23	$884	8	$1,515	31	$2,399
337110	Wood Kitchen Cabinet and Countertop	79	$1,498	112	$4,231	15	$2,840	206	$8,569
337215	Showcase, Partition, Shelving, and Locker Manufacturing	0	$0	172	$6,532	5	$947	177	$7,479
339114	Dental Equipment and Supplies Manufacturing	596	$11,286	128	$4,848	3	$568	727	$16,701
339116	Dental Laboratories	6,443	$122,002	373	$14,126	2	$379	6,818	$136,507
339910	Jewelry and Silverware Manufacturing	1,971	$37,323	610	$23,087	9	$1,704	2,590	$62,114
339950	Sign Manufacturing	119	$2,262	239	$9,049	5	$947	363	$12,258
423840	Industrial Supplies Merchant Wholesalers	791	$14,975	886	$33,565	6	$1,136	1,683	$49,676
444110	Home Centers	3	$50	104	$3,947	0	$0	107	$3,997
482110	Rail transportation	0	$0	338	$12,797	0	$63,983	338	$76,780
561730	Landscaping Services	20,883	$395,433	5,077	$192,272	22	$4,166	25,982	$591,871
621210	Offices of Dentists	7,430	$140,701	1,094	$41,437	0	$0	8,525	$182,138
	Totals	51,949	$983,691	24,271	$919,163	641	$185,433	76,861	$2,088,287

Source: OSHA, Directorate of Standards and Guidance, Office of Regulatory Analysis, based on OSHA (2016).

Training Costs for Employees in General Industry and Maritime

Communication and Training Requirements

The final standard requires two forms of hazard communication to employees: paragraph (j)(1) notes that employers must include respirable crystalline silica in their existing hazard communication programs required by the hazard communication standard (HCS) (29 CFR 1910.1200), and paragraph (j)(3) requires that employers must provide employees with specific information and training. Because the silica hazard communication under paragraph (j)(1) is already required by, and costed under, the HCS, OSHA has estimated no costs for compliance with this paragraph of the final silica rule. The costs for employers to comply with the training requirements of paragraph (j)(3) are discussed below.[39]

Under subparagraph (j)(3)(i), employers must ensure that each employee who is covered by this section can demonstrate knowledge and understanding of at least the following: (A) the health hazards associated with exposure to respirable crystalline silica; (B) specific tasks in the workplace that could result in exposure to respirable crystalline silica; (C) specific measures the employer has implemented to protect employees from exposure to respirable crystalline silica, including engineering controls, work practices, and respirators to be used; (D) the contents of this section; and (E) the purpose and a description of the silica medical surveillance program. There is no specified hours-of-training requirement; the amount of silica training an employee receives will depend on what is required for employees to demonstrate knowledge and understanding of the subjects listed under paragraphs (j)(3)(i)(A)-(E).

As specified in subparagraph (j)(3)(i) of the final rule and the HCS, training is required for all employees in general industry and maritime are covered by the standard. This requirement applies to newly hired workers who would require training before starting work, workers who change jobs within their current workplace or are assigned new tasks or exposure protection, and any covered worker an employer believes needs additional training. Thus OSHA has estimated a one-time training cost for existing employees as well as recurring training costs to account for new hires.

PEA estimates

In both the PEA and this FEA, OSHA divided the employer costs for training employees under the new standard into two categories: training materials and training time.

[39] Paragraph (j)(2) requires the posting of signs at all entrances to regulated areas, and the costs associated with this activity are estimated and discussed in the cost section on regulated areas.

In the PEA OSHA estimated the cost of training based on several key cost judgments. First, OSHA judged, for costing purposes, that employers will conduct the training in-house, relying predominately on free materials from OSHA and industry associations in order to develop and deliver the training. Second, the Agency estimated that the training materials that would need to be purchased would cost, on average, $2.00 per worker, encompassing the cost of handouts, video presentations, training manuals and exercises. Third, the training required by this standard, excluding the information-sharing already mandated by the hazardous communication standard, would last, on average, 45 minutes. Fourth, OSHA estimated that new hires would require the same amount of training as other employees. Fifth, in order to identify the number of trainers (and hence the amount of trainer time) necessary to conduct the trainings, OSHA estimated the number of employees for each training class based on the size of the establishment. Finally, OSHA used the hires rate[40] in manufacturing, which was 27.2 percent in 2008 (BLS Job Openings and Labor Turnover Survey, 2008), to estimate the amount of new hire training in general industry and maritime.

OSHA used these parameters to calculate the estimated cost of training, including the cost of instructor time, employee time, and materials.

Comments and responses on training

Training materials

In the PEA, OSHA based the training material cost estimate on ERG's judgment that $2.00 per worker could purchase sufficient training materials such as handouts, video presentations, and training manuals and exercises (Document ID 1608, p. 3-78). A number of commenters misinterpreted this figure as being OSHA's estimate of the total per-worker cost to provide training. For example, the Motor & Equipment Manufacturers Association commented that "[b]ased on the collective experience of our member companies, OSHA's training cost estimate of $2.00 per employee is considerably undervalued" (Document ID 2326, p. 3). This misinterpretation was reiterated by other commenters as well (e.g., Document ID 3391, pp. 1-2; 2370, p. 2; and 2130, p. 2). OSHA is therefore clarifying that this average per-worker cost of $2.00 is solely for training materials and is included in both the annualized training costs for employees as well as the annual cost for new-hire training.

[40] In the PEA, OSHA in some cases referred to this rate as the separations rate, but in fact the Agency was using the hiring rate reported by BLS. Because the regulatory analysis is based on steady-state economic conditions, the separations rate, the hiring rate, and the turnover rate are effectively identical.

While OSHA included costs to account for the purchase of training materials by covered employers, industry associations also have training materials that are available. For instance, James Hieb, from the Marble Institute of America (MIA), commented that “the MIA has produced videos, handouts, and training guidelines on awareness and prevention to minimize the risk of silicosis and is providing many of those resources free-of-charge to stone companies online” (Document ID 1722, p. 1).The National Ready Mix Concrete Association (NRMCA) commented that many of its members use the NRMCA’s Mixer Drum Cleaning guide (available for a fee on its website) or a guide developed by Georgia Tech’s Safety and Health Consultation Program titled “Chipping Out the Drum,” which is also available free online (Document ID 2305, p. 9). The National Precast Concrete Association (NPCA) reported that NPCA provides a Guide to Plant Safety that “includes policies and procedures for respiratory protection and a training plan” and can be downloaded for free from its website (Document ID 2067, p. 2). The International Union of Operating Engineers submitted a list of free online silica training tools. This list included the following resources:

> training materials produced by OSHA; [the National Institute of Occupational Safety and Health] NIOSH; [Center for Protection of Workers' Right] CPWR; Arizona Division of Occupational Safety and Health (ADOSH); NJ Public Health Services Branch, Division of Epidemiology, Environmental and Occupational Health Service, Occupational Health Surveillance Program; and Georgia Tech’s Safety and Health Consultation Program: Preventing Silicosis Among Masons (Document ID 4025, Attachment 1, p. 6).

Additionally, under the Small Business Regulatory Enforcement Flexibility Act, OSHA is required to provide to small businesses compliance guides that can be obtained and used by businesses of any size. These will include for this final rule a model training program and other training and compliance materials—all offered at no cost by OSHA. While OSHA does not typically endorse training products other than its own materials, and the Agency is not now endorsing any of these materials or even suggesting that following these training guides would alone bring anyone into compliance with OSHA’s training requirements, the point is that there are already a number of materials available from which employers can draw and it is likely that new training materials will be created in response to the new standards. Employers will not need to create their silica training materials from scratch.

Based on ERG’s expert judgment, OSHA’s compliance guides, the evidence of existing training materials and other guidance from industry groups and other sources, and the fact that much of the criticism of this estimate stemmed from misunderstanding, OSHA has decided to maintain the estimate of $2.00 per worker for the cost of training materials as measured in 2008 dollars, which has been updated to $2.10 per worker in 2012 dollars.

In-house training

As a threshold matter, OSHA based its estimates in the PEA on a model in which employers would use existing in-house personnel to train their employees. Several commenters nevertheless assumed, without further explanation, that employers would hire professional trainers (presumably from outside the organization) for this purpose (see, e.g., Document ID 2171, p. 5). Several commenters representing covered industries disagreed that companies have the resources to conduct training in-house. The Institute of Makers of Explosives asserted:

> Many of our member companies are small businesses that do not have adequate in-house expertise to provide the training […] that would be required under this rule. [. . .] OSHA's assumption that employers will be able to perform these tasks on their own […] is not realistic (Document ID 2213, pp. 4-5).

Justin Dyer, from Superior Graphite, and others echoed this concern, all writing in their comments that "OSHA has further made assumptions that are without foundation, such as its assumption that training […can be] performed by an organization's own staff" (Document ID 2383, p. 2; 2355, p. 2; 3391, p. 2; 2222, p. 1; 2241, p. 2; and 2130, p. 2). In criticizing OSHA's cost estimates, none of the commenters seemed to account for the availability of existing training and guidance materials or materials that would be produced prior to the effective date of the rule. Therefore, OSHA is not persuaded that the training costs would be as high as suggested by some commenters.

In this FEA, as discussed above, OSHA has introduced costs for the additional time needed for employer familiarization with the final standard—some of which the Agency expects will be spent by a supervisor learning the details of the standard and the training requirements, selecting training materials, and preparing to deliver the training. This additional time, along with the materials the employer purchases, the free training and guidance materials provided by OSHA, and other previously discussed materials developed by industry associations, will help ensure that supervisors, or those acting as trainers, understand how the rule applies to their particular establishment and will allow them to provide training to covered workers. The Agency has therefore decided, for the purpose of determining the costs of the training requirement, to maintain its assumption that training will be conducted in-house rather than contracted to outside trainers at additional cost.

Training time: employee time

In the PEA and the FEA, OSHA has accounted for the cost of the time spent in training by both the trainers (discussed later) and the employees. These training times only cover any newly required incremental training that an employer may find necessary in order to comply with the provisions of the final silica standard and do not include time spent in training that is already required by OSHA's hazard communication standard.
In the PEA, OSHA judged that a full training session for employees would last, on average, one hour. This estimate was based on the experience and expertise of both OSHA and OSHA's contractor, ERG. However, OSHA also estimated in the PEA that 50 percent of affected establishments already provide their workers, including new hires, with training that would comply with approximately 50 percent of the proposed new training requirements, so that half of covered employers would take 60 minutes to train their workers and the other half of covered employers would take 30 minutes to train their workers. This resulted in an overall average training time of 45 minutes per worker. OSHA used this 45 minute average in the PEA as the basis for costing the training time for employees.

Several commenters provided specific time estimates for employee training, but did not provide any specific support for their belief that their estimates were more accurate than OSHA's. For example, the American Fuel and Petrochemical Manufacturers commented, without further support, that it was "assuming [that] it would take an hour to train [an employee on the silica standard] and then thirty minutes to test and review the test with each employee" (Document ID 2350, p. 7). Underlying those time estimates, however, is the commenter's assertion that OSHA is requiring employers to provide "unusually rigorous" training that would inform employees of all the silica generating operations in their workplaces, all the procedures implemented to protect employees from exposure "whether or not they specifically relate to them", the entire rule text, and a description of the medical surveillance program (Document ID 2350, p. 7). First of all, OSHA disagrees because employees outside the scope of the rule do not require training. OSHA further disagrees that it is being "unusually rigorous" by ensuring that employees can "demonstrate knowledge and understanding" of the subjects on which they are trained. That is the purpose of all training. Moreover, the commenter's estimates were also based on criticism of OSHA's estimate as relying too heavily on the existing training required to comply with OSHA's hazard communication standard:

> This misguided assumption, however, ignores the many other topics outlined in the proposed rule's training requirements: (1) RCS exposure operations, (2) specific procedures implemented to reduce RCS exposure, and (3) every other provision of the rule outside of training and medical surveillance (Document ID 2350, p. 8).

The commenter apparently did not understand that OSHA's hazard communication standard already requires employers to train their employees on the health hazards of workplace exposures, the methods that can detect silica exposures, and the specific procedures in place to protect employees from silica exposures at their workplace (see 29 CFR 1910.1200(h)(3)(i) through (iii)). The Agency therefore disagrees with the commenter's assessment of the impact of the existing hazard communication requirements and believes the commenter's 90-minute estimate for new training is inflated. The Agency agrees with the commenter that some of the training time is normally allocated to an employee's demonstration of knowledge, and the Agency believes that the time allocated for training in this FEA is adequate to provide employees with both training and knowledge assessment as required by the final standard.

A different commenter, Thermcraft Inc., suggested that an even longer training session would be necessary, commenting without further explanation that "[t]he minimum time for a training session of the complexity of the silica standard will be at least 8 hours per person" (Document ID 2370, p. 2). While an employer might devote more than an hour to training per worker in some establishments, OSHA believes 8 hours per employee is well beyond the additional time the average employer would need to comply with the new training requirements of the final rule. OSHA has thus maintained its estimate that the additional training required by the final rule will take one hour per employee.

In the PEA, however, OSHA preliminarily determined that not all employees would need the full hour of training because half would have received some silica training already. Thus, based on the existing compliance rate of half of all employees, OSHA estimated an average of 45 minutes per employee for training. Some commenters agreed with OSHA that some silica training is already being provided. Angus E. Crane, from the North American Insulation Manufacturers Association (NAIMA), testified that NAIMA itself does not do any training on silica, but the member companies do (Document ID 3588, Tr. 3976). Larry Foreman, of Grede Holdings LLC, states that employees at his firm receive specific training regarding silica during HCS training (Document ID 2298, p. 4). In his testimony, William Mann, of Verallia/Saint-Gobain Containers, commented that the training program at his establishment "currently discuss[es] silica in terms of hazard communication and in terms of [the] respiratory program" (Document ID 3584, Tr. 2864). James Boland, from The International Union of Bricklayers and Allied Craftworkers (BAC), commented that it would not be difficult to mix new training into the existing training on silica:

> Silica safety is a regular topic of BAC communications with its affiliate officers and members. In many areas, the apprenticeship and training our

> members receive includes education on the use of engineered and work process controls, silica safety and silica risks (Document ID 2329, p. 5).

Other commenters, however, disagreed with OSHA's estimate of the percentage of employees who are already receiving some silica training or the amount of training those employees receive relative to the training requirements in the proposed rule. For example, James Hardie Building Products, Inc. commented that while larger companies may have comprehensive and sophisticated training programs, smaller companies such as homebuilders and their subcontractors may not (Document ID 2322, Attachment 1, p. 171). As noted above, the AFPM asserted that OSHA had improperly assumed a 50 percent baseline compliance rate based on an overestimate of the number of requirements in the new standard that could be addressed by the employers' existing training plans (Document ID 2350, pp. 7-8).

The Agency has reviewed its baseline training estimates in light of these comments and has decided to take a more conservative approach to estimating current compliance with the training provisions in the final rule. Therefore, for this FEA, OSHA is assuming no baseline respirable crystalline silica training (other than that already required under the HCS) and that a full hour of training, on average, will be required for all covered workers. This removal of baseline respirable crystalline silica training in estimating training costs has the effect, by itself, of increasing the effective training costs in the FEA relative to the PEA by 33 percent (from an average training time, per employee, of 45 minutes to 60 minutes). OSHA recognizes that this change may lead to an overestimation of training costs for some employers.

Training time: new hires

In the PEA, OSHA assumed that all new hires would receive the full silica training from their new employer. Dr. Ruth Ruttenberg, of the AFL-CIO, asserted that the cost of training as estimated by OSHA in the PEA may be overstated because of this assumption (Document ID 2256, Attachment 4, p. 5). OSHA acknowledges that many new hires in general industry and maritime may have been previously employed in the same industry and in some cases by the same establishment, so that they might have already received respirable crystalline silica training sufficient to comply with part or all of the training requirements specified in the final rule. However, the precise number of new employees who were previously trained would be difficult to ascertain for many reasons. Employer-run training programs are unlikely to come with certificates that workers can take with them to subsequent employment. Training is also based on achieving employee knowledge and understanding, and therefore cannot be completely standardized because the standard does not specify required elements of a training program. Training would depend on the employer's facility, the tasks performed, and the equipment used. OSHA has therefore decided to maintain the assumption that all new hires will receive the full hour of silica training from their new employer, while acknowledging that this may lead to an overestimation of costs.

Training time: trainers

Whereas the total training time for existing employees can be determined by multiplying the average training time (one hour) by the number of employees, it is slightly more complicated to calculate the amount of time required for the trainers to conduct the training. There are several other factors that must be accounted for. The same unit of time for the training class (45 minutes in the PEA, and 1 hour in the FEA) also applies to the amount of time each trainer needs to teach, but OSHA also had to determine the average class size for training classes in order to determine how many trainers would be required. For the PEA, OSHA enlisted ERG's expertise to develop estimates of average class sizes as a function of establishment size. For training of current employees (i.e., initial training), ERG identified an average class size of 5 workers for establishments with fewer than 20 employees; 10 workers for establishments with 20 to 499 employees; and 20 workers for establishments with 500 or more employees. For new-hire training, ERG identified an average class size of 2 workers for establishments with fewer than 20 employees; 5 workers for establishments with 20 to 499 employees; and 10 workers for establishments with 500 or more employees. OSHA did not receive comments on these estimated class sizes and has therefore retained them for this FEA.

Other potential training costs not included

OSHA also received comments on the "fixed costs" of establishing a training program. The Institute of Makers of Explosives, Superior Graphite, and others questioned whether the training could be provided for a fixed cost (e.g., Document ID 2355, p. 2; 3391, p. 2; 2222, p. 1; 2241, p. 2; and 2130, p. 2). Thermcraft Inc. stated that the fixed cost of implementing a training program is a minimum of $5,000 (Document ID 2370, p. 2) and Lapp Insulators commented that the fixed cost of implementing a training program is a minimum of $800 (Document ID 2130, p. 2). OSHA did not assume a fixed cost for implementing a training program because the training requirements are performance-driven: the employer complies with paragraph (j)(3) of the rule when its employees can demonstrate sufficient knowledge and understanding of the silica hazards and other information specified in that standard. The actual cost for each employer will vary, which is why OSHA's estimated cost is an average. Employers are already required to have training programs under the HCS, so the costs for the additional training required by the silica final rule—which will be influenced by the employer's operations and existing training programs—are unlikely to include the cost of establishing an entire training program from scratch.

Many commenters expressed a general belief that the estimated cost of training in the PEA was too low. For example, the Leading Builders of America expressed general concern in its written comments that “the costs of activities such as training, […] were materially underestimated based upon current costs of these activities” (Document ID 2269, p. 18). This concern was echoed by other commenters (e.g., Document ID 2303, p. 12; 2384, p. 12; 1992, p. 7; 2315, p. 8; and 2023, p. 6).

OSHA has reviewed the comments generally discussing the possibility that the training provision cost is underestimated. Many of the comments provide no support for their assertions, and some appeared to be based on a lack of understanding of OSHA’s economic analysis. A comment from OSCO Industries, for example, asserted that OSHA’s training cost was underestimated because it did not include the costs of a trainer, training materials, the facility, and refreshments (Document ID 1992, p. 7). While it is true that OSHA did not factor refreshments into its costs because refreshments are not essential to the training or required by the rule, the Agency did include the costs of a trainer and the training materials. OSHA also judged that training would be conducted on-site, negating the need to pay for a separate facility. Therefore, OSHA is not increasing its training cost estimate in response to these general comments. As discussed earlier, however, OSHA is increasing the average training time per worker from 45 minutes to 60 minutes, which represents a 33 percent increase from the PEA to the FEA in the time allocated for workers to receive training. Aside from increasing the per-worker training time, the only other unit cost difference between the PEA and the FEA is that the estimated unit training costs have either been inflated from 2009 to 2012 dollars or been updated to incorporate 2012 data from data sources.

Total cost estimates

The unit costs of worker training in general industry and maritime for this FEA are summarized below in Table V-22. As shown, OSHA has estimated the annualized cost (annualized over 10 years) of initial training to be between $3.39 and $4.10 per employee and the annual cost of new- hire training as between $30.90 and $47.05 per employee, depending on establishment size. OSHA updated the hiring rate in manufacturing, used to estimate the amount of new hire training in general industry and maritime, from 2008 data to 2012 data. Based on the 2012 BLS survey data cited in Table V-22, the hiring rate used in the FEA is 25.0 percent.

Table V-23 summarizes OSHA’s estimate of the annualized costs, by NAICS industry, of the training requirements in the final standard for general industry and maritime. This estimate is based on the assumption that all workers in general industry or maritime who are within the scope of the final standard would receive the required silica training. For general industry and maritime, combined over all NAICS industries, the annualized cost to provide training as required by this paragraph is estimated to be $3.9 million annually. Table V-24 summarizes for general industry and maritime, by NAICS industry, the annualized costs of employer familiarization and employee training for the final rule. For general industry and maritime, combined over all NAICS industries, the annualized cost of employer familiarization and employee training for the final rule is $6.0 million annually.

Table V-22:
Training - General Industry and Maritime
Assumptions and Unit Costs

Cost Category	Cost			Comments/Assumptions
Instructor cost per hour	$40.38			Based on supervisor wage, adjusted for fringe benefits (BLS, 2012b)
Materials for class per attendee	$2.10			Estimated cost of $2 per worker for the training/reading materials; Inflated to 2012.
Labor Costs				
Time spent in class (min)	60			Estimated average training session time
Class size by Establishment Size Class				
	Small (<20)	Medium (20-499)	Large (500+)	
Initial training	5	10	20	
New hire training	2	5	10	
Average value of worker time spent in class	$24.75	$24.75	$24.75	Based on worker wage, adjusted for fringe benefits (BLS, 2012b)

Table V-22: (continued)
Training - General Industry and Maritime
Assumptions and Unit Costs

Annualized Training Cost per Employee by Establishment Size

	Small (<20)	Medium (20-499)	Large (500+)	
Initial training				
Value of instructor's time	$8.08	$4.04	$2.02	
Value of employee's time	$24.75	$24.75	$24.75	
Cost of materials	$2.10	$2.10	$2.10	
Total	$34.93	$30.90	$28.88	
Annualized total	$4.10	$3.62	$3.39	
New hire training				
Value of instructor's time	$20.19	$8.08	$4.04	
Value of employee's time	$24.75	$24.75	$24.75	
Cost of materials	$2.10	$2.10	$2.10	
Total	$47.05	$34.93	$30.90	
Hiring rate	25.0%			2012 annual hires rate for the manufacturing industry (BLS, 2012a)

Source: OSHA, Directorate of Standards and Guidance, Office of Regulatory Analysis, based on OSHA (2016) and BLS (2012b).

Table V-23: Annualized Training Costs for General Industry and Maritime

NAICS	Industry	At-Risk (All)	Initial Training	New Hire Training	Total Training
213112	Support Activities for Oil and Gas	16,960	$62,042	$152,058	**$214,100**
324121	Asphalt Paving Mixture and Block	4,737	$18,153	$47,737	**$65,890**
324122	Asphalt Shingle and Coating Materials Manufacturing	3,158	$11,563	$28,389	**$39,952**
325510	Paint and Coating Manufacturing	2,511	$9,223	$22,846	**$32,068**
327110	Pottery, Ceramics, and Plumbing Fixture Manufacturing	6,269	$22,976	$56,947	**$79,923**
327120	Clay Building Material and Refractories Manufacturing	7,893	$28,961	$71,326	**$100,287**
327211	Flat Glass Manufacturing	221	$799	$1,927	**$2,726**
327212	Other Pressed and Blown Glass and Glassware Manufacturing	674	$2,441	$5,962	**$8,403**
327213	Glass Container Manufacturing	686	$2,482	$5,981	**$8,463**
327320	Ready-Mix Concrete Manufacturing	27,123	$103,882	$272,994	**$376,876**
327331	Concrete Block and Brick Manufacturing	7,182	$26,971	$68,861	**$95,832**
327332	Concrete Pipe Manufacturing	3,967	$14,774	$37,240	**$52,014**
327390	Other Concrete Product Manufacturing	21,832	$81,180	$204,150	**$285,330**
327991	Cut Stone and Stone Product	9,429	$35,753	$92,734	**$128,487**
327992	Ground or Treated Mineral and Earth Manufacturing	5,432	$20,108	$50,218	**$70,326**
327993	Mineral Wool Manufacturing	789	$2,870	$7,004	**$9,874**
327999	All Other Miscellaneous Nonmetallic Mineral Product Manufacturing	7,952	$29,507	$73,967	**$103,475**
331110	Iron and Steel Mills and Ferroalloy	594	$2,067	$4,826	**$6,893**
331210	Iron and Steel Pipe and Tube Manufacturing from Purchased Steel	145	$514	$1,221	**$1,735**
331221	Rolled Steel Shape Manufacturing	44	$160	$383	**$543**
331222	Steel Wire Drawing	81	$291	$699	**$990**
331314	Secondary Smelting and Alloying of	30	$110	$266	**$376**
331420	Copper Rolling, Drawing, Extruding, and	119	$428	$1,024	**$1,452**
331492	Secondary Smelting, Refining, and Alloying of Nonferrous Metal (except Copper and	62	$223	$535	**$758**
331511	Iron Foundries	13,583	$48,667	$116,725	**$165,392**
331512	Steel Investment Foundries	5,487	$19,509	$46,466	**$65,974**

Table V-23: Annualized Training Costs for General Industry and Maritime (continued)

NAICS	Industry	At-Risk (All)	Initial Training	New Hire Training	Total Training
331513	Steel Foundries (except Investment)	6,469	$23,094	$55,257	**$78,351**
331524	Aluminum Foundries (except Die-	5,601	$20,555	$50,638	**$71,193**
331529	Other Nonferrous Metal Foundries (except Die-Casting)	3,451	$12,703	$31,544	**$44,248**
332111	Iron and Steel Forging	136	$489	$1,172	**$1,661**
332112	Nonferrous Forging	35	$124	$296	**$420**
332117	Powder Metallurgy Part	46	$167	$402	**$568**
332119	Metal Crown, Closure, and Other Metal Stamping (except Automotive)	299	$1,079	$2,595	**$3,674**
332215	Metal Kitchen Cookware, Utensil, Cutlery, and Flatware (except	42	$149	$357	**$506**
332216	Saw Blade and Handtool	157	$567	$1,361	**$1,928**
332323	Ornamental and Architectural Metal Work Manufacturing	40	$150	$385	**$535**
332439	Other Metal Container Manufacturing	66	$238	$572	**$810**
332510	Hardware Manufacturing	150	$538	$1,286	**$1,824**
332613	Spring Manufacturing	84	$303	$728	**$1,031**
332618	Other Fabricated Wire Product	139	$503	$1,212	**$1,715**
332710	Machine Shops	1,387	$5,022	$12,109	**$17,131**
332812	Metal Coating, Engraving (except Jewelry and Silverware), and Allied Services to Manufacturers	4,113	$15,324	$38,654	**$53,977**
332911	Industrial Valve Manufacturing	201	$722	$1,726	**$2,448**
332912	Fluid Power Valve and Hose Fitting Manufacturing	196	$693	$1,641	**$2,334**
332913	Plumbing Fixture Fitting and Trim Manufacturing	43	$153	$364	**$516**
332919	Other Metal Valve and Pipe Fitting Manufacturing	80	$289	$693	**$983**
332991	Ball and Roller Bearing Manufacturing	127	$452	$1,072	**$1,523**
332996	Fabricated Pipe and Pipe Fitting Manufacturing	169	$609	$1,462	**$2,071**
332999	All Other Miscellaneous Fabricated Metal Product Manufacturing	405	$1,466	$3,537	**$5,003**
333318	Other Commercial and Service Industry Machinery Manufacturing	308	$1,100	$2,625	**$3,726**
333413	Industrial and Commercial Fan and Blower and Air Purification Equipment	136	$492	$1,182	**$1,673**
333414	Heating Equipment (except Warm Air Furnaces) Manufacturing	102	$368	$887	**$1,255**
333511	Industrial Mold Manufacturing	199	$719	$1,730	**$2,449**

Table V-23: Annualized Training Costs for General Industry and Maritime (continued)

NAICS	Industry	At-Risk (All)	Initial Training	New Hire Training	Total Training
333514	Special Die and Tool, Die Set, Jig, and Fixture Manufacturing	242	$873	$2,102	**$2,975**
333515	Cutting Tool and Machine Tool Accessory Manufacturing	161	$582	$1,403	**$1,984**
333517	Machine Tool Manufacturing	137	$495	$1,187	**$1,682**
333519	Rolling Mill and Other Metalworking Machinery Manufacturing	66	$237	$570	**$807**
333612	Speed Changer, Industrial High-Speed Drive, and Gear Manufacturing	91	$325	$776	**$1,100**
333613	Mechanical Power Transmission Equipment Manufacturing	88	$316	$759	**$1,075**
333911	Pump and Pumping Equipment	191	$683	$1,631	**$2,314**
333912	Air and Gas Compressor	120	$428	$1,022	**$1,450**
333991	Power-Driven Handtool	50	$178	$423	**$601**
333992	Welding and Soldering Equipment Manufacturing	89	$315	$744	**$1,059**
333993	Packaging Machinery Manufacturing	113	$407	$979	**$1,386**
333994	Industrial Process Furnace and Oven Manufacturing	62	$225	$543	**$769**
333995	Fluid Power Cylinder and Actuator Manufacturing	137	$487	$1,158	**$1,645**
333996	Fluid Power Pump and Motor	60	$213	$509	**$722**
333997	Scale and Balance Manufacturing	21	$76	$183	**$259**
333999	All Other Miscellaneous General Purpose Machinery Manufacturing	291	$1,045	$2,505	**$3,550**
334519	Other Measuring and Controlling Device Manufacturing	196	$702	$1,676	**$2,378**
335210	Small Electrical Appliance	24	$86	$205	**$291**
335221	Household Cooking Appliance	30	$105	$247	**$352**
335222	Household Refrigerator and Home Freezer Manufacturing	27	$94	$217	**$311**
335224	Household Laundry Equipment	13	$44	$100	**$144**
335228	Other Major Household Appliance Manufacturing	26	$90	$208	**$298**
336111	Automobile Manufacturing	354	$1,203	$2,751	**$3,954**
336112	Light Truck and Utility Vehicle	319	$1,083	$2,473	**$3,556**
336120	Heavy Duty Truck Manufacturing	174	$593	$1,363	**$1,956**
336211	Motor Vehicle Body Manufacturing	229	$817	$1,948	**$2,765**
336212	Truck Trailer Manufacturing	160	$568	$1,349	**$1,917**
336213	Motor Home Manufacturing	42	$144	$335	**$479**
336310	Motor Vehicle Gasoline Engine and Engine Parts Manufacturing	298	$1,049	$2,473	**$3,522**

Table V-23: Annualized Training Costs for General Industry and Maritime (continued)

NAICS	Industry	At-Risk (All)	Initial Training	New Hire Training	Total Training
336320	Motor Vehicle Electrical and Electronic Equipment Manufacturing	283	$1,000	$2,367	**$3,367**
336330	Motor Vehicle Steering and Suspension Components (except	162	$571	$1,348	**$1,919**
336340	Motor Vehicle Brake System	123	$440	$1,046	**$1,486**
336350	Motor Vehicle Transmission and Power Train Parts Manufacturing	329	$1,154	$2,713	**$3,867**
336370	Motor Vehicle Metal Stamping	458	$1,626	$3,864	**$5,490**
336390	Other Motor Vehicle Parts	689	$2,442	$5,788	**$8,230**
336611	Ship Building and Repairing	3,038	$10,512	$24,504	**$35,016**
336612	Boat Building	787	$2,868	$7,039	**$9,907**
336992	Military Armored Vehicle, Tank, and Tank Component Manufacturing	62	$216	$504	**$721**
337110	Wood Kitchen Cabinet and Countertop Manufacturing	223	$836	$2,152	**$2,988**
337215	Showcase, Partition, Shelving, and Locker Manufacturing	189	$680	$1,632	**$2,312**
339114	Dental Equipment and Supplies	4,956	$18,167	$45,113	**$63,280**
339116	Dental Laboratories	31,105	$119,903	$319,011	**$438,915**
339910	Jewelry and Silverware Manufacturing	6,772	$25,310	$64,472	**$89,782**
339950	Sign Manufacturing	384	$1,440	$3,686	**$5,126**
423840	Industrial Supplies Merchant	1,773	$6,775	$17,785	**$24,560**
444110	Home Centers	107	$388	$941	**$1,330**
482110	Rail transportation	16,895	$61,191	$147,549	**$208,740**
561730	Landscaping Services	43,033	$165,330	$437,301	**$602,631**
621210	Offices of Dentists	8,525	$34,392	$96,952	**$131,345**
	Totals	**294,844**	**$1,102,423**	**$2,805,582**	**$3,908,006**

Source: OSHA, Directorate of Standards and Guidance, Office of Regulatory Analysis, based on OSHA (2016).

Table V-24: Combined Annualized Familiarization and Training Costs for General Industry and Maritime

NAICS	Industry	Familiarization Costs	Training Costs	Total
213112	Support Activities for Oil and Gas Operations	$14,921	$214,100	**$229,021**
324121	Asphalt Paving Mixture and Block Manufacturing	$28,441	$65,890	**$94,331**
324122	Asphalt Shingle and Coating Materials	$6,362	$39,952	**$46,315**
325510	Paint and Coating Manufacturing	$22,894	$32,068	**$54,963**
327110	Pottery, Ceramics, and Plumbing Fixture	$14,902	$79,923	**$94,825**
327120	Clay Building Material and Refractories	$32,042	$100,287	**$132,328**
327211	Flat Glass Manufacturing	$2,188	$2,726	**$4,914**
327212	Other Pressed and Blown Glass and Glassware Manufacturing	$5,619	$8,403	**$14,022**
327213	Glass Container Manufacturing	$2,387	$8,463	**$10,850**
327320	Ready-Mix Concrete Manufacturing	$120,847	$376,876	**$497,723**
327331	Concrete Block and Brick Manufacturing	$20,072	$95,832	**$115,903**
327332	Concrete Pipe Manufacturing	$9,506	$52,014	**$61,520**
327390	Other Concrete Product Manufacturing	$48,551	$285,330	**$333,881**
327991	Cut Stone and Stone Product Manufacturing	$41,450	$128,487	**$169,937**
327992	Ground or Treated Mineral and Earth	$6,306	$70,326	**$76,632**
327993	Mineral Wool Manufacturing	$5,711	$9,874	**$15,585**
327999	All Other Miscellaneous Nonmetallic Mineral Product Manufacturing	$23,071	$103,475	**$126,546**
331110	Iron and Steel Mills and Ferroalloy	$17,881	$6,893	**$24,774**
331210	Iron and Steel Pipe and Tube Manufacturing from Purchased Steel	$5,394	$1,735	**$7,129**
331221	Rolled Steel Shape Manufacturing	$1,717	$543	**$2,260**
331222	Steel Wire Drawing	$3,099	$990	**$4,089**
331314	Secondary Smelting and Alloying of Aluminum	$1,154	$376	**$1,530**
331420	Copper Rolling, Drawing, Extruding, and Alloying	$4,492	$1,452	**$5,944**
331492	Secondary Smelting, Refining, and Alloying of Nonferrous Metal (except Copper and	$2,352	$758	**$3,110**
331511	Iron Foundries	$14,107	$165,392	**$179,499**
331512	Steel Investment Foundries	$5,169	$65,974	**$71,144**
331513	Steel Foundries (except Investment)	$7,025	$78,351	**$85,376**
331524	Aluminum Foundries (except Die-Casting)	$10,831	$71,193	**$82,024**
331529	Other Nonferrous Metal Foundries (except Die-	$7,896	$44,248	**$52,144**

Table V-24: Combined Annualized Familiarization and Training Costs for General Industry and Maritime

NAICS	Industry	Familiarization Costs	Training Costs	Total
33211	Iron and Steel Forging	$5,181	$1,661	**$6,842**
33211	Nonferrous Forging	$1,385	$420	**$1,805**
33211	Powder Metallurgy Part Manufacturing	$1,743	$568	**$2,311**
332119	Metal Crown, Closure, and Other Metal Stamping (except Automotive)	$11,521	$3,674	**$15,195**
332215	Metal Kitchen Cookware, Utensil, Cutlery, and Flatware (except Precious) Manufacturing	$1,688	$506	**$2,194**
33221	Saw Blade and Handtool Manufacturing	$6,173	$1,928	**$8,101**
33232	Ornamental and Architectural Metal Work	$1,711	$535	**$2,246**
33243	Other Metal Container Manufacturing	$2,650	$810	**$3,460**
33251	Hardware Manufacturing	$6,125	$1,824	**$7,949**
33261	Spring Manufacturing	$3,253	$1,031	**$4,283**
33261	Other Fabricated Wire Product Manufacturing	$5,328	$1,715	**$7,043**
33271	Machine Shops	$52,570	$17,131	**$69,701**
332812	Metal Coating, Engraving (except Jewelry and Silverware), and Allied Services to Manufacturers	$44,245	$53,977	**$98,222**
33291	Industrial Valve Manufacturing	$7,928	$2,448	**$10,376**
33291	Fluid Power Valve and Hose Fitting Manufacturing	$7,242	$2,334	**$9,576**
33291	Plumbing Fixture Fitting and Trim Manufacturing	$1,810	$516	**$2,326**
33291	Other Metal Valve and Pipe Fitting Manufacturing	$3,278	$983	**$4,260**
33299	Ball and Roller Bearing Manufacturing	$5,409	$1,523	**$6,932**
33299	Fabricated Pipe and Pipe Fitting Manufacturing	$6,513	$2,071	**$8,584**
332999	All Other Miscellaneous Fabricated Metal Product Manufacturing	$15,459	$5,003	**$20,462**
333318	Other Commercial and Service Industry Machinery Manufacturing	$11,909	$3,726	**$15,635**
333413	Industrial and Commercial Fan and Blower and Air Purification Equipment Manufacturing	$5,398	$1,673	**$7,072**
333414	Heating Equipment (except Warm Air Furnaces) Manufacturing	$3,847	$1,255	**$5,102**
33351	Industrial Mold Manufacturing	$7,661	$2,449	**$10,110**
333514	Special Die and Tool, Die Set, Jig, and Fixture Manufacturing	$9,386	$2,975	**$12,362**
333515	Cutting Tool and Machine Tool Accessory Manufacturing	$6,082	$1,984	**$8,066**
33351	Machine Tool Manufacturing	$5,334	$1,682	**$7,016**
333519	Rolling Mill and Other Metalworking Machinery Manufacturing	$2,657	$807	**$3,464**
333612	Speed Changer, Industrial High-Speed Drive, and Gear Manufacturing	$3,350	$1,100	**$4,451**

Table V-24: Combined Annualized Familiarization and Training Costs for General Industry and Maritime

NAICS	Industry	Familiarization Costs	Training Costs	Total
333613	Mechanical Power Transmission Equipment Manufacturing	$3,424	$1,075	**$4,499**
33391	Pump and Pumping Equipment Manufacturing	$7,759	$2,314	**$10,073**
33391	Air and Gas Compressor Manufacturing	$4,520	$1,450	**$5,970**
33399	Power-Driven Handtool Manufacturing	$1,714	$601	**$2,315**
33399	Welding and Soldering Equipment Manufacturing	$2,799	$1,059	**$3,858**
33399	Packaging Machinery Manufacturing	$4,382	$1,386	**$5,769**
33399	Industrial Process Furnace and Oven	$2,356	$769	**$3,124**
33399	Fluid Power Cylinder and Actuator Manufacturing	$4,766	$1,645	**$6,410**
33399	Fluid Power Pump and Motor Manufacturing	$2,384	$722	**$3,106**
33399	Scale and Balance Manufacturing	$794	$259	**$1,053**
333999	All Other Miscellaneous General Purpose Machinery Manufacturing	$10,794	$3,550	**$14,344**
33451	Other Measuring and Controlling Device	$7,265	$2,378	**$9,643**
33521	Small Electrical Appliance Manufacturing	$1,354	$291	**$1,644**
33522	Household Cooking Appliance Manufacturing	$1,299	$352	**$1,651**
335222	Household Refrigerator and Home Freezer Manufacturing	$1,324	$311	**$1,634**
33522	Household Laundry Equipment Manufacturing	$573	$144	**$717**
33522	Other Major Household Appliance Manufacturing	$1,806	$298	**$2,103**
33611	Automobile Manufacturing	$5,113	$3,954	**$9,067**
33611	Light Truck and Utility Vehicle Manufacturing	$4,212	$3,556	**$7,768**
33612	Heavy Duty Truck Manufacturing	$4,258	$1,956	**$6,214**
33621	Motor Vehicle Body Manufacturing	$9,160	$2,765	**$11,925**
33621	Truck Trailer Manufacturing	$5,954	$1,917	**$7,871**
33621	Motor Home Manufacturing	$1,218	$479	**$1,697**
336310	Motor Vehicle Gasoline Engine and Engine Parts Manufacturing	$11,357	$3,522	**$14,879**
336320	Motor Vehicle Electrical and Electronic Equipment Manufacturing	$10,164	$3,367	**$13,531**
336330	Motor Vehicle Steering and Suspension Components (except Spring) Manufacturing	$5,746	$1,919	**$7,665**
33634	Motor Vehicle Brake System Manufacturing	$4,987	$1,486	**$6,472**
336350	Motor Vehicle Transmission and Power Train Parts Manufacturing	$11,360	$3,867	**$15,227**
33637	Motor Vehicle Metal Stamping	$17,674	$5,490	**$23,164**
33639	Other Motor Vehicle Parts Manufacturing	$26,870	$8,230	**$35,101**
33661	Ship Building and Repairing	$16,146	$35,016	**$51,162**
33661	Boat Building	$11,044	$9,907	**$20,950**
336992	Military Armored Vehicle, Tank, and Tank Component Manufacturing	$2,399	$721	**$3,119**

Table V-24: Combined Annualized Familiarization and Training Costs for General Industry and Maritime

NAICS	Industry	Familiarization Costs	Training Costs	Total
33711	Wood Kitchen Cabinet and Countertop	$8,569	$2,988	**$11,557**
337215	Showcase, Partition, Shelving, and Locker Manufacturing	$7,479	$2,312	**$9,791**
33911	Dental Equipment and Supplies Manufacturing	$16,701	$63,280	**$79,981**
33911	Dental Laboratories	$136,507	$438,915	**$575,422**
33991	Jewelry and Silverware Manufacturing	$62,114	$89,782	**$151,896**
33995	Sign Manufacturing	$12,258	$5,126	**$17,384**
42384	Industrial Supplies Merchant Wholesalers	$49,676	$24,560	**$74,236**
44411	Home Centers	$3,997	$1,330	**$5,327**
48211	Rail transportation	$76,780	$208,740	**$285,520**
56173	Landscaping Services	$591,871	$602,631	**$1,194,502**
62121	Offices of Dentists	$182,138	$131,345	**$313,483**
	Totals	**$2,088,287**	**$3,908,006**	**$5,996,292**

Source: OSHA, Directorate of Standards and Guidance, Office of Regulatory Analysis, based on OSHA (2016).

Regulated Areas

Paragraph (e)(1) of the final standard requires employers in general industry and maritime to establish a regulated area wherever an employee's exposure to airborne concentrations of respirable crystalline silica is, or can reasonably be expected to be, in excess of the PEL.[41] Paragraph (e)(2)(i) requires employers to demarcate regulated areas from the rest of the workplace in a manner that minimizes the number of employees exposed to respirable crystalline silica within the regulated area. Paragraph (e)(2)(ii) requires employers to post signs at all entrances to regulated areas that bear the following legend (specified in paragraph (j)(2) of the standard): DANGER; RESPIRABLE CRYSTALLINE SILICA; MAY CAUSE CANCER; CAUSES DAMAGE TO LUNGS; WEAR RESPIRATORY PROTECTION IN THIS AREA; AUTHORIZED PERSONNEL ONLY. Under paragraph (e)(3), employers must limit access to regulated areas to: (A) persons authorized by the employer and required by work duties to be present in the regulated area; (B) designated employee representatives present to observe monitoring; and (C) persons authorized by the OSH Act or regulations issued under it to be in a regulated area. Under paragraph (e)(4), employers must provide each employee and designated employee representative entering a regulated area with an appropriate respirator (in accordance with paragraph (g) of the standard) and require each employee and designated employee representative to use the respirator while in a regulated area.

In this section, OSHA first explains the unit cost estimates for regulated areas in the PEA. Then, the Agency addresses and responds to comments on unit cost estimates. Next, the Agency addresses general comments about regulated area costs. Finally, the Agency explains its methodology for estimating costs in this FEA and provides cost tables.

PEA Estimates

In the PEA, OSHA estimated that one regulated area would be necessary for every eight workers in general industry and maritime exposed or expected to be exposed above the PEL. Unit costs included planning time, estimated at an initial seven hours of supervisor time (annualized at $238.63 in 2009 dollars) and one hour annually for changes (at $34.09 a year in 2009 dollars); material costs for signs and boundary markers (annualized at $63.64 in 2009 dollars); and costs of $500 annually for two disposable respirators per

[41] In the silica proposal, employers in construction would have been required either to establish a regulated area or a written access control plan whenever an employee was exposed above the PEL. This requirement for construction employers was removed from the final rule. Although OSHA received comments from the construction sector on the merits of this proposed provision, these comments are generally discussed in the Summary and Explanation section of the preamble, not in the FEA, except where the Agency judged that they may have some bearing on general industry or maritime regulated area costs.

day to be used by authorized persons (other than those who regularly work in the regulated area) who might need to enter the area in the course of their job duties.[42]

In addition, with respect to the proposed protective work clothing requirements in regulated areas, OSHA estimated annual clothing costs of $1,100 per regulated area. The protective clothing provision was deleted in the final rule, and the associated clothing costs are not included in OSHA's estimate of costs for the regulated area provision in the final rule.

Comments and Responses on PEA Unit Cost Estimates

One commenter, the American Foundry Society (AFS), was critical of OSHA's estimate in the PEA of seven hours of planning time to set up a regulated area:

> This activity may change throughout the year as exposure monitoring requires ongoing redefinition of areas. Unless the entire facility is designated as a regulated area (in which case OSHA's application numbers must be greatly increased) the area will evolve as exposures and controls change. Administration, notification and enforcement tasks may bring the set-up time to 10 days per year (Document ID 2379, Appendix 3, pp. 36-37).

Additionally, the National Federation of Independent Business (NFIB) commented:

> In practicality, small business owners will make their entire job sites regulated areas. The threshold for what could be considered a regulated area is a low one and to be safe small businesses will err on the side of caution. In OSHA's PEA, it derived lower costs by assuming small businesses would have the omniscience to know exactly what areas of a job site should be regulated areas. This assumption is disconnected from the reality of the workplace, particularly given the vaguely worded definition of regulated area included in the proposed rule (Document ID 2210, p. 7).

OSHA does not agree that AFS's estimate of 10 days for establishing regulated areas reflects a more accurate assessment of the amount of time required for establishing regulated areas, and disagrees with the assumption that the regulated area will encompass entire job sites. First, the silica exposure areas in many general industry and maritime worksites are relatively fixed and limited. Because most exposures are generated by processes utilizing fixed machinery, the entire facility need not be designated as a regulated area. Moreover, if engineering controls are applied consistently, changes in the

[42] See Table V-16 of the PEA.

designated regulated area should be infrequent. Second, as the commenters subsequently noted, posting signs or otherwise demarcating the regulated area is a relatively simple task; removing or moving some signage should be even simpler. Third, regarding the specific time estimates, AFS never explained how they derived the estimate of 10 days a year. Fourth, as engineering controls are added or improved, reducing worker exposures overall, one would expect exposures above the PEL to decline, possibly decreasing the size and number of regulated areas or eliminating the need for regulated areas entirely. Finally, OSHA accounted for the possibility that employers will need to modify regulated areas over time by including costs of one hour annually to cover such changes.

Other commenters had additional concerns about perceived costs associated with the regulated area provision, including the cost of garments, the cost for purchasing HEPA filter vacuums for cleaning regulated areas, the cost of air showers or vacuums for “de-dusting” workers exiting a regulated area, and the cost of respiratory protection associated with regulated areas. For example, John Burke, from OSCO Industries, Inc., stated:

> Currently, OSCO does not administer such "regulated" areas so the cost of compliance is largely speculative. Simply, [we] do not know how many such areas there might be and how many employees would be affected. Based on the proposed requirements anyone entering the "regulated" area is going to require respiratory protection, possibly uniform service or disposable outer garments and/or decontaminat[ion] might be required, periodic "de-dusting" of the regulated area and use of HEPA filter vacuums for cleanup. We are estimating the operational cost of a regulated area to be $25,000 to $35,000 per "regulated" area per year (Document ID 1992, p. 7).

Similarly, Wayne D’Angelo, from the American Petroleum Institute and the Independent Petroleum Association of America, commented:

> This proposed requirement will likely mean that hydraulic fracturing companies will need to provide multiple HEPA vacuum stations or air showers or something similar for workers exiting a regulated area. Such equipment would entail a considerable cost to purchase and then continually transport, unload, install, disassemble, and reinstall at site after site (Document ID 2301, p. 74).

Additionally, AFS disagreed with OSHA’s estimate of the number of workers in respiratory protection programs as a result of the regulated area provision, stating that the regulated area provision is unworkable:

> [M]ovement of affected employees could dictate designation of the entire foundry as a regulated area. Requiring visitors and employees with minimal exposure to respirable crystalline silica to be part of the respiratory control program is not reasonable. Furthermore, the PEA does not include costs associated with all workers being part of the respiratory protection program, which this provision would demand (Document ID 4035, Attachment 1, p. 9).

Alexandra Persichetti, representing Morgan Advanced Materials, North America, similarly commented that this rule would greatly expand respirator use due to “the creation of a regulated area or implementation of an access control plan” in every department where any employees would be exposed over the PEL (Document ID 2337, pp. 2-3). The regulated area provision requires the provision and use of respirators for workers entering a regulated area as well as demarcation of the regulated area. Regarding the comments from the AFS and Ms. Persichetti, the regulated area provision does not require all workers and visitors to be part of the respiratory protection program—only workers or persons who are authorized to enter or work in a regulated area. The regulated area provision in the final rule does not require employers to provide protective clothing, vacuum stations, or air showers or to decontaminate, de-dust, or clean the regulated areas with a HEPA filter vacuum. Protective clothing was required in the proposed rule, but the Agency has deleted that requirement in the final rule (as discussed in the Summary and Explanation of this provision in the preamble). While an employer might want to keep employees from inadvertently carrying silica dust from a regulated area to other parts of the workplace, the cost of any such action taken by the employer is already included in the costs of complying with the PEL through housekeeping and is not a cost attributable to the regulated area provision.

Finally, URS provided comments arguing for higher regulated area costs because: (1) OSHA had underestimated the number of visitors a day to each regulated area and, therefore, disposable respirator costs; and (2) OSHA had underestimated the number of regulated areas (Document 2307, Attachment 8, p. 23). Regarding (1), URS commented,

> OSHA had assumed two visitors each day to each regulated area. URS assumed very small facilities would have one visitor, small facilities would have five visitors, and large facilities would have 20 visitors each day to each regulated area. … All of these categories would greatly increase as the size of the facility gets larger. URS actually decreased the number of visitors to regulated areas for very small facilities from the OSHA estimate (Document 2307, Attachment 8, p. 23).

The Agency believes that URS has misunderstood how OSHA estimated unit costs, including respirator costs, for regulated areas. URS seems to believe that each establishment with at least one worker exposed above the PEL will have one regulated area with two visitors each day. However, OSHA's estimate reflects one regulated area for every eight workers, not for every establishment. For example, if a large establishment has 80 workers exposed above the PEL, OSHA estimated there to be ten regulated areas (80 workers/8 workers per regulated area). As URS stated, OSHA estimated there to be two visitors each day to each regulated area. In a facility with ten regulated areas, this amounts to 20 visitors each day to regulated areas at that large establishment, just as URS estimated. Thus, the Agency does not believe that URS's adjustment is significantly different from OSHA's estimate in the PEA. OSHA did not adopt URS's visitor adjustment because OSHA's costing unit is the regulated area, not the establishment.

Regarding (2), URS asserted that many more workers would exceed the PEL of 50 $\mu g/m^3$ than OSHA estimated in the PEA. The Agency has already addressed, and rejected, this URS assertion in the technological feasibility, industry profile, and engineering control cost sections of this FEA. Furthermore, in its cost model, URS applied regulated area costs to every facility in an industrial sector whenever more than 25 percent of the workers in any job were initially found to be above the PEL. OSHA rejects this modification because initial overexposures may not persist after engineering controls are applied. However, as explained in the section in this chapter of the FEA on respiratory protection costs and below in the presentation of estimated regulated area costs for this FEA, OSHA increased its estimates of the number of respirators, and proportionately the number of regulated areas, needed in general industry and maritime to reflect changes in the technological feasibility analysis (in Chapter IV of this FEA). Also, as described below, OSHA's approach to estimating the number of respirators needed under the final rule—from, in the PEA, all workers that the Agency's technological feasibility analysis has determined will require respirator use *or* 10 percent of workers currently exposed above 50 $\mu g/m^3$ whichever is larger, to, in this FEA, all workers that the Agency's technological feasibility analysis has determined will require respirator use *and* 10 percent of the remaining workers currently exposed above 50 $\mu g/m^3$—further increased the estimated number of regulated areas.

<u>Comments on methods of demarcation</u>

Some commenters expressed concern that employers would be required to undertake extensive and expensive building construction to their existing facility layouts in order to adhere to the regulated area requirements. For example, Gregory Timmons, from Eramet and Bear Metallurgical Company, wrote:

> Bear's facility consists of an open process building which cannot be broken down into regulated areas by constructing partitions, due to the

> necessary use of large machinery to move the products between areas. In order to establish a regulated area Bear would need to build a new facility that would accommodate such a breakdown… (Document ID 2082, p. 7).

Jeff Wherry, of the Unified Abrasives Manufacturers Association, raised a similar issue, and expressed concern that employers would need to spend money to construct barriers before the new engineering controls were required to be in place. He stated:

> Regulated [a]reas and [a]ccess [c]ontrol clearly requires demarcation of areas expected to be in excess of the PEL. Proper [d]emarcation would require the construction of a physical separation on these work stations yet this construction task appears to be exempt from the 1 year [e]ngineering controls extension granted under Start-up dates (k)(2)(ii) (Document ID 3398, p. 2).

James Toscas, from the Precast/Prestressed Concrete Institute (PCI), also submitted comments on the costs of constructing enclosures for regulated areas, but his comments were specific to abrasive blasting:

> A plant with limited yard space doing outdoor abrasive blasting would need to enclose the work area with a building or other enclosure at an estimated cost of $300,000 to $1,000,000 (Document ID 2276, p. 5).

OSHA notes, with respect to this comment, that the large majority of abrasive blasting occurs in construction where there is no regulated area requirement, and that the regulated area provision does not require physical enclosure to demarcate the space. Also, the OSHA standard covering abrasive blasting (29 CFR 1910.94) already contains provisions for controlling exposures outside the immediate blasting area. For the purposes of estimating costs, the Agency assumes full compliance with existing standards, so the incremental costs of the regulated area provision in the final silica rule for establishments where abrasive blasting is being performed will be minimal.

Other commenters noted that demarcating areas is both common and straightforward, even in relatively open work areas—even if the demarcated areas are not being referred to as "regulated areas." Kenny Jordan, the Executive Director of the Association of Energy Service Companies, in response to a question on how companies try to limit exposures by limiting the numbers of people who are in the exposure area, testified:

> [Those who may be exposed are] identified by job title, the scope, where those particular areas are. And the rest of the employees…they know during the [Job Safety Analysis]… that they are to stay out of those areas. Usually, they will rope those areas off and just say you

> have no business in here, you have no job function in here, don't go in here (Document ID 3589, Tr. 4079-4080).

Similarly, Dr. Franklin Mirer, speaking on behalf of the AFL-CIO, testified:

> You post signs. I mean, in a foundry the regulated area is probably a workstation or a series of workstations… you determine the extent of the dust cloud, assuming it's still there, and you post it [the sign]. … this is like a simple concept, not something very difficult (Document ID 3578, Tr. 1003).

While the physical separation of work areas might minimize worker silica exposures, the regulated area provision does not obligate establishments to construct barriers between work areas. As discussed in more detail in the preamble explanation of this requirement, this provision only requires employers to demarcate the areas where exposures exceed or can reasonably be expected to exceed the PEL. The Agency does not stipulate specific methods of demarcation—other than signage—so employers are not required to take on the types of costly modifications described by the commenters. As in the proposal, OSHA has left the method of demarcation to the employer in the final standard for general industry, so long as the demarcation is accomplished in a manner that minimizes the number of employees exposed to respirable crystalline silica within the regulated area. Cones, stanchions, tape, barricades, lines, or textured flooring may each be effective means of demarcating the boundaries of regulated areas.

The Agency notes, however, that the FEA does include costs for enclosures and control rooms for a number of operations for employers in general industry and maritime, but these enclosures and control rooms are engineering controls meant to reduce exposures, not to demarcate regulated areas. These controls and costs are therefore included in the engineering control cost analysis earlier in this chapter.

Comments on facility downtime

Regarding Mr. Wherry's concern about the timing of the regulated areas requirement, this has been resolved by a change in the final rule: OSHA will not begin enforcing any requirements of the final rule until two years after the effective date of the rule (and five years after the effective date of the rule for hydraulic fracturing operations in the oil and gas industry), giving employers ample time to comply.

Charles Drevna, of American Fuel & Petrochemical Manufacturers (AFPM), argued that implementing regulated areas would be of such magnitude as to involve facility downtime and lost productivity:

> AFPM's members will endure the direct costs of compliance up front; e.g., implementing regulated areas or access control plans…But they will also be forced to endure lost productivity from the cumulative compliance delays that will prevent the facility from re-entering production (Document ID 2350, p. 8).

OSHA does not believe that the establishment of a regulated area would be so complex or time-consuming as to require a facility to shut down just for that purpose. Furthermore, the Agency notes that most facilities periodically have downtime for maintenance or other purposes. Even if the process of establishing a regulated area is more complicated than estimated in this FEA, given the two years provided for employers to come into compliance with this final rule, and the fact that most facilities will have periodic downtime for other purposes, there is no reason to believe that facilities would incur additional downtime just to comply with this provision of the final rule.[43]

Final cost estimates

Other than the issues raised above, OSHA did not receive comments on the other elements of the PEA cost analysis for regulated areas in general industry or maritime. The Agency has therefore retained the same general cost structure used in the PEA, with the only changes being to adjust costs to 2012 dollars and to remove the costs for protective clothing (not required in the final rule). As before, OSHA estimates that one regulated area would be necessary for every eight workers in general industry and maritime exposed or expected to be exposed above the PEL.[44] Planning time for a regulated area is estimated to be an initial seven hours of supervisor time (initial cost of $282.67 in 2012 dollars), and one hour for changes annually (at a cost of $40.38 in 2012 dollars); material costs for signs and boundary markers (annualized at $73.52 in 2012 dollars); and costs of $526 annually for two disposable respirators per day to be used by authorized persons (other than those who regularly work in the regulated area) who might need to enter the area in the course of their job duties.[45] Note that these disposable

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[43] See Chapter V of this FEA, Engineering Control Costs: *Accounting for Costs of Downtime*, for further discussion of the issue of downtime.

[44] This is the same methodology OSHA used to determine the number of regulated areas in the PEA. OSHA solicited comment on its estimate of one regulated area for every 8 workers exposed above the PEL but did not receive any comments on this estimate. Thus, the Agency has retained the estimate for this FEA.

[45] The estimate of two disposable respirators per regulated area per day is intended to represent an *average* for all affected regulated areas in general industry and maritime—some will inevitably need more, some fewer; and many will require none. Establishments with more than 8 workers with exposures above the PEL will be costed as having more than one regulated area and, accordingly, more than two disposable respirators per day.

respirator costs incurred by authorized persons who need to enter a regulated area (other than those workers who regularly work in a regulated area and are required to wear a respirator to comply with the PEL requirements of the final rule) are not included in the respiratory protection costs presented in the respiratory protection cost section.

Table V-25 shows OSHA's cost assumptions and unit costs in general industry and maritime for the regulated area provision of the final rule. Overall, OSHA estimates that each regulated area in general industry and maritime would, on average, cost employers $666 annually. OSHA expects that regulated areas will be established: (1) for all workers that the Agency's technological feasibility analysis has determined will require respirator use; and (2) for ten percent of the remaining workers currently exposed above 50 $\mu g/m^3$ at covered workplaces.[46] In all, OSHA estimates that there will be 3,958 regulated areas annually in general industry and maritime. Table V-26 shows total estimated costs for regulated areas in general industry and maritime of approximately $2.6 million annually and also provides a breakdown of costs by NAICS industry.

[46] This additional 10 percent is designed to cover circumstances in which engineering controls do not reduce exposure levels to the extent anticipated by the technological feasibility analysis (e.g., because controls are not selected, used, or maintained properly).

Table V-25:
Cost Assumptions for Regulated Areas - General Industry and Maritime

	Parameter	Unit cost	Comment
Regulated area setup			
Time to set up regulated area (hours) - First year only	7	$282.67	Estimated by ERG. Valued at supervisor's wage (BLS, 2012b)
Annual time for changes to regulated areas (hours)	1	$40.38	Estimated by ERG. Valued at supervisor's wage (BLS, 2012b)
Annualized regulated area set up costs		$73.52	Annualized set up costs plus annual costs
Respirators			
Respirators per authorized person per day	2		Assumes 2 disposable respirators used per day
Cost - disposable particulate respirator (N95)		$1.05	$1.00 per respirator, typical cost for N95 disposable respirator (Lab Safety Supply, 2010); inflated to 2012
Respirator cost - annual per authorized employee		$526	
Materials			
Hazard tape per job (300 ft)		$6.10	$5.80 per roll, (Lab Safety Supply, 2010); inflated to 2012
Warning signs (6)		$159.64	$25.30 per sign; (Lab Safety Supply, 2010); inflated to 2012
Warning signs - annualized cost		$60.83	Assumes 3 year life for signs
Annualized materials cost per area		$66.93	Sum of hazard tape and annualized warning sign costs
Total annualized cost per area		$666	Sum of respirator, materials and labor cost
Assumptions			
Average number of workers above the PEL per regulated area	8		
Number of working days per year	250		
Share of workers needing regulated areas (percent of at-risk workers initially exposed above the PEL)	10.0%		

Source: OSHA, Directorate of Standards and Guidance, Office of Regulatory Analysis, based on OSHA (2016).

Table V-26: Annualized Regulated Areas Costs for General Industry and Maritime

NAICS	Industry	Workers Needing Respirators	No. of Reg Areas	Annual Costs
213112	Support Activities for Oil and Gas Operations	11,207	1401	**$933,458**
324121	Asphalt Paving Mixture and Block Manufacturing	5	1	**$666**
324122	Asphalt Shingle and Coating Materials Manufacturing	141	18	**$11,993**
325510	Paint and Coating Manufacturing	39	5	**$3,331**
327110	Pottery, Ceramics, and Plumbing Fixture Manufacturing	250	32	**$21,321**
327120	Clay Building Material and Refractories Manufacturing	1,766	221	**$147,248**
327211	Flat Glass Manufacturing	91	12	**$7,995**
327212	Other Pressed and Blown Glass and Glassware Manufacturing	275	35	**$23,320**
327213	Glass Container Manufacturing	280	36	**$23,986**
327320	Ready-Mix Concrete Manufacturing	6,833	855	**$569,669**
327331	Concrete Block and Brick Manufacturing	638	80	**$53,302**
327332	Concrete Pipe Manufacturing	352	45	**$29,983**
327390	Other Concrete Product Manufacturing	1,939	243	**$161,906**
327991	Cut Stone and Stone Product Manufacturing	524	66	**$43,974**
327992	Ground or Treated Mineral and Earth Manufacturing	115	15	**$9,994**
327993	Mineral Wool Manufacturing	316	40	**$26,651**
327999	All Other Miscellaneous Nonmetallic Mineral Product Manufacturing	169	22	**$14,658**
331110	Iron and Steel Mills and Ferroalloy Manufacturing	14	2	**$1,333**
331210	Iron and Steel Pipe and Tube Manufacturing from Purchased Steel	3	1	**$666**
331221	Rolled Steel Shape Manufacturing	1	1	**$666**
331222	Steel Wire Drawing	2	1	**$666**
331314	Secondary Smelting and Alloying of Aluminum	1	1	**$666**
331420	Copper Rolling, Drawing, Extruding, and Alloying	3	1	**$666**
331492	Secondary Smelting, Refining, and Alloying of Nonferrous Metal (except Copper and Aluminum)	1	1	**$666**
331511	Iron Foundries	1,702	213	**$141,918**
331512	Steel Investment Foundries	396	50	**$33,314**
331513	Steel Foundries (except Investment)	811	102	**$67,961**
331524	Aluminum Foundries (except Die-Casting)	150	19	**$12,659**
331529	Other Nonferrous Metal Foundries (except Die-Casting)	92	12	**$7,995**
332111	Iron and Steel Forging	3	1	**$666**
332112	Nonferrous Forging	1	1	**$666**
332117	Powder Metallurgy Part Manufacturing	1	1	**$666**
332119	Metal Crown, Closure, and Other Metal Stamping (except Automotive)	7	1	**$666**
332215	Metal Kitchen Cookware, Utensil, Cutlery, and Flatware (except	1	1	**$666**
332216	Saw Blade and Handtool Manufacturing	4	1	**$666**
332323	Ornamental and Architectural Metal Work Manufacturing	2	1	**$666**
332439	Other Metal Container Manufacturing	2	1	**$666**
332510	Hardware Manufacturing	4	1	**$666**

Table V-26: Annualized Regulated Areas Costs for General Industry and Maritime (continued)

NAICS	Industry	Workers Needing Respirators	No. of Reg Areas	Annual Costs
332613	Spring Manufacturing	2	1	**$666**
332618	Other Fabricated Wire Product Manufacturing	3	1	**$666**
332710	Machine Shops	33	5	**$3,331**
332812	Metal Coating, Engraving (except Jewelry and Silverware), and Allied	165	21	**$13,992**
332911	Industrial Valve Manufacturing	5	1	**$666**
332912	Fluid Power Valve and Hose Fitting Manufacturing	5	1	**$666**
332913	Plumbing Fixture Fitting and Trim Manufacturing	1	1	**$666**
332919	Other Metal Valve and Pipe Fitting Manufacturing	2	1	**$666**
332991	Ball and Roller Bearing Manufacturing	3	1	**$666**
332996	Fabricated Pipe and Pipe Fitting Manufacturing	4	1	**$666**
332999	All Other Miscellaneous Fabricated Metal Product Manufacturing	10	2	**$1,333**
333318	Other Commercial and Service Industry Machinery Manufacturing	7	1	**$666**
333413	Industrial and Commercial Fan and Blower and Air Purification Equipment Manufacturing	3	1	**$666**
333414	Heating Equipment (except Warm Air Furnaces) Manufacturing	2	1	**$666**
333511	Industrial Mold Manufacturing	5	1	**$666**
333514	Special Die and Tool, Die Set, Jig, and Fixture Manufacturing	6	1	**$666**
333515	Cutting Tool and Machine Tool Accessory Manufacturing	4	1	**$666**
333517	Machine Tool Manufacturing	3	1	**$666**
333519	Rolling Mill and Other Metalworking Machinery Manufacturing	2	1	**$666**
333612	Speed Changer, Industrial High-Speed Drive, and Gear Manufacturing	2	1	**$666**
333613	Mechanical Power Transmission Equipment Manufacturing	2	1	**$666**
333911	Pump and Pumping Equipment Manufacturing	5	1	**$666**
333912	Air and Gas Compressor Manufacturing	3	1	**$666**
333991	Power-Driven Handtool Manufacturing	1	1	**$666**
333992	Welding and Soldering Equipment Manufacturing	2	1	**$666**
333993	Packaging Machinery Manufacturing	3	1	**$666**
333994	Industrial Process Furnace and Oven Manufacturing	1	1	**$666**
333995	Fluid Power Cylinder and Actuator Manufacturing	3	1	**$666**
333996	Fluid Power Pump and Motor Manufacturing	1	1	**$666**
333997	Scale and Balance Manufacturing	1	1	**$666**
333999	All Other Miscellaneous General Purpose Machinery Manufacturing	7	1	**$666**
334519	Other Measuring and Controlling Device Manufacturing	5	1	**$666**
335210	Small Electrical Appliance Manufacturing	1	1	**$666**
335221	Household Cooking Appliance Manufacturing	1	1	**$666**
335222	Household Refrigerator and Home Freezer Manufacturing	1	1	**$666**
335224	Household Laundry Equipment Manufacturing	1	1	**$666**
335228	Other Major Household Appliance Manufacturing	1	1	**$666**
336111	Automobile Manufacturing	9	2	**$1,333**

Table V-26: Annualized Regulated Areas Costs for General Industry and Maritime (continued)

NAICS	Industry	Workers Needing Respirators	No. of Reg Areas	Annual Costs
336112	Light Truck and Utility Vehicle Manufacturing	8	1	**$666**
336120	Heavy Duty Truck Manufacturing	4	1	**$666**
336211	Motor Vehicle Body Manufacturing	5	1	**$666**
336212	Truck Trailer Manufacturing	4	1	**$666**
336213	Motor Home Manufacturing	1	1	**$666**
336310	Motor Vehicle Gasoline Engine and Engine Parts Manufacturing	7	1	**$666**
336320	Motor Vehicle Electrical and Electronic Equipment Manufacturing	7	1	**$666**
336330	Motor Vehicle Steering and Suspension Components (except Spring)	4	1	**$666**
336340	Motor Vehicle Brake System Manufacturing	3	1	**$666**
336350	Motor Vehicle Transmission and Power Train Parts Manufacturing	8	1	**$666**
336370	Motor Vehicle Metal Stamping	11	2	**$1,333**
336390	Other Motor Vehicle Parts Manufacturing	17	3	**$1,999**
336611	Ship Building and Repairing	182	23	**$15,324**
336612	Boat Building	47	6	**$3,998**
336992	Military Armored Vehicle, Tank, and Tank Component Manufacturing	1	1	**$666**
337110	Wood Kitchen Cabinet and Countertop Manufacturing	9	2	**$1,333**
337215	Showcase, Partition, Shelving, and Locker Manufacturing	5	1	**$666**
339114	Dental Equipment and Supplies Manufacturing	198	25	**$16,657**
339116	Dental Laboratories	86	11	**$7,329**
339910	Jewelry and Silverware Manufacturing	245	31	**$20,655**
339950	Sign Manufacturing	16	3	**$1,999**
423840	Industrial Supplies Merchant Wholesalers	591	74	**$49,305**
444110	Home Centers	4	1	**$666**
482110	Rail transportation	0	0	**$0**
561730	Landscaping Services	1,261	158	**$105,272**
621210	Offices of Dentists	24	3	**$1,999**
	Totals	**31,206**	**3958**	**$2,637,136**

Source: OSHA, Directorate of Standards and Guidance, Office of Regulatory Analysis, based on OSHA (2016).

Written Exposure Control Plan

A written exposure control plan provision was not included in the silica proposal, and no costs for a written exposure control plan were estimated in the PEA. Paragraph (f)(2) of the final standard for general industry and maritime contains requirements for a written exposure control plan. The Summary and Explanation section of the preamble provides a thorough explanation of the reasoning behind the inclusion of the written exposure control plan provision in the final standard.

As specified in paragraph (f)(2)(i), the employer must establish and implement a written exposure control plan that contains at least the following elements: (A) a description of the tasks in the workplace that involve exposure to respirable crystalline silica; (B) a description of the engineering controls, work practices, and respiratory protection used to limit employee exposure to respirable crystalline silica for each task; and (C) a description of the housekeeping measures used to limit employee exposure to respirable crystalline silica. Under paragraph (f)(2)(ii), the employer must review and evaluate the effectiveness of the written exposure control plan at least annually and update it as necessary.

As shown in Table V-27, unit costs for a written exposure control plan were calculated based on establishment size. OSHA assumed, for costing purposes, that a supervisor would develop and update the written exposure control plan for each establishment, spending one hour for establishments with fewer than 20 employees (very small establishments), four hours for those establishments with between 20 and 499 employees, and 16 hours for those establishments with 500 or more employees. OSHA estimated that one hour would be sufficient for very small establishments because there is, on average, slightly more than one worker covered by the standard per very small establishment in general industry and maritime. In general, the Agency judges the number of employees per establishment to be a fair proxy for the amount of time required to develop a written exposure control plan. OSHA expects that both the number of work stations covered and amount of time needed to control exposures will increase with the number of employees involved. Larger establishments may encounter a greater diversity of exposure sources, as well a greater challenge of coordinating control strategies for different tasks.

OSHA further estimated that the additional supervisory time needed to review and evaluate the effectiveness of the plan, and to update it as necessary, will also vary by establishment size for the same reasons as described above for the establishment of the original plan. OSHA is estimating 0.5 hours for establishments with fewer than 20 employees, two hours for those with between 20 and 499 employees, and eight hours for those with 500 or more employees to perform the annual review and update. The Agency expects that no other labor or materials will be required to implement the plan because any such labor or materials would be accounted for in the cost of the regulated area provision, so the sole cost for this provision is the time it will take to develop, review, and update the plan.

The annualized unit costs for the written exposure control plan presented in Table V-27 have been applied to the employers in general industry and maritime covered by the standard—in all, 51,949 establishments with fewer than 20 employees, 24,271 establishments with between 20 and 499 employees, and 641 establishments with 500 or more employees. The annualized costs, broken out by NAICS industry, are shown in Table V-28. For general industry and maritime, the total annualized cost of developing, reviewing, and updating the written exposure control plan is $4.1 million.

Table V-27: Unit Costs for a Written Exposure Control Plan in General Industry or Maritime

Establishment size	Small (<20)	Medium (20-499)	Large (500+)	
Time to develop plan (hours)	1.0	4.0	16.0	
Annualized cost for plan development	$5.75	$23.00	$91.99	One-time cost to develop plan annualized over ten years. Valued at weighted average of supervisors' hourly wage rate for affected industries (covered by general industry and maritime standard) of $40.38 per hour. Wages include fringe benefits. (BLS, 2012b)
Time for annual review and updating (hours)	0.5	2.0	8.0	
Annual review cost	$20.19	$80.76	$323.05	Annual cost to review plan. Valued at weighted average of supervisors' hourly wage rate for affected industries (covered by general industry and maritime standard) of $40.38 per hour. Wages include fringe benefits. (BLS, 2012b)
Total annualized cost	$25.94	$103.76	$415.04	

Source: OSHA, Directorate of Standards and Guidance, Office of Regulatory Analysis, based on OSHA (2016).

Table V-28:

Annualized Exposure Control Plan Costs by Establishment Size in General Industry or Maritime

NAICS	**Industry**	**Small (<20)**	**Medium (20-499)**	**Large (500+)**	**Total Exposure Control Plan**
213112	Support Activities for Oil and Gas Operations	$2,594	$35,693	$0	**$38,287**
324121	Asphalt Paving Mixture and Block Manufacturing	$31,699	$14,526	$0	**$46,225**
324122	Asphalt Shingle and Coating Materials Manufacturing	$2,853	$11,725	$0	**$14,578**
325510	Paint and Coating Manufacturing	$9,522	$41,608	$1,660	**$52,789**
327110	Pottery, Ceramics, and Plumbing Fixture Manufacturing	$13,982	$11,829	$830	**$26,640**
327120	Clay Building Material and Refractories Manufacturing	$14,011	$59,766	$0	**$73,777**
327211	Flat Glass Manufacturing	$92	$5,292	$415	**$5,798**
327212	Other Pressed and Blown Glass and Glassware Manufacturing	$1,991	$9,338	$1,660	**$12,989**
327213	Glass Container Manufacturing	$157	$5,707	$415	**$6,278**
327320	Ready-Mix Concrete Manufacturing	$113,410	$104,279	$0	**$217,688**
327331	Concrete Block and Brick Manufacturing	$14,890	$25,214	$0	**$40,103**
327332	Concrete Pipe Manufacturing	$5,240	$15,564	$0	**$20,804**
327390	Other Concrete Product Manufacturing	$35,849	$61,322	$0	**$97,171**
327991	Cut Stone and Stone Product Manufacturing	$39,870	$33,307	$415	**$73,592**
327992	Ground or Treated Mineral and Earth Manufacturing	$4,280	$8,716	$0	**$12,996**
327993	Mineral Wool Manufacturing	$1,598	$11,414	$830	**$13,842**
327999	All Other Miscellaneous Nonmetallic Mineral Product Manufacturing	$15,107	$32,996	$0	**$48,103**
331110	Iron and Steel Mills and Ferroalloy Manufacturing	$0	$24,089	$19,922	**$44,010**
331210	Iron and Steel Pipe and Tube Manufacturing from Purchased Steel	$0	$10,628	$3,320	**$13,948**
331221	Rolled Steel Shape Manufacturing	$0	$4,186	$415	**$4,601**
331222	Steel Wire Drawing	$0	$7,972	$415	**$8,387**
331314	Secondary Smelting and Alloying of Aluminum	$0	$3,161	$0	**$3,161**
331420	Copper Rolling, Drawing, Extruding, and Alloying	$0	$10,752	$1,245	**$11,997**
331492	Secondary Smelting, Refining, and Alloying of Nonferrous Metal (except Copper and Aluminum)	$0	$5,925	$415	**$6,340**
331511	Iron Foundries	$4,073	$24,799	$4,565	**$33,437**
331512	Steel Investment Foundries	$804	$9,442	$2,490	**$12,737**
331513	Steel Foundries (except Investment)	$2,412	$11,310	$2,490	**$16,212**
331524	Aluminum Foundries (except Die-Casting)	$6,226	$17,224	$0	**$23,450**
331529	Other Nonferrous Metal Foundries (except Die-Casting)	$4,955	$11,206	$415	**$16,576**
332111	Iron and Steel Forging	$0	$12,638	$1,245	**$13,883**
332112	Nonferrous Forging	$0	$2,756	$830	**$3,587**
332117	Powder Metallurgy Part Manufacturing	$0	$4,774	$0	**$4,774**
332119	Metal Crown, Closure, and Other Metal Stamping (except Automotive)	$0	$29,489	$1,660	**$31,149**
332215	Metal Kitchen Cookware, Utensil, Cutlery, and Flatware (except Precious) Manufacturing	$0	$3,586	$830	**$4,416**
332216	Saw Blade and Handtool Manufacturing	$0	$14,839	$1,660	**$16,499**
332323	Ornamental and Architectural Metal Work Manufacturing	$325	$2,561	$1,181	**$4,067**
332439	Other Metal Container Manufacturing	$0	$6,224	$830	**$7,054**
332510	Hardware Manufacturing	$0	$13,150	$2,905	**$16,055**

Table V-28: (continued)

Annualized Exposure Control Plan Costs by Establishment Size in General Industry or Maritime

NAICS	Industry	Small (<20)	Medium (20-499)	Large (500+)	Total Exposure Control Plan
332613	Spring Manufacturing	$0	$8,393	$415	**$8,808**
332618	Other Fabricated Wire Product Manufacturing	$0	$14,078	$415	**$14,493**
332710	Machine Shops	$0	$143,511	$415	**$143,926**
332812	Metal Coating, Engraving (except Jewelry and Silverware), and Allied Services to Manufacturers	$23,413	$74,396	$0	**$97,809**
332911	Industrial Valve Manufacturing	$0	$17,570	$3,320	**$20,890**
332912	Fluid Power Valve and Hose Fitting Manufacturing	$0	$13,097	$5,396	**$18,493**
332913	Plumbing Fixture Fitting and Trim Manufacturing	$0	$3,402	$1,245	**$4,647**
332919	Other Metal Valve and Pipe Fitting Manufacturing	$0	$7,424	$1,245	**$8,669**
332991	Ball and Roller Bearing Manufacturing	$0	$9,113	$4,565	**$13,678**
332996	Fabricated Pipe and Pipe Fitting Manufacturing	$0	$16,287	$1,245	**$17,532**
332999	All Other Miscellaneous Fabricated Metal Product Manufacturing	$93	$40,334	$1,468	**$41,896**
333318	Other Commercial and Service Industry Machinery Manufacturing	$0	$25,365	$5,811	**$31,176**
333413	Industrial and Commercial Fan and Blower and Air Purification Equipment Manufacturing	$0	$13,234	$1,245	**$14,479**
333414	Heating Equipment (except Warm Air Furnaces) Manufacturing	$0	$10,540	$0	**$10,540**
333511	Industrial Mold Manufacturing	$0	$19,952	$830	**$20,782**
333514	Special Die and Tool, Die Set, Jig, and Fixture Manufacturing	$0	$24,160	$1,245	**$25,405**
333515	Cutting Tool and Machine Tool Accessory Manufacturing	$0	$16,664	$0	**$16,664**
333517	Machine Tool Manufacturing	$0	$13,057	$1,245	**$14,302**
333519	Rolling Mill and Other Metalworking Machinery Manufacturing	$0	$6,242	$830	**$7,072**
333612	Speed Changer, Industrial High-Speed Drive, and Gear Manufacturing	$0	$7,622	$1,245	**$8,867**
333613	Mechanical Power Transmission Equipment Manufacturing	$0	$8,345	$830	**$9,175**
333911	Pump and Pumping Equipment Manufacturing	$0	$16,071	$4,150	**$20,221**
333912	Air and Gas Compressor Manufacturing	$0	$9,791	$2,075	**$11,866**
333991	Power-Driven Handtool Manufacturing	$0	$3,657	$830	**$4,487**
333992	Welding and Soldering Equipment Manufacturing	$0	$5,594	$1,660	**$7,254**
333993	Packaging Machinery Manufacturing	$0	$10,969	$830	**$11,799**
333994	Industrial Process Furnace and Oven Manufacturing	$0	$6,454	$0	**$6,454**
333995	Fluid Power Cylinder and Actuator Manufacturing	$0	$10,463	$2,075	**$12,539**
333996	Fluid Power Pump and Motor Manufacturing	$0	$4,976	$1,245	**$6,221**
333997	Scale and Balance Manufacturing	$0	$2,176	$0	**$2,176**
333999	All Other Miscellaneous General Purpose Machinery Manufacturing	$0	$26,461	$2,490	**$28,951**
334519	Other Measuring and Controlling Device Manufacturing	$0	$16,272	$2,905	**$19,177**
335210	Small Electrical Appliance Manufacturing	$30	$1,573	$1,660	**$3,263**
335221	Household Cooking Appliance Manufacturing	$20	$926	$2,075	**$3,022**
335222	Household Refrigerator and Home Freezer Manufacturing	$5	$503	$2,490	**$2,998**
335224	Household Laundry Equipment Manufacturing	$2	$9	$1,245	**$1,256**
335228	Other Major Household Appliance Manufacturing	$7	$264	$3,735	**$4,006**
336111	Automobile Manufacturing	$0	$1,559	$9,961	**$11,520**
336112	Light Truck and Utility Vehicle Manufacturing	$0	$646	$8,716	**$9,362**

Table V-28: (continued)

Annualized Exposure Control Plan Costs by Establishment Size in General Industry or Maritime

NAICS	Industry	Small (<20)	Medium (20-499)	Large (500+)	Total Exposure Control Plan
336120	Heavy Duty Truck Manufacturing	$0	$2,329	$7,471	**$9,799**
336211	Motor Vehicle Body Manufacturing	$0	$18,352	$5,396	**$23,748**
336212	Truck Trailer Manufacturing	$0	$11,643	$3,735	**$15,378**
336213	Motor Home Manufacturing	$0	$1,261	$1,660	**$2,921**
336310	Motor Vehicle Gasoline Engine and Engine Parts Manufacturing	$0	$17,628	$10,791	**$28,419**
336320	Motor Vehicle Electrical and Electronic Equipment Manufacturing	$0	$19,028	$7,056	**$26,084**
336330	Motor Vehicle Steering and Suspension Components (except Spring)	$0	$10,036	$4,565	**$14,601**
336340	Motor Vehicle Brake System Manufacturing	$0	$9,512	$3,320	**$12,832**
336350	Motor Vehicle Transmission and Power Train Parts Manufacturing	$0	$17,636	$10,791	**$28,427**
336370	Motor Vehicle Metal Stamping	$0	$33,898	$11,621	**$45,519**
336390	Other Motor Vehicle Parts Manufacturing	$0	$47,680	$20,752	**$68,432**
336611	Ship Building and Repairing	$1,781	$26,666	$11,206	**$39,654**
336612	Boat Building	$2,366	$22,412	$2,490	**$27,269**
336992	Military Armored Vehicle, Tank, and Tank Component Manufacturing	$0	$2,421	$3,320	**$5,741**
337110	Wood Kitchen Cabinet and Countertop Manufacturing	$2,052	$11,592	$6,226	**$19,870**
337215	Showcase, Partition, Shelving, and Locker Manufacturing	$0	$17,897	$2,075	**$19,972**
339114	Dental Equipment and Supplies Manufacturing	$15,460	$13,281	$1,245	**$29,987**
339116	Dental Laboratories	$167,131	$38,702	$830	**$206,664**
339910	Jewelry and Silverware Manufacturing	$51,129	$63,254	$3,735	**$118,118**
339950	Sign Manufacturing	$3,099	$24,792	$2,075	**$29,966**
423840	Industrial Supplies Merchant Wholesalers	$20,514	$91,960	$2,490	**$114,965**
444110	Home Centers	$69	$10,813	$0	**$10,882**
482110	Rail transportation	$0	$35,060	$0	**$35,060**
561730	Landscaping Services	$541,705	$526,789	$9,131	**$1,077,624**
621210	Offices of Dentists	$192,747	$113,529	$0	**$306,276**
	Totals	**$1,347,560**	**$2,518,327**	**$266,199**	**$4,132,086**

Source: OSHA, Directorate of Standards and Guidance, Office of Regulatory Analysis, based on OSHA (2016).

Combined Control, Respirator, and Program Costs

Table V-29 shows that the combined compliance costs for general industry and maritime to comply with the final silica rule are approximately $370.8 million annually. These costs include $238.1 million annually for controls and $10.5 million annually for respirators to meet the proposed PEL of 50 $\mu g/m^3$. The remaining $122.2 million annually are to meet the ancillary provisions of the proposed rule. These ancillary annual costs consist of $79.8 million for exposure monitoring; $29.7 million for medical surveillance; $6.0 million for training and familiarization; $4.1 million for written exposure control plan; and $2.6 million for regulated areas.

Table V-B-1 in Appendix B presents estimated compliance costs by NAICS industry code and program element for small business entities (as defined by the Small Business Act and the Small Business Administration's implementing regulations; see 15 U.S.C. 632 and 13 CFR 121.201) in general industry and maritime, while Table V-B-2 presents estimated compliance costs, by NAICS code and program element, for very small entities (fewer than twenty employees) in general industry and maritime.

Table V-29: Combined Annualized Compliance Costs for General Industry and Maritime

NAICS	Industry	Control Costs	Respirators	Exposure Assessment	Medical Surveillance	Control Plan	Regulated Area	Training & Familiarization	**Total**
213112	Support Activities for Oil and Gas Operations	$84,432,467	$379,743	$9,045,642	$2,869,133	$38,287	$933,458	$229,021	**$97,927,752**
324121	Asphalt Paving Mixture and Block Manufacturing	$199,831	$2,179	$159,722	$10,087	$46,225	$666	$94,331	**$513,042**
324122	Asphalt Shingle and Coating Materials Manufacturing	$1,789,474	$64,039	$1,229,578	$655,915	$14,578	$11,993	$46,315	**$3,811,893**
325510	Paint and Coating Manufacturing	$512,668	$17,575	$260,034	$107,267	$52,789	$3,331	$54,963	**$1,008,627**
327110	Pottery, Ceramics, and Plumbing Fixture Manufacturing	$5,955,772	$113,598	$1,745,664	$830,515	$26,640	$21,321	$94,825	**$8,788,336**
327120	Clay Building Material and Refractories Manufacturing	$16,423,275	$925,152	$2,528,462	$1,021,961	$73,777	$147,248	$132,328	**$21,252,204**
327211	Flat Glass Manufacturing	$557,199	$47,844	$73,983	$27,719	$5,798	$7,995	$4,914	**$725,452**
327212	Other Pressed and Blown Glass and Glassware Manufacturing	$1,677,938	$145,188	$249,885	$85,236	$12,989	$23,320	$14,022	**$2,208,578**
327213	Glass Container Manufacturing	$1,709,226	$147,503	$228,292	$86,536	$6,278	$23,986	$10,850	**$2,212,672**
327320	Ready-Mix Concrete Manufacturing	$6,171,957	$3,540,572	$14,621,725	$4,385,169	$217,688	$569,669	$497,723	**$30,004,503**
327331	Concrete Block and Brick Manufacturing	$4,153,422	$327,761	$1,720,688	$609,557	$40,103	$53,302	$115,903	**$7,020,737**
327332	Concrete Pipe Manufacturing	$2,294,454	$180,805	$887,058	$335,464	$20,804	$29,983	$61,520	**$3,810,088**
327390	Other Concrete Product Manufacturing	$12,626,461	$994,723	$4,819,265	$1,844,827	$97,171	$161,906	$333,881	**$20,878,235**
327991	Cut Stone and Stone Product Manufacturing	$8,913,357	$239,778	$3,753,513	$1,434,031	$73,592	$43,974	$169,937	**$14,628,182**
327992	Ground or Treated Mineral and Earth Manufacturing	$2,295,864	$52,428	$1,256,434	$584,074	$12,996	$9,994	$76,632	**$4,288,421**

Table V-29: Combined Annualized Compliance Costs for General Industry and Maritime (continued)

NAICS	Industry	Control Costs	Respirators	Exposure Assessment	Medical Surveillance	Control Plan	Regulated Area	Training & Familiarization	**Total**
327993	Mineral Wool Manufacturing	$2,005,181	$166,640	$286,200	$101,292	$13,842	$26,651	$15,585	**$2,615,391**
327999	All Other Miscellaneous Nonmetallic Mineral Product Manufacturing	$8,597,395	$76,785	$1,878,371	$855,948	$48,103	$14,658	$126,546	**$11,597,806**
331110	Iron and Steel Mills and Ferroalloy Manufacturing	$465,771	$6,902	$65,595	$38,017	$44,010	$1,333	$24,774	**$646,402**
331210	Iron and Steel Pipe and Tube Manufacturing from Purchased Steel	$113,363	$1,678	$16,956	$9,297	$13,948	$666	$7,129	**$163,038**
331221	Rolled Steel Shape Manufacturing	$34,766	$514	$5,393	$2,860	$4,601	$666	$2,260	**$51,060**
331222	Steel Wire Drawing	$63,076	$933	$9,863	$5,192	$8,387	$666	$4,089	**$92,206**
331314	Secondary Smelting and Alloying of Aluminum	$23,872	$353	$3,763	$1,966	$3,161	$666	$1,530	**$35,312**
331420	Copper Rolling, Drawing, Extruding, and Alloying	$93,284	$1,380	$14,370	$7,669	$11,997	$666	$5,944	**$135,310**
331492	Secondary Smelting, Refining, and Alloying of Nonferrous Metal (except Copper and Aluminum)	$48,440	$717	$7,533	$3,985	$6,340	$666	$3,110	**$70,791**
331511	Iron Foundries	$16,134,210	$858,599	$3,933,423	$2,081,869	$33,437	$141,918	$179,499	**$23,362,955**
331512	Steel Investment Foundries	$4,034,862	$205,024	$737,214	$356,141	$12,737	$33,314	$71,144	**$5,450,435**
331513	Steel Foundries (except Investment)	$7,684,814	$409,068	$1,864,039	$990,897	$16,212	$67,961	$85,376	**$11,118,366**
331524	Aluminum Foundries (except Die-Casting)	$2,780,798	$75,247	$787,396	$359,083	$23,450	$12,659	$82,024	**$4,120,657**
331529	Other Nonferrous Metal Foundries (except Die-Casting)	$1,713,267	$46,419	$511,414	$221,703	$16,576	$7,995	$52,144	**$2,569,518**
332111	Iron and Steel Forging	$106,434	$1,575	$16,473	$8,753	$13,883	$666	$6,842	**$154,626**
332112	Nonferrous Forging	$27,279	$404	$4,122	$2,239	$3,587	$666	$1,805	**$40,101**
332117	Powder Metallurgy Part Manufacturing	$36,052	$533	$5,682	$2,969	$4,774	$666	$2,311	**$52,988**
332119	Metal Crown, Closure, and Other Metal Stamping (except Automotive)	$234,189	$3,465	$36,595	$19,275	$31,149	$666	$15,195	**$340,536**
332215	Metal Kitchen Cookware, Utensil, Cutlery, and Flatware (except Precious) Manufacturing	$32,655	$483	$4,993	$2,683	$4,416	$666	$2,194	**$48,090**

Table V-29: Combined Annualized Compliance Costs for General Industry and Maritime (continued)

NAICS	Industry	Control Costs	Respirators	Exposure Assessment	Medical Surveillance	Control Plan	Regulated Area	Training & Familiarization	**Total**
332216	Saw Blade and Handtool Manufacturing	$123,396	$1,826	$19,137	$10,150	$16,499	$666	$8,101	**$179,774**
332323	Ornamental and Architectural Metal Work Manufacturing	$20,424	$735	$11,368	$4,509	$4,067	$666	$2,246	**$44,015**
332439	Other Metal Container Manufacturing	$51,863	$767	$8,040	$4,266	$7,054	$666	$3,460	**$76,117**
332510	Hardware Manufacturing	$117,483	$1,739	$18,017	$9,654	$16,055	$666	$7,949	**$171,563**
332613	Spring Manufacturing	$65,599	$970	$10,278	$5,400	$8,808	$666	$4,283	**$96,006**
332618	Other Fabricated Wire Product Manufacturing	$109,036	$1,613	$17,111	$8,978	$14,493	$666	$7,043	**$158,941**
332710	Machine Shops	$1,086,755	$16,077	$171,208	$89,509	$143,926	$3,331	$69,701	**$1,580,507**
332812	Metal Coating, Engraving (except Jewelry and Silverware), and Allied Services to Manufacturers	$1,625,192	$75,344	$1,071,632	$461,594	$97,809	$13,992	$98,222	**$3,443,786**
332911	Industrial Valve Manufacturing	$157,784	$2,335	$24,178	$12,965	$20,890	$666	$10,376	**$229,195**
332912	Fluid Power Valve and Hose Fitting Manufacturing	$153,500	$2,273	$22,691	$12,577	$18,493	$666	$9,576	**$219,774**
332913	Plumbing Fixture Fitting and Trim Manufacturing	$33,527	$496	$5,069	$2,752	$4,647	$666	$2,326	**$49,483**
332919	Other Metal Valve and Pipe Fitting Manufacturing	$63,022	$933	$9,742	$5,182	$8,669	$666	$4,260	**$92,474**
332991	Ball and Roller Bearing Manufacturing	$99,714	$1,476	$14,866	$8,175	$13,678	$666	$6,932	**$145,507**
332996	Fabricated Pipe and Pipe Fitting Manufacturing	$132,275	$1,957	$20,593	$10,884	$17,532	$666	$8,584	**$192,491**
332999	All Other Miscellaneous Fabricated Metal Product Manufacturing	$312,979	$4,825	$51,820	$27,022	$41,896	$1,333	$20,462	**$460,336**
333318	Other Commercial and Service Industry Machinery Manufacturing	$241,287	$3,571	$36,661	$19,813	$31,176	$666	$15,635	**$348,809**
333413	Industrial and Commercial Fan and Blower and Air Purification Equipment Manufacturing	$106,821	$1,580	$16,647	$8,790	$14,479	$666	$7,072	**$156,056**

Table V-29: Combined Annualized Compliance Costs for General Industry and Maritime (continued)

NAICS	Industry	Control Costs	Respirators	Exposure Assessment	Medical Surveillance	Control Plan	Regulated Area	Training & Familiarization	**Total**
333414	Heating Equipment (except Warm Air Furnaces) Manufacturing	$79,591	$1,177	$12,545	$6,556	$10,540	$666	$5,102	**$116,177**
333511	Industrial Mold Manufacturing	$155,856	$2,306	$24,423	$12,831	$20,782	$666	$10,110	**$226,974**
333514	Special Die and Tool, Die Set, Jig, and Fixture Manufacturing	$189,400	$2,802	$29,661	$15,592	$25,405	$666	$12,362	**$275,889**
333515	Cutting Tool and Machine Tool Accessory Manufacturing	$125,835	$1,861	$19,834	$10,365	$16,664	$666	$8,066	**$183,291**
333517	Machine Tool Manufacturing	$107,566	$1,592	$16,707	$8,849	$14,302	$666	$7,016	**$156,698**
333519	Rolling Mill and Other Metalworking Machinery Manufacturing	$51,625	$764	$8,013	$4,247	$7,072	$666	$3,464	**$75,852**
333612	Speed Changer, Industrial High-Speed Drive, and Gear Manufacturing	$71,161	$1,053	$10,842	$5,845	$8,867	$666	$4,451	**$102,884**
333613	Mechanical Power Transmission Equipment Manufacturing	$68,757	$1,017	$10,679	$5,656	$9,175	$666	$4,499	**$100,450**
333911	Pump and Pumping Equipment Manufacturing	$149,614	$2,214	$22,804	$12,289	$20,221	$666	$10,073	**$217,882**
333912	Air and Gas Compressor Manufacturing	$93,972	$1,391	$14,260	$7,716	$11,866	$666	$5,970	**$135,840**
333991	Power-Driven Handtool Manufacturing	$39,303	$582	$5,873	$3,223	$4,487	$666	$2,315	**$56,450**
333992	Welding and Soldering Equipment Manufacturing	$69,967	$1,036	$10,264	$5,729	$7,254	$666	$3,858	**$98,775**
333993	Packaging Machinery Manufacturing	$88,491	$1,309	$13,792	$7,282	$11,799	$666	$5,769	**$129,107**
333994	Industrial Process Furnace and Oven Manufacturing	$48,741	$721	$7,682	$4,015	$6,454	$666	$3,124	**$71,404**
333995	Fluid Power Cylinder and Actuator Manufacturing	$107,135	$1,586	$16,112	$8,790	$12,539	$666	$6,410	**$153,238**
333996	Fluid Power Pump and Motor Manufacturing	$46,708	$691	$7,111	$3,836	$6,221	$666	$3,106	**$68,340**
333997	Scale and Balance Manufacturing	$16,433	$243	$2,590	$1,354	$2,176	$666	$1,053	**$24,516**
333999	All Other Miscellaneous General Purpose Machinery Manufacturing	$227,996	$3,374	$35,160	$18,745	$28,951	$666	$14,344	**$329,237**

Table V-29: Combined Annualized Compliance Costs for General Industry and Maritime (continued)

NAICS	Industry	Control Costs	Respirators	Exposure Assessment	Medical Surveillance	Control Plan	Regulated Area	Training & Familiarization	**Total**
334519	Other Measuring and Controlling Device Manufacturing	$153,947	$2,279	$23,409	$12,642	$19,177	$666	$9,643	**$221,763**
335210	Small Electrical Appliance Manufacturing	$11,066	$435	$4,813	$2,637	$3,263	$666	$1,644	**$24,524**
335221	Household Cooking Appliance Manufacturing	$14,018	$552	$5,521	$3,318	$3,022	$666	$1,651	**$28,748**
335222	Household Refrigerator and Home Freezer Manufacturing	$12,626	$497	$4,710	$2,979	$2,998	$666	$1,634	**$26,111**
335224	Household Laundry Equipment Manufacturing	$5,977	$235	$2,145	$1,406	$1,256	$666	$717	**$12,403**
335228	Other Major Household Appliance Manufacturing	$12,201	$480	$4,496	$2,876	$4,006	$666	$2,103	**$26,829**
336111	Automobile Manufacturing	$277,561	$4,117	$36,428	$22,537	$11,520	$1,333	$9,067	**$362,562**
336112	Light Truck and Utility Vehicle Manufacturing	$250,233	$3,712	$32,683	$20,311	$9,362	$666	$7,768	**$324,735**
336120	Heavy Duty Truck Manufacturing	$135,990	$2,017	$18,173	$11,056	$9,799	$666	$6,214	**$183,916**
336211	Motor Vehicle Body Manufacturing	$179,484	$2,657	$27,163	$14,734	$23,748	$666	$11,925	**$260,377**
336212	Truck Trailer Manufacturing	$125,352	$1,856	$18,727	$10,279	$15,378	$666	$7,871	**$180,129**
336213	Motor Home Manufacturing	$32,725	$485	$4,519	$2,667	$2,921	$666	$1,697	**$45,680**
336310	Motor Vehicle Gasoline Engine and Engine Parts Manufacturing	$233,483	$3,458	$34,037	$19,108	$28,419	$666	$14,879	**$334,051**
336320	Motor Vehicle Electrical and Electronic Equipment Manufacturing	$221,367	$3,278	$32,752	$18,138	$26,084	$666	$13,531	**$315,816**
336330	Motor Vehicle Steering and Suspension Components (except Spring) Manufacturing	$126,884	$1,879	$18,592	$10,389	$14,601	$666	$7,665	**$180,676**
336340	Motor Vehicle Brake System Manufacturing	$96,722	$1,432	$14,559	$7,936	$12,832	$666	$6,472	**$140,620**
336350	Motor Vehicle Transmission and Power Train Parts Manufacturing	$257,824	$3,819	$37,205	$21,084	$28,427	$666	$15,227	**$364,252**
336370	Motor Vehicle Metal Stamping	$358,513	$5,308	$53,684	$29,404	$45,519	$1,333	$23,164	**$516,924**

Table V-29: Combined Annualized Compliance Costs for General Industry and Maritime (continued)

NAICS	Industry	Control Costs	Respirators	Exposure Assessment	Medical Surveillance	Control Plan	Regulated Area	Training & Familiarization	**Total**
336390	Other Motor Vehicle Parts Manufacturing	$540,116	$7,997	$80,172	$44,267	$68,432	$1,999	$35,101	**$778,085**
336611	Ship Building and Repairing	$8,005,888	$82,823	$852,445	$539,088	$39,654	$15,324	$51,162	**$9,586,384**
336612	Boat Building	$2,073,668	$21,464	$277,790	$141,630	$27,269	$3,998	$20,950	**$2,566,768**
336992	Military Armored Vehicle, Tank, and Tank Component Manufacturing	$48,772	$723	$6,848	$3,980	$5,741	$666	$3,119	**$69,849**
337110	Wood Kitchen Cabinet and Countertop Manufacturing	$81,270	$3,921	$62,553	$23,950	$19,870	$1,333	$11,557	**$204,454**
337215	Showcase, Partition, Shelving, and Locker Manufacturing	$147,925	$2,189	$22,964	$12,169	$19,972	$666	$9,791	**$215,675**
339114	Dental Equipment and Supplies Manufacturing	$4,355,009	$90,284	$945,808	$413,018	$29,987	$16,657	$79,981	**$5,930,743**
339116	Dental Laboratories	$1,121,590	$39,658	$3,803,758	$1,102,926	$206,664	$7,329	$575,422	**$6,857,347**
339910	Jewelry and Silverware Manufacturing	$425,899	$111,723	$1,347,221	$515,353	$118,118	$20,655	$151,896	**$2,690,864**
339950	Sign Manufacturing	$191,729	$7,438	$114,453	$45,652	$29,966	$1,999	$17,384	**$408,620**
423840	Industrial Supplies Merchant Wholesalers	$550,862	$315,992	$937,093	$250,464	$114,965	$49,305	$74,236	**$2,292,917**
444110	Home Centers	$59,213	$1,867	$21,122	$11,309	$10,882	$666	$5,327	**$110,386**
482110	Rail transportation*	$16,220,542	$0	$0	$0	$35,060	$0	$306,456	**$16,562,059**
561730	Landscaping Services	$1,276,327	$578,330	$14,994,464	$5,255,387	$1,077,624	$105,272	$1,194,502	**$24,481,907**
621210	Offices of Dentists	$307,387	$10,958	$1,343,680	$308,425	$306,276	$1,999	$313,483	**$2,592,207**
	Totals	**$238,094,052**	**$10,493,706**	**$79,750,734**	**$29,685,587**	**$4,132,086**	**$2,637,136**	**$6,017,228**	**$370,810,530**

*Rail transportation costs reflect the Agency's judgment that employers performing construction activities will achieve compliance by following Table 1.

Source: OSHA, Directorate of Standards and Guidance, Office of Regulatory Analysis, based on OSHA (2016).

COSTS FOR THE CONSTRUCTION INDUSTRY

Estimation of the costs of the final rule for the construction industry is broken out in this section for three categories of costs: (1) control costs to comply with Table 1 when available, and the PEL of 50 $\mu g/m^3$ when Table 1 is not available; (2) respirator costs, in those cases where engineering controls are not sufficient to guarantee compliance with Table 1 or the PEL; and (3) "program" and familiarization costs to comply with the ancillary provisions of the rule.

As discussed in Chapter III (and summarized in Table III-12) of this FEA, OSHA judged that there was no baseline compliance in the construction sector with any of the ancillary provisions (but 100 percent baseline compliance with the existing Hazard Communication Standard's training requirements); 56 percent baseline compliance with the respirator use and respirator program requirements; and 44 percent baseline compliance with the engineering control requirements for workers currently below the final PEL.

Construction Control Costs

In both the PEA and this FEA, OSHA determined that employers, in order to minimize exposure monitoring costs, would select appropriate controls from Table 1. The final estimate for control costs, however, includes Table 1 control costs for a larger number of employees than in the PEA. For the purpose of estimating control costs in the PEA, OSHA examined all of the employers with employees engaged in Table 1 tasks but judged that only a subset of those employers (those with workers exposed above the proposed silica PEL) would require additional engineering controls. For this final rule, OSHA has judged, for costing purposes, that all of the construction employers with employees performing any task covered in Table 1 will adopt the engineering controls for that task as specified in Table 1. Thus, in this FEA, OSHA took the more conservative approach—which may result in an overestimate of costs—of identifying the cost of controls for all employers with employees engaged in Table 1 tasks, not just the subset of employers with employees exposed above the PEL. However, as discussed in Chapter III of this FEA, OSHA did adjust control costs to reflect the 44 percent of workers in construction currently exposed at or below the PEL who are estimated to be in baseline compliance with the Table 1 requirements.

OSHA is also likely overestimating the cost of controls for another reason. If the employer is able to demonstrate by objective data, or other appropriate means, that worker exposures would be below the action level under any foreseeable conditions, the employer would be excluded from the scope of the final rule. These employers would not require additional controls. OSHA did not have sufficient data to identify this group of employers and did not try to reduce the costs to reflect this group, so OSHA's estimate of costs is therefore overestimated by an amount equal to the costs for those employers engaged in covered construction tasks but excluded from the scope of the rule.

A few tasks involving potentially hazardous levels of silica exposure are not covered in Table 1. Employers would have to engage in exposure monitoring for these tasks pursuant to paragraph (d) and use whatever feasible controls are necessary to meet the PEL specified in paragraph (d)(1). For example, tunnel boring and abrasive blasting are not covered by Table 1 and are therefore addressed separately in this cost analysis. Although several commenters identified various other activities that they believed were not covered by Table 1 that could result in crystalline silica exposure over the PEL (Document ID 2319, pp. 19-21; 2296, pp. 8-9), some of these activities were simply detailed particularized descriptions of included activities. For example, overhead drilling is addressed in the FEA, Chapter IV-5.4 Hole Drillers Using Handheld or Stand-Mounted Drills, and the demolition of concrete and masonry structures is addressed in the FEA, Chapter IV-5.3 Heavy Equipment Operators. For the remainder, the available exposure data did not indicate that these activities resulted in a serious risk of exposure to respirable crystalline silica (see Chapter III of this FEA: Industry Profile, Construction, Public Comments on the Preliminary Profile of Construction and Summary and Explanation, Scope and Application); furthermore, these other activities could be addressed using the controls identified in this FEA. Because OSHA did not have sufficient data to identify a significant number of silica exposures above the PEL of 50 $\mu g/m^3$ for these activities, the Agency did not include costs for controlling silica exposures during these activities. Nevertheless, to the extent that employers find it necessary to implement controls for any activity that OSHA did not explicitly include in this analysis, this FEA shows that those controls are clearly economically feasible.

The control costs for the construction standard are therefore based almost entirely on the tasks and controls specified in Table 1. Most of the remainder of this section is devoted to developing the Agency's costs of applying appropriate engineering controls to construction activities as required by Table 1 of the final standard. These costs are generated by the application of known dust-reducing technology, such as the application of wet methods or ventilation systems, as detailed in the technological feasibility analysis in Chapter IV of this FEA. These costs are discussed first, and, following that, the control costs for tasks not specified in Table 1 are separately estimated.

Table 1 has undergone considerable change between the PEA and the FEA. The entries included in the table have been modified with some tasks being added and some being removed.[47] In addition, the methods of controlling exposures that Table 1 requires for certain tasks have changed in response to comment and additional analysis. Excluding changes to respirator requirements, which are addressed in the preamble and in this chapter, significant and substantive revisions to Table 1 that have the potential to impact control costs include:

- New entries on Table 1—
    - Handheld power saws for cutting fiber-cement board (with blade diameter of 8 inches or less)
    - Rig-mounted core saws and drills
    - Dowel drilling rigs for concrete
    - Small drivable milling machines (less than half-lane)
    - Large drivable milling machines (half-lane and larger for cuts of any depth on asphalt only and for cuts of four inches in depth or less on any substrate)
    - Heavy equipment and utility vehicles used to abrade or fracture silica-containing materials (e.g., hoe-ramming, rock ripping) or used during demolition activities involving silica-containing materials
    - Heavy equipment and utility vehicles for tasks such as grading and excavating but not including: demolishing, abrading, or fracturing silica-containing materials
- Removed entry for drywall finishing from Table 1
- Revised entries on Table 1--
    - Drivable saw entry revised to permit outdoor use only
    - Portable walk-behind or drivable masonry saws divided into two entries—walk-behind saws and drivable saws
    - Handheld drills entry revised to include stand-mounted drills and overhead drilling
    - Combined entries for vehicle-mounted drilling rigs for rock and vehicle-mounted drilling rigs for concrete
    - Milling divided into three tasks—walk-behind milling machines and floor grinders; small drivable milling machines (less than half-lane); and large drivable milling machines (half-lane and larger for cuts any depth on asphalt only and for cuts of four inches in depth or less on any substrate)

[47] OSHA acknowledges the nomenclature changed from "Operation" in the NPRM to "Equipment/Task" in the final rule.

- Heavy equipment used during earthmoving divided into two tasks—(1) heavy equipment and utility vehicles used to abrade or fracture silica-containing materials (e.g., hoe-ramming, rock ripping) or used during demolition activities involving silica-containing materials, and (2) use of heavy equipment and utility vehicles for tasks such as grading and excavating but not including: demolishing, abrading, or fracturing silica-containing materials
- Revised crushing machines entry to require equipment designed to deliver water spray or mist for dust suppression and a ventilated booth or remote control station.

In addition to the new and revised tasks in Table 1, some of the controls and specifications required by Table 1 were revised for this final rule, including removal of "Notes/Additional Specifications" from individual Table 1 entries and addition of substantive paragraphs after the table. Those revisions include:

- Revised or newly required controls/specifications for Table 1 tasks—
    - Revised requirement to operate and maintain tools/machine/equipment in accordance with manufacturer's instructions to minimize dust emissions.
    - Revised specifications for dust collectors to require they provide at least 25 cubic feet per minute (cfm) of airflow per inch of blade/wheel diameter (for some, but not all entries that include a dust collection system as a control method).
    - Revised specification for dust collectors to require they provide the air flow recommended by the tool manufacturer, or greater, and have a filter with 99 percent or greater efficiency and a filter-cleaning mechanism (for some, but not all entries that include a dust collection system as a control method). The entries for handheld grinders for mortar removal (i.e., tuckpointing) and handheld grinders for uses other than mortar removal require a cyclonic pre-separator or filter-cleaning mechanism.
    - Revised requirement for tasks indoors or in enclosed areas to provide a means of exhaust as needed to minimize the accumulation of visible airborne dust (paragraph (c)(2)(i)).
    - Added requirement for wet methods to apply water at flow rates sufficient to minimize release of visible dust (paragraph (c)(2)(ii)).
    - Revised specifications for enclosed cabs to require that cabs: (1) are maintained as free as practicable from settled dust; (2) have door seals and closing mechanisms that work properly; (3) have gaskets and seals that are in good condition and working properly; (4) are under positive pressure maintained through continuous delivery of fresh air; (4) have intake air that is filtered through a filter that is 95% efficient in the 0.3-10.0 µm

range (e.g., MERV-16 or better); and (5) have heating and cooling capabilities (paragraph (c)(2)(iii)).

  - Added requirement to operate handheld grinders outdoors only for uses other than mortar removal, unless certain additional controls are implemented.

  - Added wet methods option for use of heavy equipment and utility vehicles for tasks such as grading and excavating but not including: demolishing, abrading, or fracturing silica-containing materials.

  - Added requirement to use wet methods when employees outside of the cab are engaged in tasks with heavy equipment used to abrade or fracture silica-containing materials (e.g., hoe-ramming, rock ripping) or used during demolition activities involving silica-containing materials.

- Removed controls/specifications for Table 1 tasks—

  - Removed requirements to change water frequently to avoid silt build-up in water.

  - Removed requirements to prevent wet slurry from accumulating and drying.
  - Removed requirements to operate equipment such that no visible dust is emitted from the process.
  - Removed local exhaust dust collection system option and requirement to ensure that saw blade is not excessively worn from the entry for handheld power saws.
  - Removed requirement to eliminate blowing or dry sweeping drilling debris from working surface from the entry for handheld and stand-mounted drills (including impact and rotary hammer drills).
  - Removed additional specifications for dust collection systems for vehicle-mounted drilling rigs for concrete (e.g., use smooth ducts and maintain duct transport velocity at 4,000 feet per minute; provide duct clean-out points; install pressure gauges across dust collection filters; activate LEV before drilling begins and deactivate after drill bit stops rotating).
  - Removed requirements to operate grinder for tuckpointing flush against the working surface and to perform the work against the natural rotation of the blade.
  - Removed dust collection system option and requirement to use an enclosed cab from crushing machines.

These and other changes to Table 1 are discussed in detail in Section XV: Summary and Explanation of the preamble. While Table 1 has changed with regard to the tasks included and the control methods required, OSHA's methodology used to estimate the costs of controls for the construction industry has remained basically the same as that explained in detail in the PEA, with steps added (and explained in the following discussion) to address cost issues raised during the comment period and the updates and revisions to Table 1. OSHA summarizes the methodology in the following discussion, but the PEA includes additional details about the methodology not repeated in this FEA. OSHA adopted the control cost methodology developed by ERG (2007a) for the PEA and subsequently for this FEA. In order to provide some guidance on that cost methodology, OSHA itemizes below the three major steps, with sub-tasks, used to estimate control costs in construction, with two additional steps added for this FEA to estimate the number of affected workers by industry and equipment category[48] (numbered Step 3) and to estimate control costs for self-employed persons (numbered Step 5):

- Step 1: Baseline daily costs, relative costs of controls, and labor share of value
  - Use RSMeans (2008) estimates to estimate the baseline daily cost for every representative job associated with each silica equipment category (Table V-30) and unit labor and equipment costs (Table V-31).
  - Use vendors' equipment prices and RSMeans estimates to estimate the unit cost of silica controls (Table V-32), and estimate the productivity impact for every silica control and representative job, to be added to the cost of the control applied to a particular job (Table V-33).[49]
  - Use the costs from Tables V-32 and V-33 to calculate the incremental productivity impact, labor cost, and equipment cost for each representative job when controls are in place (Table V-34).
  - Using Tables V-30 and V-34, calculate the percentage incremental cost of implementing silica controls for each representative job (Table V-35).
  - Calculate the weighted average incremental cost (in percentage terms) and labor share of total costs for each silica job category (outdoors and indoors estimated separately) using the assumed distribution of associated representative jobs (Tables V-36a and V-36b).

- Step 2: Total value of activities performed in all Table 1 silica equipment categories
  - Match BLS Occupational Employment Statistics OES occupational classifications for key and secondary workers with the labor requirements for each equipment category (Table V-37) and estimate the full-time-equivalent (FTE) number of employees by key and secondary occupations working on

[48] The term "equipment category" as used here matches the broad headings used in the Technological Feasibility analysis. Later on in this section, OSHA identifies which Table 1 tasks are included in each equipment category.

[49] This latter sub-step was performed in the PEA, but it was inadvertently omitted in the text summary.

each silica task (Tables V-38a and V-38b).

- o Based on the distribution of occupational employment by industry from OES, distribute the full-time-equivalent employment totals for each equipment category by NAICS construction industry (Table V-39).

- Step 3: Total affected employment by industry and equipment category
  - o Disaggregate construction industries into four distinct subsectors based on commonality of construction work (Table V-40a) and then estimate the percentage of affected workers by occupation, equipment category, and construction subsector (Table V-40b).
  - o Use the percentage of affected workers by occupation, equipment category, and construction subsector (Table V-40b) to obtain total affected employment by occupation (Table V-41) and total affected employment by industry and task (Table V-42).

- Step 4: Aggregate silica control costs (not including self-employed persons)
  - o Using the FTE employment totals for each task by NAICS construction industry (Table V-39) and the mean hourly wage data from OES, adjusted for fringe benefits, calculate the annual labor value of each Table 1 silica activity by NAICS construction industry (Table V-43).
  - o Using the labor share of value calculated for each activity performed in a silica-related equipment category (Table V-43), estimate the total value of each Table 1 equipment/task category by industry (Table V-44).
  - o Estimate the distribution of silica work by equipment type, duration of activity, and location of activity (Table V-45).
  - o Multiply the total value of Table 1 construction activities requiring controls (Table V-44) by the percentage incremental cost associated with the controls required for each activity that uses equipment in each equipment category (Tables V-36a and V-36b) and weighted by the percentage of tasks performed outdoors and indoors/within an enclosed space (Table V-45), to calculate the total control costs, adjusted for baseline compliance, by Table 1 equipment category and industry (Table V-46).
  - o Calculate engineering control costs for silica-generating construction activities not covered in Table 1 (Tables V-47a and V-47b)
  - o Combine the control costs for Table 1 construction activities (Table V-46) and the control costs for construction activities not covered in Table 1 (Tables V-47a and V-47b) to calculate the total control costs by equipment category and construction industry (Table V-48).

- Step 5: Adjust aggregate silica control costs to include self-employed persons
  - o Use data from the BLS Current Population Survey (BLS, 2013) to estimate the ratio of the number of self-employed persons to the number of employees

by occupation (Table V-49) and then redo the estimation after restricting self-employed persons to just those occupations covered by OSHA that potentially involve exposure to hazardous levels of respirable crystalline silica (Table V-50).

- o Multiply the FTE rate for each occupation (from Tables V-38a and V-38b) by the number of self-employed workers and employees in that occupation (from Table V-50) to obtain the ratio of FTE self-employed persons to FTE employees and then reduce that ratio to reflect only self-employed persons working on a multi-employer worksite where the work of the self-employed person cannot be isolated in time or space (Table V-51).
- o Increase the earlier estimate of control costs by equipment category and industry (Table V-48) by the adjusted FTE ratio of self-employed workers (Table V-40) to calculate total control costs by equipment category and industry with self-employed persons included (V-52).

Baseline Costs of Representative Jobs

Baseline Job Safety Practices

OSHA's cost estimates address the extent to which current construction practices incorporate silica dust control measures. Thus, OSHA's baseline reflects such safety measures as are currently employed. To the limited extent that silica dust control measures are already being employed, OSHA has reduced the estimates of the incremental costs of silica control measures to comply with the final PEL. As discussed in Chapter III of this FEA and summarized in Table III-22, OSHA estimates that 44 percent of workers with exposures currently below the final PEL are using the controls required in Table 1.

Representative Jobs

Unlike the situation with the general industry/maritime standard, OSHA does not have extensive data identifying the number of employees engaged in Table 1 tasks or the duration of their exposure to respirable crystalline silica during those tasks. Therefore, ERG developed a model based on "representative jobs" for the purposes of identifying the control costs necessary to comply with Table 1. Using RSMeans *Heavy Construction Cost Data* (RSMeans, 2008), which is a data source frequently used in the construction industry to develop construction bids, ERG (2007a) defined representative jobs for each silica-generating activity described in the feasibility analysis. These activities and jobs are directly related to the silica-related construction activities described in the technological feasibility chapter of the FEA. ERG (2007a) specified each job in terms of the type of work being performed (e.g., concrete demolition), the makeup of the crew necessary to do the work, and the requisite equipment. For example, for the impact drilling activity, ERG defined three representative jobs for various types of demolition work. For each job, ERG derived crew composition and equipment requirement data from the RSMeans (2008) guide and then calculated the per-day baseline cost from the labor rates, equipment charges, material costs, and overhead and profit markups presented in the cost estimating guide.

Table V-30 shows the specifications for each representative job and the associated daily labor, equipment, and material costs. Table V-31 provides a summary of the labor rates and equipment charges used to estimate the daily cost of each representative construction job in Table V-30. Note that the data on hourly wages with overhead and profit in Table V-31, obtained from RSMeans (2008), are employed here to be consistent with other RSMeans cost parameters to estimate the baseline costs of representative jobs. The RSMeans estimates are published for the purpose of helping contractors formulate job bids, so ERG relied on that data as an indicator of the amount of labor and time that would be required for each of the representative jobs in the cost model developed for this analysis. These RSMeans estimates are later used only to determine two ratios: the labor share of the costs of representative construction jobs and the percentage increase in the cost of each representative job due to the addition of controls to comply with the final rule. Everywhere else in this cost chapter, when the actual wages were important to the calculations and are expressed as fixed amounts and not just ratios, OSHA used 2012 BLS wage data (BLS, 2012b), which include fringe benefits but not overhead and profit.

For example, as shown in Table V-30, Job 4 for grinding and tuckpointing floors using hand-held tools category involves a simple crew (i.e., only two cement finishers). Other crews, such as that for impact drilling (Job 12), involve several workers, including an equipment operator, a labor foreman, and laborers. The daily labor cost for Job 4 is calculated at $896.80. The total daily costs of labor, equipment, and materials for representative jobs range from $427.42 per day for hand-held milling, wall grinding (Job 7) to $7,295.85 for asphalt cold planing and cleaning (Job 20).

Table V-30

Baseline Job Components and Costs for Construction

Task Area/	Job Description	Labor: Title	Labor: No. of Workers	Labor: Daily Wage	Labor: Wage Per Min.	Equipment: Description	Equipment: No.	Equipment: Daily Rate	Total Daily Costs: Labor	Total Daily Costs: Equip.	Total Daily Costs: Material	Total Daily Costs: Total
Rock and Concrete Drillers												
1	Drilling only, 2" hole for rock bolts, average	Blast foreman	1	$416.80	$0.87	Air track drill 4"	1	$770.35	$1,278.40	$1,209.15	$0.00	$2,487.55
		Driller	1	$392.00	$0.82	Air compressor, 600 cfm	1	$411.65				
		Equipment operator (light)	1	$469.60	$0.98	50' air hoses, 3" diameter	2	$27.15				
		Total	3									
2	Pier holes, 1500 cubic yards of media removed	Blast foreman	1	$416.80	$0.87	Air track drill 4"	1	$770.35	$1,278.40	$1,209.15	$39.60	$2,527.15
		Driller	1	$392.00	$0.82	Air compressor, 600 cfm	1	$411.65				
		Equipment operator (light)	1	$469.60	$0.98	50' air hoses, 3" diameter	2	$27.15				
		Total	3									
3	Borings, casing borings in earth, no samples, 21/2" diameter	Laborers	2	$784.00	$1.63	Auger 4"-36" diameter	1	$636.98	$1,165.20	$869.60	$0.00	$2,034.80
		Truck driver (light)	1	$381.20	$0.79	Flatbed truck, 3 ton	1	$232.63				
		Total	3									

Table V-30 (continued)

Baseline Job Components and Costs for Construction

Task Area / Job Description		Labor Title	No. of Workers	Daily Wage	Wage Per Min.	Equipment Description	No.	Daily Rate	Total Daily Costs Labor	Equip.	Material	Total
Tuck pointers and grinders (hand-held)												
4	Floors, 1/4" thick, patching concrete	Cement finisher	2	$896.80	$1.87	Tool cost included in labor rate [a]		$0.00	$896.80	$0.00	$0.00	$896.80
		Total	2									
5	Crack repair, including chipping, sand blasting, and cleaning; Epoxy injection up to 1/4" wide	Labor foreman (outside)	1	$416.80	$0.87	Air tools and accessories	2	$14.65	$1,984.80	$177.08	$15.20	$2,177.08
						Air compressor, 250 cfm	1	$151.90				
		Laborers	4	$1,568.00	$3.27	50' air hoses, 1.5" diameter	2	$10.53				
		Total	5									
6	Cut and repoint brick, hard mortar, common bond	Bricklayer	1	$491.60	$1.02	Tool cost included in labor rate [a]		$0.00	$491.60	0	$19.25	$510.85
		Total	1									
7	Hand-held milling, wall grinding	Laborer	1	$392.00	$0.82	Wall grinder	1	$35.42	$392.00	$35.42	$0.00	$427.42
Heavy construction equipment operating - I (demolition, abrading, fracturing)												
8	Demolish, remove pavement and curb; concrete to 6" thick, hydraulic hammer, mesh reinforced	Labor foreman	1	$416.80	$0.87	Backhoe loader,48 HP	1	$207.95	$2,167.60	$842.88	$0.00	$3,010.48
		Laborers	2	$784.00	$1.63	Hydraulic hammer (1200 lb)	1	$84.20				
		Equip. operator, (light	1	$469.60	$0.98	F.E. loader, 4 C.Y. (wheel-mounter)	1	$488.25				
		Equip. operator, (medium)	1	$497.20	$1.04	Pavement removal bucket	1	$62.48				
		Total	5									
9	Small building demolition, concrete, no salvage	Labor foreman	1	$416.80	$0.87	Crawler loader, 3 C.Y.	1	$881.48	$2,484.40	$1,881.48	$0.00	$4,365.88
		Laborers	2	$784.00	$1.63	Dump Trucks 12 C.Y.	2	$1,000.00				

Table V-30 (continued)

Baseline Job Components and Costs for Construction

Task Area / Job Description	Labor: Title	Labor: No. of Workers	Labor: Daily Wage	Labor: Wage Per Min.	Equipment: Description	Equipment: No.	Equipment: Daily Rate	Total Daily Costs: Labor	Total Daily Costs: Equip.	Total Daily Costs: Material	Total Daily Costs: Total
	Equip. operator, (medium)	1	$497.20	$1.04	(400 HP)						
	Truck drivers (heavy)	2	$786.40	$1.64							
	Total	6									
Heavy construction equipment operating - II (earthmoving)											
10 Backfill, structural, from existing stockpile, no compaction, 50' haul, sand and gravel	Equip. operator (medium)	1	$497.20	$1.04	Dozer, 200 HP	1	$970.68	$693.20	$970.68	$0.00	$1,663.88
	Laborers	0.5	$196.00	$0.41							
Hole drilling using hand-held and stand-mounted drills											
11 Drilling for anchors, up to 4" in depth, including bit and layout in concrete or brick walls or floors, no anchor. 3/4" diameter	Carpenter	1	$495.60	$1.03	Tool cost included in labor rate [a]		$0	$495.60	$0.00	$6.30	$501.90
	Total	1									
Jackhammers and other powered chipping tools											
12 Drilling bituminous material, with hand-held air equipment, up to 6 inches thick	Labor foreman (outside)	1	$416.80	$0.87	Breakers, pavement, 60lb	2	$14.65	$2,454.40	$177.08	$0.00	$2,631.48
					Air compressor, 250 cfm	1	$151.90				
	Laborers	4	$1,568.00	$3.27	50' air hoses, 1.5" diameter	2	$10.53				
	Equip. operator, light	1	$469.60	$0.98							
	Total	6									
13 Cutout demolition, elevated slab,	Labor foreman	1	$416.80	$0.87	Breakers, pavement, 60lb	2	$14.65	$1,984.80	$177.08	$0.00	$2,161.88

Table V-30 (continued)

Baseline Job Components and Costs for Construction

Task Area / Job Description	Labor: Title	Labor: No. of Workers	Labor: Daily Wage	Labor: Wage Per Min.	Equipment: Description	Equipment: No.	Equipment: Daily Rate	Total Daily Costs: Labor	Total Daily Costs: Equip.	Total Daily Costs: Material	Total Daily Costs: Total
bar reinforced, under 6 c.f.	(outside)				Air compressor, 250 cfm	1	$151.90				
	Laborers	4	$1,568.00	$3.27	50' air hoses, 1.5" diameter	2	$10.53				
	Total	5									
14 Remove masonry	Labor foreman	1	$416.80	$0.87	Air tools and accessories	2	$14.65	$2,979.20	$535.88	$0.00	$3,515.08
walls, block, solid	(outside)				Air compressor, 250 cfm	1	$151.90				
(presumed indoor environment)	Laborers	4	$1,568.00	$3.27	50' air hoses, 1.5" diameter	2	$10.53				
	Equip. operators	2	$994.40	$2.07	Front-end loader	1	$358.80				
	Total	7									
Masonry cutting using portable saws –I											
15 Demolition, concrete slabs, mesh	Equipment	1	$469.60	$0.98	Stakebody truck, 3 ton	1	$232.63	$861.60	$378.80	$333.20	$1,573.60
reinforcing, up to 3" deep	operator (light)				Concrete saw (walk-behind)	1	$130.68				
(walk-behind saw)	Laborer	1	$392.00	$0.82	Water tank, 65 gal	1	$15.50				
	Total	2									
16 Saw cutting, brick or masonry, with	Building laborer	1	$392.00	$0.82	Saw, portable cut-off, 8 HP	1	$30.26	$392.00	$30.26	$31.25	$453.51
hand-held saw, per inch of depth	Total	1									
17 Saw cutting, concrete walls,	Equip. operator	1	$469.60	$0.98	Wall saw, hydraulic, 10 hp	1	$89.70	$850.80	$652.15	$75.00	$1,577.95
hydraulic saw, plain, per inch of	(light)				Generator, diesel 100 kw	1	$314.33				
depth	Truck driver (light)	1	$381.20	$0.79	Water tank, 65 gal	1	$15.50				
	Total	2			Flatbed truck, 3 ton	1	$232.63				
Masonry cutting using portable saws – II											
18 Cutting and installing fiber cement	Carpenter	2	$991.20	$2.07	Tool cost included in labor rate [a]			$991.20	$0.00	$493.00	$1,484.20
siding, 8" wide, with handheld saw,											

Table V-30 (continued)

Baseline Job Components and Costs for Construction

Task Area / Job Description	Labor: Title	Labor: No. of Workers	Labor: Daily Wage	Labor: Wage Per Min.	Equipment: Description	Equipment: No.	Equipment: Daily Rate	Total Daily Costs: Labor	Total Daily Costs: Equip.	Total Daily Costs: Material	Total Daily Costs: Total
blade diameter 8 inches or less											
Masonry cutting using stationary saws											
19 Sawing brick or block,	Bricklayer	1	$491.60	$1.02	Tool cost included in labor rate [a]		$0.00	$491.60	$0.00	$0.00	$491.60
per inch in depth	Total	1									
Milling using portable or mobile machines											
20 Asphalt cold planing &	Labor foreman	1	$416.80	$0.87	Pavement profiler	1	$3,372.90	$3,084.40	$4,211.45	$0.00	$7,295.85
cleaning, 1" to 3"	Laborers	3	$1,176.00	$2.45	Road sweeper	1	$541.60				
asphalt, over 25,000 SY	Equip. oper. (med)	3	$1,491.60	$3.11	Front-end loader (1.75 CY)	1	$296.95				
	Total	7									
21 Concrete surface repair	Labor foreman (outside)	1	$416.80	$0.87	Concrete grinder, floor, electric	1	$70.75	$808.80	$70.75	$0.00	$879.55
	Laborers	1	$392.00	$0.82							
	Total	2									
Rock crushing machine tending											
22 Rock crushing, excavation	Labor foreman	1	$416.80	$0.87	Rock crushing equipment	1	$3,372.90	$3,084.40	$4,169.85	$0.00	$7,254.25
projects	Laborers	3	$1,176.00	$2.45	Front-end loader (1.75 CY)	1	$296.95				
	Equip. operator	3	$1,491.60	$3.11	Truck, dump, 3 axle, 16 ton	1	$500.00				

Table V-30 (continued)

Baseline Job Components and Costs for Construction

Task Area / Job Description	Labor: Title	Labor: No. of Workers	Labor: Daily Wage	Labor: Wage Per Min.	Equipment: Description	Equipment: No.	Equipment: Daily Rate	Total Daily Costs: Labor	Total Daily Costs: Equip.	Total Daily Costs: Material	Total Daily Costs: Total
	(medium)				payload						
	Total	7									
Underground (tunnel) construction work											
23 Tunnel construction, bored tunnels including mucking, 20' in diameter, rock excavation (average cost; assumes 100 feet/day)	Total daily crew cost, Including equipment ($1,075 per linear foot)	NA	$16,125.00	$33.59	Tunnel boring machine and support system	1	$91,375.00	$16,125.00	$91,375.00	$0.00	$107,500.00

[a] Costs for smaller hand-held tools are not separately provided, but are included in the labor rate.

Source: RS Means Co., Inc., 2009 Heavy Construction Cost Data, 23rd Annual Edition. (Kingston, MA, 2008).

Table V-31

Labor Wages and Equipment Rates in Construction

Labor Categories	**Hourly Wage**	**Hourly Wage With Overhead & Profit** [a]
Blast foreman	$33.60	$52.10
Building laborer	$31.60	$49.00
Bricklayer	$40.50	$61.45
Carpenter	$39.95	$61.95
Cement finisher	$38.30	$56.05
Driller	$31.60	$49.00
Drilling foreman	$33.60	$52.10
Equipment operator (heavy)	$42.55	$63.95
Equipment operator (medium)	$41.35	$62.15
Equipment operator (light)	$39.05	$58.70
Labor foreman (outside)	$33.60	$52.10
Laborers	$31.60	$49.00
Equipment operator (oiler)	$36.80	$55.30
Skilled worker	$40.85	$63.25
Truck driver (light)	$30.95	$47.65
Truck driver (heavy)	$31.95	$49.15

Table V-31 (continued)

Labor Wages and Equipment Rates in Construction

Equipment Categories	Daily Equipment Rate [b]	Daily Rate With Overhead & Profit [a]	
Air compressor, 250 cfm	$147.40	$151.90	
Air compressor, 600 cfm	$401.90	$411.65	
Air tools and accessories	$6.95	$7.33	
Auger 4"-36" diameter	$606.85	$636.98	
Breakers, pavement, 60lb	$6.95	$7.33	
Core drill, large	$92.45	$97.58	
Concrete saw	$126.25	$130.68	
Concrete grinder, floor, electric	$66.10	$70.75	
Air track drill 4"	$736.10	$770.35	
Crawler dozer, 200 HP	$923.05	$970.68	
Dust control, quarry drill	$16.47	$17.33	
50' air hoses, 1.5" diameter	$4.83	$5.27	
50' air hoses, 3" diameter	$12.45	$13.58	
Flatbed truck, 3 ton	$228.35	$232.63	
Front-end loader (1.75 CY)	$283.70	$296.95	
Front-end loader (2.5 CY)	$342.80	$358.80	
Generator, diesel 100 kw	$308.95	$314.33	
Hose (water), 20', 2" diameter	$1.51	$1.65	
Hose (water), 200', 2" diameter	$15.10	$16.45	[c]
Pavement profiler	$3,219.40	$3,372.90	
Quarry drill, 5" drifter	$850.00	$887.00	
Road sweeper	$515.60	$541.60	
Rock crushing equipment	$3,219.40	$3,372.90	[d]
Stakebody truck, 3 ton	$228.35	$232.63	
Saw, portable cut-off, 8 HP	$29.00	$30.26	
Truck, dump, 3 axle, 16 ton	$486.00	$500.00	[e]
Vacuum, HEPA, 16 gal., wet/dry	$14.66	$15.47	
Wall grinder, electric	$33.09	$35.42	
Wall saw, hydraulic, 10 hp	$87.00	$89.70	
Water tank, 65 gal	$14.21	$15.50	

Table V-31 (continued)

Labor Wages and Equipment Rates in Construction

Equipment Categories	Daily Equipment Rate [b]	Daily Rate With Overhead & Profit [a]
Water tank, engine driven discharge, 5000 gal.	$115.00	$121.50
Water tank, engine driven discharge, 10,000 gal.	$159.25	$168.38

NE=Not estimated

[a] Overhead and profit markups for wages as given by RS Means vary between 46 percent and 55 percent depending on the labor category. Per RS Means, a 10 percent markup is applied to equipment daily rental costs (but not operating costs).

[b] Based on monthly rental costs averaged over 20 days. Includes operation cost.

[c] 10 times the cost of 20' hose

[d] Based on costs for pavement profiler.

[e] Estimated at 90 percent of total daily crew and equipment cost, as estimated in means, 2008.

Source: RS Means, 2009 Heavy Construction Cost Data.

SBREFA Panel Comments on Cost Methodology for Construction

Prior to the publication of the PEA, one SBREFA commenter[50] criticized the methodology for estimating engineering control costs on the grounds that while RSMeans estimates were used to establish the marginal costs of new controls (as a percentage of baseline costs), average wage rates (including fringe benefits) from the BLS *Occupational Employment Statistics Survey*, 2000, were used to calculate the value of at-risk tasks without providing a justification for not using RSMeans wage data (Document ID 0968, p. 13). Since BLS wage rates are significantly lower than the RSMeans rates used by ERG in earlier parts of the analysis, the commenter argued that this would significantly lower the base to which the marginal cost factors are applied to estimate compliance costs (Id.). This SBREFA commenter further argued that the RSMeans estimates are likely to be on the high end of estimated wages because they only cover unionized labor and are therefore likely to lead to high estimates of impacts. The commenter then recommended that more appropriate indexed labor wage costs be computed and used consistently throughout the analysis (Document ID 0968, p. 14).

First, the commenter's concern is misplaced because the choice of the RSMeans source for estimates does not skew the results in the manner suggested by the commenter; nor does it even have a significant impact on the cost analysis. The RSMeans estimates was used only to develop the *ratio* of costs for the representative jobs to the total labor cost and then to determine the incremental compliance costs as a percentage of the total and the share (percentage) of project value with controls accounted for by labor. Because the RSMeans estimates are organized by project cost to assist contractors in bid planning, that data set is the logical choice for this purpose over BLS data, which provides wage data but does not provide comparable costs for projects. Dividing project labor value by the labor share of project value yields an estimate of total project value.

The absolute level of the RSMeans wage and equipment cost levels do not directly affect the resultant aggregate compliance costs. While lower wage rates would lower the baseline costs of the representative jobs, it does not follow that control costs as a percent of baseline costs would also be lower. In fact, if lower wage rates are combined with the same equipment costs, the equipment part of incremental control costs would be a *higher* percentage of total baseline costs. Only the labor share (percentage) of baseline costs, along with the incremental compliance costs as a percent of baseline costs, are taken from the analysis of representative costs and used in the subsequent estimation of aggregate costs. The absolute levels of the wage rates and equipment costs taken from RSMeans do not directly enter the aggregate cost analysis.

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[50] This commenter was a third-party stakeholder who was not a SER.

Second, OSHA notes that the BLS wage data, on which the aggregate compliance costs are based, are obtained from a statistically valid, national survey of employment and compensation levels and are the best available data characterizing national averages of wages by detailed occupation. For some of the reasons the commenter noted, OSHA believes that the BLS wage estimate provides a more accurate reflection of average wages.

Another set of SBREFA commenters criticized OSHA's cost estimation methodology, arguing that fundamental errors resulted in serious underestimates of the costs of engineering controls. The commenters asserted without any significant explanation that the task-by-task incremental cost estimates (shown in Table V-23 of the PIRFA, Document ID 1720, p. 749) should have been multiplied by two factors: (1) "the ratio of the RSMeans labor rate to the BLS wage and benefits rate," and (2) the inverse of the "percentage in key occupations working on task" from Table V-26 (also in the PIRFA, Document ID 1720, p. 766). Under this approach, the commenters argued that

> the cost of PEL controls for brickmasons, blockmasons, cement masons and concrete finishers performing grinding and tuckpointing would be approximately seventy-two (72.0) times the ERG estimate, and . . . the cost of PEL controls for drywall finishing (at the 50 μg/m3 PEL) would be approximately 7.2 times the ERG estimate (Document ID 0004 p. 34 of memo).

The rationalization for these calculations was not provided, and OSHA found these conclusions without merit. The incremental control costs shown in Table V-34 of this FEA were based on RSMeans estimates for labor and equipment costs. As shown in Table V-34, these cost estimates, after adjustments for productivity impacts, are used to calculate the percentage increase in baseline costs associated with each control. The RSMeans-based cost estimates shown in Table V-34 are also used to estimate the share of total baseline task/project costs accounted for by labor requirements. The averages of the percentage increase due to incremental control costs and the labor share (percentage) of total baseline costs are shown in Table V-37 of this FEA. These two percentages are used to extrapolate the aggregate control costs associated with each task. This extrapolation was based on (1) the full-time-equivalent employment in key and secondary occupations associated with each task, and (2) the value of the labor time as measured by the BLS occupational wage statistics, adjusted for fringe benefits.

OSHA provided similar responses in the PEA and requested comment on its responses to the SBREFA comments, but received none (see PEA, p. V-131).

The same set of SBREFA commenters further argued that OSHA's analysis contained five more "fundamental errors" (Document ID 0004, p. 35 of memo). First, the commenters asserted that OSHA's calculations understate the actual cost because they are based on old data (1999 or 2000 data from RSMeans rather than RSMeans 2003 data). OSHA used the most recent available data at the time the initial preliminary analysis was completed and subsequently updated those data for the PEA (and this FEA) using RSMeans estimates from 2008 (Document ID 1331). However, as noted previously, the RSMeans estimates do not directly determine the absolute level of aggregate compliance costs, but rather the labor share (percentage) of project costs and incremental compliance costs as a percentage of baseline costs. This aspect of the analysis received no further comment and has been retained for the FEA.

Second, the commenters asserted that there is no information to "suggest much less substantiate the premise that the exposure monitoring data in Tables 3-1 and 3-2 [in the ERG (2007a) report] (even if they were properly collected and analyzed) are in any way representative of current workplace exposures across the country" (Document ID 0004, p. 35 of memo). In response, OSHA points out that the profiles used to estimate the numbers of workers exposed in excess of each PEL option were, in fact, based on the extensively documented technological feasibility analysis with many of the data points in the exposure profiles being taken from the findings of OSHA inspections (and based on ERG, 2007a). OSHA is tasked with using the best available evidence to develop the analyses, and the data in the exposure profile represent the best available evidence on current workplace exposures to respirable crystalline silica. More importantly, for estimating the cost of controls, Table 1 in the final rule is intended to be the default option for protecting workers performing covered tasks, regardless of actual exposure level. The FEA reflects this, while recognizing that a sizable minority of workers with exposures below the PEL have limited their exposures by using such controls currently.

Third, the commenters claimed that there is

> no information to suggest much less substantiate the premise that the exposure monitoring data in Tables 3-1 and 3-2 (even if they were representative of current workplace exposures) are in any way representative of the non-existent, theoretical jobs artificially created by the FTE [full-time equivalent] analysis so as to justify their use as the foundation for Table 4-12 (Document ID 0004, p. 35 of memo).

However, OSHA notes that the representative jobs on which the cost analysis is based were designed to correspond directly to the tasks assessed in the technological feasibility analysis. Furthermore, Table 4-12 in ERG (2007a) was derived directly from Table 3-2 and is independent of the "FTE analysis."

Fourth, the commenters argued that a more logical and appropriate methodology would assume that all FTEs were exposed above the PEL in the absence of controls, and the commenter could find

> no justification, and substantial support to the contrary, for an approach that artificially condenses actual exposures into far more highly concentrated exposures (by condensing all at-risk task hours into FTEs) and then [assumes] that, despite the impact of this change, the grab bag of exposure monitoring described in ERG Tables 3-1, 3-2 and 4-12 represents these FTEs (Document ID 0004, pp. 35-36 of memo).

The commenters asserted that the effect in ERG (2007a) of

> first multiplying total project costs by the FTE percentage (from Table 4-8) and then by the 'Percentage of Workers Requiring Controls' from Table 4-12 (and then by the average 'Total Incremental Costs as % of Baseline Costs' by job category from Table 4-7) results in an unjustified double discounting of exposed workers in the incremental cost calculation (Document ID 0004, p. 36 of memo).

OSHA disagrees. The Agency notes that ERG (2007a) used the exposure profiles from the industry profile to estimate the number of full-time equivalent workers that are exposed above the PEL. In other words, this exposure profile is applicable if all exposed workers worked full time only at the specified silica-generating tasks. The *actual* number exposed above the PEL is represented by the *adjusted* FTE numbers (see Table 4-22 in ERG, 2007a). The adjusted FTE estimate takes into account that most workers, irrespective of occupation, spend some time working on jobs where no silica contamination is present. The control costs (as opposed to some program costs) are independent of the number of workers associated with these worker-days. OSHA noted in the PEA that the thrust of the comment about "double discounting" was unclear, but the commenters did not respond with clarification. Nothing is "discounted" in the estimation of aggregate control costs.

Finally, the SBREFA commenters argued that the

> application of the FTE analysis to the additional equipment costs is based on the wholly unfounded assumption, contrary to actual experience, that

> this additional equipment could be used with perfect efficiency (i.e., never idle) so that it is only at a particular site during the time the at-risk tasks are being performed (Document ID 0004, p. 36 of memo).

In response, OSHA notes that its analysis does in fact assume some efficiency with respect to the use of additional equipment required for controls. However, many of the equipment costs are based on monthly equipment rental rates provided by RSMeans that already embody some degree of idleness over the course of a year (see ERG, 2007a, Table 4-3). In other cases, daily equipment costs were directly estimated based on equipment purchase costs, annualization factors, and assumed operating and maintenance costs.[51] OSHA did receive further comment on the issue following the publication of the PEA (Document ID 4217, pp. 84-88), and, in response, the Agency developed prorated ownership costs (equivalent to twice the rental rates) for control equipment for tradespersons performing tasks involving short-term, intermittent silica work.

Comments and Responses on Engineering Control Costs in Construction

Having already incorporated comments from small business in the SBREFA panel process, the Agency produced revised estimates for the PEA in support of the proposed silica rule. In the PEA, OSHA requested comment from rulemaking participants on the Agency's preliminary estimate of control costs in construction. Below are comments representative of the prominent issues that raised concerns.

The most broad-based critique of the construction cost analysis came from the Construction Industry Safety Coalition (CISC), and its consultant Environomics (Document IDs 2319, 2320, and 4217). Several of their arguments regarding underestimation of costs related to an undercount of the affected construction population (for example, they believed the Agency should have accounted for the cost to control silica exposures for plumbers). The Agency agrees in part that there were some occupations—plumbers, plumber helpers, electricians, electrician helpers, roofers, roofer helpers, terrazzo workers and finishers, and sheet metal workers—that likely have exposure and should be included in this analysis, as they do perform some activities covered by Table 1. These are discussed in more detail in Chapter III, Industry Profile.

Owning Versus Renting Engineering Controls in Construction

[51] These were originally translated to daily costs on the assumption of full-time usage (240 days per year). However, in response to this comment, this rate was adjusted downward, assuming instead that equipment would be used 150 days per year (30 weeks), on average; OSHA applied this downward adjustment to equipment usage in the PEA and the effect of this change in equipment usage was to increase the daily cost of control equipment.

OSHA also received comment regarding the availability of control equipment. In its post-hearing brief, CISC commented:

> In the Agency's cost analysis, it has also made the entirely impractical assumption that controls (e.g., wet methods, LEV) for the tools that construction workers use in performing tasks that generate respirable silica need to be available only during the exact duration while a dusty task is performed. The CISC estimates costs instead to provide control equipment on an "always available" basis to workers who engage in dusty tasks. Control equipment must be available whenever a worker may need to perform an at-risk task, and not for only the very limited duration when the at-risk task is actually being performed. Costs for the engineering controls required to meet the reduced PEL in the proposed rule will be far higher than OSHA estimates (Document ID 4217, p. 29).

While OSHA agrees that CISC's argument has merit, during hearing testimony CISC's representative acknowledged that its estimates did not initially take into account the economic life of a control. This is reflected in the following conversation between CISC's Stuart Sessions and OSHA's Robert Stone:

> MR. STONE: So returning to the methodology for costing, you pretty much used our numbers and you used our, presumably, like you mentioned the dust shroud that has a one-year life and, therefore, after one year, you take the cost again the second year, is that right? And the third year, and so on? Okay. I think this is perhaps a problem with the way you've done your analysis. We used basically FTEs, full-time equivalents. You're using three percent of the time let's say for plumbers, as an example, you're applying it to three crews, all right? At the end of one year, you're having them buy another dust shroud. And my view . . . they will have used nine percent of the economic life of the dust shroud. Now, you can argue I'd make an adjustment because we estimate 150-[day construction work-year] use of it, for full-time use. This would suggest, though, that after one year, you will have used one-sixth of the life of that dust shroud and an employer is not going to throw it out. It's still functional. He'll use it for the next five years. He'll use it for six years. Any views on that?
>
> * * *
>
> MR. SESSIONS: Yes. That's a good point, and I hadn't thought about that.
>
> MR. STONE: Okay, thank you. A related point is actually the same issue. It would be operating in maintenance costs. You're -- it's going

> to be one-sixth of our original estimate, but I don't think you've made that adjustment.
>
> MR. SESSIONS: Correct. (Document ID 3580, Tr. 1501-1502).

After the hearing discussion, CISC revised its methodology, noting:

> After additional thought and discussion about this issue with several construction tradespeople, we … concluded that useful life is a function of both how often the tool and controls are used, but also how long they sit in the construction worker's truck and get bounced around going from job site to job site (even when they are not used), and how often they are taken out of the truck and returned to the truck (even when they are only set up then taken down at the job site but not actually used). Thus useful life will increase if a tool sits idle for some percentage of the time when it is available, but useful life will not increase to the same proportional extent as the decrease in usage. We assumed in the example in workbook Tab # X2B that using the tool and equipment 1/4 as often will double its useful life (Document ID 4217, p 89).

OSHA agrees with this updated methodology and has adopted CISC's approach—essentially assuming one-half of the usage life over which to amortize the purchased control equipment—for jobs that typically involve intermittent short-term exposure. The jobs for which the Agency assumed a half-life of the control equipment were: (1) hole drillers using hand-held or stand-mounted drills—for electricians, plumbers, carpenters, and their helpers, and for sheet metal workers; and (2) handheld power saws for carpenters and their helpers. Note that OSHA's adoption of this updated approach resolves CISC's criticism that OSHA had not accounted for productivity decreases from controls not being available when the worker needs to use them for short-term or intermittent silica jobs.

For all other construction jobs (i.e., those not itemized above involving intermittent short-term exposure), OSHA did not adopt CISC's approach but instead (as in the PEA) used the market-derived rental rate for control equipment without either doubling the rental rate to take into account "down-time" or requiring purchase of the control equipment. There are several reasons the Agency retained its PEA approach for these jobs in the final rule:

- In most cases, an employer's own/rent decision for control equipment will be determined by the own/rent decision for the construction equipment (including construction tools) to which the control equipment will be applied. If the employer rents/owns the construction equipment, the employer will rent/own the control equipment.

The major exception would be if a particular piece of control equipment could be applied to many types of construction equipment. An example might be a dust collector. In that situation, the employer might find it economic to rent the construction equipment and own the control equipment. But, in that case, the purchased control equipment will not be sitting idle.

- Construction equipment is sufficiently expensive that employers, as a general matter, will not find it economically efficient to have it sitting idle. That is why employers so frequently rent construction equipment. Of course, employers that do only one type of construction job all year (or those that are sufficiently large that they work on that particular type of construction job all year) will find it economic to own the construction equipment—as well the control equipment—but then the control equipment will not be sitting idle.
- In light of permit requirements and other job-planning requirements, in almost all cases, the employer will have advance knowledge of the details of the construction job (as opposed to, sometimes, repair work in general industry). This knowledge would include the construction equipment—and controls—required to perform the job. In fact, employers will often schedule construction jobs precisely to avoid having construction equipment sitting idle. In other words, the typical employer—and certainly the competent employer—won't come to the job site unprepared, needing to leave the job site to obtain rental equipment or controls.
- The construction sector is a significant component of the U.S. economy. There is a large, competitive construction equipment/control rental market in place to serve it. In most places, employers should be able to obtain needed construction equipment/controls in a timely manner under terms similar to those estimated here.

For the aforementioned reasons, OSHA believes that the ownership-versus-rental cost issue, except in the case of construction jobs that involve intermittent short-term exposure, is somewhat of a red herring. The difference in amortized cost should be negligible, given that employers will choose to own or rent based on whichever is the lower-cost alternative. In fact, because rental costs are typically somewhat higher than amortized ownership costs, OSHA may have overestimated compliance costs for those employers who purchase control equipment.

Self-employed Persons

CISC, and its contractor Environomics, claimed in their comments that OSHA had omitted the costs of compliance by sole proprietors (typically self-employed persons) (Document ID 4217, p. 80). The inclusion of such costs and the circumstances under which they would arise were previously discussed in Chapter III of this FEA. In this FEA OSHA has accounted for costs associated with controlling employee exposures from sole proprietor activities. The actual self-employment data and the estimated effect on employer costs are presented at the end of this section on engineering control costs in construction.

Full cost vs. incremental cost

Prior to the PEA, a participant in the SBREFA process noted that while OSHA established the total incremental cost for each silica control method (summarized for the final rule in Table V-35 of this FEA), the cost estimates were based on the application of a single control method. The commenter argued that there may be cases where two or more control methods would have to be applied concurrently to meet the exposure limits (Document ID 0968, p. 14). In response, OSHA noted in the PEA that for each task, specified control options correspond to the control methods described in the technological feasibility analysis in Chapter IV (of the PEA). These methods reflected the choices laid out in Table 1 of the proposed rule; they were also presented in Table V-25 in the PEA along with OSHA's calculation of the weighted average proportion of project costs attributable to labor and the incremental control costs as a percentage of baseline project cost.

Throughout the comment period, CISC reiterated the pre-PEA objections to OSHA's methodology of estimating incremental costs instead of the "full" compliance costs, which CISC defined as including the costs for employers to meet their existing duty to comply with OSHA's old PEL (CISC claims employers of "nearly 60,000 workers" were not in compliance with OSHA's preceding standard and would have OSHA attribute the costs of compliance with the preceding standard to the costs of this rule) (Document ID 4217, p. 33):

> In our view, OSHA has made two errors in the approach it has taken:
>
> - First, the "full" compliance costs for reducing worker exposures from their current levels to below the proposed new PEL are the conceptually correct costs to estimate when assessing economic feasibility, not the "incremental" costs for reducing exposures to below the proposed new PEL from a starting point assuming compliance with the current PEL. In practice, employers will face the full costs, not the lesser incremental costs, and the economic feasibility assessment should consider whether employers can afford these full costs, not the hypothetical and lower incremental costs.
> - Second, OSHA has made a conceptual error in the Agency's methodology for estimating compliance costs* * * Insofar as OSHA omits all costs for [employees with exposures > 250 μg/m^3] -- failing to estimate the costs to reduce their exposures all the way down below 50 μg/m^3 instead of only to below 250 μg/m^3 -- OSHA estimates costs that fall short of the incremental costs of the

> Proposed Standard that the Agency aims to estimate (Document ID 4217, pp. 96-97).

Both arguments are now largely moot because in this FEA almost all of the construction engineering control costs are based on compliance with Table 1 and encompass all employees engaged in the Table 1 tasks, regardless of their current level of exposure. OSHA has included the full incremental—*and full total*—costs for *all* employers in construction who have workers who are performing tasks listed on Table 1, even those workers with exposures currently above 250 μg/m^3.

CISC's arguments for the construction sector are now only relevant to the very few tasks not covered by Table 1, such as tunnel boring. OSHA therefore addresses CISC's arguments in the context of those few tasks.

The first argument is that employers who are not in compliance with the preceding PEL of 250 μg/m^3 will have to incur costs to achieve that PEL in addition to the costs they will incur to reach the new PEL of 50 μg/m^3. As laid out in the PEA, OSHA rejects this position, as this is inappropriate for estimating economic feasibility among firms making a good faith effort to comply with the existing silica rule. Employers who had a legal obligation to comply with OSHA's preceding PEL but failed to do so are not excused from their previous obligation by the new rule; nor can the fulfillment of a pre-existing duty be fairly re-characterized as a new duty resulting from a new rule. But this issue is not limited to construction, and a more complete discussion is presented in the general industry engineering control cost section.

The second argument can be dismissed on similar grounds. CISC's argument appears to assume that employers will incur different costs for different controls necessary to reduce exposures from above 250 μg/m^3 down to 250 μg/m^3, and from 250 μg/m^3 down to 50 μg/m^3. In many cases, however, the same controls needed to bring exposures below 250 μg/m^3 will also bring exposures below 50 μg/m^3, so there would be no cost associated with the new rule. To the extent that separate controls are required to reduce exposures down from 250 μg/m^3 to 50 μg/m^3, OSHA does account for the costs for those controls.

General Comments on Cost Methodology

James Hardie Building Products commissioned Peter Soyka of Soyka & Company LLC to perform an evaluation of the PEA. While Mr. Soyka's comments cover many aspects of the analysis and overlap with those of other commenters, some were relatively unique. In one place, Mr. Soyka questions the entire method of analyzing jobs from the level of workers and their tasks. He expressed concern about both what he termed the failure to capture the cost to the establishment, as well as the need for workers to have controls available (Document ID 2322, Attachment G, p. 165). OSHA did not, however, ignore other costs for establishments. Elements of these costs are dealt with at the establishment level for some ancillary provisions of the standard, and are discussed later in this chapter. The second element, regarding the availability of controls for certain occupations, mirrors concerns raised by Environomics and CISC, and has been dealt with above.

Elsewhere in his comments, Mr. Soyka states that “OSHA should develop revised unit costs that consider the full array of elements that affect what a business charges its customers for a unit of time expended.” Such unit costs,” he submitted, “would include direct labor, fringe benefits, overhead, SG&A, and a reasonable allowance for profit (e.g., the typical cost of capital found in a specific industry or overall)” (Document ID 2322, Attachment G, p. 182). The approach put forward in the PEA and in the FEA incorporates fringe labor costs. With respect to overhead and SG&A, OSHA recognizes that there is debate about when and whether these elements should be included and how they can be accurately measured. OSHA continues to view labor plus fringe benefits as one reasonable approach to measuring marginal costs of labor, but has provided a sensitivity analysis of the effects of including other cost elements in the sensitivity analysis section of the FEA.

The National Association of Home Builders (NAHB) faulted the costing of engineering controls in the PEA on several grounds, including several very similar to those raised by Mr. Soyka and addressed earlier. NAHB also stated that OSHA has not considered the “unique nature of construction, in that sites are not fixed in nature, and that equipment may need to be moved between several sites in a single day” or the “compliance costs for cleanup of the jobsites” (Document ID 2296, p. 38). Both are addressed in the FEA as opportunity costs or housekeeping costs.

Other Aspects of Unit Costs

Following publication of the NPRM, a representative of petrochemical employers, the American Fuel and Petrochemical Manufacturers, raised concerns about retrofitting and clean-up costs that it claimed were improperly omitted from OSHA’s analysis of engineering controls in construction:

> OSHA claims “[t]he estimated costs for the proposed silica standard rule include the additional costs necessary for employers to achieve full compliance.”[] Yet it fails to consider the additional costs of retrofitting existing equipment to comply with Table 1 in Section 1926.1053 (Table 1). In addition to acquiring new engineering controls not previously implemented, many employers will have to modify pre-existing equipment to come into compliance (*e.g.*, outfitting the cab of a heavy equipment

> bulldozer with air conditioning and positive pressure). Table V-3, found in OSHA's complete PEA, begins to address these costs by enumerating the capital and operating costs for the engineering controls required by Table 1. But it does not account for the ancillary costs of retrofitting those controls, including the cost of retrofitting the equipment itself as well as the lost time the facility may absorb in doing so.
> OSHA also fails to account for the clean-up costs associated with the natural by-products from Table 1's required engineering controls. For example, many of the engineering controls require the use of wet methods or water delivery systems. [] Employers will incur costs from removing (from the clean-up process itself and lost time) excess water to prevent ice or mold from developing. Yet these costs go unaccounted for in the PEA (Document ID 2350, pp. 6 – 7).

In the FEA, the Agency does not include any specific cost for retrofitting equipment. The record indicates that almost universally employers either already have equipment with the required controls available for use (e.g., wet method for saw), or the equipment allows for the easy addition of a control (e.g., shroud for HVAC). Furthermore, most equipment is portable and/or handheld and is relatively inexpensive with a useful life of two years or less. As a result, it would simply not make economic sense to retrofit the equipment when it would be less expensive to replace it. In addition, most other types of relevant construction equipment—heavier and drivable—generally have a useful life of ten years or less; control-ready equipment of this type has been on the market for years and is typically already in use. Thus, OSHA did not estimate any retrofitting costs. While some employers might still retain pieces of earth-moving equipment that do not have a cab that complies with Table 1, equipment with a cab is the industry standard for both purchase and rental. As discussed in this chapter in the context of productivity, the implication is that the market has shifted to heavy equipment with cabs even in the absence of a silica standard. In addition, in final Table 1 OSHA has reduced the number of tasks that require equipment with enclosed cabs to just a single task: heavy equipment and utility vehicles used to abrade or fracture silica-containing materials or used during demolition activities involving silica-containing materials. For the odd piece of old, cab-less heavy equipment which does not conform to the requirements of Table 1, individual employers have the choice of renting the required equipment to perform that single task, or simply using the cab-less equipment only on non-silica tasks (thereby ceding the one silica-abrading construction task to employers that have more up-to-date equipment). In short, the requirement to use a cab when performing Table 1 tasks is not a requirement to retrofit all existing equipment that might conceivably be used for a Table 1 task.

Regarding the question of clean-up costs, the commenter treats the issue as if there were no clean-up costs associated with generating silica currently. As discussed in the Environmental Impact Analysis (Chapter X) and in the discussion of productivity impacts later in this section, there was substantial comment to the record indicating that in many, if not most, situations, the controls associated with reducing silica exposure will lead to a net decrease in the amount of time required for cleanup after a job. While OSHA is not attempting to quantify any potential cost savings, the record likewise does not support attributing additional costs to cleanup.

Specific Industry/Equipment Category Cost Comments

Crushing Machines

William Turley, executive director of the Construction & Demolition Recycling Association (CDRA), broadly described the impacts he anticipated for his industry.

> Recyclers who crush materials for reentry into the economic mainstream as aggregate products would appear to have to do all of the following:
>
> - Purchase and install climate-controlled enclosures or cabs for all crusher operators;
> - Install crusher baghouses for particulate emission reduction;
> - Enclose conveyor belts – a measure unprecedented in our industry;
> - Install effectively designed and maintained water spraying equipment;
> - Impose full-shift use of respirators for all quality control hand pickers working on processing lines;
> - Establish and implement emission testing protocols and procedures to ensure compliance with the PEL;
> - Implement medical surveillance programs for all employees engaged in material crushing activities; and
> - Achieve a “no visible emissions” standard, which frankly is both unattainable and utterly unreasonable.
>
> To the best of our knowledge, no recycler in the United States has a system even resembling the above. The cost of such systems will unquestionably threaten the economic viability of construction & demolition debris recyclers across the Country. It must also be pointed out that the industry has an exceptionally diverse composition of larger operators with higher economic margins and small operations with limited capabilities to capitalize the type of equipment called for in this rulemaking (Document ID 2220, pp. 2-3).

The final silica rule does *not* require all the above steps. OSHA expects that crushing machines will be used for construction/demolition activities, as discussed in detail in the

Summary and Explanation of the standard. As such, OSHA anticipates that employers engaged in the recycling operation would follow Table 1 and would not need to conduct exposure monitoring.

For crushing machines, OSHA removed the “no visible emissions” requirement and the requirement for enclosed cabs, both of which had been in proposed Table 1. Employers are now required to use a spray system and comply with manufacturer instructions. Also, there is no requirement to enclose conveyor belts or install crusher baghouses. Instead, employees must use a remote control station or ventilated booth that provides fresh, climate-controlled air to the operator. For this FEA, OSHA added the cost of a ventilated booth for the use of crushing machines in construction/demolition activities. Most crushing machines are already equipped with movable controls that will allow operation of the machine from inside the booth, so no additional equipment modifications will be required for most machines. Crushers available for purchase or rental are also typically equipped with a water spray system, so OSHA has not assessed any incremental cost for sprayers.

Homebuilding – Roofing

The National Roofing Contractors Association (NRCA) objected to OSHA’s preliminary cost estimates for controls used to limit silica exposure in roofing operations, claiming that OSHA’s preliminary estimate of an average of $550 per year for firms that employ 20 workers or fewer (covering the majority of roofing contractors) had significantly underestimated the cost of specialized saws that would be required for roofing equipment. In support of the argument that OSHA had underestimated costs, NRCA identified costs for retrofitting portable saws with integrated dust collection systems along with specialized vacuums equipped with HEPA filters (Document ID 2214 p. 4).

The task of cutting most roofing materials would fall under “Handheld power saws (any blade diameter)” in Table 1, and the final version of Table 1 does not allow for the dust collection methods described, so the majority of costs quoted by NAHB are not relevant. Instead, the final version of Table 1 requires that the employer use wet methods. Second, the estimate of $550 a year in costs to very small employers was an estimated average across *all* affected establishments with fewer than 20 employees, not just roofing operations in homebuilding. Questions of small business impact or economic feasibility for the roofing industry are dealt with Chapter VI of this FEA.

The comments submitted by consultant Peter Soyka on behalf of James Hardie Building Products (“Hardie”) presented a table of typical devices with engineering controls involved in fiber cement cutting and an un-sourced range of costs for the retail prices of those types of devices and their controls (Document ID 2322, p. 13).

Hardie's inclusion of a table of retail prices for the purchase of equipment with controls suggests there may have been a misunderstanding of the nature of OSHA's cost methodology—it is not based on purchasing entirely new pieces of equipment, but making sure the equipment has the controls necessary to comply with Table 1. To the extent commenters submitted estimates addressing the latter question, the Agency has taken them into consideration in its final estimates.

Asphalt Milling

Fann Contracting, Inc. acknowledged that the availability of equipment with built-in controls is rising. However, the commenter suggested that OSHA's preliminary assessment of the design specifications and costs for the engineering controls identified in Table 1 of the proposed rule had under-counted the amount of milling machines and other paving-related equipment that the commenter believed would still require additional retrofits to enclosed cabs (sealing cracks, adding air conditioning, upgrading to HEPA filters, etc.) to satisfy the requirements in Table 1 (Document ID 2116, pp. 6-7).

Table 1 in the final rule does not require a cab for milling machines or any of the equipment identified by the commenter for paving purposes, so the commenter's concerns are not relevant. Table 1 only requires cabs for "(xvii) Heavy equipment and utility vehicles used to abrade or fracture silica-containing materials (e.g., hoe-ramming, rock ripping) or used during demolition activities involving silica-containing materials," and specifies it as an option for "(ix) Vehicle-mounted drilling rigs for rock and concrete." Table 1 requires employers to use wet methods to control dust emissions from milling machines. These costs have been accounted for in the cost analysis.

Drywall Finishing

A SBREFA commenter raised questions about the availability of silica-free joint compound for drywall finishing (Document ID 0004, p 38 of memo). In the PEA, OSHA relied on NIOSH studies showing that silica-free joint compounds had become readily available in recent years (see ERG, 2007a, Section 3.2). The cost model for the PEA assumed that 20 percent of drywall finishing jobs would continue to use conventional joint compound. Based on additional information, OSHA has determined that all commercially available joint compounds have no, or very low amounts of, silica and do not pose a risk to workers from respirable crystalline silica (Document ID 2296, pp. 32, 36; 1335, p. iii) and has therefore not included drywall finishing in Table 1 or taken any costs for this task (See Summary and Explanation, Specified Exposure Controls for more information).

Number of Days Controls Are Used Annually

Whether equipment, and the relevant controls, are rented or purchased, the effective annual cost of the equipment is based on the assumed number of days per year that it would be used. In the PEA, OSHA had estimated rental of the equipment for 150 days during each 365-day period. Based on comments received from industry representatives during the 2003 SBAR Panel process (Docket ID 0968), this estimate had been reduced from an average of 250 days in the Preliminary Initial Regulatory Flexibility Analysis (PIRFA). This reduced workday estimate presumably reflected winter weather slowdown in many parts of the country, as well as general weather conditions (such as rain) that can interfere with many construction processes, and resulted in 2/3 higher daily rental rates for control equipment.[52]

However, Environomics, in developing its own cost estimates, assumed that control equipment would be used for 250 days a year, without an articulated rationale for departing from the estimate provided during the SBAR Panel process (Document ID 4023, Attachment 2, X2B- Hole Drilling Unit Costs, Cell P:Q44). More importantly, Environomics selectively and inconsistently applied 250 days only to the frequency of usage but not to the daily rate (which OSHA had based on 150 days of usage). To see why it is a problem to apply a different number of days to the same daily rate, consider a piece of control equipment, with a one-year life, known to cost $1,500. Using a 150-day construction work-year, OSHA would estimate a daily rate for the control equipment of $10 ($1,500 / 150 days in the construction work-year). The annual cost for that control would be $1,500 ($10 multiplied by 150 days). Using the same example, Environomics would keep OSHA's daily rate of $10 (amortized over 150 days) but apply it to a 250-day calendar to arrive at an annual cost of $2,500—where the one-year cost of the equipment was known to be $1,500. In short, the selective 250-day methodology Environomics used results in an overestimation of costs by 67 percent.

Accordingly, OSHA has decided to retain the 150-day construction work year based on the best available evidence, and the Agency has consistently applied that work-year throughout the cost analysis developed in this FEA for construction. (General industry and maritime work is typically less affected by weather, so a separate work-year number of days is used for those calculations).

[52] To see the effect of this change, let X equal the yearly cost for a piece of control equipment. The daily rate over 250 days is X/250; the daily rate over 150 days is X/150. So the effect of reducing the number of workdays in a year from 250 to 150 on the daily rate is X/150 divided by X/250, or 250/150 = 1 2/3. That is, the daily rate is increased by 2/3.

Unit Control Costs

In developing the cost estimates in this FEA, OSHA defined silica dust control measures for each representative job (see ERG (2007a)). Generally, these controls involve either a water-spray approach (wet method) or a dust collection system to capture and suppress the release of respirable silica dust. Wet-method controls require a water source (e.g., tank) and hoses. The size of the tank varies with the nature of the job and ranges from a portable water tank (unspecified capacity) costing $15.50 a day to a 10,000 gallon water tank with an engine-driven discharge, costing $168.38 a day.[53] Depending on the type of tool being used, dust collection methods entail vacuum equipment, including a vacuum unit and hoses, and either a dust shroud or an extractor. The capacity of the vacuum depends on the type and size of tool being used. Some equipment, such as concrete floor grinders, comes equipped with a dust collection system and a port for a vacuum hose. The estimates of control costs for those jobs using dust collection methods also include the cost for HEPA filters.

The unit costs for most control equipment are based on price information collected from manufacturers and vendors. In some cases, control equipment costs were based on data from RSMeans (2008) on equipment rental charges. Table V-32 shows the general unit control equipment costs and the assumptions that OSHA used to estimate the costs for specific types of jobs.

For each job identified as needing engineering controls, OSHA estimated the annual cost of the appropriate controls and translated this cost to a daily charge, based on an assumed use of 150 days per year (30 weeks), as explained earlier. The only exceptions were engineering controls expected to be used for short-term, intermittent work. For these controls, consistent with the CISC methodology that OSHA adopted, carpenters and other occupational groups were estimated to purchase this control equipment, and for costing purposes, OSHA amortized the equipment over its "half-life"—that is, over 75 days rather than 150 days (effectively doubling the daily capital costs of the equipment). Accordingly, Table V-32 shows separate daily cost estimates, for regular and for infrequent use, for a dust extraction kit and for a10-15 gallon vacuum with a HEPA filter.

[53] See Chapter X in this FEA for a discussion on the environmental impacts resulting from the use of wet methods for controlling exposure to silica.

Table V-32

Unit Control Costs for Construction

Control Equipment Category	Equipment Cost	Average Lifetime (yrs)	Average Annualized Cost	Average Ann. Cost/ Day of Use [a]	Maintenance and Operating Cost/Day [b]	Total Ann. Cost/ Day of Use	Source; Comments
Wet kit, with water tank	$227	2	$118.49	$0.79	$0.17	$0.96	Contractors Direct, 2009; Berland Tools Outlet, 2009; Mytoolstore, 2009
Dust shrouds: grinder	$97	1	$97.33	$0.65	$0.14	$0.79	Contractors Direct, 2009; Bertland Tools Outlet, 2009; DustBuddy, 2009; Martin 2008
Water tank, portable (unspec. capacity)	NA	NA	NA	$15.50 [c]	$0.00 [c]	$15.50	RS Means - based on monthly rental cost
Water tank, small capacity (hand pressurized)	$74	1	$76.09	$0.51	$0.11	$0.61	Contractors Direct, 2009; Mytoolstore, 2009

Table V-32 (continued)

Unit Control Costs for Construction

Control Equipment Category	Equipment Cost	Average Lifetime (yrs)	Average Annualized Cost	Average Ann. Cost/ Day of Use [a]	Maintenance and Operating Cost/Day [b]	Total Ann. Cost/ Day of Use	Source; Comments
Hose (water), 20', 2" diameter	NA	NA	NA	$1.65 [c]	$0.00	$1.65	RS Means - based on monthly cost
Custom water spray nozzle and attachments	$363	1	$374.15	$2.49	$0.52	$3.02	Hoffer, 2007
Hose (water), 200', 2" diameter	NA	NA	NA	$16.45 [c]	$0.00 [c]	$16.45	RS Means - based on monthly rental cost
Vacuum, 10-15 gal with HEPA	$725	2	$378.89	$2.53	$0.53	$3.06	ICS, 2009; Dust Collection, 2009; Edco, 2009; CS Unitec, 2009
Vacuum, 10-15 gal with HEPA (infrequent use)	$725	2	$378.89	$5.05	$0.53	$5.58	ICS, 2009; Dust Collection, 2009; Edco, 2009; CS Unitec, 2009
Vacuum, large capacity with HEPA	$2,108	2	$1,101.66	$7.34	$1.54	$8.89	ICS, 2009; Edco, 2009; Aramsco, 2009

Table V-32 (continued)

Unit Control Costs for Construction

Control Equipment Category	Equipment Cost	Average Lifetime (yrs)	Average Annualized Cost	Average Ann. Cost/ Day of Use [a]		Maintenance and Operating Cost/Day [b]	Total Ann. Cost/ Day of Use	Source; Comments
Electric blower (1,277 cfm) and 25 ft. of duct	$950	5	$207.44	$1.38		$0.29	$1.67	Northern Safety Co., 2003. Inflated to 2009 dollars.
Dust extraction kit (rotary hammers)	$215	1	$214.81	$1.43		$0.30	$1.73	Grainger 2009; Mytoolstore, 2009; Toolmart, 2009
Dust extraction kit (rotary hammers) (infrequent use)	$215	1	$214.81	$2.86		$0.30	$3.16	Grainger 2009; Mytoolstore, 2009; Toolmart, 2009
Dust control/quarry drill	NA	NA	NA	$17.33	[c]	$0.00	$17.33	RS Means, 2008
Dustless drywall sander	$133	1	$133.33	$0.89		$0.19	$1.08	Home Depot, 2009; LSS 2009; Dustless Tech, 2009
Water misting cannon	$19,190	10	$2,249.65	$15.00		$3.15	$18.15	New Jersey Used Equipment, 2015
Cab enclosure w/ ventilation and air conditioning	$13,000	10	$1,524.00	$10.16		$2.13	$12.29	Estimates from equipment suppliers and

Table V-32 (continued)

Unit Control Costs for Construction

Control Equipment Category	Equipment Cost	Average Lifetime (yrs)	Average Annualized Cost	Average Ann. Cost/ Day of Use [a]	Maintenance and Operating Cost/Day [b]	Total Ann. Cost/ Day of Use	Source; Comments
							retrofitters.
Foam dust suppression system	$14,550	10	$1,705.70	$11.37	$2.39	$13.76	Midyett, 2003.
Water tank, engine driven discharge, 5000 gal.	NA	NA	NA	$121.50 [c]	$0.00 [c]	$121.50	RS Means - based on monthly rental cost
Water tank, engine driven discharge, 10,000 gal	NA	NA	NA	$168.38 [c]	$0.00 [c]	$168.38	RS Means - based on monthly rental cost
Half-face respirator	$27	2	$468.74	$3.12	$0.66	$3.78	[d]
Dust booth	$10,605	10	$1,243	$8.29	$1.74	$10.03	ERG estimate based on Cerala, et al, 2002 & 2005
Tunnel dust suppression system supplement	$7,928	5	$1,731.03	$11.54	$2.42	$13.96	Raring, 2003.

NA=Not applicable. For cost items that are assumed to be leased or rented (as on a per job basis), equipment lifetimes are not relevant and have not been defined.

[a] Except where noted, daily equipment cost is based on the annualized equipment cost divided by 150 to reflect the assumed average number days of use per year.

[b] Except where noted, daily operating and maintenance costs are calculated as 10% and 25%, respectively, of annualized equipment costs divided by 250, assuming full-time

Table V-32 (continued)

Unit Control Costs for Construction

Control Equipment Category	Equipment Cost	Average Lifetime (yrs)	Average Annualized Cost	Average Ann. Cost/ Day of Use [a]	Maintenance and Operating Cost/Day [b]	Total Ann. Cost/ Day of Use	Source; Comments

use.

[c] Daily equipment costs derived from RS Means monthly rental rates which include maintenance and operating costs.

[d] Derived by ERG based on vendor-derived capital cost of $27.00, 2 year equipment life, accessory cost of $295.52. Also includes annualized training cost of $50.34, fit test cost of $26.45, and respirator cleaning cost of $81.49 to derive total annual costs of $468.74.

Source: ERG estimates based on vendors' equipment prices and R.S. Means, Heavy Construction Cost Data, 2009.

Incremental Labor Costs and Productivity Impacts in Construction

In addition to incremental equipment costs, OSHA estimated in the PEA the incremental labor costs generated by implementing silica dust controls. These labor costs were generated by: (1) the extra time needed for workers to set up the control equipment; (2) potential reductions in productivity stemming from use of the controls; (3) additional time to service vacuum dust control equipment; and (4) additional housekeeping time associated with or generated by the need to reduce exposures. All additional labor costs related to the use of controls were subsumed into a single additional labor productivity impact estimate for each of the representative job categories. Except where otherwise noted, the productivity impact described is negative, meaning that the addition of the control is expected to reduce productivity. To develop estimates of the labor productivity impacts of the dust control equipment that would be required as a result of the proposed standard, ERG interviewed equipment dealers, construction contractors, industry safety personnel, and researchers working on construction health topics.

In part, because most silica dust controls are not yet the norm in construction, knowledge about the impact of dust controls on productivity was uneven and quite limited. More precisely, few individuals that ERG interviewed were in any position to compare productivity with and without controls and the literature on this topic appears deficient in this regard. Overall, telephone contacts produced a variety of opinions on labor productivity effects, but very few quantitative estimates. Of all the sources contacted, equipment rental agencies and construction firms estimated the largest (negative) productivity impacts. Some equipment vendors suggested that there are positive productivity effects from control equipment due to improved worker comfort (from the reduction in dust levels). Others suggested that the use of dust collection equipment reduces or eliminates the need to clean up dust after job completion. Comments to the record, discussed below, closely mirrored this preliminary information.

The estimation of labor productivity effects is also complicated by the job- and site-specific factors that influence silica dust exposures and requirements for silica dust control. Potential exposures vary widely with hard-to-predict characteristics of some specific work tasks (e.g., characteristics of materials being drilled), environmental factors (e.g., wet or dry conditions, soil conditions, wind conditions), work locations (e.g., varying dust control and dust cleanup requirements for inside or outside jobs), and other factors. Generalizations about productivity impacts, therefore, are hampered by the range of silica dust control requirements and work circumstances.

After considering the existing evidence OSHA concluded that labor productivity impacts are often likely to occur and accounted for them in the PEA analysis. In the PEA, depending on the general likelihood of productivity impacts for each activity, OSHA used a productivity impact ranging from zero to negative five percent of output. After considering the many comments advocating for both increasing and decreasing the productivity impact estimates, OSHA has concluded that the estimates in the PEA were approximately correct and has retained the PEA estimates for this FEA. The comments and factors influencing each selection are described in the following discussion.

SBAR Panel Comments on Productivity Impacts

In response to the SBAR Panel, the Reform OSHA Coalition commented on the estimates of the impact of exposure control equipment on productivity during construction operations. This SBREFA commenter noted that the estimates of the productivity impact of using additional control measures were based on interviews with dealers, contractors, and researchers working on construction health topics and expressed its opinion that it was not clear how this "purely qualitative analysis [was translated] into productivity [impact] rates . . . ." (Document ID 0968, p. 14). The commenter indicated that engineering control compliance costs would be sensitive to the ultimate choice of productivity impact measures (Id.).

OSHA responded to these comments in the PEA as part of the discussion of the basis for OSHA's productivity estimates. OSHA summarizes the responses to SBREFA comments here for the convenience of the reader. As described in the PEA, ERG's research revealed little substantive, quantitative evidence about the magnitude of the productivity impacts of the controls, and in some cases, the direction of the impacts (positive or negative) appeared to depend on the specific nature of the job. OSHA's estimates in the preliminary analysis reflected ERG's best professional judgment about the likely magnitude of these impacts. Some of the estimates may be conservative because under some scenarios for certain tasks the productivity impacts could be significantly smaller than those shown in Table V-23 of the PEA. In some scenarios the productivity impact may even be positive.

The same commenter also expressed a concern that even though "silica is not now considered a hazardous waste," OSHA had not analyzed the impact of the proposed rule on disposal of "[silica-]contaminated" wastes such as "filters of dust control vacuums and contaminated water discharge" (Document ID 0968, p. 28). The commenter asserted that disposal issues are "acute on the construction site where a means to readily dispose of such material or water is not available" (Id.). The comment was somewhat puzzling because the comment was premised on the fact that there is not currently any "hazardous" classification for such waste that would trigger special disposal duties, and the commenter did not explain why any additional costs would be incurred beyond normal disposal practices. OSHA did not identify any new areas of cost in its Environmental Impacts analysis presented later in this FEA, and finds no evidence that employers will be required to incur additional environmental costs as a result of this rule, other than some potential permit-modification notification costs addressed in the discussion of engineering control costs for general industry. The incremental disposal costs resulting from dust collected in vacuums, discarded filters, and other sources in construction are therefore likely to be de minimis. An analysis of wet methods for dust controls suggests that in most cases the amount of slurry discharge is not sufficient to cause a runoff to storm drains or surface water.[54]

Comment and Responses on Productivity Impacts in Construction

OSHA invited comment on the productivity impacts—positive and negative—resulting from the introduction of controls to limit exposure to silica. In the discussion below, OSHA reviews comments supporting both negative productivity impacts and positive productivity impacts. The comments supporting negative productivity impacts include assertions that OSHA underestimated the negative productivity impact of complying with the silica rule, failed to include a productivity impact on equipment, and failed to include a fixed productivity impact. OSHA considered those comments before concluding that it will generally retain the approach it used in the PEA, with the exception of selectively adding additional costs for productivity impacts on equipment in response to a point raised by CISC. OSHA will also explain separately why it is not calculating any productivity impact for two specific activities: (1) use of cabs for earthmoving equipment, and (2) drywall installation.

Public comments suggesting that OSHA underestimated the productivity impacts associated with engineering controls

The Interlocking Concrete Pavement Institute reported that “converting from in-place paver cutting to wet cutting and/or vacuum systems could induce a 50% productivity penalty,” but did not otherwise substantiate that claim beyond noting that it was a survey response from one of its members (Document ID 2246, Attachment 1, p. 3).

Mr. Soyka, in the comments prepared for Hardie, critiqued OSHA’s estimates of the productivity impact on construction operations as “far too small” and urged OSHA to adjust productivity-loss estimates based on empirical data “if available” (Document ID 2322, Appendix G, pp. 14-15 and 21-22). However, the

[54] For a more detailed discussion of this issue, see Chapter X of this FEA.

commenter did not clearly identify any such empirical data in the comments. The only labor-based engineering control cost alternative offered by the commenter that resembled "empirical data" is the addition of a seven-hour penalty per job that was "based on a JHI time-motion study" apparently conducted exclusively in a single industry (new home construction) and comprised of data from just the JHI study (Document ID 2322, Appendix G, Attachment A, p. A-8). OSHA could not determine whether it would actually supply new "empirical evidence" that would warrant a change from the preliminary estimate because the study was not submitted into the record. The commenter cites "James Hardie Building Products, Inc., undated, pg. 15," which appears to align with an entry in the list of references to an undated "James Hardie Labor Efficiency Manual," but that manual was not submitted into the record.

Mr. Soyka recommended that OSHA use time-motion studies to derive the estimated productivity impacts.

> […F]ew [of the productivity penalties estimated by OSHA] are supported by actual data (e.g., time-motion studies). OSHA should apply a more conservative approach that considers how work flow and task completion are likely to be affected by newly required changes to existing practices as well as entirely new activities (Document ID 2322, Appendix G).

In addition, Mr. Soyka developed an alternative cost model that included additional productivity impacts that OSHA did not include. In this model Mr. Soyka "assumed that wherever possible, company owners in the residential construction industry will outsource their compliance obligations to specific subcontractors . . .providing the products and services that might generate significant amounts of silica dust" (Document ID 2322, Appendix G, p. 26). In this scenario, Mr. Soyka determined that the employer would require "the subcontractor to relocate its work location outside the house(s) being constructed to a distance sufficient to ensure that silica dust concentrations remained minimal inside and around the house(s)" and that "relocating the materials and work giving rise to silica dust generation […] would add substantially to the time required to complete the associated tasks" (Document ID 2322, Appendix G, p. 30). He accounted for this additional time by increasing the productivity impact on the specialty subcontractors to seven hours per job, "based upon time-motion studies conducted by James Hardie (James Hardie Building Products, Inc., undated, pg. 15)" (Document ID 2322, Appendix G, p. 31).

Mr. Soyka's model also included a productivity impact for "wearing respirators to account for fatigue and adverse impacts on employee-to-employee communication" (Document ID 2322, Appendix G, p. 32).

OSHA fundamentally disagrees with the Mr. Soyka's assumptions. Mr. Soyka's assumption that all silica-generating tasks need to be removed from the homebuilding site results from a misunderstanding of OSHA's statement that "[i]n response to the proposed rule, many employers are likely to assign work so that fewer construction workers perform tasks involving silica exposure; correspondingly, construction work involving silica exposure will tend to become a full-time job for some construction workers" (FR, 2013, at 56357) (Document ID 2322, Appendix G, p. 25). OSHA did not mean that silica-generating tasks will be subcontracted out and that subcontractors will be forced to perform these tasks off-site. Rather, the Agency was acknowledging that construction employers would likely consolidate the responsibilities for performing silica-generating tasks to as few workers as possible in order to limit exposures to peripheral workers.

As mentioned previously, the "time-motion studies" performed by James Hardie, compiled in an unpublished reference, were not provided for public inspection. Moreover, the description of how those data were used in developing the model suggests that Mr. Soyka's relevant assumptions are not based on time-motion studies of how long it actually takes to perform specific tasks with controls added. Rather, it appears that Mr. Soyka assumed inflated times to perform the tasks, based on a misunderstanding of what the proposed rule required; in any case, it is not descriptive of the requirements for the final rule. Mr. Soyka's suggested approach contrasts with the estimates provided by CISC/Environomics, which accepted the limitations of the analytical exercise and agreed with most of the estimates in the PEA regarding the "variable" productivity effect.

Moreover, it should be noted that aside from weighing the possible competing forces on productivity in the course of a shift (e.g., more time for set up vs. less time required for clean-up), there is also a short-run/long-run phenomenon over a longer period as the standard comes into use. There may be a short learning curve until workers determine the most efficient way to perform a job when controls are introduced (Document ID 3581, p. 1700); in some cases, the effect may be relatively larger until the method of performing a job is re-conceptualized. Mr. Soyka criticizes OSHA for not recognizing "the dynamic nature of construction" (Document ID 2322, Appendix G, p. 19), but one obvious aspect of the dynamic nature of construction is that employers will be constantly adapting to changing circumstances and trying to find ways to perform the job in the most cost-effective manner. In short, the Agency believes that a time-motion study of a particular task is neither necessary to determine approximately what the effect will be in the short-run, nor would it allow OSHA to determine what the long-run cost of integrating the controls will be.

CISC and its consultant Environomics, as well as some other commenters, questioned the Agency's productivity-loss estimates associated with the required controls. CISC/Environomics claimed that overall OSHA "underestimated productivity losses associated with performing tasks using the prescribed controls by an amount roughly equal to the average equipment intensity of about 42 percent" (Document ID 2320, p. 29). CISC/Environomics reported that this underestimation came largely from OSHA failing to account for what they termed "fixed productivity impacts" and for productivity impacts to equipment. Both of these concerns are discussed below.

In its post-hearing brief, CISC/Environomics presented the results from a questionnaire and interviews conducted with employers and knowledgeable tradespeople; the results included a finding that "the variable penalty percentages […] were the same as or slightly larger than those that OSHA had estimated" (Document ID 4217, p. 92). CISC/Environomics did not submit the questionnaire or the answers received, nor the details of the interviews, to the record so OSHA could not fully evaluate the findings or compare them to its own findings. Based on the available summary information it appears that, while CISC and OSHA's estimates for variable productivity costs were nearly identical, it is not clear that CISC's estimates took current compliance into account. CISC stated that its members felt that "something greater than zero variable productivity penalty should be estimated for masons using portable saws controlled with wet methods […] and for heavy equipment operations using enclosed cabs and HEPA filters" (Document ID 4217, pp. 92-93). OSHA acknowledges that there would be a productivity impact to comply with the requirements of the silica rule relative to using no controls for those activities. However, as shown in Chapter III of this FEA, Industry Profile, OSHA has found high levels of baseline compliance with the provisions of the rule for those activities. As is standard in OSHA's costing methodology, only costs above and beyond those incurred under current standards are attributable to the final rule.

In addition, CISC argued that OSHA should take higher productivity impacts because "in some fraction of these instances [(where controls would be required)], the controls are hellaciously difficult to use" (Document ID 3580, Tr. 1321). The testimony goes on to give examples of such difficulties such as when "building houses where the utilities are not yet in and the water is not yet in," when working in places where power is not readily available such as in parking garages or on scaffolding, and when doing work that requires wet methods outdoors in extremely cold temperatures (Document ID 3580, Tr. 1321-1322). A different commenter, the National Utility Contractors Association, similarly criticized OSHA's estimates for excluding additional water-transportation costs: "there is not always a water supply available which would require trucking large volumes of water to the job site which adds additional costs" (Document ID 3729, p. 3).

Given the fact that the majority of the silica-generating equipment requiring controls under this standard—such as tuckpointing grinders and concrete drilling equipment—require electricity, OSHA does not find merit in applying any productivity impact simply because the controls for those tools may also need electricity. If the employer can find a way to power the equipment, it can also power the controls when necessary. Similarly, employers must commonly transport water to worksites without it for cleanup and sanitation purposes, and OSHA's technological feasibility analysis explains why the amount of water required to generate the spray mist is not typically very significant. Although it seems plausible that wet methods would occasionally be used outdoors by some employers in weather cold enough to freeze the water mist used to control the silica dust, this is far from a common construction occurrence. Moreover, it is not entirely clear from the record that freezing mist would decrease productivity. OSHA's estimates of productivity impacts are intended to represent an average across all situations, and the tiny fraction of time wet methods will need to be used outdoors in extremely cold weather should not skew the average productivity impact.

CISC/Environomics stated that there should also be a productivity impact on equipment rental or use as well as for the additional labor to operate that equipment longer. Environomics reported that a complete cost estimate of productivity loss would include not only the additional labor time required, but also the cost of having to rent equipment for a longer period of time.

> . . . Simply put, a productivity penalty for labor will translate to a productivity penalty for equipment. For example, if due to a labor productivity loss, the labor time required to complete a job increases from eight hours to eight hours and 15 minutes, the equipment time required for job completion will also increase to eight hours and 15 minutes. Additional equipment rental costs will be incurred for the additional 15 minutes, or equipment owned by the employer will be delayed for use on another job by 15 minutes (Document ID 2320, p. 29).

This concern was reiterated both in its hearing testimony (Document ID 3580, Tr.1323) and in its post-hearing brief where Environomics stated that "OSHA's analysis should add an equipment component to the costs associated with whatever productivity penalty is incurred in performing a construction task using the Table 1 controls" (Document ID 4217, p. 91). OSHA agrees, in part, and recognizes that there can be a productivity impact for equipment (as well as for labor) for many tasks when there is a cost created by having to extend the rental time of the equipment.

In the PEA, OSHA had estimated the labor productivity impacts associated with engineering controls to reduce silica exposure. For this FEA, the Agency has added a parallel cost for the equipment portion of the cost for a number of equipment categories. These are itemized in Table V-34. For example, for Task 15 (Demolition of concrete slabs, mesh-reinforcing, up to 3" deep), there is estimated to be a 2 percent labor increase related to maintaining wet methods for dust suppression. In the original RS Means estimates, it was estimated that approximately 70 percent of the costs of the task were labor-related, divided between an operator and a laborer. This 2 percent additional cost is estimated to amount to $9.39 in added labor cost for an equipment operator and $7.84 for a laborer, or a total labor productivity cost per job of $17.23. For the FEA, OSHA is adding an additional cost item of $7.58 to reflect an opportunity cost, in the form of a prospective extended equipment rental cost, raising the total incremental estimated cost to $24.81 per task. As with the other construction engineering control costs, this additional cost item is task-specific.

While OSHA judged that equipment productivity can be impacted negatively by the new rule for many tasks, there are two general categories for which the Agency determined that there would be no impact on equipment productivity. The first broad category is short-term, intermittent work in which the equipment and control are often idle. An example would be a plumber drilling holes in concrete. The equipment and control are sufficiently inexpensive (relatively speaking) that the construction employer or trade contractor (or possibly even the tradesperson) would typically own rather than rent the equipment and control. As discussed elsewhere in this FEA, OSHA determined that certain tradespersons, such as plumbers, electricians, and their helpers, are more likely to purchase their equipment, rather than renting it. OSHA estimated the cost of purchasing control equipment at twice the rental cost.

The second category of tasks for which the Agency did not assess any equipment productivity impact is the group of tasks in which there is not a fixed ratio of labor to capital (capital in this case including rental costs). For example, as explained in the following unit cost discussion, Task 10 (as detailed in Table V-34) involves performing earthmoving as a heavy equipment operation task. In this case, while extra time by a laborer would be required to tend to the application of wet methods, such application would be done simultaneously with actually performing the earth-moving task. Thus, while wet methods for Task 10 would require an added labor cost (itemized as a “productivity” cost), it would not actually slow down the operation so as to require the longer period of use of the equipment that would impose an equipment impact.

CISC/Environomics also argued that part of the productivity effect was fixed and would therefore need to be accounted for separately. This fixed component, CISC/Environomics reported, would be “typically involving activities such as initial set-up and final take-down and clean-up of the control equipment, [which] often occur at the beginning and end of a job or work shift" (Document ID 4217, p. 90, see also 2320, p. 28; 3580, Tr. 1320). This would mean that shorter jobs would have a relatively larger percentage loss in productivity.

Other commenters did not agree that there would be costs related to set up. During the hearings, Deven Johnson, of the Operative Plasterers' and Cement Masons' International Association, testified that the concrete grinding "tools that are on the market today come integral with the capture device[…] The hose is attached to the grinder already. The electrical cord is attached to the motor already. […] You simply plug it in and start using it […] there's no setup time" and that for "a walk-behind concrete diamond-bladed saw for cutting slabs, the setup time is, make sure there's gas in it and . . .hook a water hose up to it and turn the water on" (Document ID 3581, Tr. 1699). During the hearing, Manafort Brothers described a wheel-based machine used to suppress dust during demolition operations, which was simply wheeled onto the worksite and hooked up to a water supply and electrical source (Document ID 3583, Tr. 2430), and the Building Trades Construction Department (BCTD) of the AFL-CIO submitted an extensive list of available tools that included the controls required by the rule that would require little or no set up (Document ID 4073, Attachment 4a).

Based on the evidence in the record, OSHA determined that any time needed to set up the engineering controls required by this rule is adequately accounted for in the productivity impacts the Agency has included, particularly in light of the fact that OSHA is not making any adjustment to account for productivity improvements that are likely to result from this rule (see the discussion of comments identifying productivity improvements later in this section). Environomics' inclusion of both a "fixed" productivity impact as well as a "variable" productivity impact, without recognizing offsetting productivity benefits identified by other commenters', results in a significant overestimate of the productivity impact.

Public comments suggesting that OSHA had overestimated the productivity impacts associated with engineering controls

BCTD strongly disagreed with CISC's estimates about productivity decreases resulting from the rule, stating in their post-hearing brief:

> [a]ll that [CISC] offered to support these significant increases [in the productivity impact] is an explanation of how its approach to calculating productivity differs from OSHA's and a few examples, such as:
>
> > So in the case of the carpenters with the dust extraction equipment on the drill and the HEPA vacuum, the carpenter takes a little bit longer to do his hole-drilling task because he's got to attach the equipment to the drill. He's got to

> attach the hose to the HEPA vacuum. He's got to walk over before he drills and he's got to turn on the HEPA vacuum. Then after he drills, he's got to turn off the HEPA vacuum. He's got to periodically empty the HEPA vacuum. He's got to worry about the vacuum hose from the drill to the vacuum getting kinked and all that sort of thing. So the job takes a little bit longer. Tr:1317-18.

CISC offered no evidence that its analytical approach is more accurate than OSHA's. Moreover, this description of how its hypothetical carpenter would deploy control technology assumes the employer would select the most cumbersome and inefficient technique available, rather than taking advantage of the range of more suitable and less costly tools that are readily available on the market. See, e.g., Ex. 4073, Att.7a (ROI: hand-held drill with integrated dust collection) (Document ID 4223, pp. 55-56).

BCTD also took exception to the fact that "CISC acknowledged that 'there may be a productivity net gain in terms of cleanup from using a control,' Tr:1319 (Sessions), [but did] not appear to have taken potential gains into consideration when estimating its lost productivity cost" (Document ID 4223 pp. 55).

Dr. Ruth Ruttenberg highlighted the various areas where the PEA may have overestimated the negative productivity effect of engineering controls in construction. She stated that the assumption of a negative impact on productivity

> is yet another example of OSHA erring on the side of being conservative in cost estimates. Despite the fact that some who were interviewed suggested there could be a positive impact on productivity, OSHA's PEA assessed anywhere from 0 percent to a 5 percent penalty in productivity loss as a result of OSHA compliance with the proposed silica rule. (PEA, p. V-123-124) The impact of an assumption of lost productivity can be profound, and OSHA acknowledges this: "…the magnitude of the productivity impacts can substantially change the estimate of the overall cost increase associated with controls" (PEA, p. V-131).
>
> Despite the fact that OSHA leaves likely productivity increases out of its calculations, it does point to opportunities to increase productivity with dust control. […]
>
> Limiting dust increases visibility for workers. (PEA, p. V-126) Vacuum systems speed up drilling because continuous removal of drill cuttings from the hole, reduce the need for workers to periodically stop and clean. (PEA, p. V-128) And the list goes on. OSHA's cost estimates are conservative, and high, when it comes to productivity impact (Document ID 2256, Attachment 4, p. 7).

Productivity improvements

In addition to comment that the productivity loss due to this rule would be minimal, the Agency also received considerable comment to the record that the controls would *improve* productivity in a number of ways the Agency had not factored in—for example by reducing clean-up time by capturing dust at the source, improving worker comfort and morale, and encouraging innovation.

Productivity improvements – reduced clean-up time

Testimony at the public hearings by the International Union of Bricklayers and Allied Craftworkers on the experience by union members with engineering controls suggested that use of controls may boost productivity by reducing the amount of dust that needs to be cleaned up during a given shift. The following is a hearing dialogue between Chris Trahan of BCTD, and Sean Barrett of the International Union of Bricklayers and Allied Craftworkers:

> MS. TRAHAN: […] In your experience is there any productivity gains or benefits that you can describe?
> MR. BARRETT: I can. These machines, when running correctly, when […] the vacs are regulated, the filters are running good. You can run that machine until 3 o'clock in the afternoon, shut it off, and go home. […] If [the machine is] not [running correctly], you constantly got to keep going back and cleaning up what you already did. You're losing productivity. And over the course of […] a month you're talking 40 man-hours. You're talking a -- paying a guy for a week. It's -- that's not the case at all [if dust controls are functioning]. You would actually increase productivity by having the right equipment there and not have people have to keep coming back or jimmy-rig little things to try to get by. Just do it the way it was designed, and you'll get a lot farther. . . . (Document ID 3585, Tr. 3055-3057).

Deven Johnson of the Operative Plasterers' and Cement Masons' International Association elaborated on the potential time savings of some of the new engineering controls:

> One of the other things that collecting the dust from these operations on the front end does, it saves time on cleanup. Some of the industry people have said that it's prohibitive to do that because it takes more time to collect the dust. That's also not true. If you're collecting the dust as it's generated and it's going into a HEPA-filtered container, it's not being blown all over the job site, you don't need anybody else to clean it up (Document ID 3581, Tr. 1594).

Walter Jones of the Laborer’s Health and Safety Fund testified that, for some tasks, reducing or eliminating the need to clean up after a job can dramatically increase productivity, in this case by one-third:

> We had the Bricklayers here a few days ago and they were talking about their ability to work till 3:00, because they did not have to clean up. Instead, when they use non-dust controlling or capturing devices, they would have to stop right after lunch in order to begin cleaning up. So we're looking at adding a few more hours to the workday. So to me, in my mind, they're way more productive (Document ID 3589, Tr. 4246).

Joel Guth, President of iQ Power Tools and a mason contractor, testified that he had been able to document the savings in clean-up time.

> In certain industries we've been able to measure the time savings from cleaning up the silica dust . . . . It saves them one to two to three hours a day in cleanup time because they don't have to wash down the house or wash the windows or wash the bushes where they're inherently dry cutting (Document ID 3585, Tr. 2981).

Scott Schneider, CIH, Director of Occupational Safety and Health. Laborer’s Health and Safety Fund of North America, discussed how engineering controls contribute to a more productive workplace:

> When you control the dust and you don't have -- you're not breathing it into your lungs, but you're also not spraying it all over the construction site, all over the sidewalk, and you have to clean it up, there's a lot of other costs involved in not controlling. So I think we're going to realize those benefits by implementing the standard (Document ID 3589, Tr. 4277).

<u>Productivity improvements – improved worker comfort</u>

OSHA also heard a good deal of testimony suggesting that productivity will be improved through the use of engineering controls due to improving the working conditions for workers.

Mr. James Schultz of Wisconsin Coalition of Occupational Safety and Health described the physiological and practical benefits of introducing or enhancing engineering controls:

> I think if you would work in the work environment that was less dust or hopefully dust free, it would definitely increase the amount of productivity just because so much of the time you're spending wiping the dust off your

> brow because it's falling into your eyes or something like that. Even if you have the respirator, it still interferes with your vision and things like that. So a cleaner environment would definitely be more productive just because […], you spend less time trying to think about how you can protect yourself from this hazard, and I know myself, after working in the place for many years, I've started to have breathing problems and so if you can eliminate those breathing problems, if you can breathe freely, you're also going to be much more productive because you're not going to stop because you have [to] wheeze or go stand outside to get some fresh air for awhile or those types of things (Document ID 3586, Tr. 3253-3254).

Deven Johnson, mentioned previously, testified about the human effect of controlling silica as well:

> Another thing is, an individual who is working in an environment where […] he or she is constantly bombarded with concrete dust all day long, your productivity drops as you get more and more miserable as the day goes on. Commonsense would dictate, if you're not blasting me in the face with dust and sand and silica for eight hours a day, that I'm going to feel physically better and I'm not going to be as tired and exhausted and pissed off as I normally would be at the end of the day. Your productivity goes up […] (Document ID 3581, Tr. 1594-1595).

Mr. Javier Garcia Hernandez, from National Council for Occupational Safety and Health/ Equality State Policy Center/Laborsafe, testified on the cognitive factors that affect productivity, and why engineering controls should aid productivity:

> . . . as a construction worker, I highly believe that we're more productive when we are protected [. . .]. We spend less energy focusing on how to protect ourselves. Just imagine you're working in a roomful of dust and you're just trying to either close your eyes or cover your mouth so the less you breathe. So you're constantly thinking about how to breathe less dust but if you have the respirator or the wet, the controlled area, whether it is water or respiratory protection, you're much more productive because our mind is less occupied in how to protect ourselves and we spend that time that we would have spent protecting ourselves working (Document ID 3586, Tr. 3248-49).

Todd Ward, a bricklayer, testified that workers have some awareness of the hazards of dry cutting blocks and that

> when [workers] on the job [are] dry cutting they know -- it affects morale as well when they know […] they have some safeguards and they're protecting their lungs. So there is an increased productivity when you have a good morale then on the job (Document ID 3585, Tr. 3057).

Productivity improvements - innovation

OSHA received comments on the fact that OSHA standards often lead to innovation. The Laborers' Health and Safety Fund of North America pointed out that "[j]ust about every OSHA standard has had a look-back that has shown […that] industry has innovated to meet the new standard" and continued, saying that "[w]e believe a new OSHA standard with a lower PEL will spur innovation in the construction industry to meet the challenge" (Document ID 3589, pp. 4183-4184).

Charles Gordon observed that "reality is that the new technology will increase productivity faster, so that the actual costs will be much less than predicted" (Document ID 3855, Tr. 3815).

Conclusions regarding productivity impacts

In summary, while some commenters have asserted that OSHA has underestimated the productivity penalties of using engineering controls in construction, other evidence in the record suggests that the aggregate net productivity effect of implementing engineering controls could either be neutral, or possibly positive. In the absence of detailed quantitative data on these various potentially offsetting effects, OSHA has conservatively chosen to retain its percentage estimates from the PEA, while adding some additional productivity impacts that will cause an increase not only to labor costs but also to equipment costs.

There is one exception: OSHA has removed the productivity impact that it had included in the PEA for drywall installers. As explained in the unit cost discussion, the Agency has determined from the record that there is no economic reason why drywall installers would now use silica-based drywall installation—the U.S. market has shifted entirely to a silica-free compound (Document ID 2287, p. 38; 2296, Attachment 1, p. 30; 1335, pp. 3-4, 7, 10). Therefore, there is no longer a logical basis for a assigning a productivity loss to workers performing this task.

Table V-33 summarizes the labor productivity estimates. As discussed previously, while empirical quantitative data are quite limited on productivity, it is possible to gauge the relative productivity impacts across the principal control options. For example, OSHA judged that there are no productivity impacts for certain controls, such as mobile crushing machines. On the other hand, OSHA found that the controls required for tuckpointers and grinders may result in additional time being spent setting up and maintaining controls over the course of a workday. In Table V-34, productivity impacts, or "lost production time," are shown by task and are factors in OSHA's estimate of incremental cost per day.

As discussed, OSHA has retained most of its original estimates of the productivity effects from the PEA. In some cases, however, Table 1, which forms the basis for the equipment categories listed in Table V-33, was changed from the PEA in response to comment. (See Methods of Compliance in the preamble for further discussion on the changes to Table 1). In other cases, OSHA received clarification on the manner of exposure and added elements to Table V-33, but did not adjust the productivity impact. For example, OSHA received very specific comment on tasks involving portable masonry saws used to cut fiber cement materials (e.g. "Hardie board"), and this is reflected in specific descriptions in Table 1 and in Table V-33, but the estimated productivity impact for "masonry cutting using portable saws" remains the same. Similarly, the Table 1 task that included "heavy equipment operations" in the proposed rule has been broken out into two groups: (1) heavy equipment operators and ground crew laborers used for activities such as grading and excavating that will not involve demolition or other uses that will abrade or fracture silica-containing materials; and (2) heavy equipment operators and ground crew laborers involved in demolition or the abrading or fracturing of silica-containing materials. These two categories are now estimated to have productivity impacts of two and three percent, respectively.

Table V-33: Productivity Impact Estimates for Construction Equipment Categories

Affected by OSHA's Final Silica Standard

Productivity Impact	Source/Rationale for Productivity Impacts	Equipment Categories Affected
None	Dust control is well-integrated into equipment; control set-up can be accomplished with little or no additional effort or as part of substantial set-up effort (In some cases, dust control can improve worker comfort and might enhance productivity)	Rock and Concrete Drillers; Mobile Crushing Machine Operators and Tenders
2% (approx. 10 minutes/day)	(1) Dust control requires incremental set-up time, or (2) Incremental maintenance, or (3) Additional clean-up (Controls have little impact on job performance)	Millers Using Portable or Mobile Machines; Hole Drilling Using Handheld or Stand-mounted Drills; Masonry Cutters Using Stationary Saws; Masonry and Concrete Cutters Using Portable Saws; Heavy Equipment Operators and Ground Crew Laborers (grading and excavating)
3% (approx. 15 minutes/day)	Dust control requires incremental set-up time and some increase in maintenance or clean-up requirements	Jackhammers and Other Powered Handheld Chipping Tools (wet methods); Heavy Equipment Operators and Ground Crew Laborers (abrade or fracture silica-containing materials or demolition)
5% (approx. 24 minutes/day)	Dust control requires incremental set-up time and regular maintenance during day	Jackhammers and Other Powered Handheld Chipping Tools (where LEV is used) Tuckpointers and Grinders

Source: OSHA, Directorate of Standards and Guidance, Office of Regulatory Analysis, based on OSHA (2016).

Productivity Impact Estimates, by Equipment Category

Rock and Concrete Drilling

This equipment category includes the following Table 1 tasks:

- Dowel drilling rigs for concrete; and
- Vehicle-mounted drilling rigs for rock and concrete

This equipment category covers a range of drilling activities using truck-mounted and similar drilling equipment, such as quarry drills and crawler-type drills. Dust control requires the use of either a dust collection system or wet drilling methods. Studies of the effectiveness of available dust collection systems have not addressed performance issues, but ERG judged that their use does not affect drilling productivity. While workers must service the dust control equipment during the workday, this activity generally does not affect the rate of drilling, except perhaps for short-duration jobs. The wet drilling methods are integrated into drilling equipment and also should not adversely affect the drilling rate. Thus, OSHA estimates that there will be no lost production time for these tasks.

Tuckpointers and Grinders

This equipment category includes the following Table 1 tasks:

- Handheld grinders for mortar removal (i.e., tuckpointing); and
- Handheld grinders for uses other than mortar removal

According to ERG's search of the literature, grinding tools can be retrofitted with dust control shrouds that connect to a vacuum system (Buser, 2001 & 2002, Document ID 0577). Studies on the use of these controls indicate that extra time is required to install the shroud and periodically clean, empty, or replace the vacuum drums, filters, or bags. The estimated time to install the shroud may be as short as five minutes, although some types of shrouds take longer to install. Once installed, however, the shroud can be left in place for the work at that location, so this activity need not take place at the initiation of each grinding job.

For interior jobs and for exterior work that requires site cleanup of grinding debris, the additional work time required to use a vacuum system might be partially offset by savings in the time required to seal work areas (to prevent dust migration) and to clean the work area after task completion. Overall, clean-up times will vary depending on the size of the job site, the quantity of grinding debris, and the strength and capacity of the vacuum.

Grinding without a dust-control shroud can generate clouds of dust that might impair a worker's views of the grinding area. Whereas metal shrouds also block the view of the grinding area, plastic shrouds allow workers a view of the work area. Some contractors have noted, however, that use of shrouds does not allow for the precision required for certain tasks, such as grinding an inside corner (Lattery, 2001, Document ID 0777).

For exterior jobs where cleanup is not required and where the work area is not sealed, the use of vacuum equipment is likely to decrease productivity for the amount of time required for servicing the vacuum collectors. If, for example, five minutes were required to empty the vacuums every two hours, production time would decline about 4 percent, due simply to dumping the accumulated dust.

At some construction sites, vacuums have been used during the grinding process, but without shrouds. In these cases, one worker typically holds the vacuum nozzle near the grinding tool, which another worker operates. Switching to shrouds with a direct vacuum attachment would eliminate the need for this assistant and is a more productive operation. Manufacturers and vendors cited other benefits from using the shroud-vacuum systems. Because dust does not build up on and clog the surface of the grinding wheel, the wheels last longer, resulting in an approximate 40 percent savings on the grinding discs (Eurovac, 2001, Document ID 0688). Another source contacted by ERG estimated that shrouds can increase the abrasive life of a grinding wheel by more than 500 percent (Buser, 2001 & 2002, Document ID 0577). In this regard, workers would spend slightly less time replacing wheels over the life of the equipment.

OSHA concluded that while the productivity impacts of vacuum systems can sometimes be partly offset by other factors, net productivity impacts are likely to remain negative. For exterior work, productivity is clearly lower when workers use a vacuum system. Overall, based on ERG's research, OSHA's final cost estimates include a 5 percent impact for lost production time associated with grinding operations in construction. This productivity impact is identical to the impact estimated for this activity in the PEA.

For a tuckpointing project, NIOSH researchers examined the use of vacuum system controls at a large college building complex (Gressel et al., 1999, Document ID 0718). Workers used a shroud-vacuum system with an integral impeller and a fabric dust collection bag. This system required emptying the collection bags about once an hour. The authors reported some problems caused by blocking and kinking of the hose and occasional separations of the hose from the tool. Some of these problems can be attributed to the design of the dust control system and might be rectified by future design innovations. Overall, the vacuum control systems appeared to reduce worker output. Manufacturers and vendors contacted by ERG estimated that polyurethane shroud-vacuum systems with tuckpointing equipment, similar to those used with hand-held grinders, actually enhance productivity. Among the reasons provided for productivity improvements were: (1) fewer workers were required; (2) cleanup times were reduced; (3) workers had improved visibility of the work surface; and (4) blades last longer (Buser, 2001 & 2002, Document ID 0577; Caperton, 2002, Document ID 0580; Eurovac, 2001, Document ID 0688; Nash and Williams, 2000). These observations on productivity applied to tuckpointers with 2- to 8-inch diameter wheels. In addition, positive effects on worker productivity have also been reported for shrouds that fit on 5-inch and 7- to 8-inch (18-lb) tuckpointers with integrated dust-collection systems since equipment without integrated dust-collection systems require that an additional worker be present to continually vacuum dust away from the work area (Document ID 0577). On the equipment that can be used with the tuckpointers with 5- to 8-inch wheels, an impeller inside the tool housing pushes dust down a hose into a reusable dust-collection bag (Document ID 0577). One vendor estimated that the operational productivity of these tools is no different from that of the same tool without dust control capability. Workers would still be required to periodically empty dust bags, although other clean-up time might be somewhat reduced (Document ID 0580). Because tuckpointing work is almost exclusively exterior work, however, clean-up is often not required.

Based on the considerations for hand-held grinding tools discussed above and the findings from the NIOSH tuckpointing study, OSHA judged in the PEA that use of a vacuum system during tuckpointing operations would impose, on average, a 5 percent negative productivity impact. Based on these findings and because manufacturer optimism about any positive productivity impacts has not been documented in controlled studies, OSHA included the same 5 percent negative productivity impact for tuckpointing tasks in this FEA.

Heavy Equipment Operators and Ground Crew Laborers

This activity includes the following Table 1 tasks:

- Heavy equipment and utility vehicles used to abrade or fracture silica-containing materials (e.g., hoe-ramming, rock ripping) or used during demolition; and

- Heavy equipment and utility vehicles for tasks such as grading and excavating but not including: demolishing or abrading or fracturing silica-containing materials[55]

The control method proscribed in the proposed silica standard was to enclose and ventilate the operator's cab. The requirement for an enclosed cab is only retained in the final standard with respect to the use of heavy equipment used to abrade or fracture silica-containing materials or used during demolition. Final Table 1 allows employers to control dust from heavy equipment used for other purposes (e.g., grading or excavating) by using wet methods.

Using an enclosed cab on heavy construction equipment will not require maintenance beyond the general maintenance necessary to maintain the integrity of the cab enclosure. Therefore, OSHA estimated in the PEA that no productivity loss will be incurred for this control.

In the case of heavy equipment operations, CISC/Environomics estimated that there would be a one percent productivity penalty for enclosed cabs, due to communication issues and the need to unclog HEPA filters (Document ID 4217, p. 93). For several reasons the Agency is not persuaded that the factors CISC cites would result in a net productivity loss for enclosed cabs on heavy equipment.

First, it is not clear that communication issues are being created by setting some minimal standards for enclosed cabs. Information supplied in the record indicates that there are alternate means of communication beyond shouting from the cab to the front-line workers outside the cab, including hand signals (Document ID 3583, Tr. 2441) and existing wireless communication systems (Document ID 0805, p. 4; 2262, p. 28). Many of these work environments are noisy, which seems to make alternate means of communication desirable, if not required.

Second, it appears that it may be more economical and desirable for workers to operate in a climate-controlled cab and that equipment with enclosed cabs has become standard in the construction industry. In fact, OSHA has determined that relevant heavy equipment currently comes with an enclosed cab as standard equipment (Document ID 3813, 3814, 3815, 3816), and in pricing construction jobs, RS Means included a cab as a standard equipment (meaning that it was already included in the equipment cost, not an added engineering control). In any case, the fact that cabs are standard suggests that potential buyers do not view the presence of a cab to be undesirable. While Environomics

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[55] Heavy equipment operations (grading and excavating) was referred to as earth moving in the PEA and in comments. The term has been updated for this analysis and used throughout for the sake of consistency and to avoid confusion.

acknowledged this possibility at the hearings, their judgment remained that there would be a net productivity loss (without providing information on how these offsetting considerations were being incorporated) (Document ID 3580, Tr. 1434-1435). While OSHA is not persuaded that the evidence in the record supports Environomics conclusions, their argument is largely moot. Any productivity impact would result only from the addition of new controls, but enclosed cabs appear to have become standard on the relevant equipment, meaning that in most cases employers would not have the option of using open cabs even if OSHA's new rule was not in effect. Thus, there can be no productivity impact attributed to the requirement for a cab.

Although OSHA is not including any productivity impact to account for enclosed cabs, final Table 1 requires water, or other dust suppressants, during specified heavy equipment operations in order to protect workers outside the cab and as an alternative method of protecting operators for activities that do not involve silica abrading or fracturing. OSHA has therefore, as indicated in Table V-33, added a 2 percent productivity impact for heavy equipment tasks involving grading and excavating, and 3 percent during demolishing, abrading or fracturing silica-containing materials. OSHA judged that the abrading, fracturing, and demolition-related tasks tend to be relatively dustier, and would therefore require relatively more labor to administer.

Hole Drilling Using Handheld or Stand-mounted Drills

This equipment category includes the Table 1 task "handheld and stand-mounted drills (including impact and rotary hammer drills)."

This category includes workers in the construction industry who use handheld drills to create clearly defined holes for attachments (e.g., anchors, bolts, hangers) or for small openings for utility pass-throughs in concrete and other silica-containing construction materials. Workers use common electric drills, pneumatic drills, handheld core drills, stand-mounted drills, rotary drills, rotary hammers, percussion hammer drills, or other impact drills to drill holes. With regard to core drills, only small, handheld core drills with bits up to a few inches in diameter are included in this category. This discussion does not address the use of portable and mobile hole saws used to produce large holes or openings. That equipment is covered in the discussion of Masonry and Concrete Cutters Using Portable Saws.

Handheld and rig-mounted drills can be equipped with local exhaust ventilation to effectively capture dust generated when drilling small diameter holes. Larger core drills, also referred to as core saws, are more frequently used with water as a coolant to extend the service life of the drill bit, as well to suppress dust.

One rock-drill manufacturer asserts that use of vacuum systems speeds drilling by continuously removing the drill cuttings from the hole, making it unnecessary for workers to periodically stop drilling to accomplish this task (Atlas-Copco, 2001, Document ID 0542). On the other hand, the connection and servicing of the vacuum equipment requires incremental work that could reduce productivity. If the construction project at hand involves interior work, this impact might be offset by reductions in the time necessary for cleanup (i.e., interior work would require cleanup, while exterior drilling probably would not). In the PEA, OSHA applied a 2 percent productivity impact where this task is performed and did not receive comment suggesting that this estimate was too low, so OSHA retains the same 2 percent productivity impact in estimating compliance costs in this FEA.

Jackhammers and Other Powered Handheld Chipping Tools

This equipment category includes the Table 1 task "Jackhammers and handheld powered chipping tools."

Silica exposures generated during pavement breaking, concrete demolition, and other concrete work using jack hammers and other handheld powered chipping tools (including pavement breakers and other similar tools) are controlled through the use of wet or dry methods.

Regarding wet methods, because the work area generally cannot be presoaked effectively (i.e., dust is generated once impact drillers break through the surface), OSHA judged that adequate dust control requires a constant spray of water to the work area. Thus, dust control requires that a water sprayer be mounted onto the jackhammer (or that a mobile sprayer be set up that can move along with the work). Alternatively, a crew member can use a water hose to spray and wet the concrete and asphalt surfaces being broken, although the associated productivity loss could be substantial, and, for that reason, OSHA believes that construction firms would likely try to avoid that approach.

However, OSHA judged that the incremental productivity impact from the spraying activity is modest because various crew members could occasionally be enlisted to keep the water spray directed in the correct location. Further, because of the interactive nature of the various crew member activities, the time to move the water sprayer is unlikely to affect the overall crew output. In addition, incremental cleanup costs generally would not be significant since most drilling projects are performed outside. Nevertheless, to allow for some incremental work related to supplying water and positioning the spray when wet methods are used, as was the case in the PEA, for this FEA OSHA estimated a 3 percent productivity impact for this equipment category when wet methods are used.

A separate, higher, productivity impact was defined for use of dry methods for activities where jackhammers and other handheld powered chipping tools are used. Dry methods are somewhat less flexible and require a shroud for the close capture of dust as it is generated during operations. Workers also periodically have to empty the vacuum bags in which the dust accumulates. Thus, as discussed above with respect to the use of a shroud for grinding and tuckpointing, these controls are judged to generally have a greater productivity impact during operations and, consistent with the PEA, OSHA assigned a 5 percent productivity impact for use of this control method for this equipment category.

Masonry and Concrete Cutters Using Portable Saws

This equipment category includes the following Table 1 tasks:

- Handheld power saws (any blade diameter);
- Handheld power saws for cutting fiber-cement board (with blade diameter of 8 inches or less);
- Rig-mounted core saws or drills;
- Walk-behind saws; and
- Drivable saws

Drivable saws and walk-behind saws have an integrated water tank, and the sawing is almost always done wet (see Chapter IV, Technological Feasibility). Wet sawing keeps the blade from overheating, with the water acting as coolant. Both the PEA and this FEA included no incremental costs or productivity impacts for use of this equipment. Rig-mounted core saws used to drill larger diameter holes in concrete are typically used with water as a coolant to extend the service life of the bit, as well as to suppress dust.

As has been noted, most portable hand-held concrete saws are designed with wet-sawing capability (see Chapter IV of this FEA, Technological Feasibility). These saws have a water hookup for a hose attachment, but might also be used for dry cutting. (Dry-cut diamond blades for dry cutting are available; these are made especially so that the tips do not separate during dry cutting.)

A construction equipment distributor judged that there are no operational productivity advantages for dry cutting, as opposed to wet cutting (Healy, 2002, Document ID 0726). Wet cutting, however, requires access to water (water line or pressurized tank), and some time is needed to connect the equipment (although OSHA received a number of comments saying that this hook up is very simple and not time consuming—see “Public comments suggesting that OSHA had underestimated the productivity penalties associated with engineering controls" earlier in this section for more detail). In addition, the water hose hookup may be cumbersome and interfere with the work (Healy, 2002, Document ID 0726). For these reasons, as was estimated in the PEA, for this FEA OSHA assigned a cost of 2 percent in lost production time for equipment in this category.

For the final rule, the Agency has clarified in Table 1 that hand-held circular saws with a blade diameter of eight inches or less specially designed for cutting fiber cement board can be used outdoors without respiratory protection, when equipped with a local exhaust ventilation. The productivity impact for this group is also estimated at 2 percent because, although it does not have an impact on job performance, it involves some set-up time and incremental maintenance.

Masonry Cutters Using Stationary Saws

This equipment category includes the Table 1 task "Stationary masonry saws." Stationary saws for masonry, brick, and tile cutting come equipped with water systems for wet cutting, which is the conventional, baseline control method for this type of work. Some modest incremental time is needed to provide for and connect the water supply and to maintain the water nozzles and spray system. This incremental time was the basis for OSHA to estimate a 2 percent cost in lost production, both in the PEA and in this FEA.

Millers Using Portable or Mobile Machines

This equipment category includes the following Table 1 tasks:

- Walk-behind milling machines and floor grinders;
- Small driveable milling machine (less than half-lane);
- Large driveable milling machines (half-lane and larger with cuts of four inches in depth or less)

The activities performed using equipment in this category range from cold planing and cleaning of asphalt to surface planing or grinding of concrete. In large-scale projects, such as street resurfacing, baseline practices are judged to control silica dust exposures. No additional controls would be needed, and therefore no negative productivity impacts are expected.

While some grinding machines designed for milling concrete surfaces have built-in dust collection or wet-method systems, others must be attached to external vacuum equipment. ERG reviewed the available literature and found no evidence that the grinding operation is slowed when such vacuum equipment is attached. Nevertheless, workers must devote some time to setting up equipment, changing vacuum bags or barrels, and cleaning filters. On the other hand, using an LEV system to capture dust as it is generated reduces the time required for cleaning up the settled dust from the surfaces following completion of the grinding task. OSHA estimated in the PEA that there would be a 2 percent productivity impact for milling using wet methods and a 5 percent productivity impact when using LEV systems.[56] These estimates have been retained for this FEA.

Mobile Crushing Machine Operators and Tenders

This equipment category comprises the Table 1 task "Crushing machines."

OSHA projected in the PEA that there would be no productivity impact for this equipment category. The Table 1 requirements for this machinery have changed in the final rule, but OSHA's conclusion that there will be no productivity impact remains the same. Final Table 1 requires employers to protect employees through a combination of sprayers and requiring the operator to operate the machinery from within a ventilated booth or at a remote control station. Once installed, the sprayer systems will be part of the crushing machine operation and will not impact production rates. For the purpose of the economic analysis of this rule, OSHA has accounted for additional costs for use of the ventilated booth. Because the booth can be located close to the machinery, there would not be productivity loss from the operator having to travel to a different location for operation. In most cases the booth can be set up quickly once at each location, so in most cases there will not be any significant productivity loss associated with the use of the booth.

Baseline and Incremental Unit Control Costs

Table V-34, developed using the cost data presented in Tables V-30, V-32, and V-33, summarizes the control method and costs per day for each representative construction job. These costs include incremental equipment costs and indirect labor costs due to productivity impacts (decreases in productivity associated with the use of the control equipment).

As an example, consider Task 11: Hole drilling using hand-held or stand-mounted drills in Table V-34. The 2 percent labor productivity impact for this task (from Table V-33) was applied to the daily labor cost of this task of $495.60 (from Table V-30)—yielding a

[56] For the FEA, milling operations using LEV are accounted for under grinding operations, as indicated in Table V-24.

daily labor productivity impact of $9.91. Consistent with the CISC methodology that OSHA adopted, this task was considered short-term, intermittent work using control equipment that carpenters and other occupational groups would own. Therefore, no equipment productivity adjustment was applied to this task, and the combined daily labor and equipment productivity impact was $9.91. The daily costs for the dust extraction kit and 10-15 gallon vacuum with HEPA ($3.16 and $5.58, respectively, from Table V-32), were based on a "half-life" of the equipment because of the intermittent and short-term nature of the work (here, 75 days rather than 150 days), again consistent with the CISC methodology that OSHA adopted. Therefore, the incremental daily equipment cost of the controls for Task 11 is $8.75 ($3.16 plus $5.58, with adjustment due to earlier rounding), and the total incremental daily cost of the controls for Task 11 is $18.66 ($8.75 plus the productivity impact of $9.91).

Note that the only other silica task in Table V-34 considered to have short-term infrequent work where the employee (carpenter) would own the equipment are Task 11: Hole drilling using hand-held or stand-mounted drills and Task 18: Masonry cutting using portable saws – II. Note also that all the indoor tasks in Table V-34 have an additional daily control equipment cost of $1.67 for a fan.

Table V-35 summarizes the baseline costs and incremental control costs from Tables V-30 and V-34, respectively, for each representative silica-related job in OSHA's silica construction cost analysis, where the control costs (defined as incremental control costs per day) are shown in Table V-35 as a percentage of the baseline daily job costs. As the incremental control costs were obtained from Table V-34, they are just the sum of additional labor and equipment costs associated with the use of silica controls, including the labor and equipment productivity impacts of the use of the silica controls.

As an example, consider again Task 11: Hole drilling using hand-held or stand-mounted drills in Table V-35. The total daily baseline cost of $502 for this task was obtained from Table V-30. The total daily incremental control cost for this task of $18.66 (as well as the preceding numbers in the row) was obtained from Table V-34. The incremental control cost as a percentage of the baseline daily job costs for Task 11 is simply $18.66/$502, or 3.7 percent of the daily costs.

As shown in Table V-35, these incremental control costs range from 0.3 percent of the baseline job cost for Task 22: Rock crushing, excavation projects, to 1.5 percent of the baseline job cost for Tasks 1 and 2 under Rock and Concrete Drillers, to 7.8 percent for Task 10: Heavy construction equipment operating - II (earthmoving). As is evident from Table V-35, the magnitude of the productivity impacts can substantially change the estimate of the overall cost increase associated with the silica dust controls.

Table V-36a presents the weighted average of control costs by task category for outdoor tasks. OSHA defined “weights” for each job category (column “Relative Frequency Within Categories”) based on the projected relative applicability of the controls and/or tasks within each category (as determined in the technological feasibility analysis in Chapter IV of this FEA). For example, based on the technological feasibility analysis for jack hammers and other powered chipping tools, OSHA estimated that wet methods can be used for 80 percent of jobs but that a focused dust collection system would be required for 20 percent of the jobs. These percentages did not change from the PEA except for the two tasks that have each been further partitioned into multiple tasks in the final rule: heavy construction operators and masonry cutters using portable saws. Heavy equipment operators are subdivided into tasks that involve fracturing, abrading, or demolishing silica-containing materials such as masonry or concrete, that require use of wet methods whenever workers other than the equipment operator are present, and tasks that involve use of heavy equipment for earthmoving and excavation of soil, that require wet methods only as necessary to minimize fugitive dust. Masonry cutters using portable saws are subdivided into five categories, 1) handheld power saws such as cutoff saws, 2) handheld power saws for cutting fiber-cement board with blade diameters of less than eight inches, 3) walk-behind saws, 4) drivable saws, and 5) rig-mounted core saws. Wet methods are specified as a control method for all use of portable saws except for handheld power saws for cutting fiber-cement board, for which LEV rather than use of water to suppress dust is required. The labor cost as a percentage of project costs—which, as subsequently shown, is a critical factor in calculating the total value of all silica-generating construction activities—is derived from Table V-30. For example, for Task 11: Hole drilling using hand-held or stand-mounted drills, labor costs were $495.60 out of total project costs of $501.90, or 98.7 percent of total project costs. The incremental costs as a percentage of baseline costs were obtained directly from Table V-35.

Table V-36b presents the weighted average of control costs by task category for tasks indoors or in enclosed areas (“indoor tasks”). The procedures are identical to those used in Table V-36a, and the only difference is that the total incremental costs as a percentage of baseline costs are higher due to the addition of the cost of a fan for indoor tasks.

Once the total value of all silica-generating construction activity is calculated for each task, as shown in Table V-44, the incremental costs associated with each task category as a percentage of baseline costs (from Tables V-36a and V-36b) will determine the costs that the engineering control requirements in the final construction standard add to the costs of construction activity—that is, the incremental costs of the resulting reduction in silica exposure.

Table V-34

Silica Control Methods, Specified by Construction Activity

	Task Area/ Job Description	Control Method	Control Method Cost Summary	Indirect Labor Cost/Day (Due to productivity impact): Title	Percentage Productivity Impact	Cost per Worker Affected	Equipment Productivity Cost	Total Productivity Impact Cost	Incremental Equipment Cost/Day: Description	Daily Cost [a]	Total	Total Incremental Cost
Rock and Concrete Drillers												
1	Drilling only, 2" diameter	Dust collection	Setup and operate	Blast foreman	0.0%	$0.00	$0.00	$0.00	Dust control/quarry drill	$17.33	$37.48	$37.48
	hole for rock bolts, average		dust control system	Driller		$0.00			Water tank, portable (unspec. capacity)	$15.50		
				Equip. operator, light		$0.00			Hose (water), 20', 2" diameter	$1.65		
									Custom water spray nozzle	$3.02		
2	Pier holes, 1500 cubic yards of media	Dust collection	Setup and operate	Blast foreman	0.0%	$0.00	$0.00	$0.00	Dust control/quarry drill	$17.33	$37.48	$37.48
	removed		dust control system	Driller		$0.00			Water tank, portable (unspec. capacity)	$15.50		
				Equip. operator, light		$0.00			Hose (water), 20', 2" diameter	$1.65		
									Custom water spray nozzle	$3.02		
3	Borings, casing borings in	Dust collection	Setup and operate	Laborers	0.0%	$0.00	$0.00	$0.00	Dust control/quarry drill	$17.33	$37.48	$37.48

earth, no samples, 21/2"	dust control system	Truck driver (light)	$0.00	Water tank, portable (unspec. capacity)	$15.50
diameter				Hose (water), 20', 2" diameter	$1.65
				Custom water spray nozzle	$3.02

Table V-34 (continued)

Silica Control Methods, Specified by Construction Activity

	Task Area/ Job Description	Control Method	Control Method Cost Summary	Indirect Labor Cost/Day (Due to productivity impact)					Incremental Equipment Cost/Day			
				Title	Percentage Productivity Impact	Cost per Worker Affected	Equipment Productivity Cost	Total Productivity Impact Cost	Description	Daily Cost [a]	Total	Total Incremental Cost
Tuck pointers and grinders (hand-held)												
4	Floors, 1/4" thick, patching concrete	Dust collection	Setup and operate dust control system	Cement finisher	5.0%	$44.84	$0.00	$44.84	Vacuum, large capacity with HEPA	$8.89	$9.67	$54.51
									Dust shroud adapter	$0.79		
									Indoors: Fan	$1.67	$11.35	$56.19
5	Crack repair, including chipping, sand blasting, and cleaning. Epoxy injection up to 1/4" wide.	Dust collection	Setup and operate dust control system	Labor foreman (outside)	5.0%	$20.84	$8.85	$108.09	Vacuum, large capacity with HEPA	$8.89	$12.03	$120.12
									Dust shroud adapter (4; 1 per worker)	$3.14		
				Laborers		$78.40			Indoors: Fan	$1.67	$13.70	$121.79
6	Cut and repoint brick, hard mortar, common bond.	Dust collection	Setup and operate dust control system	Bricklayer	5.0%	$24.58	$0.00	$24.58	Dust Shroud	$0.79	$3.84	$28.42
									Vacuum, 10-15 gal with HEPA	$3.06		
7	Hand-held milling, wall grinding	Dust collection	Setup and operate dust control system	Laborer	5.0%	$19.60	$1.77	$21.37	Vacuum, 10-15 gal with HEPA	$3.06	$3.06	$24.43
									Indoors: Fan	$1.67	$4.73	$26.10
Heavy construction equipment operators - I (demolition, abrading, fracturing)												
8	Demolish, remove pavement and curb; concrete to 6" thick, hydraulic hammer,	Wet methods	Add water for dust suppression	Laborer	3.0%	$23.52	$0.00	$23.52	Water tank, engine driven discharge, 10,000 gal.	$168.38	$173.04	$196.56
									Hose (water), 20', 2" diameter	$1.65		

Table V-34 (continued)

Silica Control Methods, Specified by Construction Activity

Task Area/ Job Description		Control Method	Control Method Cost Summary	Title	Indirect Labor Cost/Day (Due to productivity impact): Percentage Productivity Impact	Cost per Worker Affected	Equipment Productivity Cost	Total Productivity Impact Cost	Incremental Equipment Cost/Day: Description	Daily Cost [a]	Total	Total Incremental Cost
	mesh reinforced								Custom water spray nozzle	$3.02		
9	Small building demolition, concrete, no salvage	Wet methods	Add water for dust suppression	Laborer	3.0%	$23.52	$0.00	$23.52	Water tank, engine driven discharge, 10,000 gal.	$168.38	$173.04	$196.56
									Hose (water), 20', 2" diameter	$1.65		
									Custom water spray nozzle	$3.02		
Heavy construction equipment operators - II (earthmoving)												
10	Backfill, structural, from existing stockpile, no compaction, 50' haul, sand and gravel	Wet methods	Add water for dust suppression, if necessary	Laborer	2.0%	$3.92	$0.00	$3.92	Water tank, engine driven discharge, 5,000 gal.	$121.50	$126.16	$130.08
									Hose (water), 20', 2" diameter	$1.65		
									Custom water spray nozzle	$3.50		
Hole drillers using hand-held or stand-mounted drills												
11	Drilling for anchors, up to 4" in depth, including bit and layout in concrete or brick walls, no anchor. 3/4" diameter	Dust collection	Setup and operate dust control system	Carpenter	2.0%	$9.91	$0.00	$9.91	Dust extraction kit (infrequent use)	$3.16	$8.75	$18.66
									Vacuum, 10-15 gal with HEPA (infrequent use)	$5.58		
Jackhammers and other powered chipping tools												

Table V-34 (continued)

Silica Control Methods, Specified by Construction Activity

	Task Area/ Job Description	Control Method	Control Method Cost Summary	Indirect Labor Cost/Day (Due to productivity impact): Title	Percentage Productivity Impact	Cost per Worker Affected	Equipment Productivity Cost	Total Productivity Impact Cost	Incremental Equipment Cost/Day: Description	Daily Cost [a]	Total	Total Incremental Cost
12	Drilling bituminous material, with hand-held air equipment, up to 6	Wet methods	Setup and operate	Labor foreman	3.0%	$12.50	$5.31	$78.94	Hose (water), 20', 2" diameter	$15.50	$20.16	$99.10
			hose/sprayer	(outside)					Air tools and accessories	$1.65		
	inches thick			Laborers		$47.04			Custom water spray nozzle	$3.02		
				Equip. operator, light		$14.09	$0.00		Indoors: Fan	$1.67	$21.83	$100.78
13	Cutout demolition, elevated slab, bar reinforced, under	Wet methods	Setup and operate	Labor foremen	3.0%	$12.50	$5.31	$64.86	Water tank, portable (unspec. capacity)	$15.50	$20.16	$85.01
	6 c.f.		hose/sprayer	Laborer		$47.04			Hose (water), 20', 2" diameter	$1.65		
									Custom water spray nozzle	$3.02		
									Indoors: Fan	$1.67	$21.83	$86.69
14	Remove masonry	Dust collection	Setup and operate	Labor foremen	5.0%	$20.84	$26.79	$175.75	Vacuum, large capacity	$8.89	$10.46	$186.21
	walls, block, solid		dust control system	Laborer		$78.40			Dust shroud adapter (2; 1 per equip. oper.)	$1.57		
				Equip. operators		$49.72			Indoors: Fan	$1.67	$12.13	$187.88
Masonry and concrete cutters using portable saws - I												
15	Demolition, concrete slabs, mesh reinforcing, up to 3" deep	Baseline includes controls, but addit.	Properly maintain wet-method	Equip. operator, light	2.0%	$9.39	$7.58	$24.81	Only incremental maintenance required	$0.00	$0.00	$24.81
									Captured in productivity impact			
		efforts needed	control	Laborer		$7.84			Indoors: Fan	$1.67	$1.67	$26.48

Table V-34 (continued)

Silica Control Methods, Specified by Construction Activity

	Task Area/ Job Description	Control Method	Control Method Cost Summary	Indirect Labor Cost/Day (Due to productivity impact): Title	Percentage Productivity Impact	Cost per Worker Affected	Equipment Productivity Cost	Total Productivity Impact Cost	Incremental Equipment Cost/Day: Description	Daily Cost [a]	Total	Total Incremental Cost
16	Saw cutting, brick or masonry, with hand-held saw, per inch of depth	Wet methods	Setup and operate water attachment accessory	Building laborer	2.0%	$7.84	$0.61	$8.45	Wet kit with water tank	$0.96	$0.96	$9.40
									Indoors: Fan	$1.67	$2.63	$11.07
17	Saw cutting, concrete walls, hydraulic saw, plain, per inch of Depth	Baseline includes controls, but addit. efforts needed or Vacuum dust control system	Properly maintain wet-method control	Equip. operator, light	2.0%	$9.39	$13.04	$30.06	Only incremental maintenance required Captured in productivity impact	$0.00	$0.00	$30.06
				Truck driver (light)		$7.62						
									Indoors: Fan	$1.67	$1.67	$31.73
Masonry and concrete cutters using portable saws – II												
18	Cutting and installing fiber cement siding, 8" wide, with handheld saw, blade diameter 8 inches or less	Vacuum dust control system	Setup and operate dust control system	Carpenters	2.0%	$19.82	NA	$19.82	Vacuum, 10-15 gal with HEPA (infrequent use)	$5.58	$5.58	$25.41
Masonry cutting using stationary saws												
19	Sawing brick or block, per inch in depth	Baseline includes controls, but addit. efforts needed	NA	Bricklayer	2.0%	$9.83	$0.00	$9.83	Only incremental maintenance required. Captured in productivity impact	$0.00	$0.00	$9.83
Milling using portable or mobile machines												
20	Asphalt cold planing &	Baseline includes	Properly maintain	Labor foreman	2.0%	$8.34	$84.23	$145.92	Only incremental maintenance required	$0.00	$0.00	$145.92

Table V-34 (continued)

Silica Control Methods, Specified by Construction Activity

	Task Area/ Job Description	Control Method	Control Method Cost Summary	Indirect Labor Cost/Day (Due to productivity impact): Title	Percentage Productivity Impact	Cost per Worker Affected	Equipment Productivity Cost	Total Productivity Impact Cost	Incremental Equipment Cost/Day: Description	Daily Cost [a]	Total	Total Incremental Cost
	cleaning, 1" to 3" asphalt, over 25,000 SY	controls, but addit. efforts needed	wet-method control	Laborers		$23.52			Captured in productivity impact			
				Equip. oper. (med)		$29.83						
21	Concrete surface repair	Wet methods	Setup and operate water attachment accessory	Labor foreman (outside)	2.0%	$8.34	$1.42	$17.59	Vacuum, large capacity with HEPA	$8.89	$8.89	$26.48
				Laborers		$7.84						
									Indoors: Fan	$1.67	$10.56	$28.15
Rock crushing machine operators and tenders												
22	Rock crushing, excavation Projects	Wet method	Setup and operate foam dust suppression system	Labor foreman	0.0%	$0.00	$0.00	$0.00	Foam dust suppression system	$13.76	$23.79	$23.79
				Laborers		$0.00			Dust booth	$10.03		
				Equip. operator		$0.00						

[a] See Table V-32.

Source: OSHA, Directorate of Standards and Guidance, Office of Regulatory Analysis, based on OSHA (2016) and Tables V-31 and V-32 of this FEA.

Table V-35

Incremental Control Costs as a Percentage of Construction Activity Costs

	Task Area/ Job Description	Total Daily Baseline Cost	Controls	Productivity Impact	Incremental Labor Cost/Day	Incremental Equipment Cost/Day	Total Incremental Cost/Day	Total Incremental Costs as % of Baseline Costs
Rock and Concrete Drillers								
1	Drilling only, 2" hole for rock bolts, Average	$2,488	Dust collection system	0.0%	$0.00	$37.48	$37.48	1.5%
2	Pier holes, up to 1500 cubic yards	$2,527	Dust collection system	0.0%	$0.00	$37.48	$37.48	1.5%
3	Borings, casing borings in earth, no samples, 21/2" diameter	$2,035	Dust collection system	0.0%	$0.00	$37.48	$37.48	1.8%
Tuck pointers and grinders (hand-held)								
4	Floors, 1/4" thick, patching concrete	$897	Dust collection system	5.0%	$44.84	$9.67	$54.51	6.1%
	Indoors:					$11.35	$56.19	6.3%
5	Crack repair, including chipping, sand blasting, and cleaning.	$2,177	Dust collection system	5.0%	$108.09	$12.03	$120.12	5.5%
	Epoxy injection up to 1/4" wide. Indoors:					$13.70	$121.79	5.6%
6	Cut and repoint brick, hard mortar, common bond.	$511	Dust collection system	5.0%	$24.58	$3.84	$28.42	5.6%
7	Hand-held milling, wall grinding	$427	Dust collection system	5.0%	$21.37	$3.06	$24.43	5.7%
	Indoors:					$4.73	$26.10	6.1%
Heavy construction equipment operators - I (demolition, abrading, fracturing)								
8	Demolish, remove pavement and curb; concrete to 6" thick, hydraulic hammer, mesh reinforced	$3,010	Wet methods	3.0%	$23.52	$173.04	$196.56	6.5%

Table V-35 (continued)

Incremental Control Costs as a Percentage of Construction Activity Costs

Task Area/ Job Description		Total Daily Baseline Cost	Controls	Productivity Impact	Incremental Labor Cost/Day	Incremental Equipment Cost/Day	Total Incremental Cost/Day	Total Incremental Costs as % of Baseline Costs
9	Small building demolition, concrete, no salvage	$4,366	Wet methods	3.0%	$23.52	$173.04	$196.56	4.5%
Heavy construction equipment operators - II								
10	Backfill, structural, from existing stockpile, no compaction, 50' haul, sand and gravel	$1,664	Wet methods	2.0%	$3.92	$126.16	$130.08	7.8%
Hole drillers using held-held or stand-mounted drills								
11	Drilling for anchors, up to 4" in diameter including bit and layout in concrete or brick walls, no anchor. 3/4" diameter	$502	Dust Shroud Vacuum system	2.0%	$9.91	$8.75	$18.66	3.7%
Jackhammers and other powered chipping tools								
12	Drilling bituminous material, with hand-held air equipment, up to 6 inches thick	$2,631	Wet method	3.0%	$78.94	$20.16	$99.10	3.8%
	Indoors:					$21.83	$100.78	3.8%
13	Cutout demolition, elevated slab, bar reinforced, under 6 c.f.	$2,162	Wet method	3.0%	$64.86	$20.16	$85.01	3.9%
	Indoors:					$21.83	$86.69	4.0%
14	Remove masonry walls, block, solid	$3,515	Dust collection system	5.0%	$175.75	$10.46	$186.21	5.3%
	Indoors:					$12.13	$187.88	5.3%
Masonry and concrete cutters using portable saws - I								
15	Demolition, concrete slabs, mesh reinforcing, up to 3" deep	$1,574	Baseline includes control measures	2.0%	$24.81	$0.00	$24.81	1.6%

Table V-35 (continued)

Incremental Control Costs as a Percentage of Construction Activity Costs

Task Area/ Job Description		Total Daily Baseline Cost	Controls	Productivity Impact	Incremental Labor Cost/Day	Incremental Equipment Cost/Day	Total Incremental Cost/Day	Total Incremental Costs as % of Baseline Costs
	Indoors:					$1.67	$26.48	1.7%
16	Saw cutting, brick or masonry, with hand-held saw, per inch of depth	$454	Wet method	2.0%	$8.45	$0.96	$9.40	2.1%
	Indoors:					$2.63	$11.07	2.4%
17	Saw cutting, concrete walls, hydraulic saw, plain, per inch of depth	$1,578	Baseline includes control measures	2.0%	$30.06	$0.00	$30.06	1.9%
	Indoors:					$1.67	$31.73	2.0%
Masonry and concrete cutters using portable saws - II								
18	Cutting and installing fiber cement siding, 8" wide, with handheld saw, blade diameter 8 inches or less	$1,484	Vacuum dust control system	2.0%	$19.82	$5.58	$25.41	1.7%
Masonry cutters using stationary saws								
19	Sawing brick or block, per inch in depth	$492	Wet method	2.0%	$9.83	$0.00	$9.83	2.0%
Millers using portable or mobile machines								
20	Asphalt cold planing & cleaning, 1" to 3" asphalt, over 25,000 SY	$7,296	Baseline includes control measures	2.0%	$145.92	$0.00	$145.92	2.0%
21	Concrete surface repair	$880	Wet methods	2.0%	$17.59	$8.89	$26.48	3.0%
	Indoors:					$1.67	$28.15	3.2%
Rock crushing machine operators and tenders								
22	Rock crushing, excavation Projects	$7,254	Setup and operate foam dust	0.0%	$0.00	$23.79	$23.79	0.3%

Table V-35 (continued)

Incremental Control Costs as a Percentage of Construction Activity Costs

	Task Area/ Job Description	Total Daily Baseline Cost	Controls	Productivity Impact	Incremental Labor Cost/Day	Incremental Equipment Cost/Day	Total Incremental Cost/Day	Total Incremental Costs as % of Baseline Costs
			suppression system					
Underground (tunnel) construction work								
23	Tunnel construction, bored tunnels Including mucking, 20' in diameter, rock excavation (average cost; assumes 400 feet/day)	$107,500	Additional maintenance	0.0%	$0.00	$13.96	$13.96	0.013%

Source: OSHA, Directorate of Standards and Guidance, Office of Regulatory Analysis, based on OSHA (2016) and Tables V-30 and V-34 of this FEA.

Table V-36a

Cost Impact Summary, by Job Category, for Outdoor Construction Tasks

Task Area/Job Description		Controls	Relative Frequency Within Categorie	Labor Costs % of Project Costs	Incrementa Costs as % of Baseline Costs
Rock and Concrete drillers					
1	Drilling only, 2" hole for rock bolts, average	Dust collection system	33.3%	51.4%	1.5%
2	Pier holes, 1500 cubic yards of media removed	Dust collection system	33.3%	50.6%	1.5%
3	Borings, casing borings in earth, no samples, 2.5" diameter	Dust collection system	33.3%	57.3%	1.8%
	Job category total, averages		100%	53.1%	1.6%
Tuck pointers and grinders (hand-held)					
4	Floors, 1/4" thick, patching concrete	Dust collection system	25.0%	100.0%	6.1%
5	Crack repair, including chipping, sand blasting, and cleaning. Epoxy injection up to 1/4" wide.	Dust collection system	25.0%	91.2%	5.5%
6	Cut and repoint brick, hard mortar, common bond.	Dust collection system	25.0%	96.2%	5.6%
7	Hand-held milling, wall grinding	Dust control	25.0%	91.7%	5.7%
	Job category total, averages		100.0%	94.8%	5.7%
Heavy construction equipment operators - I (demolition, abrading, fracturing)					
8	Demolish, remove pavement and curb; concrete to 6" thick, hydraulic hammer, mesh reinforced	Wet methods	50.0%	72.0%	6.5%
9	Small building demolition, concrete, no salvage	Wet methods	50.0%	56.9%	4.5%
	Job category total, averages		100.0%	64.5%	5.5%
Heavy construction equipment operators - II (earthmoving)					
10a	Backfill, structural, from existing stockpile, no compaction, 50' haul, sand and gravel	No controls needed	95.0%	41.7%	0.0%

Table V-36a (continued)

Cost Impact Summary, by Job Category, for Outdoor Construction Tasks

	Task Area /Job Description	Controls	Relative Frequency Within Categories	Labor Costs as % of Project Costs	Incremental Costs as % of Baseline Costs
Hole drillers using held-held or stand-mounted drills					
10b	Backfill, structural, from existing stockpile, no compaction, 50' haul, sand and gravel concrete or brick walls, no anchor ¾	Wet methods	5.0%	41.7%	7.8%
	Job category total, averages		100.0%	41.7%	0.4%
11	Drilling for anchors, up to 4" in diameter including bit and layout in concrete or brick walls, no anchor ¾	Dust Shroud Vacuum system diameter	100.0%	98.7%	3.7%
Jackhammers and other powered chipping tools					
12	Drilling bituminous material, with hand-held air equip., up to 6 in thick	Wet methods	40.0%	93.3%	3.8%
13	Cutout demolition, elevated slab, bar reinforced, under 6 c.f.	Wet methods	40.0%	91.8%	3.9%
14	Remove masonry walls, block, solid (indoor env.)	Dust collection system	20.0%	84.8%	5.3%
	Job category total, averages		100%	91.0%	4.1%
Masonry and concrete cutters using portable saws - I					
15	Demolition, concrete slabs, mesh reinforcing, up to 3" deep	Baseline includes control measures	33.3%	54.8%	1.6%
16	Saw cutting, brick or masonry, with hand-held saw, per inch of depth	Wet method	33.3%	86.4%	2.1%
17	Saw cutting, concrete walls, hydraulic saw, plain ,per inch of depth	Baseline includes control measures	33.3%	53.9%	1.9%
	Job category total, averages		100.0%	65.0%	1.9%
Masonry and concrete cutters using portable saws - II					
18	Cutting and installing fiber cement siding, 8" wide, with handheld saw, blade diameter 8 inches or less	Dust collection system	100.0%	66.8%	1.7%
Masonry cutters using stationary saws					

Table V-36a (continued)

Cost Impact Summary, by Job Category, for Outdoor Construction Tasks

Task Area /Job Description		Controls	Relative Frequency Within Categories	Labor Costs as % of Project Costs	Incremental Costs as % of Baseline Costs
19	Sawing brick or block, per inch in depth	Wet method	100.0%	100.0%	2.0%
Millers using portable or mobile machines					
20	Asphalt cold planing & cleaning, 1" to 3" asphalt, over 25,000 SY	Baseline includes control measures	20.0%	42.3%	2.0%
21	Concrete surface repair	Wet methods	80.0%	92.0%	3.0%
	Job category total, averages		100.0%	82.0%	2.8%
Rock crushing machine operators and tenders					
22	Rock crushing, excavation projects	Wet methods	100.0%	42.5%	0.3%
Underground (tunnel) construction workers					
23	Tunnel construction, bored tunnels Including mucking, 20" in diameter, rock excavation (average cost; assumes 100 feet/day)	Additional maintenance of dust suppression equipment	100.0%	15.0%	0.0%

Source: OSHA, Directorate of Standards and Guidance, Office of Regulatory Analysis, based on OSHA (2016).

V-36b

Cost Impact Summary, by Job Category - Indoor Construction Work

Task Area/Job Description		Controls	Relative Frequency Within Categories	Labor Costs as % of Project Costs		Incremental Costs as % of Baseline Costs
Tuck pointers and grinders (hand-held)						
6	Floors, 1/4" thick, patching concrete	Dust collection system	25.0%	100.0%		6.3%
7	Crack repair, including chipping, sand blasting, and cleaning. Epoxy injection up to 1/4" wide.	Dust collection system	25.0%	91.2%		5.6%
8	Cut and repoint brick, hard mortar, common bond.	Dust collection system	0.0%	96.2%		5.6%
9	Hand-held milling, wall grinding	Dust control	50.0%	96.2%		6.1%
	Job category total, averages		100.0%	94.8%		6.0%
					Indoor factor	1.052
Jackhammers and other powered chipping tools						
12	Drilling bituminous material, with hand-held air equipment, up to 6 inches thick	Wet methods	40.0%	93.3%		3.8%
13	Cutout demolition, elevated slab, bar reinforced, under 6 c.f.	Wet methods	40.0%	91.8%		4.0%
14	Remove masonry walls, block, solid	Dust collection system	20.0%	84.8%		5.3%
	Job category total, averages		100%	91.0%		4.2%
					Indoor factor	1.016
Masonry cutters using portable saws - I						
15	Demolition, concrete slabs, mesh reinforcing, up to 3" deep	Baseline includes control measures	33.3%	54.8%		1.7%
16	Saw cutting, brick or masonry, with hand-held saw, per inch of depth	Wet method	33.3%	86.4%		2.4%
17	Saw cutting, concrete walls, hydraulic saw, plain, per inch of depth	Baseline includes control measures	33.3%	53.9%		2.0%
	Job category total, averages		100.0%	100.0%		2.0%

Indoor factor	1.105

V-36b (continued)

Cost Impact Summary, by Job Category - Indoor Construction Work

Task Area /Job Description		Controls	Relative Frequency Within Categories	Labor Costs as % of Project Costs	Incremental Costs as % of Baseline Costs
Masonry cutters using portable saws - I					
Millers using portable or mobile machines					
19	Asphalt cold planing & cleaning, 1" to 3" asphalt, over 25,000 SY	Baseline includes control measures	0.0%	42.3%	2.0%
20	Concrete surface repair	Wet methods	100.0%	92.0%	3.2%
	Job category total, averages		100.0%	92.0%	3.2%

Source: OSHA, Directorate of Standards and Guidance, Office of Regulatory Analysis, based on OSHA (2016).

Aggregate "Key" and "Secondary" Labor Costs for Representative Projects

To estimate aggregate labor costs or value for each equipment category, OSHA first matched OES occupational classifications with the labor requirements for each equipment category (e.g., hole drillers using hand-held or stand-mounted drills). These matching occupations are shown in Table V-37. In order to estimate the percentage of time during each work day that workers spend on activities using equipment in the relevant categories, OSHA designated some occupations as "key" and others as "secondary." The key field in Table V-37 is set to "1", if a key occupation and to "0" if a secondary one. Even those employees who are engaged in tasks on Table 1 typically spend only a portion of their workday engaged in silica-generating tasks, so the distinction between "key" and "secondary" is needed in order to estimate the amount of time workers participate in silica-generating tasks. In the preliminary and final cost analyses, OSHA applied ERG's occupation designation, as explained in greater detail below. OSHA requested comment on the designations of "key" and "secondary" designations in the PEA, but did not receive any comments challenging those designations.

"Key" occupations refer to the worker or workers on each crew who perform the principal silica-generating activity using the equipment in each equipment category. For each equipment category, ERG estimated the overall percentage of time that workers in key occupations devote to the activity. Relying mainly on the RSMeans job specifications, ERG judged, for example, that drillers represent a key occupation for the rock and concrete drillers equipment category outlined in the analysis. For each equipment category, ERG then estimated the overall percentage of time that workers in key occupations devote to the activity. As shown in Table V-37, rock and concrete drillers spend an estimated 75 percent of their time performing relevant drilling activities, such as those that generate silica exposures. In other cases, the activities of those in key occupations are less closely correlated with the equipment in the relevant category. For example, a key occupation using jackhammers and other powered handheld chipping tools was judged to be construction laborers. This group as a whole performs many diverse construction activities, and ERG estimated in Table V-37 that the time spent using jackhammers and other powered handheld chipping tools was, on average, approximately 3 percent of the group's total construction activities.

Other "secondary" crew members (e.g., first-line supervisors/managers and construction laborers) were estimated in terms of their ratio to the number of key workers required for given task areas. The secondary crew ratios range from 0 percent (no one in a secondary occupation engaged in silica-generating tasks) to 300 percent (three times the number of secondary occupation workers, in relation to the number of key workers, exposed to silica-generating tasks). As noted above, OSHA used these percentages and ratios to estimate (on an annual basis) the amount of time these employees are using relevant equipment to engage in work that causes silica exposures. The estimate of the percentage of time performing the silica-generating activity can be viewed in terms of the full-time-equivalent (FTE) employees engaged in work that utilizes equipment in each equipment category. These estimates and the corresponding ratios for secondary workers are shown in Table V-37.

Table V-37

Key and Secondary Occupations by Construction Task Area

Task No.	Task	Occ. code	Occupation	Key (1=Yes)	FTE share	Secondary ratio
1	Rock and concrete drillers					
		47-1011	First-Line Supervisors/Managers of Construction Trades and Extraction Workers	0	0.0%	50.0%
		47-2061	Construction Laborers	0	0.0%	100.0%
		47-2073	Operating Engineers and Other Construction Equipment Operators	0	0.0%	100.0%
		47-5021	Earth Drillers, Except Oil and Gas	1	75.0%	0.0%
		47-5031	Explosives Workers, Ordnance Handling Experts, and Blasters	0	0.0%	25.0%
		47-5081	Helpers--Extraction Workers	0	0.0%	25.0%
2	Heavy construction equipment operators - I (Demolition)					
		47-2061	Construction Laborers	0	0.0%	50.0%
		47-2073	Operating Engineers and Other Construction Equipment Operators	1	2.5%	0.0%
		47-4051	Highway Maintenance Worker	1	0.5%	0.0%
		53-7032	Excavating and Loading Machine and Dragline Operators	1	2.5%	0.0%
3	Heavy construction equipment operators -II (Earthmoving)					
		47-2061	Construction Laborers	0	0.0%	50.0%
		47-2073	Operating Engineers and Other Construction Equipment Operators	1	50.0%	0.0%
		47-4051	Highway Maintenance Worker	1	10.0%	0.0%
		53-7032	Excavating and Loading Machine and Dragline Operators	1	75.0%	0.0%
4	Tuckpointers and grinders (hand-held)					
		47-2021	Brickmasons and Blockmasons	1	2.5%	0.0%
		47-2051	Cement Masons and Concrete Finishers	1	2.5%	0.0%
		47-2061	Construction Laborers	0	0.0%	300.0%
		47-3011	Helpers--Brickmasons, Blockmasons, Stonemasons, and Tile and Marble Setters	1	2.5%	0.0%

Table V-37 (continued)

Key and Secondary Occupations by Construction Task Area

Task No.	Task	Occ. code	Occupation	Key (1=Yes)	FTE share	Secondary ratio
5	Hole drillers using hand-held or stand-mounted drills					
		47-2031	Carpenters	1	1.0%	0.0%
		47-2061	Construction Laborers	0	0.0%	100.0%
		47-2111	Electricians	1	1.0%	0.0%
		47-2152	Plumbers	1	1.0%	0.0%
		47-2210	Sheet Metal Workers	1	1.0%	0.0%
		47-3012	Helpers—Carpenters	1	1.0%	0.0%
		47-3013	Helpers-Electricians	1	1.0%	0.0%
		47-3015	Helpers – Plumbers	1	1.0%	0.0%
6	Jackhammers and other powered chipping tools					
		47-1011	First-Line Supervisors/Managers of Construction Trades and Extraction Workers	0	0.0%	25.0%
		47-2061	Construction Laborers	1	3.0%	0.0%
		47-2073	Operating Engineers and Other Construction Equipment Operators	0	0.0%	25.0%
		47-4051	Highway Maintenance Worker	1	2.5%	0.0%
7	Millers using portable or mobile machines					
		47-1011	First-Line Supervisors/Managers of Construction Trades and Extraction Workers	0	0.0%	66.0%
		47-2051	Cement Masons and Concrete Finishers	1	5.0%	0.0%
		47-2053	Terrazzo Workers and Finishers	1	2.5%	0.0%
		47-2061	Construction Laborers	0	0.0%	100.0%
		47-2071	Paving, Surfacing, and Tamping Equipment Operators	1	5.0%	0.0%
8	Masonry cutters using portable saws – I					
		47-2021	Brickmasons and Blockmasons	1	10.0%	0.0%
		47-2022	Stonemasons	1	10.0%	0.0%
		47-2061	Construction Laborers	0	0.0%	100.0%
		47-3011	Helpers--Brickmasons, Blockmasons, Stonemasons, and Tile and Marble Setters	1	10.0%	0.0%

Table V-37 (continued)

Key and Secondary Occupations by Construction Task Area

Task No.	Task	Occ. code	Occupation	Key (1=Yes)	FTE share	Secondary ratio
9	Masonry cutters using portable saws – II					
		47-2031	Carpenters	1	2.5%	0.0%
		47-3012	Helpers-Carpenters	1	2.5%	0.0%
10	Masonry cutters using stationary saws					
		47-2021	Brickmasons and Blockmasons	1	10.0%	0.0%
		47-2022	Stonemasons	1	10.0%	0.0%
		47-2180	Roofers	1	2.5%	0.0%
		47-3011	Helpers--Brickmasons, Blockmasons, Stonemasons, and Tile and Marble Setters	1	10.0%	0.0%
		47-3016	Helpers—Roofers	1	2.5%	0.0%
11	Rock crushing machine operators and tenders					
		47-1011	First-Line Supervisors/Managers of Construction Trades and Extraction Workers	0	0.0%	33.0%
		47-2061	Construction Laborers	0	0.0%	100.0%
		51-9021	Crushing, Grinding, and Polishing Machine Setters, Operators, and Tenders	1	75.0%	0.0%

Source: OSHA, Directorate of Standards and Guidance, Office of Regulatory Analysis, based on ERG (2007a) and OSHA (2016).

For the key occupations, OSHA was able to obtain some data with which to estimate the proportion of time workers perform activities using silica-generating equipment. For the secondary occupations, such estimates were generally not possible. Thus, the participation of secondary occupations in silica-generating activities was defined based on their relationship to the key occupations. This participation is defined by their presence in the job crews, as shown in Table V-30. To illustrate the need for this approach, consider the difficulty in predicting how often construction foremen of all types are present during activities where silica-generating equipment is used. BLS data, for example, provide only a total number of foremen, but no information about how they might spend their time. It is reasonable to forecast, however, using the job-crew definitions, that foremen will be present in some proportion to the number of workers in key occupations using jackhammers and other powered handheld chipping tools, rock and concrete drillers, and other silica-generating equipment. OSHA presented these data in the PEA and requested comments, but did not receive any on this aspect of the analysis. Therefore, OSHA is retaining its estimates from the PEA, except as noted.

Examining jackhammers and other powered handheld chipping tools as an illustration of the use of these estimates for specific equipment categories, the construction laborer is a key occupation, and first-line supervisors and equipment operators are the secondary occupations. Because the applicable standard work crew (as specified in RSMeans, 2008) consists of a supervisor, an equipment operator, and four construction laborers, OSHA used a ratio of 1 to 4 (0.25, as shown in Table V-37)[57] for *each* of the secondary occupations: four laborers (key) to one supervisor (secondary), and four laborers (key) to one equipment operator (secondary). OSHA uses this 0.25 ratio to estimate the participation level for each of these secondary occupations relative to the key occupation in impact drilling.

In another example, for heavy equipment operators and ground crew laborers, ERG estimated that construction laborers are a secondary occupation and heavy equipment operators are the key occupation for standard work crews involving such equipment. The standard work crew in RSMeans (2008) calls for a heavy equipment operator and 0.5 construction laborers (in other words, the construction laborer is working with the heavy equipment operator half of the time). Therefore, ERG's cost model uses a ratio of 1 to 2 (0.5, as shown in Table V-37) to estimate the participation level of construction laborers relative to key occupations in the equipment category heavy equipment operators and ground crew laborers.

For some activities, the crew size and composition vary among the jobs defined in the equipment category. In those cases, OSHA used ERG determinations as to the most

[57] These estimates are ultimately derived from Table V-19.

representative crew composition and used that crew model to define the ratio of secondary to key occupations (ERG, 2007a).

The estimates of the number of FTE employees engaged in activities using silica-generating equipment are one of many factors that influence the final cost estimates. There are few data, however, on the breakdown of time spent by construction workers in various activities. The following discussion presents the basis for the time-on-task estimates for the key occupations as included in the PEA and the FEA (except where noted). OSHA presented most of these estimates for public comment in the PEA but did not receive any comments challenging them.

Rock and Concrete Drillers

A review of NIOSH reports covering rock and concrete drillers showed that over 75 percent of driller time was spent on actual drilling (NIOSH 1992a, Document ID 0911, NIOSH 1992b, Document ID 0910, NIOSH 1995, Document ID 0907).[58] Therefore, for the PEA and FEA, OSHA used 75 percent as the best indication of the time spent using dust-generating equipment for workers in this category.

Tuckpointers and Grinders

Grinding and tuckpointing are only two of the numerous jobs performed by brickmasons, cement masons, and their helpers. Workers in those trades are much more frequently performing bricklaying, cement work, and masonry construction. Where tuckpointers and grinders are being used, a review of the OSHA Special Emphasis Program reports revealed that the time spent using tuckpointers and grinders varied widely (see the technological feasibility analysis for this activity in Chapter IV of this FEA). In both the PEA and in this FEA, OSHA used ERG's estimate that 2.5 percent of the time for workers in each of the applicable occupations would be spent on using this equipment.

Heavy Equipment Operators and Ground Crew Laborers

For the final rule, heavy equipment operators and ground crew laborers were split into two categories in Table 1 based on how the heavy equipment and utility vehicles are being used, which reflects distinctions added in the final rule. This equipment is considered to either be used a) to abrade or fracture silica-containing materials (e.g., hoe-ramming, rock ripping) or used during the demolition of concrete or masonry structures; or b) for tasks such as grading and excavating but not including: demolition of concrete or masonry structures or abrading or fracturing silica-containing materials.

[58] This percentage is supported by updated data in NIOSH (1999b).

ERG estimated that workers using heavy equipment to abrade or fracture silica-containing materials or for demolition devoted only 2.5 percent of their time, on an FTE-equivalent basis, doing this work.

Key workers in the companion group using heavy equipment for grading and excavating often spend the bulk of their work shift on the equipment itself, engaged in construction work. OSHA Inspection Reports and other documentation consistently show that heavy equipment operators perform their tasks for more than 7 hours per shift (OSHA SEP Inspection Reports 122212079, 116179359; Greenspan, et al., 1995; NIOSH HETA 93-0696-2395, 1999; NIOSH, 1999b; NIOSH ECTB 233-120, 1999c). Nevertheless, the heavy equipment operator occupational category also includes operators of such equipment as pile drivers, cranes, and air compressors that are not generally associated with silica dust generation. For the PEA, OSHA used ERG's estimate of 75 percent for operating engineers and 50 percent for excavating and loading machine and dragline operators in this category to estimate the number of heavy equipment operators performing silica-generating activities. OSHA did not receive any comment on these estimates and has therefore has retained their substance for this FEA.

Hole Drilling Using Handheld or Stand-mounted Drills

While many workers might occasionally be assigned to drill holes in concrete, this equipment category represents a very small part of the activities of the occupational groups performing this work. ERG judged that carpenters, electricians, plumbers, sheet metal workers, and helpers (construction laborers) spend one percent of their time drilling holes in silica-containing materials in the affected industries. OSHA presented this estimate in the PEA and did not receive comment or alternate estimates and has therefore retained the estimate for this FEA.

Jackhammers and Other Powered Handheld Chipping Tools

OSHA estimated in the PEA that in the key occupation of construction laborers, relatively few use equipment in this category. In developing the estimate of time spent using equipment in this category for the PEA, ERG examined a snapshot of construction activities from the BLS publication, *Injuries to Construction Laborers* (BLS, 1986). That source presents a survey of injured construction workers and includes questions about their activities at the time they were injured. The survey indicated that 3 percent of construction workers were using jackhammers at the time they were injured. ERG judged that, while the survey was not intended to characterize typical construction activities, and a survey of injured workers introduces considerable potential bias into the observations, this estimate was useful as an observation of representative construction activities. ERG also judged that, because jackhammers are heavier, more cumbersome, and more powerful than much construction equipment, workers are probably injured more frequently while using jackhammers, on average, than when using all other construction equipment. Thus, the 3 percent figure is likely to be an upper bound of the amount of time spent using jackhammers and other powered handheld chipping tools. In the absence of other data, OSHA used ERG's estimate that 3 percent of laborers are using this equipment for the PEA. The Agency received no additional data or comment on this estimate and has therefore retained this estimate for the FEA.

Masonry and Concrete Cutters Using Portable Saws -- I

The key occupations using portable saws to cut masonry and concrete, namely brickmasons, blockmasons, stonemasons, and their helpers, spend, on average, a small share of their time cutting these materials with portable saws. In Table 1, OSHA notes three types of portable saws: 1) hand-held saws, 2) walk-behind saws, and 3) drivable saws. Each of those is encompassed in this analysis, although small-diameter handheld saws are addressed separately. According to OSHA and NIOSH reports, the workers in these occupations perform multiple masonry activities and might engage in cutting for only a small portion of their shift (OSHA SEP Inspection Report 300646510; NIOSH, 1999a) (Document ID 0084). Another glimpse of this activity can be gleaned from the BLS injury report for construction laborers, where 3 percent of workers were injured while breaking up or cutting concrete, asphalt, brick, rocks, etc.[59] For each of the applicable occupations, OSHA estimated in the PEA that 10 percent of the workers' time would be spent using the equipment in this category. The Agency received no comment on this estimate and has therefore retained this estimate for the FEA.

Masonry and Concrete Cutters Using Portable Saws – II - small diameter saws for cutting fiber-cement board

The task of using handheld power saws for cutting fiber-cement board (with blade diameter of 8 inches or less) was separated out in Table I in the final rule to recognize portable saws used for cutting cement fiberboard or cement fibersiding as a potential source of silica containing dust. OSHA judged that portable saws would be used by carpenters or their helpers to cut fiber-cement board and that, on average, they would spend 2.5 percent of their time using equipment in this category to cut the referenced materials.

Masonry Cutters Using Stationary Saws

[59] OSHA notes that these data are of uncertain value since they probably exclude most craft workers (i.e., masons) and may contain various other potential biases in injury data.

As noted earlier, OSHA and NIOSH surveillance publications report that saw operators perform multiple masonry cutting activities and might engage in cutting silica-containing materials for only a small portion of their shift (OSHA SEP Inspection Report 300646510; NIOSH, 1999a). For the PEA, OSHA used ERG's estimate that workers in mason occupations spend 10 percent of their time cutting silica-containing materials with stationary saws. The Agency received no comment on this estimate and has therefore retained this estimate for this FEA.

Millers Using Portable or Mobile Machines

In the PEA, ERG identified two key occupation groups where millers are using portable or mobile machines: (1) cement masons and (2) paving, surfacing, and tamping equipment operators. In response to comments (see, e.g. Document ID 3585, Tr. 3036; 4220, p. 9; 3756, Attachment 1), for the FEA, OSHA added a third key occupation group: terrazzo workers and finishers. Milling using this equipment represents a small share of the overall job duties of these applicable key occupations: in the PEA OSHA judged that 5 percent of all work for the first two occupation groups is spent using this equipment, and OSHA is retaining that estimate in the FEA because there were no comments challenging that estimate. OSHA estimates that terrazzo workers use the equipment about half as much as the other two occupation groups, so OSHA estimates that 2.5 percent of all work time spent by terrazzo workers and finishers will be spent using this equipment.

Rock Crushing Machine Operators and Tenders

According to information collected from ERG communication and OSHA SEP inspection reports, rock crushing machine operators spend most, if not all, of their shifts at and around the rock crushing process (Polhemus, 2000, Document ID 0958; Haney, 2001, Document ID 0721; OSHA SEP Inspection Report 2116507, Document ID 0186; OSHA SEP Inspection Report 300441862, Document ID 0030). OSHA estimated in the PEA that this occupational group spends 75 percent of its time using rock crushing machines and did not receive any comment on the estimate. OSHA has retained this estimate for the FEA.

Tunnel Boring

Underground workers perform both tunnel work and other types of construction work. The majority of these underground tasks still fall under Table 1 and have been accounted for elsewhere in the appropriate construction task analysis. However, a small amount of silica-generating underground construction work outside the scope of Table 1, primarily in tunnel boring, is expected to occur. The cost of engineering controls for this activity (to comply with the new PEL) is presented after the total engineering control costs to comply with Table 1 are presented.

SBAR Panel Comments on Key and Secondary Occupations

As stated in the comments during the Silica SBAR Panel process, one SBREFA commenter was "unable to reconcile ERG's statement that 'the amount of time . . . grinders and tuck-pointers perform grinding ranges widely, from about 1 hour per shift up to a full 8-hour shift (or longer)' [see the discussion on technological feasibility in Chapter IV of this FEA] with the 2.5% estimate in Table 4-8 [in the ERG report (2007a); Table V-26 in the PEA]" (Document ID 0004, p. 34, fn. 17 of memo). The commenter also asserted that masonry cutters use stationary saws approximately 20 to 30 percent of their working time (rather than 10 percent), and that masonry cutters use portable saws approximately 5 percent of their working time (rather than 10 percent) (Document ID 0004, p. 34, fn. 17 of memo).

In response, OSHA reiterated in the PEA that Table V-26 of the PEA showed the estimates of the full-time-equivalent number of workers in key and secondary occupations using equipment to perform silica-generating tasks. These occupations are taken from the BLS *Occupational Employment Survey* classification system and are much broader than the "masonry cutter" category referred to by the commenter, implying a lower percentage of time devoted to tasks involving masonry cutting.

OSHA did not receive further comment on this explanation. Therefore, OSHA has not changed these estimates in the FEA. For each occupation the estimates in Table V-37 in the FEA are meant to reflect the typical or average amount of a worker's time (over a year) devoted to the listed tasks.

FTE At-Risk Employment by Task Category

Tables V-38a and V-38b provide estimates, by occupation, of the full-time-equivalent (FTE) number of key and secondary workers, respectively, for each task category, using the percentages and ratios from Table V-37. These tables are relatively direct compilations from previous tables with adjustments needed, in a few cases, to assure that the industry-specific FTE occupational totals did not exceed the total occupational employment for any industry.

Table V-39 shows the corresponding estimates by NAICS code for the construction industry.

OSHA distributed FTE at-risk workers across NAICS codes according to the combination of task categories and occupational (key and secondary) categories (from BLS, 2012b) derived and updated by ERG for each industry group (ERG, 2007a, Document ID 1709).

For example, OSHA estimates (as shown in Table V-39) that the FTE of 26,004 construction workers use handheld or stand-mounted drills to drill into silica-materials. As shown in Table V-37, these workers can include carpenters, plumbers, electricians, sheet metal workers, or their helpers as well as construction laborers. Of these workers, 3,515 FTE workers were estimated to use handheld or stand mounted drills to drill into silica-containing material in the residential building industry, NAICS 2361. Table V-39 of this FEA also shows that, overall, 16,717 FTE-equivalent workers in the residential building industry performed work using equipment that can generate silica-containing dust, representing 3.2 percent of the industry's total employment of 519,070.
Overall, a full-time equivalent of 374,003 workers is estimated to use equipment to perform work on silica-containing materials in construction, ranging from 1,135 FTEs for rock crushing machine operators and tenders to 198,585 FTEs for heavy equipment operators and ground crew laborers (grading and excavating).

Table V-38a

FTE At-Risk Key Employment by Occupation and Construction Task Area

OES Code	Key Occupation	Total Employment*	Total Full-Time Equivalent Working on At-Risk Tasks		Rock and concrete drillers	Heavy construction equipment operators - I	Heavy construction equipment operators - II	Tuck pointers and grinders (hand-held)	Hole drillers using hand-held drills	Jack-hammers	Millers using portable or mobile machines	Masonry cutters using portable saws - I	Masonry cutters using portable saws - II	Masonry cutters using stationary saws	Rock crushing machine operators and tenders
47-1011	First-Line Supervisors/Managers of Construction Trades and Extraction Workers	328,175	0	0.0%	0	0	0	0	0	0	0	0	0	0	0
47-2061	Construction Laborers	603,049	18,088	3.0%	0	0	0	0	0	18,088	0	0	0	0	0
47-2073	Operating Engineers and Other Construction Equipment Operators	220,806	117,062	53.0%	0	5,574	111,487	0	0	0	0	0	0	0	0
53-7032	Excavating and Loading Machine and Dragline Operators	18,853	14,905	79.1%	0	481	14,424	0	0	0	0	0	0	0	0
47-2021	Brickmasons and Blockmasons	51,095	11,496	22.5%	0	0	0	1,277	0	0	0	5,110	0	5,110	0
47-2051	Cement Masons and Concrete Finishers	116,746	8,756	7.5%	0	0	0	2,919	0	0	5,837	0	0	0	0
47-3011	Helpers--Brickmasons, Blockmasons, Stonemasons, and Tile and Marble Setters	22,510	5,065	22.5%	0	0	0	563	0	0	0	2,251	0	2,251	0
47-2031	Carpenters	429,193	14,286	3.3%	0	0	0	0	4,294	0	0	0	9,993	0	0
47-2111	Electricians	383,977	3,908	1.0%	0	0	0	0	3,908	0	0	0	0	0	0
47-2152	Plumbers	272,390	2,736	1.0%	0	0	0	0	2,736	0	0	0	0	0	0
47-2210	Sheet Metal Workers	80,141	801	1.0%	0	0	0	0	801	0	0	0	0	0	0
47-3012	Helpers--Carpenters	29,389	990	3.4%	0	0	0	0	294	0	0	0	696	0	0
47-3013	Helpers-Electricians	54,952	551	1.0%	0	0	0	0	551	0	0	0	0	0	0
47-3015	Helpers - Plumbers	43,648	436	1.0%	0	0	0	0	436	0	0	0	0	0	0
47-2053	Terrazzo Workers and Finishers	2,892	72	2.5%	0	0	0	0	0	0	72	0	0	0	0
47-2071	Paving, Surfacing, and Tamping Equipment Operators	40,576	2,029	5.0%	0	0	0	0	0	0	2,029	0	0	0	0

Table V-38a (continued)

FTE At-Risk Key Employment by Occupation and Construction Task Area

OES Code	Key Occupation	Total Employment *	Total Full-Time Equivalent Working on At-Risk Tasks		Rock and concrete drillers	Heavy construction equipment operators - I	Heavy construction equipment operators - II	Tuck pointers and grinders (hand-held)	Hole drillers using hand-held drills	Jack-hammers	Millers using portable or mobile machines	Masonry cutters using portable saws - I	Masonry cutters using portable saws - II	Masonry cutters using stationary saws	Rock crushing machine operators and tenders
47-2022	Stonemasons	8,415	1,683	20.0%	0	0	0	0	0	0	0	841	0	841	0
47-2180	Roofers	91,296	2,282	2.5%	0	0	0	0	0	0	0	0	0	2,282	0
47-3016	Helpers--Roofers	11,514	288	2.5%	0	0	0	0	0	0	0	0	0	288	0
47-5021	Earth Drillers, Except Oil and Gas	9,032	6,811	75.4%	6,811	0	0	0	0	0	0	0	0	0	0
47-5031	Explosives Workers, Ordnance Handling Experts, and Blasters	650	0	0.0%	0	0	0	0	0	0	0	0	0	0	0
47-5081	Helpers--Extraction Workers	2,856	0	0.0%	0	0	0	0	0	0	0	0	0	0	0
47-4051	Highway Maintenance Worker	77,876	10,124	13.0%	0	389	7,788	0	0	1,947	0	0	0	0	0
51-9021	Crushing, Grinding, and Polishing Machine Setters, Operators, and Tenders	650	487	75.0%	0	0	0	0	0	0	0	0	0	0	487
	Totals	**2,900,681**	**222,858**	**7.7%**	**6,811**	**6,445**	**133,699**	**4,759**	**13,020**	**20,035**	**7,938**	**8,202**	**10,689**	**10,772**	**487**

Source: BLS (2012) benchmarked to 2012 County Business Patterns (Census, 2012) industry totals.

Table V-38b

FTE At-Risk Secondary Employment by Occupation and Construction Task Area

OES Code	Secondary Occupation	Total Employment	Total Full-Time Equivalent Working on At-Risk Tasks		Rock and concrete drillers	Heavy construction equipment operators - I	Heavy construction equipment operators - II	Tuck pointers and grinders (hand-held)	Hole drillers using hand-held drills	Jack-hammers	Millers using portable or mobile machines	Masonry cutters using portable saws - I	Masonry cutters using portable saws - II	Masonry cutters using stationary saws	Rock crushing machine operators and tenders
47-1011	First-Line Supervisors/Managers of Construction Trades and Extraction	328,175	18,580	5.7%	3,406	0	0	4,759	0	5,015	5,239	0	0	0	161
47-	Construction Laborers	603,049	118,65	19.7	6,780	3,125	64,886	14,273	12,984	0	7,918	8,201	0	0	487
47-2073	Operating Engineers and Other Construction	220,806	11,800	5.3%	6,811	0	0	0	0	4,989	0	0	0	0	0
53-7032	Excavating and Loading Machine and Dragline Operators	18,853	0	0.0%	0	0	0	0	0	0	0	0	0	0	0
47-2021	Brickmasons and Blockmasons	51,095	0	0.0%	0	0	0	0	0	0	0	0	0	0	0
47-2051	Cement Masons and Concrete Finishers	116,746	0	0.0%	0	0	0	0	0	0	0	0	0	0	0
47-3011	Helpers--Brickmasons, Blockmasons, Stonemasons, and Tile and Marble Setters	22,510	0	0.0%	0	0	0	0	0	0	0	0	0	0	0
47-	Carpenters	429,193	0	0.0%	0	0	0	0	0	0	0	0	0	0	0
47-	Electricians	383,977	0	0.0%	0	0	0	0	0	0	0	0	0	0	0
47-	Plumbers	272,390	0	0.0%	0	0	0	0	0	0	0	0	0	0	0
47-	Sheet Metal Workers	80,141	0	0.0%	0	0	0	0	0	0	0	0	0	0	0
47-	Helpers--Carpenters	29,389	0	0.0%	0	0	0	0	0	0	0	0	0	0	0
47-	Helpers-Electricians	54,952	0	0.0%	0	0	0	0	0	0	0	0	0	0	0
47-	Helpers - Plumbers	43,648	0	0.0%	0	0	0	0	0	0	0	0	0	0	0
47-2053	Terrazzo Workers and Finishers	2,892	0	0.0%	0	0	0	0	0	0	0	0	0	0	0

Table V-38b (continued)

FTE At-Risk Secondary Employment by Occupation and Construction Task Area

OES Code	Secondary Occupation	Total Employment	Total Full-Time Equivalent Working on At-Risk Tasks		Rock and concrete drillers	Heavy construction equipment operators - I	Heavy construction equipment operators - II	Tuck pointers and grinders (hand-held)	Hole drillers using hand-held drills	Jack-hammers	Millers using portable or mobile machines	Masonry cutters using portable saws - I	Masonry cutters using portable saws - II	Masonry cutters using stationary saws	Rock crushing machine operators and tenders
47-2071	Paving, Surfacing, and Tamping Equipment Operators	40,576	0	0.0%	0	0	0	0	0	0	0	0	0	0	0
47-2022	Stonemasons	8,415	0	0.0%	0	0	0	0	0	0	0	0	0	0	0
47-2180	Roofers	91,296	0	0.0%	0	0	0	0	0	0	0	0	0	0	0
47-3016	Helpers--Roofers	11,514	0	0.0%	0	0	0	0	0	0	0	0	0	0	0
47-5021	Earth Drillers, Except Oil and Gas	9,032	0	0.0%	0	0	0	0	0	0	0	0	0	0	0
47-5031	Explosives Workers, Ordnance Handling Experts, and Blasters	650	432	66.4%	432	0	0	0	0	0	0	0	0	0	0
47-5081	Helpers--Extraction Workers	2,856	1,680	58.8%	1,680	0	0	0	0	0	0	0	0	0	0
47-4051	Highway Maintenance Worker	77,876	0	0.0%	0	0	0	0	0	0	0	0	0	0	0
51-9021	Crushing, Grinding, and Polishing Machine Setters, Operators, and Tenders	650	0	0.0%	0	0	0	0	0	0	0	0	0	0	0
	Totals	**2,900,681**	**151,146**	**5.2%**	**19,109**	**3,125**	**64,886**	**19,032**	**12,984**	**10,004**	**13,157**	**8,201**	**0**	**0**	**648**

Source: BLS (2012) benchmarked to 2012 County Business Patterns (Census, 2012) industry totals.

Table V-39

Total FTE At-Risk Employment by Construction Industry and Task Area [†]

NAICS	Industry	Total Employment*	Total Full-Time Equivalent Working on At-Risk Tasks FTE	FTE %	Rock and concrete drillers	Heavy construction equipment operators - I	Heavy construction equipment operators - II	Tuck pointers and grinders (hand-held)	Hole drillers using hand-held drills	Jack-hammers	Millers using portable or mobile machines	Masonry cutters using portable saws - I	Masonry cutters using portable saws - II	Masonry cutters using stationary saws	Rock crushing machine operators and tenders
236100	Residential Building Construction	519,070	16,717	3.2%	0	127	2,656	991	3,515	3,606	748	542	4,220	313	0
236200	Nonresidential Building Construction	521,112	22,796	4.4%	0	449	9,459	1,906	2,327	3,596	1,527	822	2,278	432	0
237100	Utility System Construction	466,099	65,949	14.1%	18,601	1,899	39,295	433	792	4,265	652	8	0	4	0
237200	Land Subdivision	53,045	1,519	2.9%	0	61	1,245	26	14	136	37	0	0	0	0
237300	Highway, Street, and Bridge Construction	251,065	38,104	15.2%	465	1,380	28,257	1,285	257	2,899	3,357	30	0	15	159
237900	Other Heavy and Civil Engineering Construction	79,390	11,077	14.0%	923	402	8,387	114	101	913	229	6	0	3	0
238100	Foundation, Structure, and Building Exterior Contractors	657,508	56,183	8.5%	0	236	4,833	14,711	1,540	3,463	8,184	12,822	1,545	8,849	0
238200	Building Equipment Contractors	1,629,581	21,455	1.3%	303	206	4,494	81	14,664	1,412	72	46	136	40	0
238300	Building Finishing Contractors	608,945	10,560	1.7%	0	11	219	1,229	1,879	1,176	586	1,665	2,242	874	679
238900	Other Specialty Trade Contractors	475,127	83,107	17.5%	5,338	2,894	61,065	2,890	309	4,905	4,593	407	266	210	230
221100	Electric Utilities	509,704	2,363	0.5%	125	92	1,965	0	152	29	0	0	0	0	0
999200	State Governments	2,201,490	8,088	0.4%	107	335	6,722	5	46	805	64	3	0	3	0
999300	Local Governments	5,473,350	36,084	0.7%	58	1,480	29,988	120	406	2,835	1,046	53	0	30	68
	Totals	**13,445,486**	**374,003**	**2.8%**	**25,920**	**9,569**	**198,585**	**23,791**	**26,004**	**30,039**	**21,096**	**16,403**	**10,689**	**10,772**	**1,135**

[†] Table 1 task areas only.

*County Business Patterns (Census, 2012).

Source: OSHA, Directorate of Standards and Guidance, Office of Regulatory Analysis, based on task percentages shown in Table V-37.

Total At-Risk Employment

In the PEA, OSHA used a relatively crude approach to convert the estimated number of FTE affected construction workers to the number at-risk construction workers. There, OSHA used a multiplier of 2 or 5, depending on the industry, to convert the number of FTEs to the number of at-risk workers (in Table V-37 of the PEA).

OSHA received several comments regarding the analysis used in the PEA as being too simplistic. Joseph Liss challenged OSHA's methodology:

> Even though OSHA estimates the number of workers needing training for silica exposure under the proposed rule by multiplying full-time equivalents by a factor of either 2 or 5, depending upon the sub-industry, the multiplicative factor for training purposes is likely to be much higher. For example, while paving, surfacing, and tamping operators spend a total of only 5% of their time on tasks exposed to silica, as estimated by ERG, it is not unlikely that many of the 51,857 workers in that industry sub-group will do silica-exposed work at some point, and, thus, require training. There are 823,737 construction laborers, and ERG estimated that 3% of their time is spent on silica-exposed work, but the severe turnover in that industry means firms may need to train many of those workers in silica safety procedures and health effects. OSHA estimates the nation's 575,000 residential construction workers spend 5% of their time on construction work and uses a multiplicative factor of two, thus assuming that only 10% of those workers require training and exposure monitoring. Costs may increase if the number of workers exposed increases, since OSHA requires training for all newly hired workers as well as all initial training for all workers exposed to silica (citations omitted) (Document ID 1950, p. 9).

Additionally, the Construction Industry Safety Coalition (CISC) submitted calculations to arrive at their own results of at-risk workers. They note:

> These percentages represent our quick judgement across both the key occupations and the secondary occupations that OSHA identifies as participating in the crew when the at-risk task is performed. If we had more time, we would like to make this judgement more carefully (Document ID 4032, Tab 6).

For this FEA, in response to comments, OSHA refined its process, as described below, to allow for a more nuanced approach to estimating the number of affected workers. As a result of this revised approach, the ratio of the estimated number of at-risk construction workers to the estimated number of FTE-affected construction workers increased from approximately three to one in the PEA to over five to one in this FEA. OSHA first assigned each of the affected NAICS construction industries into one of four subsectors in order to account for likely differences among specific industries with respect to the frequency with which silica-generating equipment is used. These subsectors are shown below in Table V-40a. Note that non-construction industries doing construction work—state and local governments and electric utilities are included in Subsector 3.

Table V-40a

NAICS Construction Industries by Subsector

Subsector Designation	NAICS	Industry
1	236100	Residential Building Construction
2	236200	Nonresidential Building Construction
3	237100	Utility System Construction
3	237200	Land Subdivision
3	237300	Highway, Street, and Bridge Construction
3	237900	Other Heavy and Civil Engineering Construction
4	238100	Foundation, Structure, and Building Exterior Contractors
4	238200	Building Equipment Contractors
4	238300	Building Finishing Contractors
4	238900	Other Specialty Trade Contractors

Source: US Census, http://www.census.gov/eos/www/naics/.

Second, because at-risk workers do not necessarily specialize in jobs that use equipment that generates silica-containing dust, ERG independently estimated the number of "affected" workers based on judgments of the share of workers in each occupation that would likely ever perform these tasks. These judgments were also made on a subsector-by-subsector basis. In most cases, costs for program requirements (but not for engineering controls) are based on the numbers of affected workers performing each task in a given industry. The estimated share of affected workers for the key occupations, taking into account the specific construction subsector and task, is shown in Table V-40b.

Using the FTE rates, secondary ratios, and affected rate parameters displayed in Table V-37, OSHA calculated, in Table V-39, that there are an estimated 374,003 FTEs affected by the rule. Table V-41 converts these FTEs to 2.02 million affected construction workers disaggregated by occupation based on 2012 County Business Pattern (CBP) (Census, 2012) total employment of 2.93 million in affected occupations in construction industries. Thus, as shown in Table V-41, about 68.9 percent of construction workers in affected occupations will be affected by the final rule. Table V-42 shows the same estimated number of affected workers, but disaggregated by NAICS industries and equipment category. There are an estimated 13.45 million workers total in the affected industries, meaning that about 15 percent of the workers in these industries are affected by the final rule. That percentage is misleading, however, because almost 7.7 million of total employment in affected industries (almost 60 percent) are employed in state and local governments, of which only 2 percent are affected by the final rule. When these public workers are removed, approximately 32 percent of the construction workers in affected private industries are affected by the final rule.

All of the above statistics do not include the estimated 11,640 at-risk abrasive blasters working in construction industries. Also, because some occupations are associated with the use of more than one equipment category, the “affected” totals are constrained to be less than or equal to the industry total for each at-risk occupation.

Table V-40b

Estimated Percentage of Affected Workers by Occupation, Task Area, and Construction Sector

Construction Subsector	Task No	Task	Occ. code	Occupation	Affected Rate
1	2	Heavy construction equipment operators - I	53-7032	Excavating and Loading Machine and Dragline Operators	5.0%
1	2	Heavy construction equipment operators - I	47-2073	Operating Engineers and Other Construction Equipment Operators	10.0%
1	3	Heavy construction equipment operators - II	53-7032	Excavating and Loading Machine and Dragline Operators	100.0%
1	3	Heavy construction equipment operators - II	47-2073	Operating Engineers and Other Construction Equipment Operators	75.0%
1	4	Grinders and tuck pointers using hand-held tools	47-2021	Brickmasons and Blockmasons	20.0%
1	4	Grinders and tuck pointers using hand-held tools	47-2051	Cement Masons and Concrete Finishers	40.0%
1	4	Grinders and tuck pointers using hand-held tools	47-3011	Helpers--Brickmasons, Blockmasons, Stonemasons, and Tile and Marble Setters	20.0%
1	5	Hole drillers using hand-held or stand-mounted drills	47-2031	Carpenters	60.0%
1	5	Hole drillers using hand-held or stand-mounted drills	47-2111	Electricians	30.0%
1	5	Hole drillers using hand-held or stand-mounted drills	47-3015	Helpers – Plumbers	30.0%
1	5	Hole drillers using hand-held or stand-mounted drills	47-3012	Helpers—Carpenters	60.0%
1	5	Hole drillers using hand-held or stand-mounted drills	47-3013	Helpers-Electricians	30.0%
1	5	Hole drillers using hand-held or stand-mounted drills	47-2152	Plumbers	30.0%
1	5	Hole drillers using hand-held or stand-mounted drills	47-2210	Sheet Metal Workers	10.0%
1	6	Impact drillers	47-2061	Construction Laborers	20.0%
1	7	Millers using portable or mobile machines	47-2051	Cement Masons and Concrete Finishers	40.0%
1	7	Millers using portable or mobile machines	47-2071	Paving, Surfacing, and Tamping Equipment Operators	40.0%
1	7	Millers using portable or mobile machines	47-2053	Terrazzo Workers and Finishers	40.0%
1	8	Masonry cutters using portable saws	47-2021	Brickmasons and Blockmasons	40.0%

1	8	Masonry cutters using portable saws	47-3011	Helpers--Brickmasons, Blockmasons, Stonemasons, and Tile and Marble Setters	40.0%
1	8	Masonry cutters using portable saws	47-2022	Stonemasons	40.0%

Table V-40b (continued)

Estimated Percentage of Affected Workers by Occupation, Task Area, and Construction Sector

Construction Subsector	Task No	Task	Occ. code	Occupation	Affected Rate
1	9	Masonry cutters using portable saws – II	47-2031	Carpenters	5.0%
1	9	Masonry cutters using portable saws - II	47-3012	Helpers—Carpenters	5.0%
1	10	Masonry cutters using stationary saws	47-2021	Brickmasons and Blockmasons	40.0%
1	10	Masonry cutters using stationary saws	47-3011	Helpers--Brickmasons, Blockmasons, Stonemasons, and Tile and Marble Setters	40.0%
1	10	Masonry cutters using stationary saws	47-3016	Helpers—Roofers	20.0%
1	10	Masonry cutters using stationary saws	47-2180	Roofers	20.0%
1	10	Masonry cutters using stationary saws	47-2022	Stonemasons	40.0%
2	2	Heavy construction equipment operators - I	53-7032	Excavating and Loading Machine and Dragline Operators	5.0%
2	2	Heavy construction equipment operators - I	47-2073	Operating Engineers and Other Construction Equipment Operators	20.0%
2	3	Heavy construction equipment operators - II	53-7032	Excavating and Loading Machine and Dragline Operators	100.0%
2	3	Heavy construction equipment operators - II	47-2073	Operating Engineers and Other Construction Equipment Operators	75.0%
2	3	Grinders and tuck pointers using hand-held tools	47-2021	Brickmasons and Blockmasons	20.0%
2	4	Grinders and tuck pointers using hand-held tools	47-2051	Cement Masons and Concrete Finishers	40.0%
2	4	Grinders and tuck pointers using hand-held tools	47-3011	Helpers--Brickmasons, Blockmasons, Stonemasons, and Tile and Marble Setters	20.0%
2	5	Hole drillers using hand-held or stand-mounted drills	47-2031	Carpenters	80.0%
2	5	Hole drillers using hand-held or stand-mounted drills	47-2111	Electricians	40.0%
2	5	Hole drillers using hand-held or stand-mounted drills	47-3015	Helpers – Plumbers	40.0%
2	5	Hole drillers using hand-held or stand-mounted drills	47-3012	Helpers—Carpenters	80.0%
2	5	Hole drillers using hand-held or stand-mounted drills	47-3013	Helpers-Electricians	40.0%
2	5	Hole drillers using hand-held or stand-mounted drills	47-2152	Plumbers	40.0%
2	5	Hole drillers using hand-held or stand-mounted drills	47-2210	Sheet Metal Workers	20.0%
2	6	Impact drillers	47-2061	Construction Laborers	20.0%
2	7	Millers using portable or mobile machines	47-2051	Cement Masons and Concrete Finishers	40.0%
2	7	Millers using portable or mobile machines	47-2071	Paving, Surfacing, and Tamping Equipment Operators	40.0%

Table V-40b (continued)

Estimated Percentage of Affected Workers by Occupation, Task Area, and Construction Sector

Construction Subsector	Task No	Task	Occ. code	Occupation	Affected Rate
2	7	Millers using portable or mobile machines	47-2053	Terrazzo Workers and Finishers	40.0%
2	8	Masonry cutters using portable saws	47-2021	Brickmasons and Blockmasons	40.0%
2	8	Masonry cutters using portable saws	47-3011	Helpers--Brickmasons, Blockmasons, Stonemasons, and Tile and Marble Setters	40.0%
2	8	Masonry cutters using portable saws	47-2022	Stonemasons	40.0%
2	9	Masonry cutters using portable saws - II	47-2031	Carpenters	10.0%
2	9	Masonry cutters using portable saws - II	47-3012	Helpers—Carpenters	10.0%
2	10	Masonry cutters using stationary saws	47-2021	Brickmasons and Blockmasons	40.0%
2	10	Masonry cutters using stationary saws	47-3011	Helpers--Brickmasons, Blockmasons, Stonemasons, and Tile and Marble Setters	40.0%
2	10	Masonry cutters using stationary saws	47-3016	Helpers--Roofers	20.0%
2	10	Masonry cutters using stationary saws	47-2180	Roofers	20.0%
2	10	Masonry cutters using stationary saws	47-2022	Stonemasons	40.0%
3	1	Earth drillers	47-5021	Earth Drillers, Except Oil and Gas	100.0%
3	2	Heavy construction equipment operators - I	53-7032	Excavating and Loading Machine and Dragline Operators	10.0%
3	2	Heavy construction equipment operators - I	47-4051	Highway Maintenance Worker	10.0%
3	2	Heavy construction equipment operators - I	47-2073	Operating Engineers and Other Construction Equipment Operators	30.0%
3	3	Heavy construction equipment operators -II	53-7032	Excavating and Loading Machine and Dragline Operators	100.0%
3	3	Heavy construction equipment operators -II	47-4051	Highway Maintenance Worker	75.0%
3	3	Heavy construction equipment operators -II	47-2073	Operating Engineers and Other Construction Equipment Operators	50.0%
3	4	Grinders and tuck pointers using hand-held tools	47-2021	Brickmasons and Blockmasons	20.0%
3	4	Grinders and tuck pointers using hand-held tools	47-2051	Cement Masons and Concrete Finishers	40.0%
3	5	Hole drillers using hand-held or stand-mounted drills	47-2031	Carpenters	80.0%
3	5	Hole drillers using hand-held or stand-mounted drills	47-2111	Electricians	40.0%

Table V-40b (continued)

Estimated Percentage of Affected Workers by Occupation, Task Area, and Construction Sector

Construction Subsector	Task No	Task	Occ. code	Occupation	Affected Rate
3	5	Hole drillers using hand-held or stand-mounted drills	47-3015	Helpers - Plumbers	40.0%
3	5	Hole drillers using hand-held or stand-mounted drills	47-3012	Helpers--Carpenters	80.0%
3	5	Hole drillers using hand-held or stand-mounted drills	47-3013	Helpers-Electricians	40.0%
3	5	Hole drillers using hand-held or stand-mounted drills	47-2152	Plumbers	40.0%
3	5	Hole drillers using hand-held or stand-mounted drills	47-2210	Sheet Metal Workers	20.0%
3	6	Impact drillers	47-2061	Construction Laborers	40.0%
3	6	Impact drillers	47-4051	Highway Maintenance Worker	40.0%
3	7	Millers using portable or mobile machines	47-2051	Cement Masons and Concrete Finishers	60.0%
3	7	Millers using portable or mobile machines	47-2071	Paving, Surfacing, and Tamping Equipment Operators	40.0%
3	8	Masonry cutters using portable saws	47-2021	Brickmasons and Blockmasons	40.0%
3	10	Masonry cutters using stationary saws	47-2021	Brickmasons and Blockmasons	40.0%
4	11	Rock crushing machines and tenders	51-9021	Crushing, Grinding, and Polishing Machine Setters, Operators, and Tenders	100.0%
4	1	Earth drillers	47-5021	Earth Drillers, Except Oil and Gas	100.0%
4	2	Heavy construction equipment operators - I	53-7032	Excavating and Loading Machine and Dragline Operators	10.0%
4	2	Heavy construction equipment operators - I	47-4051	Highway Maintenance Worker	10.0%
4	2	Heavy construction equipment operators - I	47-2073	Operating Engineers and Other Construction Equipment Operators	30.0%
4	3	Heavy construction equipment operators - II	53-7032	Excavating and Loading Machine and Dragline Operators	100.0%
4	3	Heavy construction equipment operators - II	47-4051	Highway Maintenance Worker	50.0%
4	3	Heavy construction equipment operators - II	47-2073	Operating Engineers and Other Construction Equipment Operators	75.0%
4	4	Grinders and tuck pointers using hand-held tools	47-2021	Brickmasons and Blockmasons	20.0%
4	4	Grinders and tuck pointers using hand-held tools	47-2051	Cement Masons and Concrete Finishers	40.0%
4	4	Grinders and tuck pointers using hand-held tools	47-3011	Helpers--Brickmasons, Blockmasons, Stonemasons, and Tile and Marble Setters	20.0%
4	5	Hole drillers using hand-held or stand-mounted drills	47-2031	Carpenters	80.0%
4	5	Hole drillers using hand-held or stand-mounted drills	47-2111	Electricians	40.0%

Table V-40b (continued)

Estimated Percentage of Affected Workers by Occupation, Task Area, and Construction Sector

Construction Subsector	Task No	Task	Occ. code	Occupation	Affected Rate
4	5	Hole drillers using hand-held or stand-mounted drills	47-3015	Helpers - Plumbers	40.0%
4	5	Hole drillers using hand-held or stand-mounted drills	47-3012	Helpers--Carpenters	80.0%
4	5	Hole drillers using hand-held or stand-mounted drills	47-3013	Helpers-Electricians	40.0%
4	5	Hole drillers using hand-held or stand-mounted drills	47-2152	Plumbers	40.0%
4	5	Hole drillers using hand-held or stand-mounted drills	47-2210	Sheet Metal Workers	20.0%
4	6	Impact drillers	47-2061	Construction Laborers	40.0%
4	6	Impact drillers	47-4051	Highway Maintenance Worker	40.0%
4	7	Millers using portable or mobile machines	47-2051	Cement Masons and Concrete Finishers	60.0%
4	7	Millers using portable or mobile machines	47-2071	Paving, Surfacing, and Tamping Equipment Operators	40.0%
4	7	Millers using portable or mobile machines	47-2053	Terrazzo Workers and Finishers	40.0%
4	8	Masonry cutters using portable saws - I	47-2021	Brickmasons and Blockmasons	40.0%
4	8	Masonry cutters using portable saws - I	47-2022	Stonemasons	40.0%
4	8	Masonry cutters using portable saws - I	47-3011	Helpers--Brickmasons, Blockmasons, Stonemasons, and Tile and Marble Setters	40.0%
4	9	Masonry cutters using portable saws - II	47-2031	Carpenters	15.0%
4	9	Masonry cutters using portable saws - II	47-3012	Helpers--Carpenters	15.0%
4	10	Masonry cutters using stationary saws	47-2021	Brickmasons and Blockmasons	40.0%
4	10	Masonry cutters using stationary saws	47-3011	Helpers--Brickmasons, Blockmasons, Stonemasons, and Tile and Marble Setters	40.0%
4	10	Masonry cutters using stationary saws	47-3016	Helpers--Roofers	20.0%
4	10	Masonry cutters using stationary saws	47-2180	Roofers	20.0%
4	10	Masonry cutters using stationary saws	47-2022	Stonemasons	40.0%
4	11	Rock crushing machines and tenders	51-9021	Crushing, Grinding, and Polishing Machine Setters, Operators, and Tenders	100.0%

Source: OSHA, Directorate of Standards and Guidance, Office of Regulatory Analysis, based on OSHA (2016).

Table V-41: Total Affected Construction Employment by Occupation

Occ. Code	Occupation	Total Employment [a]	Affected Employment [b]	
47-1011	First-Line Supervisors/Managers of Construction Trades and Extraction Workers	329,985	144,850	43.9%
47-2061	Construction Laborers	603,769	598,633	99.1%
47-2073	Operating Engineers and Other Construction Equipment Operators	223,016	222,428	99.7%
53-7032	Excavating and Loading Machine and Dragline Operators	19,233	19,233	100.0%
47-2021	Brickmasons and Blockmasons	51,095	51,095	100.0%
47-2051	Cement Masons and Concrete Finishers	116,746	113,405	97.1%
47-3011	Helpers--Brickmasons, Blockmasons, Stonemasons, and Tile and Marble Setters	22,510	22,510	100.0%
47-2031	Carpenters	429,383	352,508	82.1%
47-2111	Electricians	390,787	156,010	39.9%
47-2152	Plumbers	273,600	109,186	39.9%
47-2210	Sheet Metal Workers	80,141	15,948	19.9%
47-3012	Helpers—Carpenters	29,389	23,447	79.8%
47-3013	Helpers-Electricians	55,062	21,987	39.9%
47-3015	Helpers – Plumbers	43,648	17,441	40.0%
47-2053	Terrazzo Workers and Finishers	2,892	1,157	40.0%
47-2071	Paving, Surfacing, and Tamping Equipment Operators	40,576	16,231	40.0%
47-2022	Stonemasons	8,415	6,732	80.0%
47-2180	Roofers	91,296	18,259	20.0%
47-3016	Helpers—Roofers	11,514	2,303	20.0%
47-5021	Earth Drillers, Except Oil and Gas	9,082	9,082	100.0%
47-5031	Explosives Workers, Ordnance Handling Experts, and Blasters	650	543	83.5%
47-5081	Helpers--Extraction Workers	2,856	2,198	77.0%
47-4051	Highway Maintenance Worker	77,876	77,876	100.0%
51-9021	Crushing, Grinding, and Polishing Machine Setters, Operators, and Tenders	650	650	100.0%
NA	Tunnel Workers	2,067	2,067	100.0%
NA	Abrasive blasters	11,640	11,640	100.0%
	Total	**2,927,878**	**2,017,417**	**68.9%**

[a] BLS (2013).

[b] ERG estimate.

Source: OSHA, Directorate of Standards and Guidance, Office of Regulatory Analysis, based on BLS (2013) and OSHA (2016).

Table V-42

Total Affected Employment by Construction Industry and Task Area

NAICS	Industry	Total Employment	Total Affected Workers		Rock and concrete drillers	Heavy construction equipment operators - I	Heavy construction equipment operators - II	Tuck pointers and grinders (hand-held)	Hole drillers using hand-held drills	Jack-hammers	Millers using portable or mobile machines	Masonry cutters using portable saws - I	Masonry cutters using portable saws - II	Masonry cutters using stationary saws	Rock crushing machine operators and tenders
236100	Residential Building Construction	519,070	210,773	40.6%	0	660	13,808	12,993	125,794	35,735	7,360	4,565	8,440	1,417	0
236200	Nonresidential Building Construction	521,112	209,136	40.1%	0	1,830	38,456	20,759	92,803	26,331	12,730	5,298	9,112	1,815	0
237100	Utility System Construction	466,099	190,044	40.8%	25,852	9,189	53,569	6,895	38,977	48,474	7,041	31	0	16	0
237200	Land Subdivision	53,045	5,726	10.8%	0	694	1,275	410	1,123	1,815	409	0	0	0	0
237300	Highway, Street, and Bridge Construction	251,065	146,187	58.2%	1,003	12,550	62,459	11,571	10,587	21,703	25,706	125	0	60	423
237900	Other Heavy and Civil Engineering Construction	79,390	37,611	47.4%	1,324	1,977	12,475	1,802	7,285	10,415	2,301	22	0	11	0
238100	Foundation, Structure, and Building Exterior Contractors	657,508	324,954	49.4%	0	513	10,485	84,406	55,339	12,459	60,319	47,015	9,273	45,145	0
238200	Building Equipment Contractors	1,629,581	326,154	20.0%	578	436	9,435	582	306,850	6,478	582	164	819	229	0
238300	Building Finishing Contractors	608,945	133,388	21.9%	0	34	687	10,261	79,168	8,323	6,269	9,019	13,454	3,663	2,509
238900	Other Specialty Trade Contractors	475,127	255,691	53.8%	15,295	6,884	144,276	19,941	10,804	20,030	33,685	1,556	1,599	866	755
221100	Electric Utilities	509,704	6,541	1.3%	156	702	2,048	0	3,473	162	0	0	0	0	0
999200	State Governments	2,201,490	33,558	1.5%	156	2,450	17,957	42	1,748	10,735	448	10	0	13	0
999300	Local Governments	5,473,350	123,946	2.3%	89	7,497	68,505	769	9,959	30,716	6,036	146	0	134	95
	Totals	**13,445,486**	**2,003,710**	**14.9%**	**44,452**	**45,418**	**435,435**	**170,430**	**743,910**	**233,377**	**162,886**	**67,953**	**42,697**	**53,370**	**3,781**

Note: Excludes abrasive blasters and tunnel borers.

Source: OSHA, Directorate of Standards and Guidance, Office of Regulatory Analysis, based on OSHA (2016).

Labor Cost and Total Value of Work Performed Using Silica Exposure-Generating Equipment

To derive labor costs and project value for construction work done using the specified equipment where occupational exposure to silica is found, OSHA multiplied the mean hourly wage, as reported by OES (BLS, 2012b) for each affected occupation within each affected industry, by 2,000 hours. Then, to derive the total value of annual wages expended for work done using specified equipment to perform silica exposure-generating activities, OSHA multiplied that product by the number of affected full-time-equivalent employees. These estimates were then inflated to adjust for fringe benefits.[60] These loaded-wage costs, totaled by industry and equipment category, are summarized in Table V-43 as the annual labor value (or labor cost) of silica-generating projects. Thus for rock and concrete drillers, for example, OSHA estimated the labor share of the project value, or cost, was $1,568.5 million annually. Overall, OSHA estimated the labor value of all silica-generating construction work performed with the specified equipment to be $21.8 billion annually.

OSHA then converted the labor values for each industry and task category from Table V-43 to the total project value by dividing by the labor share of project costs. This conversion is possible because the labor share for each task category equals the labor value divided by project value, so dividing the labor value by the labor share generates an estimate of project value. The corresponding estimates of total project value for each industry and equipment category are shown in Table V-44. For example, for rock and concrete drillers, the labor share of costs was estimated at 53.1 percent (from Table V-36a).[61] The total project value for these drilling tasks was estimated, therefore, at 1.88 (1 divided by 0.531) times the labor value of $1,568.5 million—or $2,955 million annually. Overall, OSHA estimated the value of silica-generating construction work performed with the specified equipment at $41.2 billion. The values for specific equipment categories ranged from $136.2 million for rock crushing machine operators and tenders to $28.0 billion for heavy construction equipment operations-II.

The value of work performed using the specified equipment was then summed by NAICS industry to derive the total value of at-risk projects, a base from which OSHA calculated control costs associated with compliance with Table 1 or the final PEL.

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[60] Bureau of Labor Statistics, Table 1, *Employer Costs for Employee Compensation*, (BLS, 2015). For civilian workers, wages and salaries comprised 68.4 percent of total compensation in the fourth quarter of 2014.

[61] Note that the baseline labor costs and project costs are the same for indoor and outdoor tasks. Only the control costs would be different.

Table V-43

Estimated Labor Value of Silica Activities, by Construction Industry and Task Area ($millions)

NAICS	Industry	Total	Rock and concrete drillers	Heavy construction equipment operators - I	Heavy construction equipment operators - II	Tuck pointers and grinders (hand-held)	Hole drillers using hand-held drills	Jack-hammers	Millers using portable or mobile machines	Masonry cutters using portable saws - I	Masonry cutters using portable saws - II	Masonry cutters using stationary saws	Rock crushing machine operators and tenders
236100	Residential Building Construction	$913.8	$0.0	$7.3	$153.9	$53.8	$177.6	$195.2	$42.8	$28.3	$236.7	$18.2	$0.0
236200	Nonresidential Building Construction	$1,416.4	$0.0	$28.2	$588.9	$117.0	$136.1	$219.2	$97.5	$51.2	$146.8	$31.5	$0.0
237100	Utility System Construction	$3,985.6	$1,114.3	$116.0	$2,395.6	$25.4	$44.8	$248.0	$40.8	$0.4	$0.0	$0.3	$0.0
237200	Land Subdivision	$84.5	$0.0	$3.4	$69.2	$1.4	$0.8	$7.5	$2.2	$0.0	$0.0	$0.0	$0.0
237300	Highway, Street, and Bridge Construction	$2,461.0	$31.3	$90.0	$1,836.8	$79.4	$16.0	$180.7	$214.9	$1.8	$0.0	$1.0	$9.2
237900	Other Heavy and Civil Engineering Construction	$673.9	$56.9	$24.5	$510.0	$6.9	$6.0	$55.1	$14.1	$0.3	$0.0	$0.1	$0.0
238100	Foundation, Structure, and Building Exterior Contractors	$3,113.6	$0.0	$14.8	$302.6	$798.9	$78.0	$191.8	$465.3	$669.3	$86.0	$506.8	$0.0
238200	Building Equipment Contractors	$1,272.7	$20.3	$12.9	$280.7	$4.8	$852.9	$83.4	$4.4	$2.5	$8.5	$2.3	$0.0
238300	Building Finishing Contractors	$583.9	$0.0	$0.7	$13.2	$66.5	$100.4	$64.0	$34.1	$84.2	$138.0	$49.1	$33.8
238900	Other Specialty Trade Contractors	$4,739.2	$326.7	$164.8	$3,467.3	$159.9	$17.1	$269.2	$266.1	$24.0	$17.9	$14.9	$11.2
221100	Electric Utilities	$171.1	$9.4	$6.6	$141.8	$0.0	$11.1	$2.1	$0.0	$0.0	$0.0	$0.0	$0.0
999200	State Governments	$396.0	$6.0	$16.1	$324.3	$0.3	$2.8	$42.7	$3.4	$0.2	$0.0	$0.2	$0.0
999300	Local Governments	$1,945.6	$3.6	$78.9	$1,598.3	$7.3	$25.1	$160.3	$62.5	$3.5	$0.0	$2.4	$3.8
	Total	**$21,757.25**	**$1,568.48**	**$564.23**	**$11,682.52**	**$1,321.55**	**$1,468.81**	**$1,719.09**	**$1,248.34**	**$865.76**	**$633.83**	**$626.70**	**$57.93**

Note: Excludes self-employed workers.

Source: OSHA, Directorate of Standards and Guidance, Office of Regulatory Analysis, based on OSHA (2016).

Table V-44

Estimated Total Value of Silica Activities, by Construction Industry and Task Area ($millions)

NAICS	Industry	Total	Rock and concrete drillers	Heavy construction equipment operators - I	Heavy construction equipment operators - II	Tuck pointers and grinders (hand-held)	Hole drillers using hand-held drills	Jack-hammers	Millers using portable or mobile machines	Masonry cutters using portable saws - I	Masonry cutters using portable saws - II	Masonry cutters using stationary saws	Rock crushing machine operators and tenders
236100	Residential Building Construction	$1,300.28	$0.00	$11.38	$369.38	$56.80	$179.82	$214.53	$52.24	$43.58	$354.38	$18.16	$0.00
236200	Nonresidential Building Construction	$2,408.34	$0.00	$43.70	$1,413.51	$123.42	$137.87	$240.89	$118.85	$78.73	$219.87	$31.50	$0.00
237100	Utility System Construction	$8,424.76	$2,099.28	$179.97	$5,750.06	$26.77	$45.36	$272.60	$49.79	$0.68	$0.00	$0.25	$0.00
237200	Land Subdivision	$184.62	$0.00	$5.24	$166.14	$1.51	$0.76	$8.28	$2.69	$0.00	$0.00	$0.00	$0.00
237300	Highway, Street, and Bridge Construction	$5,193.37	$59.02	$139.56	$4,408.90	$83.76	$16.25	$198.57	$262.06	$2.71	$0.00	$0.97	$21.57
237900	Other Heavy and Civil Engineering Construction	$1,460.94	$107.12	$38.09	$1,224.08	$7.24	$6.11	$60.52	$17.21	$0.44	$0.00	$0.14	$0.00
238100	Foundation, Structure, and Building Exterior Contractors	$4,114.02	$0.00	$23.00	$726.22	$842.91	$79.01	$210.77	$567.34	$1,029.19	$128.74	$506.84	$0.00
238200	Building Equipment Contractors	$1,716.66	$38.28	$20.00	$673.68	$5.06	$863.72	$91.68	$5.40	$3.83	$12.69	$2.33	$0.00
238300	Building Finishing Contractors	$780.94	$0.00	$1.02	$31.57	$70.17	$101.69	$70.39	$41.60	$129.47	$206.56	$49.07	$79.39
238900	Other Specialty Trade Contractors	$10,105.15	$615.53	$255.71	$8,322.55	$168.75	$17.33	$295.87	$324.47	$36.96	$26.84	$14.89	$26.25
221100	Electric Utilities	$381.94	$17.63	$10.28	$340.45	$0.00	$11.28	$2.30	$0.00	$0.00	$0.00	$0.00	$0.00
999200	State Governments	$869.43	$11.23	$25.06	$778.44	$0.29	$2.85	$46.90	$4.20	$0.28	$0.00	$0.19	$0.00
999300	Local Governments	$4,267.73	$6.81	$122.41	$3,836.36	$7.69	$25.43	$176.17	$76.16	$5.32	$0.00	$2.36	$9.02
	Total	**$41,208.17**	**$2,954.90**	**$875.41**	**$28,041.34**	**$1,394.36**	**$1,487.48**	**$1,889.46**	**$1,521.99**	**$1,331.20**	**$949.09**	**$626.70**	**$136.24**

Note: Excludes self-employed workers

Source: OSHA, Directorate of Standards and Guidance, Office of Regulatory Analysis, based on OSHA (2016).

Aggregate Control Costs in Construction to Comply with Table 1 or the New PEL

For the final rule, OSHA revised Table 1 to include separate engineering control and respirator requirements for tasks indoors or in enclosed areas ("indoor tasks") to provide a means of exhaust as needed to minimize the accumulation of visible airborne dust. As a result, indoor tasks will have an additional cost to reflect use of control equipment (e.g., a fan or "blower")[62] providing a means of exhaust as needed to minimize the accumulation of visible airborne dust. These additional indoor costs were included in Table V-34. However, to properly reflect these costs in the aggregate control costs in construction, OSHA had to add an additional methodological step. OSHA's Office of Technological Feasibility helped to develop estimates of the distribution of silica-related work disaggregated by the type of control equipment used, the duration of the task, and the location of the task (i.e., indoors or outdoors). The resulting distribution of silica-related work, which is later used to weight costs by the percentage of tasks performed indoors or outdoors, is displayed in Table V-45.

To derive estimates in Table V-46 of aggregate incremental compliance costs to meet the final Table 1, the total value of construction work using the specified equipment and requiring controls (in Table V-44) was multiplied by the percentage of incremental cost associated with the controls required for each equipment category (in Tables V-36a and V-36b), weighted by the percentage of work using each type of equipment performed outdoors and indoors (in Table V-45), and reduced by the percentage of baseline compliance.

Using the equipment category "hole drilling using handheld or stand-mounted drills" as an example, projects requiring additional engineering controls are estimated in Table V-36a to incur a 3.7 percent increase in total costs. As shown in Table V-44, the total annual value of the work done drilling holes using handheld or stand-mounted drills is estimated to be $179.82 million per year in the residential building construction industry (NAICS 2361). Baseline compliance is estimated to be 23.04 percent—derived from 52.4 percent of workers engaged in this task who are currently exposed below the PEL of 50 $\mu g/m^3$ (from Table III-8 in Chapter III of this FEA) multiplied by 44 percent baseline compliance for workers already below the PEL. After adjusting for baseline compliance, the annual incremental cost of silica controls in this industry is estimated to be $5.1 million (3.72% x (100% - 23.04%) x $179.82 million) as shown in Table V-46. Any construction work done using the specified equipment and involving both outdoor and indoor work (e.g., masonry and concrete cutters using portable saws-I) would be estimated in a similar fashion, but would have the added steps of compliance cost increases from both Tables V-36a and V-36b, weighted by the relative frequency of outdoor/indoor work locations from Table V-45.

OSHA performed this type of calculation for each construction work using equipment from each specified equipment category and NAICS industry code. As indicated in Table V-46, OSHA estimates that the incremental compliance costs for engineering controls (excluding tunnel boring and abrasive blasting) will total $386.4 million for construction work performed using the specified equipment affected by the final standard.

[62] Specifically, the FEA in Table V-32 estimates a cost of an electric blower (1,277 cfm) and 25 ft. of duct to reach the outside. Note that any additional respirator use required for indoor activities is addressed in a separate section.

As shown in Table V-46, the largest share of annualized engineering control costs, roughly 19 percent, is forecast for the tuckpointers and grinders equipment category ($74.7 million), while jackhammers and other handheld powered chipping tools and heavy equipment operators and ground crew laborers-II are expected to incur the next highest engineering control costs ($68.3 million and $67.4 million, respectively). Examining incremental control costs by NAICS industry for the new PEL of 50 μg/m^3, OSHA estimates that foundation, structure, and building exterior contractors (NAICS 2381) will incur the highest costs of any NAICS industry at $94.0 million per year. Other specialty trade contractors (NAICS 2389) and utility system construction (NAICS 2371) are also expected to incur sizable control costs to comply with the new Table 1 requirements ($63.1 million and $58.8 million, respectively). Almost half of the engineering control costs borne by foundation, structure, and building exterior contractors will involve work done using tuckpointers and grinders, whereas for other specialty trade contractors and utility system contractors, the equipment categories that accounted for the largest share of engineering control costs were, respectively, heavy construction equipment operators -II and rock and concrete drillers.

Table V-45

Distribution of Silica Work by Construction Task Area/Equipment Category, Duration, and Location

Task Area/Equipment Category	Equipment Use Shares	Indoors Share	Outdoor Share	<4 Hours Share	<4 Hours Share	Total Distribution of Work			
						Indoors		Outdoor	
						<4 hrs	>4hrs	<4 hrs	>4hrs
Rock and Concrete drillers									
Vehicle-mounted dowel drilling rigs for concrete	10.0%	0.0%	100.0%	20.0%	80.0%	0.0%	0.0%	2.0%	8.0%
Rig-mounted core drills	60.0%	0.0%	100.0%	20.0%	80.0%	0.0%	0.0%	12.0%	48.0%
Vehicle-mounted drilling rigs for rock	30.0%	0.0%	100.0%	20.0%	80.0%	0.0%	0.0%	6.0%	24.0%
Total	100.0%	0.0%	100.0%	20.0%	80.0%	0.0%	0.0%	20.0%	80.0%
Heavy construction equipment operators - I (demolition, abrading, fracturing)									
Heavy equip used in demolition of concrete or masonry structures	100.0%	5.0%	95.0%	10.0%	90.0%	0.5%	4.5%	9.5%	85.5%
Heavy construction equipment operators - II (earthmoving)									
Heavy equip used in earth moving tasks	100.0%	0.0%	100.0%	10.0%	90.0%	0.0%	0.0%	10.0%	90.0%
Tuck pointers and grinders (hand-held)									
Handheld grinders or motor removal while tuckpointing	25.0%	65.0%	35.0%	75.0%	25.0%	12.2%	4.1%	6.6%	2.2%
Handheld grinders for other uses	75.0%	75.0%	25.0%	75.0%	25.0%	42.2%	14.1%	14.1%	4.7%
Total	100.0%	72.5%	27.5%	75.0%	25.0%	54.4%	18.1%	20.6%	6.9%
Hole drillers using hand-held or stand-mounted drills									
Hand drills or rotary hammers	100.0%	0.0%	100.0%	50.0%	50.0%	0.0%	0.0%	50.0%	50.0%
Jackhammers and other powered chipping tools									
Hand-operated jackhammers, chipping hammers, and impact drills	100.0%	55.0%	45.0%	60.0%	40.0%	33.0%	22.0%	27.0%	18.0%

Table V-45 (continued)

Distribution of Silica Work by Construction Task Area/Equipment Category, Duration, and Location

Task Area/Equipment Category	Equipment Use Shares	Indoors Share	Outdoor Share	<4 Hours Share	<4 Hours Share	Total Distribution of Work			
						Indoors		Outdoor	
						<4 hrs	>4hrs	<4 hrs	>4hrs
Millers using portable or mobile machines									
Walk-behind milling machines and floor grinders (wet methods)	40.0%	25.0%	75.0%	50.0%	50.0%	5.0%	5.0%	15.0%	15.0%
Walk-behind milling machines and floor grinders (dust collection)	40.0%	25.0%	75.0%	50.0%	50.0%	5.0%	5.0%	15.0%	15.0%
Small driven milling machines (less than half lane)	10.0%	0.0%	100.0%	25.0%	75.0%	0.0%	0.0%	2.5%	7.5%
Milling machines (half lane or wider) – (water or water with surfactant)	10.0%	0.0%	100.0%	50.0%	50.0%	0.0%	0.0%	5.0%	5.0%
Total	100.0%	20.0%	80.0%	47.5%	52.5%	10.0%	10.0%	37.5%	42.5%
Masonry cutters using portable saws - I				.					
Handheld power saws	80.0%	50.0%	50.0%	50.0%	50.0%	20.0%	20.0%	20.0%	20.0%
Walk behind saws	10.0%	50.0%	50.0%	50.0%	50.0%	2.5%	2.5%	2.5%	2.5%
Drivable or ride-on concrete saw	10.0%	0.0%	100.0%	25.0%	75.0%	0.0%	0.0%	2.5%	7.5%
Total	100.0%	45.0%	55.0%	47.5%	52.5%	22.5%	22.5%	25.0%	30.0%
Masonry cutters using portable saws - II									
Handheld power saws (blade diameter 8" or less) [for cement fiber board]	100.0%	0.0%	100.0%	50.0%	50.0%	0.0%	0.0%	50.0%	50.0%
Masonry cutting using stationary saws									
Stationary masonry saws	100.0%	0.0%	100.0%	50.0%	50.0%	0.0%	0.0%	50.0%	50.0%
Rock-crushing machine operators and tenders									
Crushing machines	100.0%	0.0%	100.0%	25.0%	75.0%	0.0%	0.0%	25.0%	75.0%

Source: OSHA, Directorate of Standards and Guidance, Office of Regulatory Analysis, based on OSHA (2016).

Table V-46

Estimated Annualized Control Costs for Table 1 Silica Activities, by Construction Industry and Task Area ($millions) [No Self-employment Covered]

NAICS	Industry	Total	Rock and concrete drillers	Heavy construction equipment operators - I	Heavy construction equipment operators - II	Tuck pointers and grinders (hand-held)	Hole drillers using hand-held drills	Jackhammers and other powered chipping tools	Millers using portable or mobile machines	Masonry cutters using portable saws – I	Masonry cutters using portable saws - II	Masonry cutters using stationary saws	Rock crushing machines and tenders
236100	Residential Building Construction	$22.7	$0.0	$0.3	$0.9	$3.0	$5.1	$7.8	$1.0	$0.7	$3.5	$0.3	$0.0
236200	Nonresidential Building Construction	$30.2	$0.0	$1.3	$3.4	$6.6	$3.9	$8.7	$2.3	$1.2	$2.2	$0.5	$0.0
237100	Utility System Construction	$58.8	$25.9	$5.5	$13.8	$1.4	$1.3	$9.8	$1.0	$0.0	$0.0	$0.0	$0.0
237200	Land Subdivision	$1.0	$0.0	$0.2	$0.4	$0.1	$0.0	$0.3	$0.1	$0.0	$0.0	$0.0	$0.0
237300	Highway, Street, and Bridge Construction	$32.9	$0.7	$4.3	$10.6	$4.5	$0.5	$7.2	$5.1	$0.0	$0.0	$0.0	$0.1
237900	Other Heavy and Civil Engineering Construction	$8.5	$1.3	$1.2	$2.9	$0.4	$0.2	$2.2	$0.3	$0.0	$0.0	$0.0	$0.0
238100	Foundation, Structure, and Building Exterior Contractors	$94.0	$0.0	$0.7	$1.7	$45.2	$2.3	$7.6	$11.0	$16.3	$1.3	$7.9	$0.0
238200	Building Equipment Contractors	$31.3	$0.5	$0.6	$1.6	$0.3	$24.7	$3.3	$0.1	$0.1	$0.1	$0.0	$0.0
238300	Building Finishing Contractors	$15.2	$0.0	$0.0	$0.1	$3.8	$2.9	$2.5	$0.8	$2.0	$2.1	$0.8	$0.2
238900	Other Specialty Trade Contractors	$63.1	$7.6	$7.8	$20.0	$9.0	$0.5	$10.7	$6.3	$0.6	$0.3	$0.2	$0.1
221100	Electric Utilities	$1.8	$0.2	$0.3	$0.8	$0.0	$0.3	$0.1	$0.0	$0.0	$0.0	$0.0	$0.0
999200	State Governments	$4.7	$0.1	$0.8	$1.9	$0.0	$0.1	$1.7	$0.1	$0.0	$0.0	$0.0	$0.0

999300	Local Governments	$22.2	$0.1	$3.7	$9.2	$0.4	$0.7	$6.4	$1.5	$0.1	$0.0	$0.0	$0.0
	Total	**$386.4**	**$36.5**	**$26.7**	**$67.4**	**$74.7**	**$42.6**	**$68.3**	**$29.5**	**$21.1**	**$9.5**	**$9.8**	**$0.4**

Source: OSHA, Directorate of Standards and Guidance, Office of Regulatory Analysis, based on OSHA (2016).

Control Costs for Construction Tasks Not Under Table 1

Abrasive Blasting

In the PEA, OSHA estimated that some abrasive blasting crews were not currently using all feasible engineering controls and added costs for wet methods for them to achieve the proposed PEL. OSHA did not receive comments on the PEA estimates of engineering control costs for abrasive blasting crews and has retained the same methodology to estimate costs for this FEA.

Consistent with what was done in the PEA, Table V-47a presents the unit costs and analytical assumptions applied in OSHA's cost analysis of controlling silica exposures during abrasive blasting operations. As shown in the table, after accounting for the number of affected workers, crew size, daily output, blasting cost per square foot, number of blasting days per year, and the percentage of crews using sand, OSHA estimates that baseline annual costs for sand blasting total $126.7 million. As in the PEA, ERG estimated that the incremental cost for wet blasting is 30 percent of baseline costs and that 50 percent of crews currently use wet methods. Therefore, the annual costs to comply with the final standard by using wet methods during sand blasting are expected to total $19.0 million, or $2,366 per worker for the approximately 8,033 workers exposed to silica dust.

Distributing these annualized costs by industry, OSHA estimates that employers in NAICS 238200, Building Finishing Contractors, will incur compliance costs of $12.1 million annually, while firms in NAICS 238900, Other Specialty Trade Contractors, will incur compliance costs of $6.9 million annually.

Table 47a

Engineering Costs for Abrasive Blasting Operations in Construction

Numbers of workers in blasting operations with exposures >50 μg/m^3			
238300	Building Finishing Contractors	5,124	
238900	Other Specialty Trade Contractors	2,909	
	Total	8,033	
Blasting crew size		4	ERG estimate based on Means, 2008
Ouput per day (square ft.)		1,500	ERG estimate based on Means, 2008
Blasting cost per square foot (dry blasting)		$2.10	ERG estimate based on Means, 2008; inflated to 2012
Blasting days per year		100	ERG estimate
Percent of blasting crews using sand		20.0%	ERG estimate
Annual costs of sand blasting		$126,723,549	
Incremental cost for wet blasting		30.0%	ERG estimate based on Means, 2008
Share of blasting currently with wet methods		50.0%	ERG estimate
Cost of requiring all sand blasting to use wet methods		$19,008,532	
Cost per blasting worker		$2,366	
Costs by Industry			
238300	Building Finishing Contractors	$12,125,288	
238900	Other Specialty Trade Contractors	$6,883,244	

Sources: ERG, 2007; U.S. Census Bureau, County Business Patterns, 2012; RS Means, Heavy Construction Cost Data, 2008

Tunnel Boring

Tunnel boring is not included on Table 1 of the final rule. An employer engaged in tunnel boring must comply with the PEL of 50 μg/m^3 specified in §1926.1153(d). Employers in tunnel boring must already comply with the ventilation and dust suppressant requirements in subpart S of Part 1926 (Underground construction), which would have allowed those employers to meet the previous PEL of 250 μg/m^3. Therefore, OSHA calculates the additional controls necessary to reduce exposures from the preceding PEL to the new PEL of 50 μg/m^3.

In most cases, employers are able to reduce exposures to the preceding PEL by providing suction at the drill head, removing the dust as soon as it is generated. The technological feasibility chapter of this FEA demonstrates that employers can do so by extending the existing suction controls as the drill head progresses. There are limits on these extensions, however, and the amount of worker exposure can increase if the suction is not extended frequently enough to keep it at the drill head. This extension does not require additional machinery, but it is likely to require the employer to invest more labor time to extend the suction device more frequently to meet the new PEL than previously necessary to meet the preceding PEL. The Agency has estimated in Table V-47b the control costs for tunnel boring using the same cost methodology applied in the PEA (see Tables V-21 and V-24 in the PEA) to calculate the incremental cost as a percentage of baseline control costs (0.013 percent). The rest of the calculations in Table V-47b reflect 2012 data on the number of affected FTE tunnel workers and 2012 hourly wage rates. The resulting estimate of annualized incremental control costs for tunnel boring is about 0.02 million.

Table V-48 of the FEA just adds the abrasive blasting and tunnel boring control costs in construction above to the control costs for Table 1 tasks presented in Table V-46.

Table V-47b Estimated Annualized Control Costs for Underground Tunneling Workers

Representative Job description		Tunnel construction, bored tunnels, including mucking; 20' in diameter, rock excavation (average cost; assumes 100 feet/day)	
Daily Costs [a]		Cost	Share
	Labor	$16,125	15.00%
	Equipment	$91,375	85.00%
	Total	$107,500	100.00%
Control measure		Supplemental spray points in dust control system: Install 3 additional spray points on material handling equipment.	
Daily control cost [b]		$13.96	
Incremental control cost		0.013%	
FTE Tunnel workers [c]		2,067	
Hourly labor rate per worker (including fringes) [d]		$25.36	
Annual labor value of tunneling tasks ($M)		$114.8	
Total value of tunneling work ($M)		$765.3	
Percent needing controls		22.22%	
Incremental control costs ($M)		$0.02	

[a] RS Means, 2008.

[b] Assumes 150 working days a year

[c] OSHA estimate.

[d] BLS Occupational Employment Statistics Survey, 2012b.

NAICS	Industry	Total	Rock and concrete drillers	Heavy construction equipment operators - I	Heavy construction equipment operators - II	Tuck pointers and grinders (hand-held)	Hole drillers using held-held drills	Jack-hammers	Millers using portable or mobile machines	Masonry cutters using portable saws - I	Masonry cutters using portable saws - II	Masonry cutters using stationary saws	Rock crushing machine operators and tenders	Under-ground tunnel work	Abrasive blasting
236100	Residential Building Construction	$22.7	$0.0	$0.3	$0.9	$3.0	$5.1	$7.8	$1.0	$0.7	$3.5	$0.3	$0.0	$0.00	$0.00
236200	Nonresidential Building Construction	$30.2	$0.0	$1.3	$3.4	$6.6	$3.9	$8.7	$2.3	$1.2	$2.2	$0.5	$0.0	$0.00	$0.00
237100	Utility System Construction	$58.8	$25.9	$5.5	$13.8	$1.4	$1.3	$9.8	$1.0	$0.0	$0.0	$0.0	$0.0	$0.00	$0.00
237200	Land Subdivision	$1.0	$0.0	$0.2	$0.4	$0.1	$0.0	$0.3	$0.1	$0.0	$0.0	$0.0	$0.0	$0.00	$0.00
237300	Highway, Street, and Bridge Construction	$32.9	$0.7	$4.3	$10.6	$4.5	$0.5	$7.2	$5.1	$0.0	$0.0	$0.0	$0.1	$0.02	$0.00
237900	Other Heavy and Civil Engineering Construction	$8.5	$1.3	$1.2	$2.9	$0.4	$0.2	$2.2	$0.3	$0.0	$0.0	$0.0	$0.0	$0.00	$0.00
238100	Foundation, Structure, and Building Exterior Contractors	$94.0	$0.0	$0.7	$1.7	$45.2	$2.3	$7.6	$11.0	$16.3	$1.3	$7.9	$0.0	$0.00	$0.00
238200	Building Equipment Contractors	$31.3	$0.5	$0.6	$1.6	$0.3	$24.7	$3.3	$0.1	$0.1	$0.1	$0.0	$0.0	$0.00	$0.00
238300	Building Finishing Contractors	$27.3	$0.0	$0.0	$0.1	$3.8	$2.9	$2.5	$0.8	$2.0	$2.1	$0.8	$0.2	$0.00	$12.13
238900	Other Specialty Trade Contractors	$70.0	$7.6	$7.8	$20.0	$9.0	$0.5	$10.7	$6.3	$0.6	$0.3	$0.2	$0.1	$0.00	$6.88
221100	Electric Utilities	$1.8	$0.2	$0.3	$0.8	$0.0	$0.3	$0.1	$0.0	$0.0	$0.0	$0.0	$0.0	$0.00	$0.00
999200	State Governments	$4.7	$0.1	$0.8	$1.9	$0.0	$0.1	$1.7	$0.1	$0.0	$0.0	$0.0	$0.0	$0.00	$0.00
999300	Local Governments	$22.2	$0.1	$3.7	$9.2	$0.4	$0.7	$6.4	$1.5	$0.1	$0.0	$0.0	$0.0	$0.00	$0.00
	Total	**$405.5**	**$36.5**	**$26.7**	**$67.4**	**$74.7**	**$42.6**	**$68.3**	**$29.5**	**$21.1**	**$9.5**	**$9.8**	**$0.4**	**$0.02**	**$19.01**

Source: OSHA, Directorate of Standards and Guidance, Office of Regulatory Analysis, based on OSHA (2016).

Adjustment for Self-Employed Workers on a Multi-employer Worksite

The OSH Act provides authority for OSHA to regulate employers for the protection of their employees. Because sole proprietors without employees, referred to as "self-employed workers" for the purposes of this discussion, are not "employers" under the Act, OSHA cannot require them to comply with the silica standard. On a multi-employer worksite, however, their silica activities could expose employees protected by the Act to respirable crystalline silica.

Employers must still protect their employees from exposure to silica in accordance with the standard, whether it is generated by work performed by their own employees or by the work performed by a sole proprietor not regulated by the Act (see the summary and explanation of the written exposure control plan requirements in paragraph §1926.1153(g)(1)(iv)). Under OSHA's multi-employer citation policy (CPL 02-00-124), employers of workers who may be exposed to silica are considered "exposing employers" who have a duty to protect their employees, even from hazards they do not correct themselves. However, the controlling employer, the employer in overall charge of the worksite or project, also has a duty to exercise reasonable care to prevent and detect violations of the silica standard on the multi-employer worksite. The silica standard does not limit the means by which either employer may fulfill this duty, and in many cases the issue may be resolved if the work schedule does not place the self-employed worker in the same area of the worksite at the same time as employees, thereby avoiding the need for additional measures.

As discussed in Chapter III of the FEA, CISC requested that the Agency account for the costs arising from self-employed workers separately based on the theory that self-employed workers will use the controls necessary to comply with Table 1 to reduce exposures to others when working on a multi-employer worksite where employees are present (Document ID 4217, p. 80). CISC identified several reasons why this might happen, including self-interested recognition of "Table 1 specifications as the safe way to perform their work"; demands by construction general contractors that anyone working on their site, whether self-employed or not, conform to regulatory requirements; and demands by nearby employers that their employees "not suffer increased silica exposures from inappropriate practices by self-employed workers."

While these are not costs that OSHA typically includes in its analysis, OSHA recognizes that Table 1 is unique among OSHA standards, and that it is possible that controlling employers on a multi-employer construction worksite may assume some costs of engineering controls—either by providing the controls or by reimbursing the self-employed persons for the costs of the controls through increased fees—when they cannot resolve the issue through simple scheduling choices. Therefore, OSHA is estimating the additional cost of the engineering controls in that scenario.

In order to estimate the number of self-employed persons in construction, CISC's contractor, Environomics, Inc., did the following:

> The U.S. Census Bureau, in Revised 2008 Nonemployer Statistics Reflecting 2009 Methodology Changes, provides information on the number of self-employed individuals ("nonemployers") working in each of the 4-digit construction industries (total of 2.52 million self-employed construction workers), but no further information on the occupations of these self-employed workers. In order to estimate the number of self-employed workers in each of the various at-risk construction occupations that OSHA identified and that we added, we simply assumed that these 2.52 million "nonemployers" are distributed among occupations within each construction NAICS in the same proportion as employed workers are distributed among occupations within the NAICS (Document ID 4217, p. 80).

Note that the Census data that Environomics used provides detail on self-employed persons by 4-digit NAICS construction industries but not by occupation. Hence, in the absence of occupational data, Environomics simply assumed that the number of self-employed persons by occupation was proportional to the number of employees by occupation—which implies that the ratio of the number of self-employed persons to employees was the same for each occupation. Using this database and approach, Environomics estimated that the ratio of self-employed persons to employees for all occupations affected by the rule was 40.1 percent (1,811,009 self-employed relative to 4,519,889 employees). Based on the full-time-equivalent (FTE) number of workers—which, in OSHA's estimation methodology, determines the amount of engineering control equipment used— Environomics calculated that the ratio of FTE self-employed persons to FTE employees for all occupations affected by the rule was 35.7 percent.

Having reviewed the Environomics self-employment analysis, the Agency has concluded that the occupation of the self-employed persons is a much more relevant factor for estimating costs than the 4-digit construction industry in which self-employed persons work. Therefore, for its analysis, OSHA has chosen to rely on data from the 2013 BLS Current Population Survey, with the goal of estimating the ratio of the number of self-employed persons to the number of employees by occupation. Table V-49 below presents data from the 2013 BLS Current Population Survey (BLS, 2013) with the focus on the ratio of the self-employed to the non-self-employed (i.e., employees).[63] Note that this table includes many occupations that do not involve silica exposure (e.g., boilermakers, paperhangers, glaziers) and others that are not covered by OSHA (e.g., mining machine operators; roof bolters, mining—covered by MSHA).

[63] The absolute number of self-employed and employed in construction by occupation from this survey is not, itself, relevant for this analysis. What matters is the ratio of self-employed to non-self-employed in construction where the estimates of both types of workers are derived from a single source.

Table V-49

Self-Employment in Construction Occupations

Occ. Code	Occupation	Workers in All Construction Occupations [a] Self-employed	Non-Self-Employed	Total	Ratio of Self-Employed to Non-Self-Employed
47-1011	First-Line Supervisors of Construction Trades and Extraction Workers	114,000	517,000	631,000	22.1%
47-2010	Boilermakers	0	18,000	18,000	0.0%
47-2021; 47-2022	Brickmasons, Blockmasons, and stonemasons	26,000	104,000	130,000	25.0%
47-2031	Carpenters	375,000	789,000	1,164,000	47.5%
47-2040	Carpet, Floor, and Tile Installers and Finishers	47,000	95,000	142,000	49.5%
47-2051	Cement Masons and Concrete Finishers (including terrazzo workers)	2,000	50,000	52,000	4.0%
47-2061	Construction Laborers	298,000	1,238,000	1,536,000	24.1%
47-2071	Paving, Surfacing, and Tamping Equipment Operators	2,000	20,000	22,000	10.0%
47-2072	Pile-Driver Operators	0	1,000	1,000	0.0%
47-2073	Operating Engineers and Other Construction Equipment Operators	25,000	327,000	352,000	7.6%
47-2081; 47-2082	Drywall, Ceiling Tile Installers, and Tapers	28,000	98,000	126,000	28.6%
47-2111	Electricians	81,000	649,000	730,000	12.5%
47-2121	Glaziers	4,000	33,000	37,000	12.1%
47-2131; 47-2132	Insulation Workers, Insulation Workers, Floor, Ceiling, Mechanical and Wall	2,000	48,000	50,000	4.2%
47-2141	Painters, Construction and Maintenance	171,000	346,000	517,000	49.4%
47-2142	Paperhangers	2,000	0	2,000	NA
47-2150	Pipelayers, Plumbers, Pipefitters, and Steamfitters	78,000	475,000	553,000	16.4%
47-2161	Plasterers and Stucco Masons	3,000	24,000	27,000	12.5%
47-2171	Reinforcing Iron and Rebar Workers	0	9,000	9,000	0.0%
47-2181	Roofers	29,000	174,000	203,000	16.7%
47-2211	Sheet Metal Workers	9,000	104,000	113,000	8.7%
47-2221	Structural Iron and Steel Workers	2,000	47,000	49,000	4.3%
47-2231	Solar Photovoltaic Installers	1,000	4,000	5,000	25.0%
47-3011; 47-3012	Helpers--Brickmasons, Blockmasons, Carpenters, Stonemasons, and Tile and Marble Setters	6,000	57,000	63,000	10.5%
47-4011	Construction and Building Inspectors	20,000	81,000	101,000	24.7%

Table V-49 (continued)

Self-Employment in Construction Occupations

Occ. Code	Occupation	Workers in All Construction Occupations [a] Self-employed	Non-Self-Employed	Total	Ratio of Self-Employed to Non-Self-Employed
47-4021	Elevator Installers and Repairers	1,000	23,000	24,000	4.3%
47-4031	Fence Erectors	9,000	26,000	35,000	34.6%
47-4041	Hazardous Materials Removal Workers	1,000	31,000	32,000	3.2%
47-4051	Highway Maintenance Workers	1,000	96,000	97,000	1.0%
47-4061	Rail-Track Laying and Maintenance Equipment Operators	0	13,000	13,000	0.0%
47-4071	Septic Tank Servicers and Sewer Pipe Cleaners	0	10,000	10,000	0.0%
47-4090	Miscellaneous Construction and Related Workers	3,000	26,000	29,000	11.5%
47-5011	Derrick Operators, Oil and Gas	0	43,000	43,000	0.0%
47-5021	Earth Drillers, Except Oil and Gas	5,000	28,000	33,000	17.9%
47-5031	Explosives Workers, Ordnance Handling Experts, and Blasters	0	8,000	8,000	0.0%
47-5040	Mining Machine Operators	0	58,000	58,000	0.0%
47-5061	Roof Bolters, Mining	0	3,000	3,000	0.0%
47-5071	Roustabouts, Oil and Gas	0	12,000	12,000	0.0%
47-5081	Helpers--Extraction Workers	0	3,000	3,000	0.0%
47-5099	Extraction Workers, All Other	4,000	91,000	95,000	4.4%
51-9021	Crushing, Grinding, and Polishing Machine Setters, Operators, and Tenders	0	87,000	87,000	0.0%
53-7032	Excavating and Loading Machine and Dragline Operators	9,000	31,000	40,000	29.0%
	Totals	**1,358,000**	**5,897,000**	**7,255,000**	**23.0%**

[a] Source: BLS (2013). These employment estimates are based on a household survey and include individuals working in construction as well as non-construction industries. Self-employment statistics by occupation and industry are not available.

Table V-50 presents the same data as shown in Table V-49, but restricted to just those occupations where OSHA estimated that workers are potentially exposed to hazardous levels of respirable crystalline silica. One thing that is immediately obvious in this table is the very wide variation from occupation to occupation in the ratio of the self-employed to the employed, with the ratio ranging from 0 percent to 47.53 percent. This wide variation is clearly incompatible with the assumption made by Environomics that the ratio of the number of self-employed to employees is the same for all occupations. Table V-50 also shows that average ratio of self-employed to employees over all construction occupations involving silica exposure (when the ratio is allowed to vary by occupation) is 22.82 percent when weighted by the number of employees (as compared to 40.1 percent as estimated by Environomics).

As noted above, in OSHA's methodology, the amount of engineering control equipment used is based on the FTE number of workers. In Table V-51, OSHA multiplied the FTE rate for each occupation (from Tables V-38a and V-38b) by the number of self-employed workers and employees in that occupation (from Table V-48). As shown in Table V-51, there are an estimated 69,461 FTE self-employed workers in at-risk occupations, relative to the total of 377,913 FTE employees in at-risk occupations. In other words, the number of at-risk FTE self-employed workers is 18.38 percent of the number of at-risk FTE employees (as compared to 35.7 percent as estimated by Environomics).

The analysis of the number of self-employed persons conducted by Environomics stopped at this point. However, as OSHA explained in Chapter III of this FEA, self-employed workers are not required to comply with the final rule and are only likely to do so in two situations: (1) where self-employed workers are generating silica dust while working in a multi-employer construction worksite such that their activities could expose the employees of others, and (2) where the host employer (or competent person) is unable to schedule the self-employed worker's activities or location so as to prevent the exposure or overexposure of other, covered workers. The Agency does not have data on the likelihood of either of these two conditions. OSHA judges that self-employed workers work at multi-employer construction sites at the same times as others a minority of their worktime, and work even less frequently within the same area such that covered employees could be exposed. Nevertheless, OSHA is conservatively estimating here that they do so 50 percent of the time. OSHA also judges that the host contractor (with the assistance of the competent person) would be able to schedule the self-employed workers' activities or location so as to prevent the exposure or overexposure of other, covered workers a majority of the time. This makes sense because self-employed workers are often used on multi-employer sites because they possess special skills not otherwise available onsite. Therefore, their work frequently could be performed at a different time or location from the other work. In any case, for costing purposes, OSHA is conservatively estimating that the work of self-employed persons cannot be isolated in time or space so as to prevent the exposure or overexposure of other, covered workers 50 percent of the time that those self-employed workers are on the multi-employer worksite.

Based on these estimates, OSHA calculates that only 25 percent of the at-risk work of self-employed workers would meet the conditions in which a host or controlling employer would incur engineering control costs to mitigate the exposures to employees on the site. At the bottom of Table V-51, OSHA has accordingly reduced the number of FTE self-employed workers using equipment to perform silica-dust-producing work relative to the number of FTE at-risk employees to 25 percent of the earlier estimate of 18.38 percent. OSHA therefore concludes that the number of FTE at-risk self-employed workers imposing costs on host employers is equal to 4.60 percent of the number of FTE at-risk employees. This result is shown at the bottom of Table V-51.

Finally, in Table V-52, OSHA increased the estimates of the control costs for work performed using the specified equipment in construction presented in Table V-48 by 4.60 percent to include the engineering control costs that would be incurred by host or controlling employers to control the exposures caused by self-employed workers. This increases the annualized cost of engineering controls needed in construction to comply with the final rule from $405.5 million to $423.4 million.

Table V-50

Self-Employment Statistics

Occ. Code	Occupation	Workers in At-Risk Occupations [a] Self-employed	Non-Self-Employed	Total	Ratio of Self-Employed to Non-Self-Employed
47-1011	First-Line Supervisors of Construction Trades and Extraction Workers	114,000	517,000	631,000	22.05%
47-2021; 47-2022	Brickmasons, Blockmasons, and stonemasons	26,000	104,000	130,000	25.00%
47-2031	Carpenters	375,000	789,000	1,164,000	47.53%
47-2051	Cement Masons and Concrete Finishers (including terrazzo workers)	2,000	50,000	52,000	4.00%
47-2061	Construction Laborers	298,000	1,238,000	1,536,000	24.07%
47-2071	Paving, Surfacing, and Tamping Equipment Operators	2,000	20,000	22,000	10.00%
47-2073	Operating Engineers and Other Construction Equipment Operators	25,000	327,000	352,000	7.65%
47-2111	Electricians	81,000	649,000	730,000	12.48%
47-2150	Pipelayers, Plumbers, Pipefitters, and Steamfitters	78,000	475,000	553,000	16.42%
47-3011; 47-3012	Helpers--Brickmasons, Blockmasons, Carpenters, Stonemasons, and Tile and Marble Setters	6,000	57,000	63,000	10.53%
47-4051	Highway Maintenance Workers	1,000	96,000	97,000	1.04%
47-5021	Earth Drillers, Except Oil and Gas	5,000	28,000	33,000	17.86%
47-5031	Explosives Workers, Ordnance Handling Experts, and Blasters	0	8,000	8,000	0.00%
47-5081	Helpers--Extraction Workers	0	3,000	3,000	0.00%
51-9021	Crushing, Grinding, and Polishing Machine Setters, Operators, and Tenders	0	87,000	87,000	0.00%
53-7032	Excavating and Loading Machine and Dragline Operators	9,000	31,000	40,000	29.03%
	Total	**1,022,000**	**4,479,000**	**5,501,000**	**22.82%**

[a] Source: BLS (2013). These employment estimates are based on a household survey and include individuals working in construction as well as non- construction industries. Self-employment statistics by occupation and industry are not available.

Table V-51

FTE Workers Performing At-Risk Construction Tasks

Occ.. Code	**Occupation**	**FTE rate [a]**	**Self-employed**	**Non-Self-Employed**	**Ratio of Self-Employed to Non-Self-Employed**
47-1011	First-Line Supervisors of Construction Trades and Extraction Workers	5.65%	6,446	29,232	22.05%
47-2021; 47-2022	Brickmasons, Blockmasons, and stonemasons	22.50%	5,850	23,400	25.00%
47-2031	Carpenters	3.33%	12,483	26,263	47.53%
47-2051	Cement Masons and Concrete Finishers (including terrazzo workers)	7.50%	150	3,750	4.00%
47-2061	Construction Laborers	11.92%	35,528	147,597	24.07%
47-2071	Paving, Surfacing, and Tamping Equipment Operators	5.00%	100	1,000	10.00%
47-2073	Operating Engineers and Other Construction Equipment Operators	7.84%	1,959	25,625	7.65%
47-2111	Electricians	1.00%	810	6,490	12.48%
47-2150	Pipelayers, Plumbers, Pipefitters, and Steamfitters	1.00%	780	4,750	16.42%
47-3011; 47-3012	Helpers--Brickmasons, Blockmasons, Carpenters, Stonemasons, and Tile and Marble Setters	22.50%	1,350	12,825	10.53%
47-4051	Highway Maintenance Workers	3.00%	30	2,880	1.04%
47-5021	Earth Drillers, Except Oil and Gas	75.00%	3,750	21,000	17.86%
47-5031	Explosives Workers, Ordnance Handling Experts, and Blasters	66.40%	0	5,312	0.00%
47-5081	Helpers--Extraction Workers	58.82%	0	1,765	0.00%
51-9021	Crushing, Grinding, and Polishing Machine Setters, Operators, and Tenders	75.00%	0	65,250	0.00%
53-7032	Excavating and Loading Machine and Dragline Operators	2.50%	225	775	29.03%
	Total		69,461	377,913	18.38%
		Share in scope of standard			25.00%
		Self-Employment adjustment factor			4.60%

[a] From ERG FTE analysis of in-scope workers. See Tables V-38a and V-38b.

Table V-52

Estimated Annualized Control Costs for All Silica Activities, by Construction Industry and Task Area ($millions) [Self-employment Included]

NAICS	Industry	Total	Rock and concrete drillers	Heavy construction equipment operators - I	Heavy construction equipment operators - II	Tuck pointers and grinders (hand-held)	Hole drillers using held-held drills	Jack-hammers	Millers using portable or mobile machines	Masonry cutters using portable saws - I	Masonry cutters using portable saws - II	Masonry cutters using stationary saws	Rock crushing machine operators and tenders	Underground tunnel work	Abrasive Blasting
236100	Residential Building Construction	$23.7	$0.0	$0.4	$0.9	$3.2	$5.4	$8.1	$1.1	$0.7	$3.7	$0.3	$0.0	$0.00	$0.00
236200	Nonresidential Building Construction	$31.6	$0.0	$1.4	$3.6	$6.9	$4.1	$9.1	$2.4	$1.3	$2.3	$0.5	$0.0	$0.00	$0.00
237100	Utility System Construction	$61.6	$27.2	$5.8	$14.5	$1.5	$1.4	$10.3	$1.0	$0.0	$0.0	$0.0	$0.0	$0.00	$0.00
237200	Land Subdivision	$1.1	$0.0	$0.2	$0.4	$0.1	$0.0	$0.3	$0.1	$0.0	$0.0	$0.0	$0.0	$0.00	$0.00
237300	Highway, Street, and Bridge Construction	$34.5	$0.8	$4.5	$11.1	$4.7	$0.5	$7.5	$5.3	$0.0	$0.0	$0.0	$0.1	$0.02	$0.00
237900	Other Heavy and Civil Engineering Construction	$8.9	$1.4	$1.2	$3.1	$0.4	$0.2	$2.3	$0.3	$0.0	$0.0	$0.0	$0.0	$0.00	$0.00
238100	Foundation, Structure, and Building Exterior Contractors	$98.3	$0.0	$0.7	$1.8	$47.2	$2.4	$8.0	$11.5	$17.0	$1.3	$8.3	$0.0	$0.00	$0.00
238200	Building Equipment Contractors	$32.8	$0.5	$0.6	$1.7	$0.3	$25.8	$3.5	$0.1	$0.1	$0.1	$0.0	$0.0	$0.00	$0.00
238300	Building Finishing Contractors	$28.0	$0.0	$0.0	$0.1	$3.9	$3.0	$2.7	$0.8	$2.1	$2.2	$0.8	$0.2	$0.00	$12.13
238900	Other Specialty Trade Contractors	$72.9	$8.0	$8.2	$20.9	$9.5	$0.5	$11.2	$6.6	$0.6	$0.3	$0.2	$0.1	$0.00	$6.88
221100	Electric Utilities	$1.8	$0.2	$0.3	$0.9	$0.0	$0.3	$0.1	$0.0	$0.0	$0.0	$0.0	$0.0	$0.00	$0.00
999200	State Governments	$4.9	$0.1	$0.8	$2.0	$0.0	$0.1	$1.8	$0.1	$0.0	$0.0	$0.0	$0.0	$0.00	$0.00
999300	Local Governments	$23.2	$0.1	$3.9	$9.6	$0.4	$0.8	$6.7	$1.5	$0.1	$0.0	$0.0	$0.0	$0.00	$0.00
	Total	**$423.4**	**$38.3**	**$28.0**	**$70.5**	**$78.2**	**$44.5**	**$71.4**	**$30.9**	**$22.0**	**$9.9**	**$10.2**	**$0.4**	**$0.02**	**$19.01**

Source: OSHA, Directorate of Standards and Guidance, Office of Regulatory Analysis, based on OSHA (2016).

Respiratory Protection Costs

This section presents OSHA's estimate of the costs for construction employers to comply with the respiratory protection requirements of the final rule. Contained below is an overview of the estimated costs associated with respirator use presented in the PEA, comments received on the preliminary estimates and OSHA's response to those comments, the changes made in this FEA, and finally the estimated costs associated with respirator use as required by the final rule.

PEA Estimates of Respiratory Protection Costs

In the PEA, employers in the construction sector whose workers were exposed to respirable silica above the proposed PEL were assumed to adopt the appropriate task-specific engineering controls and, where required, respirators prescribed in Table 1 and paragraph (g)(1) in the proposed standard.

In developing the estimates of respirator costs for the PEA, respirator requirements were identified for each of the tasks evaluated in the engineering control cost analysis. Where respirator requirements varied among different control methods that could be used for a given task, the respirator type associated with the most commonly selected control method was used. Respirator costs by Table 1 task were calculated assuming 4 hours or less of use for 50 percent of workers and more than 4 hours of use for the other 50 percent of workers. The annualized cost per worker, derived by ERG in an earlier respirator study conducted for OSHA (ERG, 2003), was estimated to be $570 per year (in 2009 dollars) to use a half-mask nonpowered air-purifying respirator and $638 per year (in 2009 dollars) to use a full-face nonpowered air-purifying respirator. These unit costs reflected the annualized cost of respirator use, including accessories (e.g., filters), training, fit testing, and cleaning.

OSHA utilized a baseline compliance rate of 56 percent based on a NIOSH respirator survey (NIOSH/BLS, 2003) and as calculated in the PEA. Using the annualized unit respirator costs, and accounting for baseline respirator use, the PEA estimated that the cost of respirator use in construction was $80.8 million annually.[64]

[64] Note that these respirator costs did not include the costs of disposable respirators used in regulated areas or as part of an access control plan. The costs for these disposable respirators were separately estimated as part of the costs of a regulated area or an access control plan.

Comments and Responses on PEA Estimate of Respiratory Protection Costs

OSHA received only a few comments on the issue of respirator use in construction and associated costs.

The Interlocking Concrete Pavement Institute (ICPI), whose members include manufacturers of segmental pavement systems and paver installation contractors, estimated that for construction employers, "[a]dditional respirator costs could be up to $1,000 to $2,000 per year per employee, and cost a firm $1,000s per year in total" (Document ID 2246, p. 3). ICPI provided no further data on their method for calculating those costs, such as what elements they considered to be part of the cost of respirator use, how many workers would be using what type of respiratory protection, and the cost of respirators. It is therefore impossible for OSHA to further evaluate ICPI's estimates or to compare them to OSHA's estimates.

The General Contractors Association of New York estimated that a fit test and qualifying medical exam would cost $275 per worker and that respirators would cost $250 per worker per year (Document ID 2314, p. 2). This estimate is in line with OSHA's estimates, which are presented in more detail below.

Kellie Vazquez, with Holes Incorporated, submitted that "with the reduction of the PEL and our historical data, every equipment operator will be required to have a PAPR respirator" and included cost data for OSHA to consider (Document ID 2338, p. 5). Holes Incorporated equipment operators, as OSHA understands it, engage in a variety of silica-related tasks, and the need to wear a respirator depends on the requirements specified in Table 1 for each task. For example, one of Holes Incorporated's tasks, core drilling, would require no respiratory protection if wet methods are used.

In both the PEA and FEA, OSHA estimated respirator use in construction based on Table 1 requirements, which in turn depend on the type of task performed, the duration of the task, and the location of the task (indoors or outdoors). The number of equipment operators requiring respirators under the final rule depends on the tasks that they perform and whether Table 1 requires respirator use for those tasks (type, duration, and location). OSHA has therefore costed respirator use according to the respirator requirements specified in Table 1.

SBAR Panel Comments on Respiratory Protection Costs

A SBREFA commenter questioned how the Agency determined the full-time-equivalent (FTE) number of at-risk construction workers who are exposed above the PEL

(Document ID 0968, p. 18). The PEA noted that aggregate respirator costs were estimated for *all* workers at risk above the proposed PEL, by task and industry. The total number of at-risk workers was derived from estimates in Table 4-9 (full-time equivalent workers by occupation and task) and Table 4-22 (profile of worker exposures to crystalline silica in construction) in ERG (2007a).[65] In the FEA, a similar methodology was used to estimate aggregate respirator costs for all workers—with respirator equipment costs based on FTE usage and respirator fit testing and training costs based on the number of workers engaging in Table 1 tasks that require respirator use. This is shown in Table V-60 later in this section.

Another commenter asserted that the Agency's respirator analysis was based on two incorrect assumptions: (1) a condensed group of FTE employees wear a respirator full-time rather than a larger pool of workers wearing respirators on an intermittent basis; and (2) the respirators are shared among workers who do not perform silica-generating tasks full-time (Document ID 0004, p. 29 of memo). In response to these criticisms, OSHA emphasizes that, in both the PEA and the FEA, estimates of total respiratory protection compliance costs are based on respirators for *all* workers at risk above the PEL of 50 $\mu g/m^3$.[66] Furthermore, as discussed below, OSHA estimates that most workers in construction will use disposable N95 respirators, which are not shared. As indicated above, total respirator equipment costs are based on FTE usage, but, because workers can use disposable N95 respirators, the FTE approach is fully compatible with workers wearing respirators on an intermittent basis. (A small percentage of workers in construction are estimated to wear non-disposable respirators, but those workers would typically be frequent or full-time respirator users who are not expected to share their respiratory protection equipment.) It makes no difference in equipment costs if one worker wears disposable respirators full-time for a year or ten workers wear disposable respirators part-time such that their usage totals one full-time equivalent year of usage. With respect to respirator fit testing and training, however, individual worker usage matters, and OSHA accounts for that by basing fit testing and training costs on the number of workers (not FTEs) engaged in Table 1 tasks that require respirator use.

Final Estimates of Respiratory Protection Costs

Paragraph (e) of this final rule requires that when respiratory protection is required, employers provide each employee an appropriate respirator that complies with the requirements of paragraph (e) and also with 29 CFR 1910.134. This final rule requires respiratory protection where specified by Table 1 (paragraph (c) of the rule) or, for tasks

[65] Total workers at risk above the PEL were referred to as "adjusted full-time-equivalent workers" or "adjusted workers at risk" in ERG (2007a).

[66] This is explained in the note to Table 4-28 in ERG (2007a).

not listed in Table 1 or where the employer does not fully and properly implement the engineering controls, work practices, and respiratory protection described in Table 1, during the installation or implementation of engineering and work practice controls when employees are exposed above the PEL; during tasks, such as certain maintenance and repair tasks, for which engineering and work practice controls are not feasible and employees are exposed above the PEL; and in situations where all feasible engineering and work practice controls have been installed and such controls are not sufficient to reduce exposures to or below the PEL. The final rule also requires, where respirator use is required, that the employer institute a respiratory protection program in accordance with 29 CFR 1910.134.

Changes in Table 1 entries in the final rule have resulted in revised respirator requirements for certain tasks relative to Table 1 in the PEA. These include:

- Stationary masonry saws—The requirement for a half-mask respirator (APF 10) for >4 hours/day was removed.
- Vehicle-mounted drilling rigs for concrete and rock—The requirement for a half-mask respirator (APF 10) for >4 hours/day for concrete was removed.
- Hand-operated jackhammers and chipping hammers—A requirement for a respirator with APF 10 when used indoors or in an enclosed area for ≤4 hours/day was added.
- Handheld grinders for mortar removal—The requirement for respiratory protection was revised from APF 25 to APF 10 for ≤4 hours/day.
- Handheld grinders for uses other than mortar removal—The requirements for a half-mask respirator (APF 10) outdoors and for ≤4 hours/day indoors were removed.
- Walk-behind milling machines and floor grinders—The requirement for a half-mask respirator (APF 10) for >4 hours/day was removed.
- Crushing machines—All requirements for respirators were removed.
- Milling machines – All requirements for respirators were removed.
- Dowel drilling rigs for concrete – New entry in Table 1 with respirator requirement (APF 10).

The methodology for estimating the costs to construction employers of respiratory protection in this FEA is largely similar to the methodology employed in the PEA. OSHA has updated the profile numbers that serve as input to the model (i.e., the number of employees, the number of establishments, and wage rates) and has updated all costs to reflect 2012 dollars. The PEA estimated that, with the exception of workers who are entering regulated areas,[67] all workers in construction who would need respirators with an APF of 10 would use non-disposable, half-face respirators. The FEA, in contrast, estimates that 10 percent of workers needing respirators will use elastomeric half-face respirators and 90 percent will use disposable N95 respirators. That is because the final rule clarifies that both disposable and non-disposable respirators are available with an APF of 10.[68] Where an APF of 25 is required by Table 1, OSHA assumes that an elastomeric full-face respirator will be used.

According to OSHA's Respiratory Protection Standard, employers whose workers are required to wear respirators during the course of their job duties must establish a written respiratory protection program. The required elements are presented earlier in this section as part of the discussion of respiratory protection costs for general industry and maritime employers.

For this FEA, OSHA estimated the costs for developing a respiratory protection program, the costs for annual fit testing, the costs for equipment (which includes the cost for respirators, any necessary accessories, and cleaning where non-disposable respirators are used), and the costs of annual training. The costs for medical clearance required by the Respiratory Protection Standard are included as part of medical surveillance costs, and recordkeeping costs are included in the respirator program costs.

Similar to general industry, OSHA estimates that a human resources manager or equivalent with an hourly wage rate of $74.97 will be responsible for developing the respiratory protection program and providing the appropriate recordkeeping (BLS, 2012b). As in the PEA, the Agency estimates that a large employer with 500 or more employees will take 8 hours to develop this program and provide the appropriate recordkeeping, and employers of all other sizes will take 4 hours. In addition, as in the PEA, OSHA estimates that it will take half as much time (2 hours for small and medium employers and 4 hours for large employers) to review and update the respirator plan (including appropriate recordkeeping), and that 20 percent of establishments will do so in any given year. The unit costs for respiratory protection program development and updating in construction are displayed in Table V-53 below.

[67] The final rule contains no regulated area provisions in construction.

[68] In Table 1 for the proposed construction rule, the stated requirement was for a "half-mask (10)," with "(10)" referring to the APF, while in the final rule the stated requirement is simply for an "APF 10." As a result, in the PEA in support of proposal, the OSHA economists erroneously assumed that disposable N95 respirators would not satisfy the "half-mask (10)" requirement and only estimated costs for non-disposable half-mask respirators.

Table V-53: Respirator Program Unit Costs in Construction

		Establishment Size		
		Small (<20)	**Medium** (20-499)	**Large** (500+)
Respirator users per establishment with respirators		2	4	6
Program development (hours)				
	Hours	4	4	8
	Labor value	$297	$297	$594
Program Updates				
	Hours	2	2	4
	Labor value	$149	$149	$297
Establishments updating program				
	Per year	20.0%	20.0%	20.0%
Compliance rate		56.0%	56.0%	56.0%

Source: OSHA, Directorate of Standards and Guidance, Office of Regulatory Analysis, based on OSHA (2016), and BLS (2012b).

The Respiratory Protection Standard requires that, before a worker is required to use a respirator with a negative or positive pressure tight-fitting facepiece, the employee must be fit-tested with the same make, model, style, and size of respirator that will be used (29 CFR 1926.103, referencing 29 CFR 1910.134). OSHA estimates that qualitative fit testing will be performed by a supervisor on groups of four employees. This fit testing is estimated to take a total of one hour total for each employee and fifteen minutes of a supervisor's time per-employee (one hour divided by the four employees in the group). The total cost per-employee for fit testing in construction is shown below in Table V-54.

Table V-54: Fit Testing in Construction - Qualitative

Testing group size	4
Employee hours	1
Supervisor hours	0.25
Loaded employee hourly wage	$31.63
Loaded supervisor hourly wage	$44.04
Cost per employee	$42.64

Source: OSHA, Directorate of Standards and Guidance, Office of Regulatory Analysis, based on OSHA (2016), and BLS (2012b).

OSHA revised Table 1 for this final rule. Whereas the PEA judged that workers needing respirators with an APF of 10 would use reusable half-face elastomeric respirators, this FEA reflects that workers performing Table 1 tasks requiring a respirator with an APF of 10 will be able to use either disposable N95 filtering facepiece respirators or reusable half-face respirators. For this FEA, OSHA has estimated that 90 percent of workers in construction who need respirators with an APF of 10 will use a disposable N95 respirator and that 10 percent will use an elastomeric reusable half-face respirator. This is because very few workers in construction engage in tasks requiring respirator use full-time. Under those circumstances, disposable respirators are both more convenient to use and much less expensive than reusable respirators. As in the PEA, OSHA judges for this FEA that any workers needing respirators with an APF of 25 will use an elastomeric full-face respirator to meet the requirements of this final rule.

The unit equipment costs for each type of respirator are shown in Table V-55 below. OSHA estimates that, for cost purposes in construction, respirator use for one FTE employee is equivalent to respirator use every workday for that worker. However, in practice, respirator use for individual workers may vary from day to day and during any particular day. Hence, respirator fit testing and training costs are based on the number of employees performing tasks requiring respirator use and not on the number of respirators used. The employer could choose to supply disposable N95 respirators, which the employee would replace every day but which would need no cleaning or additional accessories, or a reusable elastomeric half-mask respirators, which can be used for two years but which will require daily cleaning and additional accessories[69] that will need to be replaced regularly.

[69] OSHA's respirator costs are based on estimates of the annual costs of respirator use derived in an earlier study (ERG, 2003). These costs include not only the purchase cost of the respirator itself, but the ancillary costs of accessories (e.g., filters) and other costs associated with respirator cleaning and required training and fit testing. The 2003 estimates were based on a unit cost of $3.57 for a replacement pair of filters for half-mask negative-pressure air-purifying respirators. In the PEA, these were extrapolated to an annual cost of $285.52 per year (and inflated to $333.07 in 2009 dollars), erroneously assuming that the filters would be changed 80 times a year, or roughly every 3 days for a working year of approximately 240 days. For this FEA, OSHA corrected these estimates to reflect a construction working year of approximately 150 days, with filters changed 50 times a year, or roughly every three days.

In the PEA cost analysis, respirator costs from the 2003 study were used, but inflated from 2003 to 2009 dollars using the implicit price deflator for this period. For this FEA, those costs have again been adjusted for inflation to 2012 dollars, resulting in an annual cost for filters of $184.70. OSHA's internal research, reported on page V-170 the PEA, showed that filter prices have not, in fact, increased since 2003, and might well have declined, at least for the N95 particulate filters used for silica protection. Thus, it is possible that OSHA has overestimated the cost for accessories for reusable respirators in this FEA.

Table V-55: Respirator Unit Costs in Construction

Equipment	Disposable Filtering Facepiece	Elastomeric Half-Mask Respirator	Elastomeric Full-Face Respirator
Equipment Cost (each)	$1.05	$32.74	$269.78
Equipment Service Life (years)	1	2	2
Annualized Equipment Cost	$1.05	$17.11	$140.99
Accessory Cost	0	$184.70	$184.70
Accessory Service Life (years)	1	1	1
Annualized Accessory Cost	$0.00	$184.70	$184.70
Total Annualized Equipment Costs	$1.05	$201.81	$325.69
No. per year	150	1	1
Total Annualized Cost	**$157.75**	**$201.81**	**$325.69**

Source: OSHA, Directorate of Standards and Guidance, Office of Regulatory Analysis, based on OSHA (2016).

Workers who are provided with reusable respirators will need to clean those respirators. OSHA estimates that this will happen weekly and take five minutes (0.08 hours) of the worker's time. On a yearly basis this will cost $79.08 for a worker in construction who uses a non-disposable respirator. These costs are shown below in Table V-56.

Table V-56: Respirator Cleaning Costs in Construction (non-disposable only)

Cleaning	
Frequency per year	30
Time (hours)	0.08
Loaded employee wage	$31.63
Yearly cost	$79.08

Source: OSHA, Directorate of Standards and Guidance, Office of Regulatory Analysis, based on OSHA (2016) and BLS (2012b).

The final cost component of a respirator program is training workers in respiratory hazards and in the proper use of respiratory protection. OSHA estimates that this training will take two hours and that it will be provided by a supervisor to a group of four employees at a time. The total per-employee cost for training on respiratory hazards and respirator use will be equal to two hours of the worker's wage plus one half hour of the supervisor’s wage (two hours of supervisor time total divided among the four workers). The unit costs for this training are shown below in Table V-57.

Table V-57: Respirator Training Costs in Construction

Class size	4
Employee training hours	2
Supervisor training hours	0.5
Loaded employee hourly wage	$31.63
Loaded supervisor hourly wage	$44.04
Cost per employee	$85.28

Source: OSHA, Directorate of Standards and Guidance, Office of Regulatory Analysis.

The total unit costs for respirators in construction are shown below in Table V-58.

Table V-58: Total Annual Costs for Respirators in Construction (Excluding Programmatic Costs)

	Disposable Filtering Facepiece	Elastomeric Half-Mask Respirator	Elastomeric Full-Face Respirator
Equipment	$157.75	$201.81	$325.69
Fit testing, training, & cleaning [a]	$127.92	$207.00	$207.00
Total	$285.67	$408.81	$532.69

[a] Cleaning applies to reusable elastomeric respirators only

Source: OSHA, Directorate of Standards and Guidance, Office of Regulatory Analysis, based on OSHA (2016), and BLS (2012b).

Table V-59 shows, by task and NAICS industry, the aggregate respirator costs for workers requiring respirators, as prescribed in Table 1. Table 1 does not specify respirators for some tasks, such as heavy equipment operators, hand-held hole drilling, and some other categories of workers. Also, abrasive blasting helpers and underground tunnel workers are not covered in Table 1. Table V-59 does not show any costs for abrasive blasting helpers and underground tunnel workers. Costs for these workers are included in Table V-60.

The number of FTE construction workers needing respirators, and the number of employees who will be wearing respirators sometime during the year (and who are therefore subject to the training and fit testing requirements of this provision) is presented below in Table V-60. Table V-60 also aggregates unit costs and calculates the costs for providing equipment, the programmatic costs associated with respirator use, and the total costs to each industry for respiratory protection requirements. As previously noted, Table V-60 includes respiratory protection costs for abrasive blaster helpers[70] (within NAICS 238300 and NAICS 238900) and underground tunnel workers (within NAICS 237300)—as justified in the technological feasibility analysis presented in Chapter IV of this FEA—even though there are no Table 1 tasks that cover them.

As previously explained, the costs in Table V-60 have been adjusted, both in the PEA and in this FEA, to take into account OSHA's estimate—consistent with the findings from the NIOSH Respirator Survey (NIOSH 2003)—that 56 percent of employees in the construction sector whose exposures are high enough that they would need respirators under the final silica rule are already using respirators that would bring them into compliance. The total cost of respiratory protection in the construction sector decreased from about $84.0 million in the PEA to about $22.4 million in the FEA. This reduction is due to a decline in the number of workers in construction from 2006 to 2012, and to the revisions to Table 1 that significantly reduced the occasions when respirator use would be required under the final rule.

Table V-60 also indicates the extent of respirator use expected in construction as a result of the final rule. Of the approximately 2.0 million workers in construction affected by the final rule (from Table III-13 in Chapter III of this FEA), approximately 265,000 (or about 13 percent) will be required to wear respirators at some point during the year. At any point in time during a construction workday, approximately 24,000 workers (from the FTE total in Table V-60) will be required to wear respirators to comply with the final silica rule.

[70] Abrasive blasters in construction, but not their helpers, already have respiratory protection in accordance with existing OSHA standards.

Table V-59: Total Annualized Costs for Respirator Use (excluding program costs) in Construction Industries under Table 1 of the Silica Standard* (2012 dollars)

NAICS/ Industry	Total	Rock and concrete drillers	Heavy construction equipment operators – I	Heavy construction equipment operators - II	Tuck pointers and grinders (hand-held)	Hole drillers using held-held drills	Impact drillers	Millers using portable or mobile machines	Masonry cutters using portable saws - I	Masonry cutters using portable saws - II	Masonry cutters using stationary saws	Rock crushing machines and tenders
236100 - Residential Building Construction	$2,044,683	$0	$0	$0	$185,992	$0	$1,665,317	$0	$193,373	$0	$0	$0
236200 - Nonresidential Building Construction	$1,815,565	$0	$0	$0	$303,382	$0	$1,278,356	$0	$233,827	$0	$0	$0
237100 - Utility System Construction	$2,607,841	$284,698	$0	$0	$96,913	$0	$2,224,716	$0	$1,514	$0	$0	$0
237200 - Land Subdivision	$87,761	$0	$0	$0	$5,761	$0	$82,000	$0	$0	$0	$0	$0
237300 - Highway, Street, and Bridge Construction	$1,238,680	$9,127	$0	$0	$173,410	$0	$1,050,109	$0	$6,034	$0	$0	$0
237900 - Other Heavy and Civil Engineering Construction	$518,596	$14,354	$0	$0	$25,346	$0	$477,816	$0	$1,081	$0	$0	$0
238100 - Foundation, Structure, and Building Exterior Contractors	$4,412,961	$0	$0	$0	$1,368,152	$0	$701,068	$0	$2,343,742	$0	$0	$0
238200 - Building Equipment Contractors	$366,112	$5,520	$0	$0	$9,051	$0	$343,294	$0	$8,248	$0	$0	$0

Table V-59: Total Annualized Costs for Respirator Use (excluding program costs) in Construction Industries under Table 1 of the Silica Standard* (2012 dollars) (continued)

NAICS/ Industry	Total	Rock and concrete drillers	Heavy construction equipment operators – I	Heavy construction equipment operators - II	Tuck pointers and grinders (hand-held)	Hole drillers using held-held drills	Impact drillers	Millers using portable or mobile machines	Masonry cutters using portable saws - I	Masonry cutters using portable saws - II	Masonry cutters using stationary saws	Rock crushing machines and tenders
238300 - Building Finishing Contractors	$972,634	$0	$0	$0	$155,495	$0	$406,192	$0	$410,947	$0	$0	$0
238900 - Other Specialty Trade Contractors	$1,605,609	$126,035	$0	$0	$311,921	$0	$1,090,941	$0	$76,713	$0	$0	$0
221100 – Electric Utilities	$19,237	$1,961	$0	$0	$0	$0	$17,276	$0	$0	$0	$0	$0
999200 - State Governments	$487,875	$1,679	$0	$0	$624	$0	$485,073	$0	$499	$0	$0	$0
999300 - Local Governments	$1,438,012	$935	$0	$0	$12,188	$0	$1,416,951	$0	$7,938	$0	$0	$0
Total	**$17,615,567**	**$444,308**	**$0**	**$0**	**$2,648,233**	**$0**	**$11,239,109**	**$0**	**$3,283,916**	**$0**	**$0**	**$0**

*Note: Does not include respirator costs for abrasive blasting helpers or underground tunnel workers.

Source: OSHA, Directorate of Standards and Guidance, Office of Regulatory Analysis, based on ERG (2007a) and OSHA (2016).

Table V-60
Combined Construction Sector Respirator Use and Annualized Program Costs

NAICS	Industry	Respirator Users: FTEs	Respirator Users: Total	Annual Equipment and	Respirator Program Cost	Annualized Costs
236100	Residential Building	1,413	32,018	$2,044,683	$616,511	$2,661,194
236200	Nonresidential Building Construction	1,581	27,401	$1,815,565	$420,833	$2,236,399
237100	Utility System	2,234	39,565	$2,607,841	$561,963	$3,169,804
237200	Land Subdivision	46	1,418	$87,761	$21,652	$109,414
237300*	Highway, Street, and Bridge Construction	1,751	19,583	$1,535,555	$263,108	$1,798,662
237900	Other Heavy and Civil Engineering Construction	347	8,161	$518,596	$119,972	$638,568
238100	Foundation, Structure, and Building Exterior	6,256	58,910	$4,412,961	$965,417	$5,378,378
238200	Building Equipment Contractors	488	5,026	$366,112	$79,611	$445,723
238300**	Building Finishing Contractors	4,690	17,991	$1,216,014	$307,756	$1,523,769
238900**	Other Specialty Trade Contractors	4,324	23,819	$1,743,771	$391,667	$2,135,438
221100	Electric Utilities	15	297	$19,237	$3,936	$23,173
999200	State Governments	265	7,868	$487,875	$88,563	$576,438
999300	Local Governments	940	22,702	$1,438,012	$255,546	$1,693,558
	Total	**24,350**	**264,761**	**$18,293,983**	**$4,096,535**	**$22,390,518**

*Note: Includes respirator users and costs associated with construction sector underground tunnel workers.

**Note: Includes respirator users and costs associated with construction sector abrasive blaster helpers.

Source: OSHA, Directorate of Standards and Guidance, Office of Regulatory Analysis, based on ERG (2007a) and OSHA (2016).

Exposure Assessment Costs

Overview of regulatory requirement

Paragraph (d) requires employers who do not fully and properly implement the engineering controls, work practices, and respiratory protection described in Table 1 to assess the exposure of each employee who is or may reasonably be expected to be exposed to respirable crystalline silica at or above the action level in accordance with either the performance option in paragraph (d)(2)(ii) or the scheduled monitoring option in paragraph (d)(2)(iii) of the standard. Under the performance option, the employer must assess the 8-hour TWA exposure for each employee on the basis of any combination of air monitoring data or objective data sufficient to accurately characterize employee exposures to respirable crystalline silica.

Under the scheduled monitoring option (termed the "periodic" monitoring option in the proposal), the employer must perform initial monitoring to assess the 8-hour TWA exposure for each employee on the basis of one or more personal breathing zone (PBZ) air samples that reflect the exposures of employees on each shift, for each job classification, in each work area. Where several employees perform the same job tasks on the same shift and in the same work area, the employer may sample a representative fraction of these employees in order to meet this requirement. In representative sampling, the employer must sample the employee(s) who are expected to have the highest exposure to respirable crystalline silica. Under the scheduled monitoring option, requirements for periodic monitoring depend on the results of initial monitoring. If the initial monitoring indicates that employee exposures are below the action level, no further monitoring is required. If the most recent exposure monitoring reveals employee exposures to be at or above the action level but at or below the PEL, the employer must repeat monitoring within six months of the most recent monitoring. If the most recent exposure monitoring reveals employee exposures to be above the PEL, the employer must repeat monitoring within three months of the most recent monitoring.

Under paragraph (d)(2)(iv), employers must reassess exposures whenever a change in the production, process, control equipment, personnel, or work practices may reasonably be expected to result in new or additional exposures at or above the action level, or when the employer has any reason to believe that new or additional exposures at or above the action level have occurred. Also, paragraph (d)(2)(v) requires employers to ensure that samples taken are evaluated in accordance with the procedures in Appendix A of the final standard.

In addition, paragraph (d)(2)(vi) requires the employer to individually notify each affected employee in writing of the results of an exposure assessment conducted in accordance with paragraph (d)(2) of that section or post the results in an appropriate location accessible to all affected employees.

Paragraph (d)(2)(vii) requires the employer to provide affected employees or their designated representatives the opportunity to observe any monitoring.

PEA cost estimates

In the PEA, the costing methodology and unit costs were identical to those used in general industry and maritime with the exception that construction industry wages are used to calculate productivity losses and recordkeeping costs.

As with general industry and maritime, OSHA assumed that establishments performing exposure monitoring would require the assistance of an outside consulting industrial hygienist (IH) to obtain accurate results because the testing protocols were judged to be too challenging for firms to adequately perform using their own staff. OSHA also estimated in the PEA that, on average, there are four workers per work area.

In the PEA, OSHA expected that many employers, aware that their operations exposed their workers to silica levels above the proposed PEL, would simply choose to comply with Table 1 and avoid the costs of conducting exposure assessments. For purposes of estimating costs, however, OSHA conservatively estimated exposure monitoring costs by assuming all employers would follow the scheduled monitoring option, rather than the performance option, to comply with paragraph (d)(2). While this likely resulted in an overestimation of costs because the scheduled monitoring option has more stringent requirements than the performance option, OSHA chose this approach because of insufficient data about how many employers would choose the performance option.

In addition to the initial exposure monitoring, OSHA, for costing purposes, estimated that exposure monitoring would be conducted twice a year where initial or subsequent exposure monitoring reveals that employee exposures are at or above the action level but at or below the PEL. For initial exposures above the PEL, OSHA judged that all employers in construction would choose to comply with Table 1 and therefore would not have to conduct periodic exposure monitoring. For the PEA, OSHA judged that approximately 15 percent of workers whose initial exposure or subsequent monitoring was at or above the action level would require resampling.

Further, OSHA estimated in the PEA that an IH would spend one day, at a cost of $500, to obtain the following number of PBZ samples: 2 for establishments with fewer than 20 employees; 6 for establishments with 20-499 employees; and 8 for establishments with 500 or more employees. In addition, OSHA estimated that analysis of each sample would cost $133.38 in lab fees and shipping costs. When combined with the IH fee, the cost per PBZ sample was projected to range from $195.88 to $383.38 (depending on establishment size).

In the PEA, the Agency indicated that it was not aware of any published studies presenting data on the frequency with which employee-designated representatives observe exposure monitoring but stated its belief that in some cases union officials are given the opportunity to observe monitoring at no direct cost to the employer. For these reasons, in the PEA, OSHA included no additional cost for this provision (Document ID 1720, p. V-181).

OSHA also accounted for the estimated 30-minute loss in employee time while attaching the pump and the 15 minutes required for recordkeeping, which includes recording the sampling results and notifying the employee of the sampling results. The loss in employee time was multiplied by an average employee hourly wage rate, including fringe benefits, to estimate the associated cost. The recordkeeping time was multiplied by a manager's hourly wage rate, including fringe benefits, to estimate the associated costs. Overall, in the PEA, OSHA estimated that unit costs in construction would range from approximately $227.98 to $415.98 per sample. OSHA believed that some establishments in construction were conducting exposure monitoring but had no evidence to estimate how many establishments were doing so. The Agency therefore conservatively estimated that no establishments in construction were currently conducting exposure monitoring and assumed no current compliance with the proposed exposure monitoring requirements.

Comments and responses on exposure monitoring

OSHA received a number of comments on the costs of exposure monitoring, with some commenters stating that OSHA had underestimated costs and others stating that OSHA had overestimated costs. As OSHA has retained the same cost methodology and unit costing used in general industry and maritime for construction, some of the relevant comments from that section are again discussed below. Note, however, that many of the construction industry comments are moot points in that, in the final rule, almost all silica-generating tasks would fall under Table 1 and require no exposure monitoring at all if employers fully and properly implement the engineering controls, work practices, and respiratory protection specified by Table 1. Sampling would be only conducted under rare conditions (as subsequently discussed) as the expectation is that most establishments will be complying with Table 1 protocols.

Robert Matuga, from the National Association of Home Builders (NAHB), commented that:

> [Trade contractors] also work on multiple jobsites in a day, sometimes three to four, and their tasks and work conditions vary. …. In this instance, an industrial hygiene firm would be required to take multiple tests at multiple jobsites in a single day. These jobsites can be spread over a large geographic area covering fifty miles or more. Because of these conditions, exposure monitoring would be a constant ongoing activity (Document ID 2334, p. 6).

OSHA disagrees with NAHB's assertion that exposure monitoring would be a constant activity. Most or all of these establishments would choose to follow Table 1, negating the need for monitoring. For establishments who would be performing tasks on Table 1 but not using Table 1, OSHA expects that the reason would likely be the availability of objective data (e.g., provided by professional trade or industry associations) showing that the exposures are below the threshold for engineering controls (or exposure monitoring) requirements to apply.

Commenters also disagreed with the estimate of 15 percent of workers requiring reassessment. In particular, in his testimony, Jack Waggener, speaking for URS, testified that:

> For the periodic monitoring, OSHA, who we believe is unrealistically low, assumed that 15 percent of the workers would be over the action level and that no worker would be over the PEL. We expect many people to be over the PEL and many more people to be over the action level (Document ID 3582, Tr. 2019).

The Agency believes that Mr. Waggener simply misunderstood the Agency's methodology here. OSHA estimated that there would be an additional 15 percent of those at or over the action level performing additional testing due to a change in the production, process, control equipment, personnel, or work practices may reasonably be expected to result in new or additional exposures at or above the action level. OSHA was not suggesting that only 15 percent of worker exposures would be over the action level and none over the PEL.

Additionally, the American Foundry Society (AFS) asserted that the percentage of exposure sampling should be increased by 25 percent for reassessment based on experience (Document ID 2379, Attachment 3, p. 35). OSHA does not have strong evidence to dispute the AFS estimate, so the Agency has adopted AFS's 25 percent estimate for this FEA.

Under paragraph (d)(2)(vii)(B) of the final rule, the employer must provide any required PPE at no cost to the observer. One commenter, the Korte Company, asserted that OSHA had omitted the cost of PPE for an employee's designated representative during observation of monitoring "without regards to whether or not the representative is trained or qualified to be wearing the required PPE" (Document ID 3230, p.1). In response, OSHA would like to make several points. In most cases, observation of monitoring is expected to occur during the set-up and at the end of the exposure monitoring—where a respirator would not be required. Exposure monitoring is expected to occur relatively infrequently in construction under the final rule because OSHA expects most employers to rely on Table 1, which does not require exposure monitoring. OSHA judges that when exposure monitoring is conducted, observation of monitoring is typically a relatively rare occurrence. In most cases, designated representatives have experience in observing monitoring, often in the presence of chemicals for which respirators would be required; therefore, the designated representatives would be expected to be trained and qualified to wear a respirator and may own their own respirators with an APF of at least 10. For these reasons, OSHA has not included additional exposure monitoring costs for PPE during observation of monitoring.

Alternatives to hiring an industrial hygienist

Please see the discussion under this identical subheading (Alternatives to hiring an industrial hygienist) earlier in this chapter of the FEA in "General Industry and Maritime: Exposure Assessment Costs."

Cost of industrial hygienist

Please see the discussion under this identical subheading (Cost of industrial hygienist) earlier in this chapter of the FEA in "General Industry and Maritime: Exposure Assessment Costs." Note that only the IH exposure monitoring cost of $2,500 applies in the construction sector.

Laboratory fees

Please see the discussion under this identical subheading (Laboratory fees) earlier in this chapter of the FEA in "General Industry and Maritime: Exposure Assessment Costs."

When the laboratory fee is combined with the IH fee, the direct cost per PBZ sample in construction is projected to range from $452.77 to $1,390.27—depending on establishment size. This is an increase from the range of $195.88 to $383.38 estimated in the PEA.

Other unit costs

OSHA did not receive comment on the other exposure monitoring unit costs in the PEA and has retained them in the FEA. These include the costs to reflect a 30-minute loss in employee time while attaching the pump and the 15 minutes required for recordkeeping, including recording the sampling results and notifying the employee of the sampling results. The only difference from the PEA to the FEA is that these costs were updated to 2012 dollars. The loss in employee time was multiplied by the employee's hourly wage rate, including fringe benefits, to estimate the associated cost. The recordkeeping time was multiplied by a manager's hourly wage rate, including fringe benefits, to estimate the associated costs.

Summary of updated unit costs

Overall, in the FEA, OSHA estimated that the total unit costs of an exposure sample for either initial or periodic monitoring in construction would range from approximately $487.15 to $1,424.65 (depending on establishment size). This is an increase from the range of $227.98 to $415.48 estimated in the PEA.

Aside from updating the costs to reflect 2012 dollars, the only changes to the unit costs of exposure monitoring in construction are due to the increased unit cost of a PBZ sample based on the increased cost to hire an IH consultant, as explained above.

Table V-61 shows the unit costs and associated assumptions used to estimate the cost of an exposure assessment in construction.

Table V-61
Exposure Assessment - Construction
Assumptions and Unit Costs

Costs and Parameters				**Comments/Assumptions**
Direct Costs by Establishment Size				
	Small (<20)	Medium (20-499)	Large (500+)	
Initial Monitoring				
IH fees/PBZ sample	$1,250.00	$416.67	$312.50	Consulting CIH - cost per sample. Assumes IH fee of $2,500 for 2, 6, and 8 samples for small, medium, and large
Scheduled Monitoring (Construction and hydraulic fracturing				
	$1,250.00	$416.67	$312.50	Consulting CIH - cost per sample. Assumes IH fee of $2,500 for 2, 6, and 8 samples for small, medium, and large
Lab Fees and shipping cost	$140.27	$140.27	$140.27	Lab fees per sample (EMSL Laboratory, 2000) and OSHA estimates. Inflated to
Total - per PBZ sample - Initial	$1,390.27	$556.94	$452.77	
Total - per PBZ sample - Scheduled, Construction (and Hydraulic Fracturing)	$1,390.27	$556.94	$452.77	

Table V-61 (continued)
Exposure Assessment - Construction
Assumptions and Unit Costs

Costs and Parameters				**Comments/Assumptions**
Number of workers per work area	4			ERG assumption
Initial Monitoring Frequency (first year only)	1			Based on requirements in standard
Periodic Monitoring Frequency (per year)				
Exposed < Action Level	0			Based on requirements in standard
Exposed <PEL and >AL	2			Based on requirements in standard
Exposed >PEL	4			Based on requirements in standard
Percentage of workers requiring reassessment	25.0%			Revised estimate based on comments
Time Requirements (minutes)				
Lost production time while pump Is attached to worker	30			ERG assumption
Recordkeeping by a manager per sample	15			Includes employee notification of monitoring results
Unit Costs by Establishment Size				
	Small (<20)	Medium (20-499)	Large (500+)	
Cost per sample (PBZ) - Initial or Scheduled Monitoring, Construction				
Direct Costs	$1,390.27	$556.94	$452.77	
Productivity Loss	$15.82	$15.82	$15.82	Based on average construction worker wage, adjusted for benefits (BLS, 2012b)
Recordkeeping	$18.56	$18.56	$18.56	Based on HR manager's wage rate, adjusted for benefits (BLS, 2012b)
Total	**$1,424.65**	**$591.32**	**$487.15**	

Source: OSHA, Directorate of Standards and Guidance, Office of Regulatory Analysis, based on OSHA (2016).

Number of Exposure Samples Taken Annually

Changes from the proposed to the final rule have resulted in a significant reduction in OSHA's estimate of the annual number of samples taken by construction employers. In the PEA in support of the proposal, OSHA estimated that all employers in construction would perform initial exposure assessments and that exposure monitoring would be conducted (a) twice a year where initial or subsequent exposure monitoring revealed that employee exposures are at or above the action level but at or below the PEL, and (b) four times a year where initial or subsequent exposure monitoring reveals that employee exposures are above the PEL.

For the final rule, employers following Table 1 are not required to engage in initial or subsequent exposure monitoring for those construction workers engaged in tasks on Table 1. Therefore, OSHA is only estimating scheduled semi-annual exposure monitoring (for expected exposures at or above the action level but at or below the PEL) and scheduled quarterly exposure monitoring costs (for expected exposures above the PEL) for tunnel workers (in NAICS 237300) and scheduled quarterly exposure monitoring costs (for expected exposures above the PEL) for abrasive blasters (in NAICS 238300 and 238900) because those operations are not listed on Table 1. In addition, OSHA is estimating that some small fraction of employers—1 percent—will choose to conduct initial sampling to investigate the possibility that exposures are so low (below the action level) that Table 1 need not be followed. A larger estimate would, in reality, probably reflect larger cost *savings*, not larger costs, because the exposure monitoring estimated to occur for employees working under Table 1 may allow employees to be scoped out of the rule because their exposures are below the action level and, therefore, actually be indicative of avoided compliance costs relative to the costs that OSHA has estimated in this FEA. However, the Agency has made no such adjustment.

OSHA also notes that the National Association of Manufacturers (NAM) argued that in order to "demonstrate results meeting the 95 percent confidence limit […] it would be necessary to take 20 or more samples under substantially identical conditions" (Document ID 2380, Attachment 2, p. 17). OSHA disagrees with NAM's justification for the extensive sampling and has discussed the 95-percent-confidence-interval issue in greater detail in the Summary and Explanation section of the preamble concerning general industry and maritime compliance with the PEL. OSHA therefore estimated that employers would not need to repeat sampling in order to achieve any particular confidence level.

Existing Compliance Rate

Dr. Ruth Ruttenberg on behalf of the AFL-CIO noted that OSHA's costs for exposure monitoring assumed that employers are not already conducting exposure monitoring and contended that OSHA is therefore overestimating the costs of compliance because those employers already engaging in exposure monitoring would not need to incur additional costs to comply with the new exposure monitoring requirements (Document ID 2256, Attachment 4, p. 5). The Agency agrees that it is very likely that some employers already conduct exposure monitoring, but concludes that there is not sufficient evidence in the record as to how many establishments currently conduct exposure monitoring. Therefore, for costing purposes for the FEA, as in the PEA, OSHA has conservatively assumed no current compliance with the exposure monitoring requirements.

Conclusion

Based on the unit costs of exposure monitoring presented in Table V-61, OSHA provides, in Table V-62a and Table V-62b, the estimated annual exposure monitoring costs for construction, by NAICS industry and size of establishment (since exposure monitoring unit costs vary by the size of the establishment), for the final rule. As shown, the combined costs of the exposure monitoring requirements for construction are an estimated $16.5 million annually.

Table V-62a Annualized Exposure Monitoring Costs: Construction

NAICS	Industry	Workers: Initial Sampling	Workers: Semi-annual Sampling	Workers: Quarterly Sampling	Costs: Initial Sampling	Costs: Semi-annual Sampling	Costs: Quarterly Sampling	Total
Small (<20)								
236100	Residential Building Construction	1,488	0	0	$529,812	$0	$0	**$529,812**
236200	Nonresidential Building Construction	699	0	0	$249,104	$0	$0	**$249,104**
237100	Utility System Construction	307	0	0	$109,459	$0	$0	**$109,459**
237200	Land Subdivision	17	0	0	$6,162	$0	$0	**$6,162**
237300	Highway, Street, and Bridge Construction	548	59	71	$94,798	$42,076	$100,982	**$237,856**
237900	Other Heavy and Civil Engineering Construction	75	0	0	$26,766	$0	$0	**$26,766**
238100	Foundation, Structure, and Building Exterior Contractors	1,449	0	0	$515,954	$0	$0	**$515,954**
238200	Building Equipment Contractors	1,258	0	0	$447,938	$0	$0	**$447,938**
238300	Building Finishing Contractors	677	0	3,769	$241,129	$0	$5,368,947	**$5,610,077**
238900	Other Specialty Trade Contractors	1,136	0	1,873	$404,658	$0	$2,668,269	**$3,072,927**
221100	Electric Utilities	5	0	0	$1,716	$0	$0	**$1,716**
999200	State Governments	0	0	0	$0	$0	$0	**$0**
999300	Local Governments	0	0	0	$0	$0	$0	**$0**
	Total (small)	7,659	59	5,712	$2,627,496	$42,076	$8,138,199	**$10,807,770**
Medium (20-499)								
236100	Residential Building Construction	590	0	0	$87,181	$0	$0	**$87,181**
236200	Nonresidential Building Construction	1,204	0	0	$177,982	$0	$0	**$177,982**
237100	Utility System Construction	1,022	0	0	$151,128	$0	$0	**$151,128**
237200	Land Subdivision	31	0	0	$4,534	$0	$0	**$4,534**
237300	Highway, Street, and Bridge Construction	2,584	279	334	$185,614	$82,385	$197,723	**$465,723**

Table V-62a Annualized Exposure Monitoring Costs: Construction (continued)

NAICS	Industry	Workers: Initial Sampling	Workers: Semi-annual Sampling	Workers: Quarterly Sampling	Costs: Initial Sampling	Costs: Semi-annual Sampling	Costs: Quarterly Sampling	Total
237900	Other Heavy and Civil Engineering Construction	181	0	0	$26,774	$0	$0	**$26,774**
238100	Foundation, Structure, and Building Exterior Contractors	1,703	0	0	$251,700	$0	$0	**$251,700**
238200	Building Equipment Contractors	1,794	0	0	$265,215	$0	$0	**$265,215**
238300	Building Finishing Contractors	609	0	3,387	$89,956	$0	$2,002,940	**$2,092,895**
238900	Other Specialty Trade Contractors	1,295	0	2,134	$191,396	$0	$1,262,045	**$1,453,441**
221100	Electric Utilities	41	0	0	$5,992	$0	$0	**$5,992**
999200	State Governments	336	0	0	$49,609	$0	$0	**$49,609**
999300	Local Governments	1,239	0	0	$183,229	$0	$0	**$183,229**
	Total (medium)	12,627	279	5,856	$1,670,310	$82,385	$3,462,708	**$5,215,403**
Large (500+)								
236100	Residential Building Construction	30	0	0	$3,706	$0	$0	**$3,706**
236200	Nonresidential Building Construction	188	0	0	$22,893	$0	$0	**$22,893**
237100	Utility System Construction	571	0	0	$69,516	$0	$0	**$69,516**
237200	Land Subdivision	9	0	0	$1,131	$0	$0	**$1,131**
237300	Highway, Street, and Bridge Construction	418	45	54	$24,735	$10,978	$26,348	**$62,061**
237900	Other Heavy and Civil Engineering Construction	120	0	0	$14,596	$0	$0	**$14,596**
238100	Foundation, Structure, and Building Exterior Contractors	98	0	0	$11,966	$0	$0	**$11,966**
238200	Building Equipment Contractors	210	0	0	$25,551	$0	$0	**$25,551**
238300	Building Finishing Contractors	48	0	269	$5,888	$0	$131,112	**$137,001**
238900	Other Specialty Trade Contractors	126	0	208	$15,350	$0	$101,218	**$116,568**
221100	Electric Utilities	20	0	0	$2,443	$0	$0	**$2,443**
999200	State Governments	0	0	0	$0	$0	$0	**$0**
999300	Local Governments	0	0	0	$0	$0	$0	**$0**
	Total (large)	**1,839**	**45**	**531**	**$197,776**	**$10,978**	**$258,678**	**$467,432**

Source: OSHA, Directorate of Standards and Guidance, Office of Regulatory Analysis, based on OSHA (2016).

Table V-62b Annualized Exposure Monitoring Costs: Construction (All Establishments)

		Total Costs
236100	Residential Building Construction	**$620,700**
236200	Nonresidential Building Construction	**$449,980**
237100	Utility System Construction	**$330,103**
237200	Land Subdivision	**$11,827**
237300	Highway, Street, and Bridge Construction	**$765,640**
237900	Other Heavy and Civil Engineering Construction	**$68,136**
238100	Foundation, Structure, and Building Exterior Contractors	**$779,620**
238200	Building Equipment Contractors	**$738,704**
238300	Building Finishing Contractors	**$7,839,972**
238900	Other Specialty Trade Contractors	**$4,642,936**
221100	Electric Utilities	**$10,151**
999200	State Governments	**$49,609**
999300	Local Governments	**$183,229**
	Total (all establishments)	**$16,490,605**

Source: OSHA, Directorate of Standards and Guidance, Office of Regulatory Analysis, based on OSHA (2016).

Medical Surveillance Costs

The medical surveillance requirements in the construction standard are generally the same as those in the general industry and maritime standard, although the triggers for the requirements are different. The methodology for calculating the costs of the medical surveillance requirements in the construction standard is therefore largely the same as that used for the general industry standard, but OSHA presents the costs for each standard separately. OSHA requested comments on the estimated costs in the PEA, but the comments, which are addressed in the following discussion, did not provide a persuasive argument that the Agency should use alternative costs in its final estimates. Accordingly, based on the rationale provided in the PEA and consideration of the issues identified in the following discussion and the record as a whole, OSHA has decided to maintain the same unit cost structure and time requirements used in the PEA. The only change from the PEA to the FEA was to update unit costs from 2009 to 2012 dollars.

Explanation of Medical Surveillance Provision

Paragraph (h) of the final standard requires the employer to make available medical surveillance for each employee who will be required under the rule to use a respirator for 30 or more days per year. This is a change from the proposed standard, which required medical surveillance for workers exposed to respirable crystalline silica above the PEL of 50 $\mu g/m^3$. The Summary and Explanation section of the preamble on medical surveillance provides a discussion of the rationale for this change.

Medical surveillance will include an initial (baseline) medical examination and periodic examinations. The initial medical examination must be made available to the employee within 30 days after initial assignment, unless the employee has received an equivalent medical examination within the last three years. The periodic medical examination must be made available to the employee at least every three years, or more frequently if recommended by the physician or licensed health care professional (PLHCP).

In accordance with paragraph (h)(2) of the final standard, the initial medical examination will consist of (1) a medical and work history, (2) a physical examination with special emphasis on the respiratory system, (3) a chest x-ray interpreted and classified according to the International Labour Office (ILO) International Classification of Radiographs of Pneumoconioses by a NIOSH-certified B Reader, (4) a pulmonary function test administered by a spirometry technician with a current certificate from a NIOSH approved course, (5) testing for latent tuberculosis (TB) infection, and (6) any other tests deemed appropriate by the PLHCP. In accordance with paragraph (h)(3) of the final standard, the contents of the periodic medical examinations are the same as those for the initial examination, with the exception that testing for latent TB infection is not required. However, consistent with what was done in the PEA (without subsequent comment), OSHA medical experts in the Office of Occupational Medicine and Nursing estimated that the PLHCP will recommend testing for latent TB during the periodic medical examination for 20 percent of construction workers (Document ID 1720, p. V-191).[71]

Note that the relevant language in both the proposed and final rule requires "the employer to make medical surveillance available for each employee…" For costing purposes, in both the PEA and FEA, OSHA assumed that all eligible employees would take advantage of the medical surveillance made available by the employer. In fact, to the extent that this is not true, OSHA will have overestimated the cost to employers of the medical surveillance provision. As evidence illustrating less than 100 percent employee participation, the record includes a study of miner participation rates in medical surveillance programs indicating that participation over the time span of the study ranged from 25 percent to 41.7 percent (Document ID 3998, Attachment 15; see also Document ID 3587, Tr. 3616-3617).

PEA estimates of unit costs

As presented in Table V-39 of the PEA, OSHA's medical experts in its Office of Occupational Medicine and Nursing provided estimates in 2009 dollars of the following medical costs: a complete medical and work history, a triennial review and updating of health history, a physical examination by a PLHCP, a chest x-ray, the classification of a chest x-ray by a NIOSH-certified B Reader, a pulmonary function test, an examination by a specialist (defined in the standard as an American Board Certified Pulmonary Disease or Occupational Medicine Specialist), other necessary tests (the medical experts estimated that these would likely be required by 10 percent of examined workers), and a latent TB test (Document ID 1720, p. V-187). OSHA also used the research and expertise of staff from its Office of Occupational Medicine and Nursing and from OSHA's contractor, ERG, to provide preliminary estimates in the PEA for how much time each medical activity would take, and requested comment on those estimates. These estimates included, for each employee, 120 minutes for the health history survey and exam, including x-ray; 30 minutes to review the health history; 60 minutes for the physical exam and tests, including pulmonary function but excluding x-ray; 30 minutes for the chest x-ray. OSHA also estimated 5 minutes for the reading of the latent TB test

[71] The 20-percent estimate for the construction sector is higher than the 15-percent estimate for general industry and maritime because OSHA's medical experts judged that workers in the construction sector would have a higher percentage of workers who recently lived in or visited foreign countries with elevated tuberculosis rates.

(return visit to receive results); and 60 minutes for an examination by a specialist (Document ID 1720, pp. V-187-191).

The PEA also accounted for round-trip travel costs necessary to see an off-site physician. Off-site travel time for a construction worker was estimated to be 90 minutes—as opposed to 60 minutes for an employee in general industry or maritime—for medical surveillance at any off-site location because OSHA expected that construction workers would be more likely to work in remote locations. OSHA further enumerated in the PEA the percentage of employees seeing an off-site physician by establishment size. For the initial examination, it was estimated that 20 percent of employees in small establishments (with fewer than 20 employees), 75 percent in medium-sized establishments (with 20 – 499 employees), and 100 percent in large establishments (with 500 or more employees) would see an on-site physician. For new hires, OSHA had estimated that the percentages of on-site medical examinations will decrease to 10 percent of employees in small establishments, 50 percent in medium establishments, and 90 percent in large establishments because OSHA expects that physicians would be less willing to travel to an establishment for the fewer patients that new hires represent. For the construction sector, OSHA also estimated a hiring rate[72] of 64.0 percent (utilizing 2008 data from the Bureau of Labor Statistics Job Openings and Labor Turnover Survey) and judged that 40 percent of new hires would require an initial health screening (the other 60 percent of new hires would have previous job experience covered by either the general industry and maritime standard or the construction silica standard such they would have had a compliant health screening within the prior three years). OSHA did not receive comment on this 40 percent estimate, other than from commenters questioning whether it accounted for persons who would not need to be re-screened, which it does. The initial screening for current employees was estimated to range in cost from $389.38 to $424.94 per employee, depending on establishment size, and the initial screening for new hires was estimated to range in cost from $393.82 to $429.38 per employee, again depending on establishment size.

Comments and Responses on Medical Surveillance

Unit costs

[72] In the PEA, OSHA in some cases referred to this rate as the separations rate, but in fact the Agency was using the hiring rate reported by BLS. Because the regulatory analysis is based on steady-state economic conditions, the separations rate, the hiring rate, and the turnover rate are effectively identical.

A frequent criticism expressed by commenters was that OSHA had underestimated the costs for the construction sector associated with the medical surveillance provision. See, e.g., comments from the Leading Builders of America (Document ID 2269, p. 18) and Fann Contracting, Inc. (Document ID 2116, Silica Comments 1, p. 18). However, the Leading Builders of America did not offer alternative estimates for the Agency to consider and Fann Contracting's only alternative estimate was an observation that travel time in Arizona could take many hours. While the Agency recognizes that there will be instances where the travel time for a particular construction worker would be greater than what OSHA has estimated in its unit costs, there will be other instances when the travel time is much less, considering that this estimate represents a national average for construction workers. Logically, more rural, geographically dispersed jobs are likely to require more travel time to medical facilities; this is offset, however, by the concentration of jobs in other areas with available nearby medical services. Note, however, that travel time was estimated to be 90 minutes for construction workers versus 60 minutes for workers in general industry or maritime to reflect the anticipated larger percentage of jobs in rural or remote areas. Further, as discussed in the general industry section, after reviewing other OSHA rulemakings, OSHA concludes that it is likely being conservative and overestimating the amount of travel time necessary and will revisit the issue in future rulemakings. For example, the asbestos in construction rule only includes 30 minutes of travel round trip for medical examinations. However, because the record was not further developed in this rulemaking, OSHA is not now reducing its estimate from the PEA.

A number of commenters from the construction sector provided specific cost estimates for initial medical examinations that were consistent with, or less than, OSHA's estimates of $389.38 to $424.94 per employee. In some cases, the submitted cost estimates were bundled with costs representing other provisions of the standard. The Associated General Contractors of Michigan (AGCM) commented that "[t]he cost of training and medical health evaluations for each individual worker would cost more than $300 per person" (Document ID 2265, Attachment 2, p. 2). The American Subcontractors Association reported average member estimates of $250 to $300 per employee for the required medical examinations (Document ID 2187, p. 7). The General Contractors Association of New York commented that "[t]he average cost of a single fit test and doctor exam to qualify employees for work is $275" (Document ID 2314, p. 2). The Precast/Prestressed Concrete Institute (PCI) stated that "fit testing and associated medical clearance for one worker [would] cost between $75 and $400, depending on location" (Document ID 4029, p. 3). Note that OSHA judged that the medical and work history required by the medical surveillance provisions of the final rule could also provide respirator fitness results required by the RPP, but for costing purposes for the final rule, the Agency assumed no current compliance with the health evaluation requirements for RPP in the final rule.

Eric Olson, from the Western Construction Group, commented that "the local [occupational medicine clinic] stated that this evaluation would cost approximately $150 per person because of the x-ray requirement… [s]o the financial impact of the average union mason in St. Louis at $36 per hour is $222 per worker" (Document ID 2183, pp. 3-4). Peter Soyka of Soyka & Company LLC reviewed OSHA's proposal for James Hardie Building Products, Inc. and found OSHA's medical surveillance unit costs "unrealistically low" (Document ID 2322, Attachment G, p. 16). Mr. Soyka indicated that to arrive at his estimate he "retained OSHA's existing methodology … adjust[ed] this number to 2012 dollars, applied this average cost to the corrected number of affected workers" and "used a three-year amortization period to annualize the costs of medical surveillance" (Document ID 2322, Attachment G, p. 28). Mr. Soyka arrives at an average annualized cost per at-risk worker of $229.40, which is only slightly higher than OSHA's estimated annualized cost of about $226 (Document ID 2322, Attachment G, Appendix A, p. A-4). In conclusion, OSHA estimated in the PEA that medical surveillance would cost between $389 and $425 per worker for initial screening (annualized cost of $226), depending on establishment size, which is comparable with the estimates presented above by the PCI and James Hardie Building Products and is higher than the estimates provided above by the ACGM, the Western Construction Group, and the General Contractors Association of New York.

Mr. Toscas of the Precast/Prestressed Concrete Institute (PCI) also argued that "an additional employee may also be needed to manage the new [medical surveillance] program at a cost of $50,000 - $60,000 per year" (Document ID 2276, p. 10). It was not explained why an employer would need to hire a new employee to manage a medical surveillance program; the actual performance of the medical surveillance would be performed by medical staff, which has already been captured as an employer expense. The administrative element of keeping track of when employees are due for another medical examination or related information is a simple administrative task, as is any potential recordkeeping. Many OSHA rules require medical examinations and medical surveillance, including 29 CFR 1910.1027 (Cadmium), 29 CFR 1910.1026 (Chromium VI), and 29 CFR 1926.1101 (Asbestos), and OSHA has never estimated costs for adding a medical surveillance manager. To OSHA's knowledge (and no evidence has been presented otherwise in this record), employers have been able to meet the requirements of these rules without having to hire additional employees for administrative oversight.

Total costs

Some commenters used the Agency's cost estimates to provide an independent calculation of the costs. In its post-hearing comment, the CISC submitted calculations relating to the costs of the medical surveillance provision (Document ID 4023, Silica Cost Analysis, spreadsheet tab 16). These calculations, however, did not provide new information on the unit costs related to medical surveillance. The NAHB, commented that “[i]f each construction employee required only one screening per year at $377.77, the total cost would be roughly $1.2 billion” (Document ID 2296, p. 18). OSHA does not take issue with the unit cost. However, as widespread as silica exposure is in construction, the Agency estimates that less than forty percent of all construction workers have jobs that are potentially at risk for any silica exposure (see Table III-9 of this FEA). And of those, only construction workers required to wear respirators for 30 or more days per year would need to be offered medical surveillance. Unlike in the proposal, OSHA has included Table 1 in the final rule as a separate means of compliance for the majority of silica-generating tasks likely to arise in construction, and most of those tasks would not require respirator use under normal conditions. Additionally, as in the proposal, the final rule generally requires employers to offer full medical screenings for all affected workers initially and then every three years— not annually, as implied by the NAHB’s estimates.

Current compliance

Although OSHA believes that some affected establishments in construction currently provide some medical testing to their silica-exposed employees, there was significant testimony in the record that many employers would at least have to make changes to their existing practices in order to comply with the new standard (See, e.g., Document ID 3580, Tr. 1535; Document ID 3585, Tr. 3004). Therefore, for costing purposes, the Agency assumed no current compliance with the health screening requirements of the rule. Given this assumption, OSHA is likely overestimating costs as the Agency believes there are currently establishments in construction that utilize medical testing for silica-exposed employees.

Employee Turnover

For the PEA, OSHA estimated a hiring rate in the construction sector of 64.0 percent (utilizing 2008 data from the Bureau of Labor Statistics Job Openings and Labor Turnover Survey) and judged that 40 percent of new hires would require an initial health screening. OSHA did not receive comment on this 40 percent estimate, other than from commenters questioning whether it accounted for persons who would not need to be re-screened, which it does.

A concern among the commenters was that the amount of turnover in the construction industry rendered the medical surveillance requirement impractical, or at least very expensive. For example, NAHB commented that "in both home building and remodeling, workforce is transitory by nature and there is a very high rate of turnover in the workforce" (Document ID 2296, p. 44). Kelli Vazquez, from Holes Incorporated, presented cost estimates for her company based on an assumption that every new hire will need an initial exam (Document ID 2338, p. 6). The FEA does take into account a high turnover rate in construction. For the FEA, in order to estimate turnover rates in construction, OSHA (2016) used the hiring rate of 70.3 percent in construction as estimated in 2012 by the Bureau of Labor Statistics (BLS, 2012a), as opposed to the 64.0 percent rate from the PEA, which was based on the older 2008 data from the same source. As specified in paragraph (h)(2) of the rule, employees who had received a medical examination that meets the requirements of this section within the previous three years would be exempt from undergoing a second "initial" medical examination. Therefore, not all new hires would require initial medical testing even if they otherwise qualified for such testing as measured by foreseeable respirator use alone. However, as explained in the discussion of the costs of the general industry standard, OSHA lacks sufficient data to identify the percentage who would remain in silica construction jobs but would not require re-testing. Therefore, the Agency is not changing its estimate that 100 percent of current affected employees and 40 percent of new hires (reflecting the large percentage of construction workers who are rehired in the construction sector) who meet the criteria for receiving medical surveillance will be tested in the initial year after promulgation of this final rule.

Final cost estimates

In summary, OSHA's estimates of the unit costs presented in this FEA for medical surveillance in the construction sector are broadly consistent with the estimates put forth by the Agency in the PEA. The comments on this issue did not identify significant issues with OSHA's methodology or estimates in the PEA or provide a persuasive argument that the Agency should use alternative costs in its final estimates. OSHA explained the basis for each of those estimates in the PEA, and the same basis applies in the FEA. The only change from the PEA to the FEA was to update unit costs from 2009 to 2012 dollars.

As in the PEA, OSHA estimated separate costs for current employees and for new hires as a function of the employment size (i.e., 1-19, 20-499, or 500+) of affected establishments. Table V-63 presents ERG's unit cost data and modeling assumptions used by OSHA to estimate medical surveillance costs. As shown in Table V-63, the estimated unit cost of the initial health screening for current employees in construction ranges from $428.55 to $466.50 and includes direct medical costs, the opportunity cost of worker time (i.e., lost work time, evaluated at the worker's 2012 hourly wage, including fringe benefits) for offsite travel and for the initial health screening itself, and recordkeeping costs. As in the PEA, the variation in the unit cost of the initial health screening by employment size is due entirely to differences in the percentage of workers expected to travel offsite for the health screening. In general, OSHA expects that the larger the establishment, the more likely it is that the selected PLHCP would provide the health screening services at the establishment's worksite. As was done in the PEA, OSHA estimates that, on average, 20 percent of establishments with fewer than 20 employees, 75 percent of establishments with 20-499 employees, and 100 percent of establishments with 500 or more employees will have the initial health screening for current employees conducted onsite.

The unit cost components of the initial health screening for new hires in construction are identical to those for existing construction employees with the exception that the percentage of workers expected to travel offsite for the health screening will be somewhat larger, as explained above. As shown in Table V-63, the estimated unit cost of the initial health screening for new hires in construction ranges from approximately $433.29 to $471.25.

The periodic medical examination would occur every three years, or more frequently if recommended by the PLHCP. As previously noted, the contents of the periodic medical examination are identical to those for the initial examination, with the exception that testing for latent tuberculosis infection is not required.

The estimated unit cost of periodic health screening includes direct medical costs, the opportunity cost of worker time, and recordkeeping costs for the employer. As shown in Table V-63, these unit costs vary from roughly $428.55 to $466.50 every third year. The variation in the unit cost is due entirely to differences in the percentage of workers expected to travel offsite for the periodic health screening. OSHA estimated that the share of workers traveling offsite, as a function of establishment size, would be the same for the periodic health screening as for the initial health screening for existing employees.

Table V-63

Medical Surveillance and TB Testing - Construction Industry

Assumptions and Unit Costs

Coverage: All employees using respirators

Screening Tool	Cost	Initial	Periodic	Comments/Assumptions
Direct Costs				
Complete medical and work history	$36.94	Yes	NA	Assumed one third of physical exam cost
Periodic review and updating of health history	$36.94	NA	Yes	Assumed one third of physical exam cost
Physical examination by PLHCP [a]	$110.83	Yes	Yes	Evaluation and office consultation including detailed examination ($100, inflated to 2012).
Chest x-ray [a]	$88.24	Yes	Triennial	Radiologic examination (a single posteroanterior radiographic projection) ($62.97; inflated to 2012). Costs include consultation and written report.
Chest X-ray classified by a NIOSH-certified B Reader [a]	$43.44	Yes	Triennial	Average of three estimates provided by B Readers to ERG, inflated to 2012.
Pulmonary function test [a]	$60.62	Yes	Triennial	Spirometry, including reports showing graphical displays and numerical results for measurements of Forced Vital Capacity (FVC), Forced Expiratory Volume in One Second (FEV1), and FEV1/FVC ($43.26; inflated to 2012).
Examination by a specialist [b]	$210.89	Yes	NA	Office consultation and evaluation by a specialist ($158.07; inflated to 2012)

Table V-63 (continued)
Medical Surveillance and TB Testing - Construction Industry
Assumptions and Unit Costs
Coverage: All employees using respirators

Screening Tool	Cost	Initial	Periodic		Comments/Assumptions
Other necessary tests	$66.50	Yes	Yes		Assumed required for 10 percent of workers ($60; inflated to 2012)
Latent TB Test [a]	$16.63				$15; inflated to 2012
Time Requirements for Medical Examinations (minutes)					
Travel time for off-site exam	90				National average
Complete medical and work history and exam, including x-ray	120				Per survey and exam
Health history review and update	30				Per review
Physical exam and tests (including PFT but excluding x-ray)	60				Per exam
Chest x-ray	30				Per x-ray
Examination by a specialist	60				
Recordkeeping (initial and periodic	15				Average per screening
Recordkeeping (specialist referrals and recordkeeping)	60				Includes time for referrals
Percentage of employees seeing off-site physician by establishment					
		Small (<20)	Medium (20-499)	Large (500+	
Initial examination		80.0%	25.0%	0.0%	
New hires		90.0%	50.0%	10.0%	
Time Requirements for TB Testing (minutes)					
Initial test	NA			Included in initial exam visit	
Return for reading	5				
Travel Times (minutes) - off-site location					
Initial test	NA			Included in initial exam visit	
Return for reading	90				

Table V-63 (continued)

Medical Surveillance and TB Testing - Construction Industry

Assumptions and Unit Costs

Coverage: All employees using respirators

Hiring rate	70.3%			2012 hiring rate for construction industries. BLS, Job Openings and Labor Turnover Survey
Share of turnover associated with new hires to the industry	40.0%			

Unit Costs	Establishment Size			
	Small (<20)	Medium (20-499)	Large (500+)	
Initial screening:				
Medical costs	$346.72	$346.72	$346.72	Including components specified above in "Direct Costs"
Lost work time – exam	$63.26	$63.26	$63.26	Based on average construction worker wage, adjusted for benefits (BLS, 2012b)
Lost work time – travel	$37.96	$11.86	$0.00	Based on average construction worker wage, adjusted for benefits (BLS, 2012b)
Record keeping	$18.56	$18.56	$18.56	Based on construction manager's wage rate, adjusted for benefits (BLS, 2012b)
Total	$466.50	$440.41	$428.55	
Initial screening: New hires				
Medical costs	$346.72	$346.72	$346.72	Including components specified above in "Direct Costs"

Unit Costs	Establishment Size			
	Small (<20)	Medium (20-499)	Large (500+)	

Table V-63 (continued)
Medical Surveillance and TB Testing - Construction Industry
Assumptions and Unit Costs
Coverage: All employees using respirators

Unit Costs	Establishment Size			
Lost work time – exam	$63.26	$63.26	$63.26	Based on average construction worker wage, adjusted for benefits (BLS, 2012b)
Lost work time – travel	$42.70	$23.72	$4.74	Based on average construction worker wage, adjusted for benefits (BLS, 2012b)
Record keeping	$18.56	$18.56	$18.56	Based on construction manager's wage rate, adjusted for benefits (BLS, 2012b)
Total	$471.25	$452.27	$433.29	
Triennial screening (with x-ray and pulmonary function test)				
Medical costs	$346.72	$346.72	$346.72	Including components specified above in "Direct Costs"
Lost work time – exam	$63.26	$63.26	$63.26	Based on average construction worker wage, adjusted for benefits (BLS, 2012b).
Lost work time – travel	$37.96	$11.86	$0.00	Based on average construction worker wage, adjusted for benefits (BLS, 2012b).
Record keeping	$18.56	$18.56	$18.56	Based on manager's wage rate, adjusted for benefits (BLS, 2012b).
Total	$466.50	$440.41	$428.55	
Examination by specialist				
Medical costs	$210.89	$210.89	$210.89	Including components specified above in "Direct Costs"

Table V-63 (continued)
Medical Surveillance and TB Testing - Construction Industry
Assumptions and Unit Costs
Coverage: All employees using respirators

	Small (<20)	Medium (20-499)	Large (500+)	
Lost work time – exam	$31.63	$31.63	$31.63	Based on average construction worker wage, adjusted for benefits (BLS, 2012b).
Lost work time – travel	$47.45	$47.45	$47.45	Based on average construction worker wage, adjusted for benefits (BLS, 2012b). All exams are off-site for all workers.
Record keeping	$74.26	$74.26	$74.26	Based on manager's wage rate, adjusted for benefits (BLS, 2012b).
Total	$364.23	$364.23	$364.23	
Initial TB testing				
Test cost	$16.63	$16.63	$16.63	
Lost work time – exam	$2.64	$2.64	$2.64	Based on average construction worker wage, adjusted for benefits (BLS, 2012b).
Lost work time – travel	$25.30	$7.91	$0.00	Based on average construction worker wage, adjusted for benefits (BLS, 2012b).
Total	$44.56	$27.17	$19.26	
New hire and subsequent TB testing				
Test cost	$16.63	$16.63	$16.63	
Lost work time – exam	$2.64	$2.64	$2.64	Based on average construction worker wage, adjusted for benefits (BLS, 2012b).
Lost work time – travel	$28.47	$15.82	$3.16	Based on average construction worker wage, adjusted for benefits (BLS, 2012b).

Table V-63 (continued)

Medical Surveillance and TB Testing - Construction Industry

Assumptions and Unit Costs

Coverage: All employees using respirators

Total	$47.73	$35.08	$22.42
Unit Costs	**Establishment Size**		
	Small	Medium	Large
	(<20)	(20-499)	(500+)
Annualized costs - initial testing	$5.22	$3.18	$2.26
Annualized costs - new hire and subsequent testing	$47.73	$35.08	$22.42
Percentage of employees tested in initial year			
Current Employees	100.0%		
New Hires	40.0%		
Percentage of employees recommended for periodic TB testing [c]	20.0%		

[a] Typical charge based on ERG contacts with occupational health providers.

[b] Mean expense per office-based physician visit to a specialist for diagnosis and treatment, based on data from the 2004 MEPS. Inflated to 2009 levels using the consumer price index.

[c] The corresponding table in the PEA erroneously referred to this as annual TB testing. This typographical error did not impact the costs in the PEA.

Source: OSHA, Directorate of Standards and Guidance, Office of Regulatory Analysis.

The final rule requires employers in the construction sector to make medical surveillance available to each employee who will be required to use a respirator under this section for 30 or more days per year. The Agency applied this requirement to the unit costs to estimate total health screening costs. Based on a ten-year time horizon, OSHA estimated the total annualized costs in construction for health screenings (to include initial health screenings for existing employees and new hires and periodic health screenings) as required by the final rule. These estimates, disaggregated by affected NAICS industry, are presented in Table V-64.

Finally, OSHA estimated the unit cost of a medical examination by a specialist for those employees found to have signs of silica-related disease (1/0 or higher on the ILO scale) or are otherwise referred by the PLHCP. As shown in Table V-63, the estimated unit cost of a medical examination by a specialist is $364.23. This cost includes direct medical costs, the opportunity cost of worker time, and recordkeeping costs, including the cost of the employer's time to make a referral to a specialist. In all cases, regardless of establishment size, OSHA anticipates that the worker will spend 90 minutes in travel-time cost to travel offsite to receive the medical examination by a specialist.

Based on Buchanan et al. (2003), OSHA estimated that, for those workers in construction under medical surveillance (required by the final rule to wear a respirator for 30 or more days per year), there would be 445 new cases of silicosis a year (based on an x-ray of silica-exposed employees classified as 1/0 or higher) identified by medical surveillance.[73] For the purpose of estimating costs, OSHA assumes that the PLHCP would refer the employee to a specialist only if the employee was diagnosed with silicosis. ERG distributed these disease cases among industries in proportion to the number of workers currently exposed above the PEL of 50 $\mu g/m^3$. Table V-65, which multiplies the unit cost by the number of referred workers, shows the total annualized cost in the construction sector of medical examinations by a specialist.

Table V-66, which combines total health screening costs and the total costs of medical examinations by a specialist, shows the aggregate annual cost in construction, by NAICS industry, for the medical surveillance requirements in the rule. Combined over all affected NAICS construction industries, the estimated cost of these medical surveillance requirements is $66.7 million annually.

[73] OSHA has estimated many more specialist referrals in general industry and maritime than in construction even though many more workers in construction, relative to those in general industry and maritime, are estimated to receive medical surveillance. There are two reasons for this: (1) Only 38 percent of workers in construction with current exposures above the PEL will have medical surveillance (which is triggered by respirator use as specified in Table 1) whereas 100 percent of workers at or above the action level will have medical surveillance. (2) The relationship between exposure and silicosis is much stronger in GI/M because the exposure is typically full-time in GI/M and part-time in construction.

Table V-64: Annualized Health Screening Costs: Construction

NAICS	Industry	Using Respirator	Initial Screening	Screening for New Hires	Triennial Screening	Total Cost of Examinations	Total Cost of TB Testing	Total Cost
236100	Residential Building	32,018	$1,721,569	$4,190,161	$1,880,936	$7,792,666	$265,634	**$8,058,300**
236200	Nonresidential Building Construction	27,401	$1,439,319	$3,520,610	$1,569,361	$6,529,290	$195,956	**$6,725,245**
237100	Utility System Construction	39,565	$2,045,740	$5,002,480	$2,226,345	$9,274,565	$249,108	**$9,523,672**
237200	Land Subdivision	1,418	$74,217	$181,437	$80,881	$336,536	$9,830	**$346,366**
237300	Highway, Street, and Bridge Construction	19,583	$1,017,118	$2,494,410	$1,107,930	$4,619,458	$129,486	**$4,748,944**
237900	Other Heavy and Civil Engineering Construction	8,161	$422,704	$1,032,689	$460,061	$1,915,453	$51,950	**$1,967,403**
238100	Foundation, Structure, and Building Exterior	58,910	$3,119,346	$7,622,719	$3,403,927	$14,145,992	$445,526	**$14,591,518**
238200	Building Equipment Contractors	5,026	$264,994	$647,879	$289,041	$1,201,914	$36,879	**$1,238,793**
238300	Building Finishing Contractors	21,704	$1,153,163	$2,814,855	$1,258,677	$5,226,696	$167,535	**$5,394,230**
238900	Other Specialty Trade Contractors	25,927	$1,372,057	$3,352,008	$1,497,078	$6,221,143	$195,070	**$6,416,213**
221100	Electric Utilities	297	$15,292	$37,446	$16,635	$69,373	$1,798	**$71,171**
999200	State Governments	7,868	$406,208	$1,000,611	$442,427	$1,849,246	$50,436	**$1,899,682**
999300	Local Governments	22,702	$1,172,099	$2,887,227	$1,276,605	$5,335,932	$145,531	**$5,481,462**
	Totals	**270,581**	**$14,223,826**	**$34,784,533**	**$15,509,904**	**$64,518,263**	**$1,944,737**	**$66,463,000**

Source: OSHA, Directorate of Standards and Guidance, Office of Regulatory Analysis.

Table V-65: Medical Examination by a Specialist: Construction

		Using Respirators	No. of Annual Referrals	Annual Costs
236100	Residential Building Construction	32,018	67	**$24,250**
236200	Nonresidential Building Construction	27,401	57	**$20,753**
237100	Utility System Construction	39,565	82	**$29,965**
237200	Land Subdivision	1,418	3	**$1,074**
237300	Highway, Street, and Bridge Construction	19,583	41	**$14,832**
237900	Other Heavy and Civil Engineering Construction	8,161	17	**$6,181**
238100	Foundation, Structure, and Building Exterior Contractors	58,910	122	**$44,617**
238200	Building Equipment Contractors	5,026	10	**$3,807**
238300	Building Finishing Contractors	21,704	45	**$16,438**
238900	Other Specialty Trade Contractors	25,927	54	**$19,637**
221100	Electric Utilities	297	1	**$225**
999200	State Governments	7,868	16	**$5,959**
999300	Local Governments	22,702	47	**$17,194**
	Totals	**270,581**	**563**	**$204,933**

Source: OSHA, Directorate of Standards and Guidance, Office of Regulatory Analysis.

Table V-66: Total Annualized Medical Surveillance Costs: Construction

		Total Examinations	Specialist Examinations	Total
236100	Residential Building Construction	$8,058,300	$24,250	**$8,082,550**
236200	Nonresidential Building Construction	$6,725,245	$20,753	**$6,745,998**
237100	Utility System Construction	$9,523,672	$29,965	**$9,553,638**
237200	Land Subdivision	$346,366	$1,074	**$347,440**
237300	Highway, Street, and Bridge Construction	$4,748,944	$14,832	**$4,763,776**
237900	Other Heavy and Civil Engineering Construction	$1,967,403	$6,181	**$1,973,584**
238100	Foundation, Structure, and Building Exterior Contractors	$14,591,518	$44,617	**$14,636,135**
238200	Building Equipment Contractors	$1,238,793	$3,807	**$1,242,600**
238300	Building Finishing Contractors	$5,394,230	$16,438	**$5,410,669**
238900	Other Specialty Trade Contractors	$6,416,213	$19,637	**$6,435,850**
221100	Electric Utilities	$71,171	$225	**$71,396**
999200	State Governments	$1,899,682	$5,959	**$1,905,641**
999300	Local Governments	$5,481,462	$17,194	**$5,498,657**
	Totals	**$66,463,000**	**$204,933**	**$66,667,933**

Source: OSHA, Directorate of Standards and Guidance, Office of Regulatory Analysis.

Familiarization Costs and Costs of Communication of Silica Hazards to Employees

In this section, OSHA presents its cost estimates for two employer information activities arising from the silica final rule: (1) employer familiarization with the final rule, and (2) training on, and communication of, respirable crystalline silica hazards to employees as required by the final rule.

Familiarization Costs

OSHA did not estimate any employer familiarization costs in the PEA in support of the proposed rule. However, for the same reasons explained in the discussion of familiarization costs for employers in general industry and maritime, OSHA is including familiarization costs in this FEA for employers in the construction sector. As was done for general industry and maritime, OSHA's estimate of familiarization costs for construction reflects the total familiarization time, costed at a supervisory wage, for each covered employer and is a function of establishment size. OSHA estimates that the average familiarization time will be the same as needed in general industry work: 4 hours per covered employer with fewer than 20 employees; 8 hours per covered employer with 20 to 499 employees; and 40 hours per covered employer with 500 or more employees. These estimates represent an average familiarization time for an establishment of a given size and, as a result, it is expected that some establishments will spend less time on familiarization than estimated here (e.g., if worker exposure never meets or exceeds the action level) and some will spend more time on familiarization than estimated here.

OSHA notes that, in addition to its other purposes, the familiarization time will help supervisors to prepare or select training to provide to other supervisors and to other employees of the firm. Although the construction standard has several differences from the general industry standard, OSHA anticipates that the average familiarization time will not vary significantly from the general industry standard. In fact, the familiarization time may be over-estimated in construction because many employers will be able to save time by identifying their activities on Table 1 and following the specific guidance that OSHA has provided for complying with the standard with respect to those activities. However, for this FEA, OSHA anticipates that the average familiarization times in construction, general industry, and maritime will not vary appreciably. Commenters who argued in favor of OSHA including familiarization costs did not suggest that one standard would require more familiarization time than the other.

Table V-67 shows the unit cost by establishment size for employers in construction to become familiar with the final rule. Note that for an establishment of any given size, the unit cost in construction is higher than the unit cost for general industry and maritime because the supervisor wage is higher in construction. Table V-68, which multiplies the unit familiarization costs per construction establishment from Table V-67 by the corresponding number of affected establishments, displays OSHA's estimate of the annualized familiarization costs of the final rule in the construction sector, by NAICS industry.[74] For the construction sector, the total annualized familiarization cost of the final rule is $13.8 million.

Table V-67

Familiarization - Construction
Assumptions and Unit Costs

Cost Category	**Cost**			**Comments/Assumptions**
	Small (<20)	Medium (20-499)	Large (500+)	
Hours per establishment	4.0	8.0	40.0	
Total cost per establishment	$176	$352	$1,762	Based on supervisor wage of $44.04, inclusive of fringe benefits
Annualized cost	**$20.65**	**$41.31**	**$206.53**	

Source: OSHA, Directorate of Standards and Guidance, Office of Regulatory Analysis, based on OSHA (2016) and BLS (2012b).

[74] Due to rounding, the totals do not match the products of their components.

Table V-68: Annualized Familiarization Costs

		Small (<20)		Medium (20-499)		Large (500+)		Total Affected Establishments	
		Establishments	**Costs**	**Establishments**	**Costs**	**Establishments**	**Costs**	**Establishments**	**Costs**
236100	Residential Building	147,605	$3,048,532	3,421	$141,310	8	$1,652	151,034	**$3,191,494**
236200	Nonresidential Building	35,272	$728,483	5,697	$235,324	49	$10,120	41,018	**$973,927**
237100	Utility System	14,975	$309,283	3,618	$149,447	93	$19,208	18,686	**$477,938**
237200	Land Subdivision	1,730	$35,732	410	$16,936	10	$2,065	2,150	**$54,733**
237300	Highway, Street, and Bridge Construction	7,385	$152,525	2,625	$108,430	33	$6,816	10,043	**$267,770**
237900	Other Heavy and Civil Engineering Construction	3,637	$75,116	570	$23,545	15	$3,098	4,222	**$101,759**
238100	Foundation, Structure, and Building Exterior	78,749	$1,626,427	7,030	$290,386	22	$4,544	85,801	**$1,921,357**
238200	Building Equipment	125,768	$2,597,521	16,649	$687,714	119	$24,577	142,536	**$3,309,813**
238300	Building Finishing	71,471	$1,476,105	5,844	$241,396	15	$3,098	77,330	**$1,720,599**
238900	Other Specialty Trade	58,344	$1,204,997	4,844	$200,089	26	$5,370	63,214	**$1,410,456**
221100	Electric Utilities	482	$9,953	4,010	$165,640	170	$35,111	4,662	**$210,703**
999200	State Governments	0	$0	25	$1,033	0	$0	25	**$1,033**
999300	Local Governments	0	$0	5,000	$206,533	0	$0	5,000	**$206,533**
	Totals	**545,417**	**$11,264,675**	**59,743**	**$2,467,781**	**560**	**$115,659**	**605,720**	**$13,848,114**

Source: OSHA, Directorate of Standards and Guidance, Office of Regulatory Analysis, based on OSHA (2016).

Costs for Training on, and Communication of, Silica Hazards to Employees in Construction

Paragraphs (i)(1) and (i)(2) of the final construction rule parallel paragraphs (j)(1) and (j)(3) of the general industry standard, and includes hazard communication under paragraph (i)(1) and employee information and training under paragraph (i)(2). Most of the comments received on the general industry rule were applicable to the construction rule as well because they addressed types of costs or unit costs. OSHA has therefore estimated the costs for training in the same way and for the same reasons as discussed earlier in the section on general industry, although certain cost components, such as the average supervisor and employee wages, are different in construction and general industry. As with the general industry standard, the hazard communication required under paragraph (i)(1) is already required and costed under OSHA's hazard communication standard (HCS) (29 CFR 1910.1200, made applicable to construction through 29 CFR 1926.59). Therefore, OSHA has estimated no costs for compliance with this paragraph of the final silica rule. The silica construction standard includes a requirement for a competent person, but the costs for competent persons to receive training are estimated and discussed in the cost section on the written exposure control plan.

Training requirements in the construction rule

Employers covered by the standard are required to include respirable crystalline silica in the program established to comply with the HCS. The employer must ensure that each employee has access to labels on containers of crystalline silica and safety data sheets, and is trained in accordance with the provisions of the HCS and paragraph (i)(2) of the respirable crystalline silica standard. The employer must also ensure that at least the following hazards are addressed: Cancer, lung effects, immune system effects, and kidney effects.

Paragraph (i)(2) of the construction standard requires that employers ensure that each employee who is covered by this section can demonstrate knowledge and understanding of at least the following: (A) the health hazards associated with exposure to respirable crystalline silica; (B) specific tasks in the workplace that could result in exposure to respirable crystalline silica; (C) specific measures the employer has implemented to protect employees from exposure to respirable crystalline silica, including engineering controls, work practices, and respirators to be used; (D) the requirements of the silica rule; (E) the identity of the "competent person" designated by the employer in accordance with the requirements of the standard and (F) the purpose and a description of the silica medical surveillance program. This requirement applies to existing employees, newly hired workers who would require training before starting work, workers who change jobs within their current workplace or are assigned new tasks or exposure protection, and any covered worker an employer believes needs additional training. As this is a performance standard, there is not a specified hours-of-training requirement; the amount of silica training an employee receives will depend on what is required for employees to demonstrate knowledge and understanding of the subjects listed under paragraphs (i)(2)(i)(A)-(F).

A few commenters from the construction sector provided specific comments on OSHA's estimate of training time. For example, Fann Contracting, Inc. considered OSHA's estimates reasonable and noted that it already provides training classes and could work in silica without a significant problem:

> OSHA's cost estimates of training employees on respirable crystalline silica-related hazards is probably not too far off …. Fann Contracting, Inc. has 26 actual training classes it offers to its employees * * * It would be easy for Fann Contracting, Inc. to change the required health and safety related topic in its OSHA 10 hour training, which all employees are required to attend within three months of being hired, from asbestos … to safety and health related hazards of silica (Document ID 2116, Attachment 1, p. 21).

Kellie Vazquez, from Holes Incorporated, testified that the training on the silica hazards in her firm consists of employees watching a video, going over a booklet, and taking a test on the materials presented. She reported that this training took "an hour or two" (Document ID 3580, Tr. 1389). While Ms. Vazquez did not clarify whether the training provided by her firm exceeded the requirements of the OSHA standard or would be representative of the minimum training time for other employers in the construction industry, OSHA notes that its estimate of one hour for training time is not inconsistent with the Holes Incorporated estimate. George Kennedy, from the National Utility Contractors Association, estimated the instructor's charge to be $20.00 per hour and stated that training the employees is "likely to take 3-to-4 hours to train each employee," (Document ID 2171, p. 5). Mr. Kennedy did not provide any further explanation as to what this time estimate entails or specify whether that training time would encompass information already required (and costed) under OSHA's hazard communication standard. OSHA also notes that Mr. Kennedy estimated a training professional's wage of $20 per hour, while the Agency used an hourly wage more than twice that amount—over $44 an hour for a construction supervisor.

OSHA has explained the basis for its estimate of one hour of training time for the general industry standard, and is not persuaded that employees would require any significant increase in training time in order to comply with the construction standard. OSHA updated the wage rates to 2012 wage rates for the supervisor who will be providing the training and the workers who will be receiving the training (shown below in Table V-69). The Agency has reviewed its baseline training estimates in light of the comments discussed in the general industry analysis and additional comments submitted by employers in the construction sector. In particular, some commenters in the construction sector, such as the International Union of Bricklayers and Allied Craftworkers, provided anecdotal evidence that many employers are already training their employees regarding silica (Document ID 2329, p. 5).

Commenter Joseph Liss disagreed with OSHA's multiplier for determining the number of employees requiring training because the "multiplicative factor for training purposes is likely to be much higher" than the FTE multiplied by a factor of 2 or 5, depending on the sub-industry (Document ID 1950, p. 9). OSHA has reviewed the comment submissions and revised the estimation procedures by developing occupation- and industry-specific estimates of the ratio between the number of affected workers and the associated number of FTEs.

Mr. Liss also questioned the methodology of the training cost calculation in the PEA, including job seasonality and the turnover rate in construction (Document ID 1950, p. 9). Mr. Liss commented that OSHA had not included initial training for all of the full-time-equivalent (FTE) workers exposed to silica (Document ID 1950, p. 9). Mr. Liss's analysis appears to contain two errors: (1) his use of OSHA's unit costs for initial training failed to recognize that the costs reported in Table V-44 of the PEA were annualized costs, not total costs; (2) OSHA did not estimate costs for FTE workers but did in fact account for the initial training costs for all workers contributing to the FTE work estimates. Those costs can be seen in the PEA on Table V-44 and can be found in the FEA in Table V-70. Finally, OSHA accounted for the seasonality and turnover in the construction industry by incorporating the BLS hiring rate[75] of 64.0 percent in the PEA (BLS, 2008) and 70.3 percent in the FEA (BLS, 2012a). A breakdown of OSHA's training cost methodology, including turnover in the construction industry, can be found in Table V-69.

The training requirements are generally the same under the construction standard as under the general industry standard, and OSHA generally used the same approach in determining the costs for training under the construction standard (note that "competent person" training is costed separately with the costs for the written exposure control plan.) As with the cost estimates for the general industry rule, OSHA concludes that the

[75] In the PEA, OSHA in some cases referred to this rate as the separations rate, but in fact the Agency was using the hiring rate reported by BLS. Because the regulatory analysis is based on steady-state economic conditions, the separations rate, the hiring rate, and the turnover rate are effectively identical.

additional silica training required in the final rule is sufficiently specific to the provisions of the final rule that baseline silica training would make only a minor contribution to employer compliance with the (additional) training required in the final rule. Therefore, for this FEA, OSHA is assuming no baseline respirable crystalline silica training in construction (other than that already required under the HCS), but that a full hour of training, on average, will be required for all covered workers. This removal of baseline respirable crystalline silica training in estimating training costs has the effect, by itself, of increasing the effective training costs for construction in the FEA relative to the PEA by 33 percent (from an average training time, per employer, from 45 minutes to 60 minutes). OSHA again recognizes that this change will likely lead to an overestimation of training costs for some employers.

Otherwise, OSHA did not change the unit cost parameters used in the PEA. For example, for costing purposes, in the PEA, OSHA assumed that all new hires would receive the full silica training from their new employer. OSHA has maintained this assumption in the FEA despite the fact that many new hires in construction may have been previously employed in the same industry and in some cases by the same establishment, so that they might have already received respirable crystalline silica training sufficient to comply with part or all of the training requirements specified in the final rule. The only unit cost difference between the PEA and the FEA is that the estimate of unit training costs has been inflated from 2009 to 2012 dollars. In addition, the hiring rate in the construction sector—used to estimate the amount of new hire training—increased from 64.0 percent (2008 data used in the PEA) to 70.3 percent (2012 data used in the FEA) in construction.

Also, as was done in the PEA, OSHA developed estimates of average class sizes as a function of establishment size. For training of current employees (i.e., initial training), OSHA is adopting the same estimated class sizes as in the general industry analysis, which are also the same as used in the PEA: 5 workers for establishments with fewer than 20 employees; 10 workers for establishments with 20 to 499 employees; and 20 workers for establishments with 500 or more employees. For new-hire training, OSHA estimated an average class size of 2 workers for establishments with fewer than 20 employees; 5 workers for establishments with 20 to 499 employees; and 10 workers for establishments with 500 or more employees.

The unit costs of training for this FEA are summarized below in Table V-69. As shown, OSHA has estimated the annualized cost (annualized over 10 years) of initial training to be between $4.21 and $4.99 per employee and the annual cost of new hire training at between $38.14 and $55.76 per employee, depending on establishment size.

Table V-70 summarizes OSHA's estimate of the annualized costs, by NAICS industry, of the training requirements in the final standard for the construction sector. This estimate is based on the assumption that all workers in the construction sector who are within the scope of the final standard would receive the required silica training. Combined over all NAICS construction industries, the cost of the training requirements is $76.1 million annually.

Table V-71 summarizes for the construction sector, by NAICS industry, the annualized costs of employer familiarization and employee training for the final rule. For the construction sector, combined over all NAICS industries, the annualized cost of employer familiarization and employee training for the final rule is $89.9 million annually.

Table V-69
Training - Construction
Assumptions and Unit Costs

Cost Category	Cost			Comments/Assumptions
Direct Costs				
Instructor cost per hour	$44.04			Based on supervisor wage, adjusted for fringe benefits (BLS, 2012b)
Materials for class per attendee	$2.10			Estimated cost of $2 per worker for the training/reading materials; Inflated to 2012.
Labor Costs				
Time spent in class (min)	60			Estimated average training session time
Class size by Establishment Size				
	Small (<20)	Medium (20-499)	Large (500+	
Initial training	5	10	20	
New hire training	2	5	10	
Value of worker time spent in class	$31.63	$31.63	$31.63	Based on worker wage, adjusted for fringe benefits (BLS, 2012b)

Source: OSHA, Directorate of Standards and Guidance, Office of Regulatory Analysis, based on OSHA (2016).

Table V-69 (continued)
Training - Construction
Assumptions and Unit Costs

Annualized Training Cost per Employee by Establishment Size				
	Small (<20)	Medium (20-499)	Large (500+	
Initial training				
Value of instructor's time	$8.81	$4.40	$2.20	
Value of employee's time	$31.63	$31.63	$31.63	
Cost of materials	$2.10	$2.10	$2.10	
Total	$42.54	$38.14	$35.94	
Annualized total	$4.99	$4.47	$4.21	
New hire training				
Value of instructor's time	$22.02	$8.81	$4.40	
Value of employee's time	$31.63	$31.63	$31.63	
Cost of materials	$2.10	$2.10	$2.10	
Total	$55.76	$42.54	$38.14	
Hiring rate	70.3%			2012 annual hires rate for the construction industry (BLS Job Openings and Labor Turnover Survey)

Source: OSHA, Directorate of Standards and Guidance, Office of Regulatory Analysis, based on OSHA (2016).

Table V-70: Annualized Training Costs Construction

NAICS	Industry	Covered (All)	Initial Training	New Hire Training	Total Training Costs
		All Establishments			
236100	Residential Building Construction	210,773	$1,018,370	$7,675,989	**$8,694,359**
236200	Nonresidential Building Construction	209,136	$966,289	$6,846,144	**$7,812,433**
237100	Utility System Construction	190,044	$850,802	$5,792,417	**$6,643,219**
237200	Land Subdivision	5,726	$26,253	$184,436	**$210,688**
237300	Highway, Street, and Bridge Construction	148,254	$670,135	$4,592,306	**$5,262,442**
237900	Other Heavy and Civil Engineering Construction	37,611	$168,942	$1,157,539	**$1,326,481**
238100	Foundation, Structure, and Building Exterior Contractors	324,954	$1,525,104	$11,033,680	**$12,558,784**
238200	Building Equipment Contractors	326,154	$1,517,729	$10,857,641	**$12,375,370**
238300	Building Finishing Contractors	140,813	$665,148	$4,859,405	**$5,524,554**
238900	Other Specialty Trade Contractors	259,906	$1,218,340	$8,806,155	**$10,024,495**
221100	Electric Utilities	6,541	$28,975	$193,888	**$222,863**
999200	State Governments	33,558	$150,036	$1,003,635	**$1,153,671**
999300	Local Governments	123,946	$554,152	$3,706,876	**$4,261,028**
	Totals	**$2,017,417**	**$9,360,277**	**$66,710,111**	**$76,070,388**

Source: OSHA, Directorate of Standards and Guidance, Office of Regulatory Analysis, based on OSHA (2016).

Table V-71: Combined Training and Familiarization Annualized Costs: Construction

NAICS	Industry	Familiarization Costs	Training Costs	Total
236100	Residential Building Construction	$3,191,494	$8,694,359	**$11,885,853**
236200	Nonresidential Building Construction	$973,927	$7,812,433	**$8,786,361**
237100	Utility System Construction	$477,938	$6,643,219	**$7,121,157**
237200	Land Subdivision	$54,733	$210,688	**$265,422**
237300	Highway, Street, and Bridge Construction	$267,770	$5,262,442	**$5,530,212**
237900	Other Heavy and Civil Engineering Construction	$101,759	$1,326,481	**$1,428,240**
238100	Foundation, Structure, and Building Exterior Contractors	$1,921,357	$12,558,784	**$14,480,141**
238200	Building Equipment Contractors	$3,309,813	$12,375,370	**$15,685,182**
238300	Building Finishing Contractors	$1,720,599	$5,524,554	**$7,245,153**
238900	Other Specialty Trade Contractors	$1,410,456	$10,024,495	**$11,434,951**
221100	Electric Utilities	$210,703	$222,863	**$433,566**
999200	State Governments	$1,033	$1,153,671	**$1,154,704**
999300	Local Governments	$206,533	$4,261,028	**$4,467,561**
	Totals	**$13,848,114**	**$76,070,388**	**$89,918,502**

Source: OSHA, Directorate of Standards and Guidance, Office of Regulatory Analysis, based on OSHA (2016).

Written Exposure Control Plan

A written exposure control plan provision was not included in the silica proposal, and no costs for a written exposure control plan were estimated in the PEA. Paragraph (g) of the final standard for the construction sector contains requirements for a written exposure control plan. The Summary and Explanation section of the preamble provides a thorough explanation of the reasoning behind the inclusion of the written exposure control plan provision in the final standard.

As specified in paragraph (g)(1) of the construction standard, an employer must establish and implement a written exposure control plan that contains at least the following elements: (i) a description of the tasks in the workplace that involve exposure to respirable crystalline silica; (ii) a description of the engineering controls, work practices, and respiratory protection used to limit employee exposure to respirable crystalline silica for each task; (iii) a description of housekeeping measures used to limit employee exposure to respirable crystalline silica; and (iv) a description of the procedures used to restrict access to work areas, when necessary, to minimize the number of employees exposed to respirable crystalline silica and their level of exposure, including exposures generated by other employers or sole proprietors. Under paragraph (g)(2), the employer must review and evaluate the effectiveness of the written exposure control plan at least annually and update it as necessary. Under paragraph (g)(4), the employer must designate a competent person to make frequent and regular inspections of job sites, materials, and equipment to implement the written exposure control plan.

Developing, reviewing, and updating a written exposure control plan

OSHA has estimated the cost of a written exposure control plan for the construction sector using the same time estimates (but sector-specific supervisory wages) as for the general industry/maritime requirement: 1 hour for establishments with fewer than 20 employees, 4 hours for those establishments with between 20 and 499 employees, and 16 hours for those establishments with 500 or more employees. OSHA estimated that 1 hour would be sufficient for very small establishments because there is, on average, slightly more than 1 worker covered by the standard per very small establishment in construction. As with the requirement in general industry, the Agency believes that the number of employees in the establishment serves as a reasonable proxy for the amount of time required to develop the written exposure control plan. The Agency expects this to be especially true in construction, as construction sites often involve workers performing several different tasks, requiring more coordination and planning. In addition, the employer may need to make some provision in the plan to limit access of persons not engaged in respirable crystalline silica-generating tasks to certain areas in certain situations.

OSHA further determined that the additional supervisory time needed to review and evaluate the effectiveness of the plan and to update it as necessary will also be based on establishment size. OSHA is estimating 0.5 hours for establishments for fewer than 20 employees, 2 hours for those with between 20-499 employees, and 8 hours for those with 500 or more employees to perform the annual review and update.

Although OSHA did not include the written exposure control plan in the proposal, OSHA received comments confirming that a written exposure control plan provision would be simple and inexpensive to create. The International Union of Bricklayers and Allied Craftworkers noted that “creating control plans is simple and cost effective for all contractors” because of the availability of online tools such as the Center for Construction Research and Training's Work Safely with Silica website (Document ID 2329, p. 5).

The annualized unit costs to develop, review and evaluate, and update the written exposure control plan, presented in Table V-72, have been applied to the employers in the construction sector covered by the standard—in all, 534,133 establishments with fewer than 20 employees, 59,744 establishments with between 20 and 499 employees, and 560 establishments with 500 or more employees. The annualized costs, broken out by NAICS construction industry, are shown in Table V-73. For the construction sector, the total annualized cost of developing, reviewing, and updating the written exposure control plan is $22.4 million.

Table V-72: Unit Costs for Developing a Written Exposure Control Plan in Construction

Develop exposure control plan

	Small (<20)	Medium (20-499)	Large (500+)	
Time to develop plan (hours)	1.0	4.0	16.0	
Annualized cost for plan development	$6.27	$25.08	$100.33	Annualized one-time cost to develop plan. Valued at weighted average of supervisors' hourly wage rate for affected construction industries of $44.04 per hour. Wages include fringe benefits. (BLS, 2012b).
Time for annual review and updating (hours)	0.5	2.0	8.0	
Annual review cost	$22.02	$88.09	$352.35	Annual cost to review plan. Valued at weighted average of supervisors' hourly wage rate for affected construction industries of $44.04 per hour. Wages include fringe benefits. (BLS, 2012b)
Total annualized cost	$28.29	$113.17	$452.69	

Source: OSHA, Directorate of Standards and Guidance, Office of Regulatory Analysis, based on OSHA (2016).

Table V-73: Annualized Exposure Control Plan Development Costs by Establishment Size

NAICS	Industry	Small (<20)	Medium (20-499)	Large (500+)	Total Exposure Control Plan Development Cost
236100	Residential Building Construction	$4,176,191	$387,162	$3,622	**$4,566,974**
236200	Nonresidential Building Construction	$997,951	$644,741	$22,182	**$1,664,874**
237100	Utility System Construction	$423,688	$409,457	$42,100	**$875,245**
237200	Land Subdivision	$48,949	$46,401	$4,527	**$99,877**
237300	Highway, Street, and Bridge Construction	$208,944	$297,077	$14,939	**$520,959**
237900	Other Heavy and Civil Engineering Construction	$102,902	$64,508	$6,790	**$174,200**
238100	Foundation, Structure, and Building Exterior Contractors	$2,228,047	$795,600	$9,959	**$3,033,606**
238200	Building Equipment Contractors	$3,558,351	$1,884,202	$53,870	**$5,496,423**
238300	Building Finishing Contractors	$2,022,120	$661,378	$6,790	**$2,690,288**
238900	Other Specialty Trade Contractors	$1,650,728	$548,206	$11,770	**$2,210,703**
221100	Electric Utilities	$13,635	$453,820	$76,957	**$544,412**
999200	State Governments	$0	$2,829	$0	**$2,829**
999300	Local Governments	$0	$565,860	$0	**$565,860**
	Totals	**$15,431,507**	**$6,761,240**	**$253,505**	**$22,446,252**

Source: OSHA, Directorate of Standards and Guidance, Office of Regulatory Analysis, based on OSHA (2016).

Implementing the access restriction provision of the written exposure control plan

In construction, there is no regulated area requirement, and employers may be faced with new costs due to activities necessary to implement the written exposure plan as they move from site to site. OSHA has therefore included costs for implementation, in addition to the costs for development of the plan, for construction employers. Paragraph (g)(4) requires the employer to designate a competent person to implement the plan, and OSHA has addressed the additional costs for training the competent person after the discussion of the implementation costs.

Paragraph (g)(1)(iv) requires that the written exposure control plan include provisions to restrict access to work areas, when necessary, to minimize the number of employees exposed to respirable crystalline silica and their level of exposure, including exposures generated by other employers or sole proprietors. The competent person has two broad options to restrict access to work areas when necessary: (1) notifying or briefing employees, or (2) direct access control. The direct access control component is similar to the written access control plan included in the PEA, which OSHA has replaced with the written exposure control plan in the final rule. While the requirements for the written exposure control plan are more performance-oriented and thus should provide more flexibility for employers and reduce the cost of compliance, OSHA has estimated the costs of these options using, where appropriate, comparable components of the regulated area and written access control plan costs estimated in the PEA.[76]

Employee Notification or Briefing

For the employee notification or briefing option, OSHA estimated that, on average, it will take the competent person 15 minutes (0.25 hours) per job to revise the briefing plan, that each job will last 10 work-days, and that there are 150 construction working days in a year (Document ID 1709, p. 4-6). OSHA further estimated that it will take the competent person 6 minutes (0.1 hours) to brief each at-risk crew member (where an at-risk crew member could be an employee, a contractor, a subcontractor, or other worker under the control of the competent person) and that each crew consists of 4 at-risk workers

[76] For example, the time needed to identify and set up the direct access control area was estimated to be the same as the time needed to identify and set up the regulated area. Many costs in the PEA were not included here—for example, the costs for disposable clothing and extra respirators—because the written exposure control plan provisions do not require them.

(Document ID 1720, Table V-19, pp. V-108-112). As shown in Table V-74, the annual cost of the briefing option is $105.25 per at-risk crew member.[77]

Marcus Kuizenga, of James Hardie Building Products, Inc., commenting on OSHA's estimates for communication under the regulated area and written access control plan requirements in the PEA, stated that OSHA had estimated costs only to communicate to employees, but not to subcontractors at the same worksite (Document ID 2322, Attachment 1, p. 177). The Agency's preliminary estimate in the PEA encompassed communication to all at-risk workers at a worksite, where a worker could be an employee, a contractor, a subcontractor, or other worker under the control of the employer. OSHA assumed that each worker's employer, and not necessarily the general contractor at a worksite, would be responsible for employee communication. This all-inclusive group of workers requiring communication under the requirements in the proposed rule for regulated work areas and written access controls is the same group that would require job briefings under the written exposure control requirements in the final rule (although some of these workers will be addressed through direct access controls rather than job briefings).

For the FEA, OSHA is retaining the underlying assumptions used in the PEA. Despite the fact that there may be employees of many different employers at a worksite, OSHA did not increase the crew size for its estimates in the FEA both because subcontractors are likely to have their own competent person (which means that costs for the employee briefing provision to be implemented for the subcontractor's workers will be borne by the subcontractor and not the contracting employer) and because in many situations the workers generating the silica dust are the only ones at the jobsite at the time. This latter point was noted in the case of granite countertop installation in a comment by Tony Zimbelman representing the National Association of Homebuilders (Document 2334, pp. 5 and 7).

Direct Access Control

For the direct access control option, OSHA has estimated that, in addition to developing the overall written exposure control plan, it will take the employer, on average, 15 minutes (0.25 hours) per job to revise the plan concerning direct access control in order to tailor it to the specific conditions of the worksite and, again, that each job will last 10 work-days and that there are 150 construction working days in a year. Thus, OSHA estimates that, on average, each employer would implement direct access control 15 times per year over a total of 3.75 hours per year. OSHA then multiplied the number of

[77] The per worker cost is equal to the total cost for job briefing divided by the number of workers per crew times the number of jobs per year.

hours by the supervisory hourly wage to determine the cost per job, and divided this cost by the crew size of 4 to obtain the cost per worker.

For the direct access control option, OSHA has also added the cost of signage and tape for constructing physical barriers: 100 feet of hazard tape (per job) and three warning signs. OSHA presented these costs in the PEA as the cost of materials to establish a regulated area. Because the Agency received no comment on these costs and because, functionally, the act of establishing a restricted access area and a regulated area are the same, these costs were used for this FEA estimate of the cost of materials to establish a restricted access area. These costs are presented in Table V-74. As also shown there, the annualized cost of the direct access control option is $71.40 per at-risk crew member.[78] In developing an alternative cost model, Mr. Kuizenga added costs through a productivity penalty

> associated with wearing personal protective equipment (PPE) and/or observing the boundaries of access control areas, because it is simply not realistic to believe that work can be conducted as quickly and efficiently while wearing PPE as with normal work clothing and equipment or while taking a more circuitous path to reach and work on different areas within a work site (Document 2322, p. 190).

Mr. Kuizenga also included costs for the controlled access area to be established three times on each project, and estimated that a project would take sixty days and that workers would work 250 days per year (Document 2322, pp. 189-190). OSHA disagrees with all of these assumptions and the resulting additional cost estimates. As has been previously explained in the discussion of engineering control costs in construction, workers in construction are estimated to work an average of 150 days a year, not 250. More importantly, the written exposure control plan included in this final rule does not require those entering the controlled access area to wear PPE. In addition, the access restrictions need to be implemented only under certain circumstances, such as when Table 1 tasks that require workers to wear a respirator are being performed. Finally, Mr. Kuizenga's industry, residential building construction, would only infrequently involve Table 1 tasks that require a respirator.

Kellie Vasquez, of Holes Incorporated, also suggested that there might be a productivity penalty for her workers associated with access control plans:

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[78] The per-worker cost is equal to the competent person cost per job to identify and set up the controlled access area divided by the number of workers per crew times the number of jobs per year plus the per worker per year cost of materials.

> My equipment operators are the first ones to arrive onsite to review the site conditions. They have enough room on their trucks for the equipment necessary to cut concrete and perform their duties but they do not have room on their trucks to carry equipment to set up these areas (Document 2338, Attachment 1, p. 5).

Ms. Vazquez's comment was directed at regulated area and controlled access plan requirements in the proposed rule. These requirements were not included in the final construction standard; the related requirement in the final construction standard is for a written exposure control plan. However, restricted access as needed to comply with the written exposure control plan can be accomplished by a job briefing as well as through the use of access control materials. For that reason, the difficulties Ms. Vazquez envisions need not arise in the final rule.

As discussed in the Summary and Explanation section of the preamble concerning the written exposure control plan, restricting access is necessary where respirator use is required under Table 1 or when an exposure assessment reveals that exposures are in excess of the PEL, or in other situations identified by the competent person.[79] On the other hand, when exposure to respirable crystalline silica is being successfully contained by engineering controls and work practices specified in Table 1 and no respirator use is required by Table 1, implementation of access control procedures is not required.

OSHA assumed that, in restricting access, half the time employers would use the briefing option and the other half of the time they would use direct access control. Consequently, as shown in Table V-74, the annualized cost of restricting access to work areas is $88.33 per at-risk crew member.[80]

The annualized unit costs for the competent person to implement the written exposure control plan to restrict access to work areas, presented in Table V-74, have been applied to the covered employers in the construction sector with workers using respirators required by Table 1 and where workers are performing abrasive blasting and tunneling work. The annualized costs, broken out by NAICS construction industry, are shown in Table V-75. For the construction sector, the total annualized cost for the competent person to implement the written exposure control plan is $2.7 million.

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[79] In addition, as explained in the Summary & Explanation, the written exposure control plan must also provide for situations where employees could encounter potential overexposures generated by unusual circumstances, such as excessive exposures generated by other employers or sole proprietors.

[80] This weighted average is equal to the per employee cost per briefing times 50 percent plus the per employee cost of direct access control times 50 percent.

Table V-74: Unit Costs for Implementing Access Restriction Provisions of a Written Exposure Control Plan in

Option 1: Job Briefing			
Revise plan for specific job (hours)	0.25	$11.01	Per job. Valued at supervisor's wage
Communication of plan provisions (hours)	0.1		Per job. Value of supervisors' and workers' time for briefing on job specific site-control provisions.
Communication of plan provisions (cost, supervisor wage)		$4.40	Per job. Valued at supervisor's wage
Communication of plan provisions (cost, crew wage)		$12.65	Crew members; based on crew size assumption below
Total cost per crew for implementing plan through job briefing (per job)		$28.07	
Option 2: Direct Access Control			
Access control materials (per crew)			
Hazard tape per job (100 ft)		$6.03	(Lab Safety Supply, 2010, inflated to
Warning signs (3)		$78.86	$25.30 per sign (Lab Safety Supply, 2010, inflated to 2012)
Warning signs - annualized cost		$30.05	Assumes 3 year life
Total annualized costs		$120.44	Based on job frequency and crew size assumptions below
Material cost per worker (per year)		$30.11	
Supervisor time to identify and set up direct access control areas (hours)	0.25	$11.01	Per job
Job Frequency and Crew Size Assumptions			
Share of jobs requiring direct access control measures	50.0%		Estimated by ERG
Average crew size (workers)	4		Estimated by ERG
Average job length (days)	10		Estimated by ERG
Working days per year	150		Based on comments during SBAR Panel
Per-worker costs for plan implementation or direct access control implementation			
Annual cost per worker - briefing only		$105.25	
Annual cost per worker – direct access control only		$71.40	
Weighted average annual cost per worker		$88.33	

Source: OSHA, Directorate of Standards and Guidance, Office of Regulatory Analysis, based on OSHA (2016).

Table V-75: Annualized Access Restriction Implementation Costs in Construction

NAICS	Industry	Control Plan Implementation	
		At-Risk w/ Respirators (FTEs)	Exposure Control Plan Implementation Cost
236100	Residential Building Construction	1,413	$124,783
236200	Nonresidential Building Construction	1,581	$139,685
237100	Utility System Construction	2,234	$197,324
237200	Land Subdivision	46	$4,089
237300	Highway, Street, and Bridge Construction	1,751	$154,619
237900	Other Heavy and Civil Engineering Construction	347	$30,645
238100	Foundation, Structure, and Building Exterior Contractors	6,256	$552,571
238200	Building Equipment Contractors	488	$43,111
238300	Building Finishing Contractors	8,402	$742,126
238900	Other Specialty Trade Contractors	6,432	$568,103
221100	Electric Utilities	15	$1,299
999200	State Governments	265	$23,381
999300	Local Governments	940	$83,059
	Totals	**30,170**	**$2,664,794**

Source: OSHA, Directorate of Standards and Guidance, Office of Regulatory Analysis, based on OSHA (2016).

Training the competent person

As specified in paragraph (g)(4) of the final standard, a competent person must carry out the responsibilities of implementing the written exposure control plan. As defined in the standard, "competent person" means an individual who is capable of identifying existing and foreseeable respirable crystalline silica hazards in the workplace and who has authorization to take prompt corrective measures to eliminate or minimize them, as well as has the knowledge and ability necessary to fulfill the responsibilities set forth in paragraph (g) of the standard. Employers in construction are already required, under Subpart C—General Safety and Health Provisions; 1926.20(b)(1) and (2), to initiate and maintain programs as may be necessary to comply with the safety and health provisions of that Part. These programs, if necessary, must include provisions for a competent person, designated by the employer, to perform "frequent and regular inspections of the job sites, materials, and equipment."

OSHA has utilized the competent person provision in other construction standards, such as 1926.1127, Cadmium, and 1926.1101, Asbestos, so the Agency expects that there is widespread familiarity with both the concept and the responsibilities of competent person in the construction sector. As in other OSHA construction rules, a major purpose of the competent person provision in this final silica standard is to identify who has the responsibility for inspections of the job sites, materials, and equipment. Thus, OSHA expects that most employers will have training programs in place to produce competent persons, and the cost of training someone will only be a relatively small marginal increase in the overall training cost.

OSHA does not anticipate any additional costs beyond training costs to be associated with the requirement that a competent person implement the written exposure control plan. Any corrective measures involving control equipment that result from the inspections performed by the competent person would be covered under the maintenance and repair costs that OSHA has already estimated as part of the costs for engineering controls.

In paragraph (e) of the proposed rule, employers had the option of controlling access through either a regulated area or a written access control plan. The role of the competent person was limited to the implementation of a written access control plan, which required the competent person to have the "knowledge and experience necessary to identify in advance tasks or operations during which exposures are reasonably be expected to exceed the PEL" (78 FR 56443, Sept. 12, 2013). Comments on competent person costs focused on the cost of training the competent person. Because the competent person would need to have a similar knowledge base and skill set to implement the written exposure control plan as required by the final rule, OSHA has treated the comments on competent person training as directly relevant to training under the final rule.

CISC opposed the inclusion of the competent person provision as unnecessary but also believed that a competent person, if required by the final standard, would not need additional training. Bradford Hammock, representing the CISC, commented that:

> An individual's experience, job training, and silica awareness training, in the CISC's view, will provide the capabilities envisioned by OSHA for a competent person with respect to crystalline silica. For silica in construction, the CISC respectfully believes that no specific training for a "competent person" is required (Document ID 2319, p. 128).

Other commenters disagreed, indicating that the training required by the proposed competent person provision was insufficient. The International Union of Operating Engineers (IUOE) suggested requiring that each competent person receive “specific hands on training on the engineering controls and work practices associated with the employee’s tasks, including the applicable work practices” (Document ID 2262, pp. 38-39). Additionally, Tom Nunziata, from the Laborers’ International Union of North America Training and Education Fund, testified that:

> Because by definition the competent person is one who is capable of identifying an existing, predictable respirable crystalline silica hazards in the surroundings or working conditions, and has the authorization to take prompt corrective measures to eliminate them, it is imperative that they have a detailed knowledge in the safe operation of the tools and engineering controls being employed on the job, and be capable of identifying when the controls are not functioning or being employed properly (Document ID 3589, Tr. 4221).

While the competent person provision does not specify a training requirement, the competent person is required to possess the knowledge and skills to perform the functions required by the standard. For that reason, the Agency expects that many employees designated as competent persons will undergo some training for the position. IUOE commented that competent persons should have at least “the same level of training for those workers performing silica dust-generating tasks, including hands-on training addressing the safe operation of tools and associated engineering controls” (Document ID 3589, Tr. 4221). OSHA agrees that the competent person will need training to, among other things, be able to ensure the safe operation of all tools used in silica-generating activities and implement the applicable controls. However, OSHA expects the competent person to require more training than the average worker since the competent person will need to have knowledge of all tools and silica-generating processes on the worksite.

Therefore, the Agency is estimating that each competent person will, on average, undergo two hours of training—in addition to the one hour of silica training estimated for all construction employees.

Because employers in construction are already required to have a competent person to comply safety and health provisions of Subpart C—General Safety and Health Provisions; 1926.20(b)(1) and (2), OSHA expects that each establishment will already have a competent person program in place. OSHA is therefore not including additional costs for the administration or management of a competent person program because the Agency expects employers will already be familiar with the concept of a competent person. The specific number of competent persons at each establishment would be determined by establishment size. Based on OSHA's knowledge of the typical crew, worksite, and workflow in the construction industry, the Agency estimates that, on average, there will be 1 competent person for each establishment with fewer than 20 employees,[81] 5 competent persons for each establishment with 20-499 employees, and 10 competent persons for each establishment with 500 or more employees.

OSHA expects that competent persons will be trained by a supervisor, presumably one who went through the process to become familiar with the requirements of the respirable crystalline silica standard, or by a combination of supervisory and/or technical staff that are familiar with the operation of the engineering controls. While the competent persons are not required to be supervisors and some of the staff providing the training may not be supervisors, OSHA is using a supervisor's wage to estimate the costs for time spent by both the trainers and the trainees in order to provide the upper cost limit, realizing that the cost for establishments who do not designate supervisors as the competent person will be lower.

The annualized cost for an employer to provide competent person training, by establishment size, is shown in Table V-76. The total cost for competent person training, by NAICS construction industry, is shown in Table V-77. For the construction sector, the total annualized cost for training the competent person to perform the responsibilities laid out in the final rule is $15.0 million.

[81] The Agency expects that most establishments have at least two competent persons, with one serving as back-up on any particular shift. However, establishments with fewer than 20 employees have an average of only about one affected worker. Hence, if that worker were unavailable, there would be no one left to engage in a silica-generating task, and a back-up competent person would be unnecessary. Alternatively, if some of these very small establishments have two or more affected workers, there will be others with no affected workers (and OSHA will have overestimated the number of affected establishments).

Table V-76: Unit Costs for Competent Person Training in Construction

	Small (<20)	Medium (20-499)	Large (500+)	
Persons per establishment	1.0	5.0	10.0	
Training time (hours)	2.0			Assumes all are trained in the same class. Time for the trainer and trainee valued at the supervisor wage (BLS, 2012b)
Total cost per establishment	$176.18	$528.53	$968.97	
Annualized cost	$20.65	$61.96	$113.59	

Source: OSHA, Directorate of Standards and Guidance, Office of Regulatory Analysis, based on OSHA (2016).

Table V-77: Training Costs for Competent Person in Construction

Related to the Written Exposure Control Plan

		Annualized Competent Person Training Costs by Establishment Size			
NAICS	**Industry**	**Small (<20)**	**Medium (20-499)**	**Large (500+)**	**Total Competent Person Cost**
236100	Residential Building Construction	$3,048,532	$211,965	$909	**$3,261,405**
236200	Nonresidential Building Construction	$728,483	$352,986	$5,566	**$1,087,035**
237100	Utility System Construction	$309,283	$224,171	$10,564	**$544,018**
237200	Land Subdivision	$35,732	$25,404	$1,136	**$62,272**
237300	Highway, Street, and Bridge Construction	$152,525	$162,645	$3,749	**$318,918**
237900	Other Heavy and Civil Engineering Construction	$75,116	$35,317	$1,704	**$112,137**
238100	Foundation, Structure, and Building Exterior Contractors	$1,626,427	$435,578	$2,499	**$2,064,505**
238200	Building Equipment Contractors	$2,597,521	$1,031,571	$13,518	**$3,642,610**
238300	Building Finishing Contractors	$1,476,105	$362,094	$1,704	**$1,839,903**
238900	Other Specialty Trade Contractors	$1,204,997	$300,134	$2,953	**$1,508,084**
221100	Electric Utilities	$9,953	$248,459	$19,311	**$277,723**
999200	State Governments	$0	$1,549	$0	**$1,549**
999300	Local Governments	$0	$309,800	$0	**$309,800**
482110	Railroads*	$0	$20,936	$0	**$20,936**
	Totals	**$11,264,675**	**$3,701,672**	**$63,612**	**$15,029,958**

Source: OSHA, Directorate of Standards and Guidance, Office of Regulatory Analysis, based on OSHA (2016).

*Any railroad costs calculated for the construction sector have been incorporated in general industry costs for NAICS 482110.

The annualized unit costs for the written exposure control plan have been applied to the employers in construction covered by the standard. These annualized costs, broken out by NAICS construction industry, are shown in Table V-78. Combined over all affected construction industries, the estimated annualized cost of the written exposure control plan provision is $40.1 million, which includes an annualized cost of $22.4 million to develop the written exposure control plan, $2.7 million to implement the access restriction provisions of the plan, and $15.0 million for competent person training.

Table V-78: Total Annualized Costs of Exposure Control Plan in Construction

NAICS	Industry	Total Exposure Control Plan Development Cost	Exposure Control Plan Implementation Cost	Total Competent Person Cost	Total Annual Exposure Control Plan Cost
236100	Residential Building Construction	$4,566,974	$124,783	$3,261,405	**$7,953,162**
236200	Nonresidential Building Construction	$1,664,874	$139,685	$1,087,035	**$2,891,594**
237100	Utility System Construction	$875,245	$197,324	$544,018	**$1,616,587**
237200	Land Subdivision	$99,877	$4,089	$62,272	**$166,237**
237300	Highway, Street, and Bridge Construction	$520,959	$154,619	$318,918	**$994,496**
237900	Other Heavy and Civil Engineering Construction	$174,200	$30,645	$112,137	**$316,982**
238100	Foundation, Structure, and Building Exterior Contractors	$3,033,606	$552,571	$2,064,505	**$5,650,682**
238200	Building Equipment Contractors	$5,496,423	$43,111	$3,642,610	**$9,182,144**
238300	Building Finishing Contractors	$2,690,288	$742,126	$1,839,903	**$5,272,317**
238900	Other Specialty Trade Contractors	$2,210,703	$568,103	$1,508,084	**$4,286,890**
221100	Electric Utilities	$544,412	$1,299	$277,723	**$823,434**
999200	State Governments	$2,829	$23,381	$1,549	**$27,759**
999300	Local Governments	$565,860	$83,059	$309,800	**$958,719**
	Totals	**$22,446,252**	**$2,664,794**	**$15,029,958**	**$40,141,004**

Source: OSHA, Directorate of Standards and Guidance, Office of Regulatory Analysis, based on OSHA (2016).

Combined Construction Control, Respirator, and Program Costs

Table V-79 summarizes the engineering control costs, respirator costs, and program costs of the rule for the construction sector. Annualized compliance costs in construction are expected to total $659.0 million, of which $423.4 million are for engineering controls, $22.4 million are for respirators, and $213.2 million are to meet the ancillary provisions of the rule. These ancillary annual costs consist of $16.5 million for exposure monitoring; $66.7 million for medical surveillance; $89.9 million for familiarization and training; and $40.1 million for the written exposure control plan.

Table V-B-1 in Appendix B presents estimated compliance costs by NAICS industry code and program element for small entities (as defined by the Small Business Administration) in construction, while Table V-B-2 presents estimated compliance costs, by NAICS code and program element, for very small entities (fewer than twenty employees) in construction.

Table V-79: Annualized Compliance Costs for Construction Employers Affected by OSHA's Silica Standard (2012 Dollars)

NAICS	Industry	Control Costs	Respirators	Exposure Assessment	Medical Surveillance	Control Plan	Training & Familiarization	Total
236100	Residential Building Construction	$23,741,539	$2,661,194	$620,700	$8,082,550	$7,953,162	$11,885,853	**$54,944,997**
236200	Nonresidential Building Construction	$31,622,794	$2,236,399	$449,980	$6,745,998	$2,891,594	$8,786,361	**$52,733,126**
237100	Utility System Construction	$61,606,007	$3,169,804	$330,103	$9,553,638	$1,616,587	$7,121,157	**$83,397,297**
237200	Land Subdivision	$1,060,496	$109,414	$11,827	$347,440	$166,237	$265,422	**$1,960,835**
237300	Highway, Street, and Bridge Construction	$34,461,947	$1,798,662	$765,640	$4,763,776	$994,496	$5,530,212	**$48,314,733**
237900	Other Heavy and Civil Engineering Construction	$8,916,607	$638,568	$68,136	$1,973,584	$316,982	$1,428,240	**$13,342,117**
238100	Foundation, Structure, and Building Exterior Contractors	$98,302,150	$5,378,378	$779,620	$14,636,135	$5,650,682	$14,480,141	**$139,227,106**
238200	Building Equipment Contractors	$32,764,558	$445,723	$738,704	$1,242,600	$9,182,144	$15,685,182	**$60,058,912**
238300	Building Finishing Contractors	$28,048,297	$1,523,769	$7,839,972	$5,410,669	$5,272,317	$7,245,153	**$55,340,177**
238900	Other Specialty Trade Contractors	$72,894,824	$2,135,438	$4,642,936	$6,435,850	$4,286,890	$11,434,951	**$101,830,889**
221100	Electric Utilities	$1,841,529	$23,173	$10,151	$71,396	$823,434	$433,566	**$3,203,249**
999200	State Governments	$4,906,494	$576,438	$49,609	$1,905,641	$27,759	$1,154,704	**$8,620,645**
999300	Local Governments	$23,195,442	$1,693,558	$183,229	$5,498,657	$958,719	$4,467,561	**$35,997,165**
	Totals	**$423,362,684**	**$22,390,518**	**$16,490,605**	**$66,667,933**	**$40,141,004**	**$89,918,502**	**$658,971,248**

Source: OSHA, Directorate of Standards and Guidance, Office of Regulatory Analysis, based on OSHA (2016).

TOTAL COST SUMMARY

As shown in Table V-80, annualized compliance costs associated with the rule are expected to total $1,029.8 million. Table V-80 also provides total annualized costs for general industry, maritime, and construction separately, by major provision or program element included in the rule. This table shows that engineering control costs represent 64 percent of the costs of the standard for general industry and maritime and 64 percent of the costs of the standard for construction. Considering other leading cost categories, costs for exposure assessment and for medical surveillance represent, respectively, 22 percent and 8 percent of the costs of the standard for general industry and maritime; costs for training and familiarization and for medical surveillance represent, respectively, 14 percent and 10 percent of the costs of the standard for construction.

While the costs presented here represent the Agency's best estimate of the costs to industry of complying with the rule under static conditions (that is, using existing technology and the current deployment of workers), OSHA recognizes that actual costs could be somewhat higher or lower, depending on the Agency's possible overestimation or underestimation of various cost factors. In Chapter VII of this FEA, OSHA provides a sensitivity analysis of its cost estimates by modifying certain critical unit cost factors. Beyond this sensitivity analysis, OSHA notes that its cost estimates do not reflect the possibility that, in response to the rule, industry may find ways to reduce compliance costs.

This could be achieved in three ways. First, in construction, 36 percent of the estimated costs of the rule (all costs except engineering controls) vary directly with the number of workers exposed to silica. However, as shown in Table III-5 in this FEA, more than five times as many construction workers will be affected by the rule as will the number of full-time-equivalent construction workers necessary to do the work. This is because most construction workers currently doing work involving silica exposure perform such tasks for only a portion of their workday. In response to the rule, many employers are likely to assign work so that fewer construction workers perform tasks involving silica exposure; correspondingly, construction work involving silica exposure will tend to become a full-time job for some construction workers.[82] Were this approach fully implemented in construction, the actual cost of the rule would decline because employers would have to

[82] There are numerous instances of job reassignments and job specialties arising in response to OSHA regulation. For example, asbestos removal and confined space work in construction have become activities performed by well-trained specialized employees, not general laborers (whose only responsibility is to identify the presence of asbestos or a confined space situation and then to notify the appropriate specialist).

comply with the ancillary provisions of the final rule for fewer workers.[83] However, these workers would be subject to the full protections of the final rule.

Second, industry could demonstrate that certain construction activities result in exposures below the action level under any foreseeable conditions—in which case, workers engaged only in those silica-generating activities would not be subject to the requirements of the final rule. For example, an employer could make this demonstration by using objective data developed for short-term, intermittent tasks involving limited generation of silica dust. In estimating the costs for this final rule, however, OSHA included all costs, including ancillary costs as appropriate, associated with short-term intermittent silica tasks.

Third, the costs presented here do not take into account the possible development and dissemination of cost-reducing compliance technology in response to the rule.[84] One possible example is the development of safe substitutes for silica sand in activities such as abrasive blasting operations, repair and replacement of refractory materials, foundry operations, and in the railroad transportation industry. Another is expanded use of automated processes which would allow workers to be isolated from the points of operation that involve silica exposure (such as tasks between the furnace and the pouring machine in foundries and at sand transfer stations in structural clay production facilities). Yet another example is the further development and use of bags with valves that seal effectively when filled, thereby preventing product leakage and worker exposure (for example, in mineral processing and concrete products industries). Probably the most pervasive and significant technological advances, however, will likely come from the integration of compliant control technology into standard production equipment. Such advances would both increase the effectiveness and reduce the costs of silica controls when compared to retrofitted production equipment. Possible examples include local exhaust ventilation (LEV) systems attached to portable tools used by grinders and tuckpointers; enclosed operator cabs equipped with air filtration and air conditioning in

[83] OSHA expects that such a structural change in construction work assignments would not have a significant effect on the benefits of the rule. As discussed in Chapter VII of this PEA, the estimated benefits of the rule are relatively insensitive to changes in average occupational tenure or how total silica exposure in an industry is distributed among individual workers.

[84] Evidence of such technological responses to regulation includes Ashford, Ayers, and Stone (1985), OTA (1995), and OSHA's regulatory reviews of existing standards under § 610 of the Regulatory Flexibility Act ("610 lookback reviews"). On the other hand, supplemental evidence from Harrington et al. (2000) finds that OSHA does not systematically overestimate costs on a per-unit basis; nevertheless, the authors provide several examples of OSHA's overestimation of costs due to technological improvements.

industries that mechanically transfer silica or silica-containing materials; and machine-integrated wet dust suppression systems used, for example, in road milling operations.[85]

OSHA has decided not to include in its analysis any possible cost-reducing technological advances or worker specialization because the technological and economic feasibility of the rule can easily be demonstrated using existing technology and employment patterns. However, OSHA believes that actual costs, which will incorporate any future developments of this type, will likely be lower than those estimated here.

[85] A dramatic example from OSHA's 610 lookback review of its 1984 ethylene oxide (EtO) standard is the use of EtO as a sterilant. OSHA estimated the costs of then existing add-on controls for EtO sterilization, but in response to the standard, improved EtO sterilizers with built-in controls were developed and widely disseminated at about half the cost of the equipment with add-on controls. (See OSHA, 2005.) Lower-cost EtO sterilizers with built-in controls did not exist, and their development had not been predicted by OSHA, at the time the final rule was published in 1984.

Table V-80: Annualized Compliance Costs for Employers in General Industry, Maritime, and Construction Affected by OSHA's Silica Standard (2012 Dollars)

Industry	Engineering Controls	Respirators	Exposure Assessment	Medical Surveillance	Exposure Control Plan	Regulated Areas	Training & Familiarization	Total
General Industry	$228,014,496	$10,389,419	$78,620,499	$29,004,870	$4,065,164	$2,617,814	$5,945,116	**$358,657,378**
Maritime	$10,079,555	$104,287	$1,130,235	$680,718	$66,922	$19,322	$72,112	**$12,153,151**
Construction	$423,362,684	$22,390,518	$16,490,605	$66,667,933	$40,141,004	Not Applicable	$89,918,502	**$658,971,248**
Total	**$661,456,736**	**$32,884,224**	**$96,241,339**	**$96,353,520**	**$44,273,091**	**$2,637,136**	**$95,935,731**	**$1,029,781,777**

Source: OSHA, Directorate of Standards and Guidance, Office of Regulatory Analysis, based on OSHA (2016).

COSTS UNDER ALTERNATIVE PEL (100 $\mu G/M^3$) SCENARIO

Appendix V-C presents, for analytical purposes, costs for an alternative PEL of 100 μg/m^3. Total annualized compliance costs under this alternative are $649.3 million. Table V-C-1 displays costs for general industry, maritime, and construction by each program element. Table V-C-2 shows total costs by NAICS industry code for all affected general industry and maritime establishments, for business entities in general industry and maritime defined as small by the Small Business Administration, and for very small business entities in general industry and maritime (those with fewer than twenty employees). Table V-C-3 shows total costs by NAICS industry code for all affected construction establishments, for business entities in construction defined as small by the Small Business Administration, and for very small business entities in construction (those with fewer than twenty employees). The costs in Table V-C-3 reflect the assumption that all employers in construction would use Table 1 to comply with the alternative rule. Some employers, however, may find it less expensive not to use Table 1—in which case, these costs will be lower than OSHA's estimates.

COSTS UNDER ALTERNATIVE DISCOUNT RATES

An appropriate discount rate[86] is needed to reflect the timing of costs after the rule takes effect and to allow conversion to an equivalent steady stream of annualized costs.

Alternative Discount Rates for Annualizing Costs

Following OMB (2003) guidelines, OSHA has estimated the annualized costs of the rule using separate discount rates of 3 percent and 7 percent. Consistent with the Agency's own practices in recent proposed and final rules,[87] OSHA has also estimated, for benchmarking purposes, undiscounted costs—that is, costs using a zero percent discount rate.

Summary of Annualized Costs under Alternative Discount Rates

In addition to using a 3 percent discount rate in its main cost analysis, OSHA estimated compliance costs, in Appendix V-D, using alternative discount rates of 7 percent and zero percent. Table V-D-1 and V-D-2 in Appendix V-D present total costs at a 7 percent discount rate for both (1) all employers by major industry category and program element, and (2) affected employers by NAICS industry code and employment size class (all establishments, small entities, and very small entities). Tables V-D-3 and V-D-4 present the same breakdowns of total costs estimated at a zero percent discount rate.

As shown in Appendix V-D, the choice of discount rate has only a minor effect on total annualized compliance costs, with annualized costs increasing from $1,029.8 million using a three percent discount rate to $1,056.1 million using a seven percent discount rate, and decreasing to $1,011.6 million using a zero percent discount rate.

TIME DISTRIBUTION OF COSTS

OSHA analyzed the stream of (unannualized) compliance costs, by industry sector, for the first ten years after the rule takes effect under the simplifying assumption that no provisions of the rule are phased in. As shown in Table V-81, total compliance costs are expected to peak in Year 1 totaling almost $1.5 billion. After that, costs are estimated to decline and remain relatively flat after the initial set of capital and program start-up expenditures has been incurred. Costs are projected to rise somewhat in Year 4 as a result of the triennial medical examinations and in Year 6 because of a second cycle of control equipment purchases in construction for short-term,

[86] Here and elsewhere throughout this FEA, unless otherwise noted, the term "discount rate" always refers to the real discount rate—that is, the discount rate net of any inflationary effects.

[87] See, for example, 71 FR 10099, the preamble for the final hexavalent chromium rule.

intermittent work. Thereafter there are fluctuations but no strong trend. OSHA notes that the differences between costs for Year 1 and costs for subsequent years are narrower than might otherwise be the case due to (1) the expectation that, in the construction sector, a large percentage of control equipment will be rented (leading to constant annual expenses for the rented control equipment) rather than purchased as capital in Year 1; and (2) the expectation that the only engineering controls needed in the maritime sector will be wet methods, which do not require capital expenditures. On the other hand, the ancillary provisions are expected to have a relatively large number of initial costs (mainly labor rather than capital) in Year 1.

Table V-81: Distribution of Compliance Costs by Year for Establishments Affected by the Silica Standard (2012 Dollars)

Year	Engineering Controls	Program Requirements	Total
General Industry			
1	$351,150,221	$226,474,187	$577,624,408
2	$88,019,935	$96,902,383	$184,922,318
3	$88,335,426	$96,902,383	$185,237,809
4	$88,019,935	$128,722,760	$216,742,695
5	$88,335,426	$102,868,704	$191,204,130
6	$97,750,338	$103,313,313	$201,063,651
7	$88,335,426	$119,936,421	$208,271,847
8	$88,019,935	$106,068,901	$194,088,835
9	$88,335,426	$106,068,901	$194,404,327
10	$88,019,935	$115,223,631	$203,243,565
Maritime			
1	$3,508,723	$5,103,417	$8,612,140
2	$2,061,181	$1,479,402	$3,540,584
3	$2,061,181	$1,479,402	$3,540,584
4	$2,061,181	$2,221,245	$4,282,426
5	$2,061,181	$1,618,498	$3,679,679
6	$3,508,723	$1,503,124	$5,011,848
7	$2,061,181	$2,016,405	$4,077,586
8	$2,061,181	$1,693,105	$3,754,287
9	$2,061,181	$1,693,105	$3,754,287
10	$2,061,181	$1,906,534	$3,967,715
Construction			
1	$494,322,820	$404,082,164	$898,404,984
2	$402,508,839	$90,472,782	$492,981,621
3	$402,508,839	$90,472,782	$492,981,621
4	$402,508,839	$124,698,143	$527,206,982
5	$402,508,839	$100,096,954	$502,605,793
6	$494,322,820	$98,584,007	$592,906,827
7	$402,508,839	$112,807,735	$515,316,574
8	$402,508,839	$103,671,225	$506,180,065
9	$402,508,839	$103,671,225	$506,180,065
10	$402,508,839	$108,391,817	$510,900,656

Table V-81: Distribution of Compliance Costs by Year for Establishments Affected by the Silica Standard (2012 Dollars) (continued)

Year	Engineering Controls	Program Requirements	Total
Total			
1	$848,981,764	$635,659,768	$1,484,641,532
2	$492,589,955	$188,854,568	$681,444,523
3	$492,905,447	$188,854,568	$681,760,014
4	$492,589,955	$255,642,148	$748,232,103
5	$492,905,447	$204,584,155	$697,489,602
6	$595,581,881	$203,400,445	$798,982,326
7	$492,905,447	$234,760,561	$727,666,007
8	$492,589,955	$211,433,232	$704,023,187
9	$492,905,447	$211,433,232	$704,338,678
10	$492,589,955	$225,521,982	$718,111,937

[a] Includes costs for respirators and respirator programs.

[b] Engineering control costs for construction based on short term equipment rental rates.

Source: OSHA, Directorate of Standards and Guidance, Office of Regulatory Analysis, based on OSHA (2016)

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APPENDIX V-A
Background Data Supporting OSHA's Analysis of Control costs for General Industry and Maritime

Table V-A-1: Detailed Exposure Control Requirements, Analytical Assumptions and Sources for the Cost Data Applied in OSHA's Analysis of Control Costs in General Industry and Maritime

Sector/Job Category	Control Requirements	Control Description	LEV CFM	Annualized Cost (a)	Applicability [b]	Estimate Source
Cut stone						
Sawyer	Control other dust sources in area	Addressed by other controls	NA	NA	NA	No cost estimated
	Rigorous housekeeping- capital	HEPA vacuum	NA	$937	100%	Nilfisk, 15 gallon capacity
	Rigorous housekeeping- labor	Labor costs	NA	$997	100%	Additional 10 minutes/day
	Manage slurry-assumed included in housekeeping costs	No incremental costs	NA	NA	NA	No cost estimated
	Pre-wash stone to be cut	Labor	NA	$499	100%	5 min/wrkr/day
	Improve drainage	Plumbing enhancements	NA	$7,592	100%	ERG estimate based on discussions with contractors
	Increase water use at saw blade	Extra saw maintenance	NA	$499	100%	5 min/worker/day;Equipment has water capabilties
	Enclose saw	Build enclosure	NA	$230	100%	8x8x8 dust partition, with plastic sheeting, assumes 5 year life (Means, 2003)
	Exhaust saw	LEV	645	$3,394	100%	Based on saw LEV (e.g., pg. 10-158, 159, 160, ACGIH, 2001)
Fabricator	Use water fed equipment	No cost, most tools have water capability	NA	NA	NA	No cost estimated
	Manage slurry-assumed included in housekeeping costs	No incremental costs	NA	NA	NA	Assumes no incremental costs
	Rigorous housekeeping- capital	HEPA vacuum	NA	$937	100%	Nilfisk, 15 gallon capacity
	Rigorous housekeeping- labor	Labor costs	NA	$997	100%	10 min/wrkr/day
Splitter/ chipper	Use work practices to position work near duct	Judged to be a negligible cost	NA	NA	NA	Work practices adjustments judged to be negligible cost.
	Rigorous housekeeping- capital	HEPA vacuum	NA	$937	100%	Nilfisk, 15 gallon capacity
	Rigorous housekeeping- labor	Labor costs	NA	$997	100%	Additional 10 minutes/day
	Pre-wash stone	Labor	NA	$997	100%	10 min/wrkr/day
	Use flexible trunk LEV for hand chipping	Flexible trunk LEV	600	$3,158	100%	Granite cutting and finishing;pg. 10-94 (ACGIH, 2001)
	Tool-mounted LEV for hand-held chipping tools	Shroud and vacuum	NA	$812	100%	Proventilation.com

Table V-A-1: Detailed Exposure Control Requirements, Analytical Assumptions and Sources for the Cost Data Applied in OSHA's Analysis of Control Costs in General Industry and Maritime (continued)

Sector/Job Category	- Control Requirements	Control Description	LEV CFM	Annualized Cost (a)	Applicability [b]	Estimate Source
	Keep floors wet; wash down with high pressure hose	Already costed (see sawyers)	NA	NA	NA	High-pressure hose and floor trough installation
Machine operator	Control other dust sources in area	Addressed by other controls	NA	NA	NA	No cost estimated
	Rigorous housekeeping- capital	HEPA vacuum	NA	$1,304	100%	Nilfisk, 15 gallon capacity
	Rigorous housekeeping- labor	Labor costs	NA	$997	100%	Additional 10 minutes/day
	Wash stone before and after each process	Add misters to conveyor line	NA	$281	100%	Judged to require 8 hrs of shop labor,$200 in materials to fabricate; 2-year life
	Keep conveyor clean and damp	Addressed in other	NA	NA	NA	No cost estimated
	Management of dust-carrying water	Included in housekeeping	NA	NA	NA	No cost estimated
	Enclose machinery	Build enclosure in machine shop	NA	$168	100%	8x8x8 enclosure, plastic sheeting, from Means, 2003. Five-year life.
	Exhaust trimming machine	LEV	500	$2,631	100%	Based on abrasive cut-off saw; (pg. 10-134) (ACGIH, 2001)
Abrasive Blaster	For use of maintained, interlocked, ventilated glove-box cabinet	Cost of maintaining blast cabinet	NA	$1,287	100%	Assumes 50% increase in maintenance costs (of up to $2,000) and purchase of new cabinets (25%) at $8,000/cabinet (Norton, 2003), or addit. interlocks at $1,800/cabinet (Heastrup, 2003).
	Use only non-silica blasting media	Neglible incremental cost	NA	NA	100%	Manufacturer calls indicted no use of sand, and neglible cost difference
	Increase blasting cabinet ventilation	Incremental LEV	1,225	$6,447	100%	Judged to require an increase in CFM for a 7x7 booth, approximately 25% of ACGIH recommended 100 cfm per square ft of opening, or 4900 cfm in total.
	Use HEPA vacuums for machine cleaning	Vacuum replaces compressed air cleaning	NA	$937	100%	Judged to create a negligible impact on labor requirements for cleaning

Table V-A-1: Detailed Exposure Control Requirements, Analytical Assumptions and Sources for the Cost Data Applied in OSHA's Analysis of Control Costs in General Industry and Maritime (continued)

Sector/Job Category	Control Requirements	Control Description	LEV CFM	Annualized Cost (a)	Applicability [b]	Estimate Source
Flat glass						
Material Handler	Automated and ventilated unloading equipment	Not costed	NA	NA	NA	No cost estimated
	Conveyor enclosures	Limit dust and spills	NA	$901	100%	ERG estimates based on discussions with industrial ventilation consultants
	Conveyor ventilation	LEV	4,900	$25,787	100%	Per 200 ft of conveyor enclosure (Pg. 10-70, ACGIH)
Batch Operator	Conveyor enclosures	Limit dust and spills	NA	$901	100%	ERG estimates based on discussions with industrial
	Conveyor ventilation	LEV	4,900	$25,787	100%	Per 200 ft of conveyor enclosure (Pg. 10-70, ACGIH)
	LEV for batch operator workstation	LEV	1,050	$5,526	100%	Bin & hopper ventilation and unvented mixers (pg. 10-69, ACGIH, 2001)
	Dust suppressants	Use commercial dry suppressants	NA	$676	100%	Oil-based sawdust sweeping compound
	Substitute wider HEPA vacuum use for compressed air	HEPA available, requires more labor	NA	$1,010	100%	10min/wrker/day
	HEPA vacuums	Small HEPA needed	NA	$1,304	100%	Nilfisk, 15 gallon capacity
	Half mask respirator		NA	$520	NA	Annual cost of respirator use
Other glass						

Table V-A-1: Detailed Exposure Control Requirements, Analytical Assumptions and Sources for the Cost Data Applied in OSHA's Analysis of Control Costs in General Industry and Maritime (continued)

Sector/Job Category - Control Requirements		Control Description	LEV CFM	Annualized Cost (a)	Applicability [b]	Estimate Source
Material Handler	Automated and ventilated unloading equipment	Not costed	NA	NA	NA	No cost estimated
	Conveyor enclosures	Limit dust and spills	NA	$901	100%	ERG estimates based on discussions with industrial ventilation consultants
	Conveyor ventilation	LEV	4,900	$25,787	100%	Per 200 ft of conveyor enclosure (Pg. 10-70, ACGIH)
Batch Operator	Conveyor enclosures	Limit dust and spills	NA	$901	100%	ERG estimates based on discussions with industrial ventilation consultants
	Conveyor ventilation	LEV	4,900	$25,787	100%	Per 200 ft of conveyor enclosure (Pg. 10-70, ACGIH)
	LEV for batch operator workstation	LEV	1,050	$5,526	100%	$0.22/lb, from www.fastenal.com; Assumed rate of
	Dust suppressants	Use commercial dry suppressants	NA	$676	100%	Oil-based sawdust sweeping compound
	Substitute wider HEPA vacuum use for compressed air	HEPA available, requires more labor	NA	$1,010	100%	10 min/wrker/day
	HEPA vacuums	Small HEPA needed		$937		Nilfisk, 15 gallon capacity
	Half mask respirator		NA	$520	100%	Annual cost of respirator use
Min Wool						
Material Handler	Automated and ventilated unloading equipment	Not costed	NA	NA	NA	No cost estimated
	Conveyor enclosures	Limit dust and spills	NA	$901	100%	ERG estimates based on discussions with industrial ventilation consultants
	Conveyor ventilation	LEV	4,900	$25,787	100%	Per 200 ft of conveyor enclosure (Pg. 10-70, ACGIH)
	Conveyor enclosures	Limit dust and spills	NA	$901	100%	ERG estimates based on discussions with industrial ventilation consultants

Table V-A-1: Detailed Exposure Control Requirements, Analytical Assumptions and Sources for the Cost Data Applied in OSHA's Analysis of Control Costs in General Industry and Maritime (continued)

Sector/Job Category - Control Requirements		Control Description	LEV CFM	Annualized Cost (a)	Applicability [b]	Estimate Source
Batch Operator	Conveyor ventilation	LEV	NA	$25,787	100%	Per 200 ft of conveyor enclosure (Pg. 10-70, ACGIH)
	LEV for batch operator workstation	LEV	1,050	$5,526	100%	Bin & hopper ventilation and unvented mixers (pg. 10-69, ACGIH, 2001)
	Dust suppressants	Use commercial dry	NA	$676	100%	Oil-based sawdust sweeping compound
	Substitute wider HEPA vacuum use for compressed air	HEPA available, requires more labor	NA	$1,096	100%	10 min/wrker/day
	HEPA vacuums	Small HEPA needed	NA	$1,304	100%	Nilfisk, 15 gallon capacity
	Half mask respirator		NA	$520	100%	Annual cost of respirator use
Concrete I						
	Yard dust suppression	Wetting with yard hose	NA	$1,647	100%	Per facility; 2 year life. .25 hour of labor time per day per worker
	Enclosed cabs	Retrofit with cab or replacement equip	NA	$7,365	100%	Per machine. Assumes 35% annual maintenance costs
Material handlers	LEV for blender and hoppers	LEV	1,050	$5,526	100%	Per ACGIH design parameters (pg. 10-69; ACGIH, 2001)
	Improved housekeeping - HEPA vacuum	HEPA vacuum cost	NA	$1,304	100%	Nilfisk, 15 gallon capacity
	Improved housekeeping - additional labor	Labor cost	NA	$1,024	100%	10 min/wrker/day
Mixer operators	Wet methods to clean equipment	Additional cleaning time	NA	$1,024	100%	Per day/per operator
	LEV for bag opening stations	LEV with bag dumping station	1,513	$7,962	75%	Bag opening station; pg. 10-19) (ACGIH, 2001)
	Ventilated control room and HEPA filter	LEV	200	$3,123	25%	ERG estimates based on Means and ACGIH
	Dust control for adjacent operations	Addressed by other controls	NA	NA	NA	No cost estimated

Table V-A-1: Detailed Exposure Control Requirements, Analytical Assumptions and Sources for the Cost Data Applied in OSHA's Analysis of Control Costs in General Industry and Maritime (continued)

Sector/Job Category - Control Requirements		Control Description	LEV CFM	Annualized Cost (a)	Applicability [b]	Estimate Source
Forming operators	LEV for forming operator workstations	Moveable LEV duct	600	$3,158	100%	See similar control for granite cutting and finishing; p.10-94 (ACGIH, 2001)
	Initial thorough cleaning	Cost per square foot, per facility	NA	$0	100%	ERG estimate. One time cleaning
	Improve housekeeping - capital	HEPA vacuum cost	NA	$1,304	100%	Nilfisk, 15 gallon capacity
	Improve housekeeping - labor	Additional cleaning time	NA	$1,024	100%	10 min/wrker/day
Abrasive blasting operators	Use wet process	Shop built sprayer	NA	$133	80%	Assumes 2-year life
	Use alternative blast media	Use of more expensive non-silica media	NA	$5,156	20%	Based on 220,000 square feet of coverage per year per crew of 4
	Half mask respirator		NA	$520	100%	Annual cost of respirator use
Finishing operators	Work concrete green	Penalty for overall productivity	NA	$2,393	100%	Assumes 5% productivity penalty per worker
	Use wet process	Shop built sprayer	NA	$133	50%	Assumes 2-year life
Finishing operators	LEV where wet methods are infeasible	Shroud and vacuum	NA	$988	50%	Proventilation.com
Packaging operators	LEV for bag filling stations	LEV with bag filling station	1,500	$7,894	100%	Bag filling station (pg. 10-15, ACGIH, 2001)
	Extended polyethylene bag valves to reduce dust release	Use bags with dust-control feature	NA	$4,915	100%	Assumes 5 bags per minute; 200 days a year
Concrete II						
Production worker	Enclosed ventilation equipment		NA	$901	100%	ERG estimates based on discussions with industrial ventilation consultants
	Conveyor ventilation	LEV	4,900	$25,787	100%	Per 200 ft of conveyor enclosure (Pg. 10-70, ACGIH)
	Improved maintenance on process equipment enclosures	Additional maintenance	NA	$554	100%	Incremental cost for annual maintenance
	Improved maintenance		NA	$571	100%	0.5 hr additional maintenance time per week per production worker
	Initial thorough cleaning	Cost per square foot, per facility	NA	$0	100%	ERG estimate. One time cleaning
	Improved area cleanup with HEPA	Equipment cost	NA	$1,304	100%	Nilfisk, 15 gallon capacity
	Enhanced housekeeping with HEPA vacuums	Additional labor time	NA	$997	100%	Additional 20 minutes/day

Table V-A-1: Detailed Exposure Control Requirements, Analytical Assumptions and Sources for the Cost Data Applied in OSHA's Analysis of Control Costs in General Industry and Maritime (continued)

Sector/Job Category	Control Requirements	Control Description	LEV CFM	Annualized Cost (a)	Applicability [b]	Estimate Source
	Ventilated bag dumping stations with bag compactor	LEV	1,513	$7,962	100%	Bag opening station; (pg. 10-19, ACGIH, 2001)
Pottery						
Material Handler	Well-ventilated bag dumping stations	LEV	1,513	$7,962	100%	Bag opening station; (pg. 10-19) (ACGIH, 2001)
	Ventilated cab enclosures	Retrofit with cab or replacement equip	NA	$7,365	100%	ERG estimate based on vendor interviews.
	Apply LEV to conveyors in material handling area	LEV	10,000	$52,626	100%	ERG estimates based on discussions with industrial ventilation consultants
	Initial thorough cleaning	Cost per square foot, per facility	NA	$0	100%	ERG estimate. One time cleaning
	Improve housekeeping - capital	HEPA vacuum cost	NA	$1,304	100%	Nilfisk, 15 gallon capacity
	Improve housekeeping - labor	Additional cleaning time	NA	$961	100%	10 min/wrker/day
Forming Line Operator	LEV- hand grinding bench controls	LEV	1,400	$7,368	100%	Welding ventilation bench hood (pg. 10-149, ACGIH
	Eliminate compressed air (switch to vacuum)	HEPA vacuum plus additional time	NA	$1,474	100%	Includes 5 incremental minutes per day.
	Reduce dust generation during mold parting (redesign talc bag)	Cost judged negligible	NA	NA	NA	No cost estimated
Finishing operator	LEV- hand grinding bench controls	LEV	2,400	$12,630	100%	Hand grinding bench (pg. 10-135, ACGIH, 2001)
	Wet finishing	Option not costed	NA	NA	NA	Assume 5% penalty
Coatings preparer	Well-ventilated bag dumping stations	LEV	1,513	$7,962	100%	Bag opening station; pg. 10-19) (ACGIH, 2001)
	Well-ventilated or enclosed, automated systems for charging mixing equipment with glaze materials	LEV	1,050	$5,526	100%	Bin & hopper ventilation and unvented mixers (pg. 10-69, ACGIH, 2001)
	Eliminate compressed air	Covered by improved housekeeping	NA	NA	0%	No cost estimated
	Improve housekeeping - capital	HEPA vacuum cost	NA	$1,304	100%	Nilfisk, 15 gallon capacity

Table V-A-1: Detailed Exposure Control Requirements, Analytical Assumptions and Sources for the Cost Data Applied in OSHA's Analysis of Control Costs in General Industry and Maritime (continued)

Sector/Job Category	Control Requirements	Control Description	LEV CFM	Annualized Cost (a)	Applicability [b]	Estimate Source
	Improve housekeeping - labor	Additional cleaning time	NA	$961	100%	10 min/wrker/day
Coatings Operator	Substitute low silica content inputs	Option not costed	NA	NA	NA	No cost estimated
	Improved LEV for spray booths and enclosures	Increased airflow, additional CFM	250	$622	100%	Increment judged adequate for spray booth
	Spray booth maintenance	Booth repairs	NA	$240	100%	Annual incremental costs of $100 materials plus 4 hours maintenance time [a]
Paint						
Material handler	No overexposure	No control needed	NA	NA	NA	No cost estimated
Mixer operator	Ventilated bag dumping stations with bag compactor	LEV	1,513	$7,962	100%	Bag opening station; pg. 10-19) (ACGIH, 2001)
Struc clay						
Material Handler (Loader Operators	Enclosed, ventilated cab	Retrofit with cab or replace equipment	NA	$7,365	100%	Per machine
	Rigorous housekeeping- capital	HEPA Vacuum	NA	$1,304	100%	Nilfisk, 15 gallon capacity
	Rigorous housekeeping- labor	Housekeeping - labor	NA	$961	100%	10 min/wrker/day
	Improve cab maintenance and keep windows closed	Use existing cabs for dust control	NA	$788	100%	Judged to be incremental cost equal to one-half normal maintenance cost
	Cover conveyors in material handling area	Conveyor covers	NA	$901	100%	ERG estimates based on discussions with industrial ventilation consultants
	Apply LEV to conveyors in material handling area	LEV	10,000	$52,626	100%	ERG estimate of CFM requirements. See supporting write up.
Material Handler (Produc-tion Line Handlers)	Use low-silica gravel	Option not costed; substitutes available	NA	NA	NA	No cost estimated
	Misters on conveyor line	Water spray to suppress dust	NA	$2,305	100%	Assumes 100 ft. length of conveyor in this area
	Exhaust LEV and clean air island (CAI)	LEV	4,000	$21,050	100%	Assumes clean air island plus 1500 cfm.

Table V-A-1: Detailed Exposure Control Requirements, Analytical Assumptions and Sources for the Cost Data Applied in OSHA's Analysis of Control Costs in General Industry and Maritime (continued)

Sector/Job Category	Control Requirements	Control Description	LEV CFM	Annualized Cost (a)	Applicability [b]	Estimate Source
Material Handler (Post-Production	Misters on conveyor line	Water spray to suppress dust	NA	$2,305	100%	Assumes 100 ft. length of conveyor in this area
	Improved dust suppression	hose spraying 0.25/hr/day 250 days/yr	NA	$1,647	100%	Per facility; 2 year life. .25 hour of labor time per day per worker
	Improve housekeeping - capital	HEPA vacuum cost	NA	$1,304	100%	Nilfisk, 15 gallon capacity
	Improve housekeeping - labor	Additional cleaning time	NA	$961	100%	10 min/wrker/day
Grinding Operators Forming Line operators (Pug mill operators)	Ventilated control room and HEPA filter	LEV	200	$3,123	100%	ERG estimates based on Means and ACGIH
	Control room improvements and repairs	In-house repairs	NA	$263	100%	ERG estimate
	Enclosures with LEV for grinding equipment	LEV	17,000	$89,464	100%	One half of the total 34,000 cfm estimated by Knutson for a medium sized brick facility
	Purchase additional HEPA vacuums	HEPA vacuum	NA	$1,304	100%	Nilfisk, 15 gallon capacity
	Enhanced housekeeping with HEPA vacuums	Labor costs	NA	$961	100%	10 min/wrker/day
	Cover conveyors in grinding area	Conveyor covers	NA	$901	100%	ERG estimates based on discussions with industrial ventilation consultants
	Dust suppression for raw materials	Dust suppression activity	NA	$676	100%	Use of oil-based sawdust dust suppressant
	Tightly sealed storage units	Option not costed	NA	NA	NA	No incremental costs estimated
	Initial thorough cleaning	Cost per square foot, per facility	NA	$0	100%	ERG estimate of costs per square foot of floorspace
	Half mask respirator	Respirator	NA	$520	100%	Annual cost of respirator use
	Enclosed and ventilated pug mill equipment	LEV	6,000	$31,576	100%	Estimated by Knutson. See "Brick Manufacturing.xls"
	Initial thorough cleaning	See grinding operator	NA	NA	NA	No cost estimated
	Misters on conveyor line	Misting	NA	$2,305	100%	National Environmental Services Company (Kestner, 2003). [a]
	Improve housekeeping - capital	HEPA vacuum cost	NA	$1,304	100%	Nilfisk, 15 gallon capacity

Table V-A-1: Detailed Exposure Control Requirements, Analytical Assumptions and Sources for the Cost Data Applied in OSHA's Analysis of Control Costs in General Industry and Maritime (continued)

Sector/Job Category - Control Requirements		Control Description	LEV CFM	Annualized Cost (a)	Applicability [b]	Estimate Source
	Improve housekeeping - labor	Additional cleaning time	NA	$961	100%	10 min/wrker/day
	Half mask respirator	Respirator	NA	$520	100%	Annual cost of respirator use
Forming Line Operators (Coatings Blenders)	Initial thorough cleaning	See grinding operator	NA	NA	NA	No cost estimated
	Well-ventilated bag dumping stations	LEV	1,513	$7,962	100%	Based on ACGIH design parameters for bag opening station; (pg. 10-19, ACGIH, 2001)
	Enclosed and ventilated feed hopper, conveyors, tumble tote charging, and transfer to transfer tote	Best judgment	9,000	$47,363	100%	Estimated by Knutson. See "Brick Manufacturing.xls" (10,000 cfm typical, including bag dumping)
	Improve housekeeping - capital	HEPA vacuum cost	NA	$1,304	100%	Nilfisk, 15 gallon capacity
	Improve housekeeping - labor	Additional cleaning time	NA	$961	100%	10 min/wrker/day
Forming Line Operators	Initial thorough cleaning	See grinding operator	NA	NA	NA	No cost estimated
	Improve housekeeping - capital	HEPA vacuum cost	NA	$1,304	100%	Nilfisk, 15 gallon capacity
	Improve housekeeping - labor	Additional cleaning time	NA	$961	100%	10 min/wrker/day
	Well-ventilated bag dumping stations	LEV	1,513	$7,962	100%	Based on ACGIH design parameters for bag opening station; (pg. 10-19, ACGIH, 2001)
	Enclosed and ventilated workstations	LEV plus clean air island	3,550	$18,682	100%	From Knutson estimates; avg for several production workers
	Half mask respirator	Respirator	NA	$520	100%	Annual cost of respirator use
Dental labs						
Dental Techni-cians	Improved LEV in grinding, blasting	Dental lab dust control systems	NA	$174	100%	Self-contained dust collection system. Darby Dental Lab Supply, 2005 (www.darbylab.com)
	Improve housekeeping - capital	HEPA vacuum cost	NA	$1,304	100%	Nilfisk, 15 gallon capacity
	Improve housekeeping - labor	Additional cleaning time	NA	$1,118	100%	10 min/wrker/day
Jewelry1						

Table V-A-1: Detailed Exposure Control Requirements, Analytical Assumptions and Sources for the Cost Data Applied in OSHA's Analysis of Control Costs in General Industry and Maritime (continued)

Sector/Job Category - Control Requirements		Control Description	LEV CFM	Annualized Cost (a)	Applicability [b]	Estimate Source
Jewelry workers	Substitution of low-silica modeling/investment materials	Not costed	NA	NA	NA	Judged that LEV controls will be favored method
	LEV for abrasive blasting and finishing	Small-scale jewelry bench LEV	100	$526	100%	Small-scale LEV should be adequate
Jewelry2						
Jewelry workers	Substitution of low-silica modeling/investment materials	Not costed	NA	NA	NA	Judged that LEV controls will be favored method
	LEV for abrasive blasting and finishing	Small-scale jewelry bench LEV	100	$526	100%	Small-scale LEV should be adequate
Refractories						
Material handler	Ventilated bag dumping stations with bag compactor	LEV	1,513	$7,962	100%	ACGIH-based estimate. See "orig sources"
	Enclosed and ventilated mixing equipment	LEV	1,050	$5,526	100%	ACGIH-based estimate. See "orig sources"
Forming Operator	Increased LEV maintenance	Additional cost per operator	NA	$355	100%	Assumes 1 hour additional maintenance time per operator per month
	Wet methods for mold cleaning	Additional cleaning time	NA	$961	100%	Assumes 10 additional minutes of cleaning time
Finishing operator	No overexposures	NA	NA	NA	NA	No cost estimated
Ceramic fiber furnace operator	No overexposures	NA	NA	NA	NA	No cost estimated
Packaging operator	LEV for bag filling stations	LEV/ per cfm	1,500	$7,894	100%	ACGIH-based estimate. See "orig sources"
	Bag valves to reduce dust release	Per operator	NA	$4,915	100%	Assumes 5 bags per minute; 200 days a year
Enameling-services						
Enamel preparer	Bag dumping station maintenance	Materials plus labor	NA	$240	100%	Annual: $100 materials plus 4 hours maintenance time [a]

Table V-A-1: Detailed Exposure Control Requirements, Analytical Assumptions and Sources for the Cost Data Applied in OSHA's Analysis of Control Costs in General Industry and Maritime (continued)

Sector/Job Category - Control Requirements		Control Description	LEV CFM	Annualized Cost (a)	Applicability [b]	Estimate Source
	Rigorous housekeeping- capital	HEPA vacuum	NA	$1,304	100%	Nilfisk, 15 gallon capacity
	Rigorous housekeeping- labor	Labor costs	NA	$1,019	100%	10 min/wrker/day
	Eliminate compressed air	Included in rigorous housekeeping	NA	NA	NA	No cost estimated
Porcelain applicator	Improved LEV for spray booths and enclosures	Increased airflow¥cfm	1,000	$1,316	100%	Allotment of 1,000 CFM of additional airflow
	Rigorous housekeeping- capital	HEPA vacuum	NA	$1,304	100%	Nilfisk, 15 gallon capacity
	Rigorous housekeeping- labor	Labor costs	NA	$1,019	100%	10 min/wrker/day
Enameling-						
Enamel preparer	Bag dumping station maintenance	Materials plus labor	NA	$240	100%	Annual: $100 materials plus 4 hours maintenance time [a]
	Rigorous housekeeping- capital	HEPA vacuum	NA	$1,304	100%	Nilfisk, 15 gallon capacity
	Rigorous housekeeping- labor	Labor costs	NA	$1,019	100%	10 min/wrker/day
	Eliminate compressed air	Included in rigorous housekeeping	NA	NA	NA	No cost estimated
Porcelain applicator	Improved LEV for spray booths and enclosures	Increased airflow¥cfm	1,000	$1,316	100%	Allotment of 1,000 CFM of additional airflow
	Rigorous housekeeping- capital	HEPA vacuum	NA	$1,304	100%	Nilfisk, 15 gallon capacity
	Rigorous housekeeping- labor	Labor costs	NA	$1,019	100%	10 min/wrker/day
Enameling-architecture						
Enamel preparer	Bag dumping station maintenance	Materials plus labor	NA	$240	100%	Annual: $100 materials plus 4 hours maintenance time [a]
	Rigorous housekeeping- capital	HEPA vacuum	NA	$1,304	100%	Nilfisk, 15 gallon capacity
	Rigorous housekeeping- labor	Labor costs	NA	$1,019	100%	10 min/wrker/day
	Eliminate compressed air	Included in rigorous housekeeping	NA	NA	NA	No cost estimated

Table V-A-1: Detailed Exposure Control Requirements, Analytical Assumptions and Sources for the Cost Data Applied in OSHA's Analysis of Control Costs in General Industry and Maritime (continued)

Sector/Job Category - Control Requirements		Control Description	LEV CFM	Annualized Cost (a)	Applicability [b]	Estimate Source
Porcelain applicator	Improved LEV for spray booths and enclosures	Increased airflow¥cfm	1,000	$1,316	100%	Allotment of 1,000 CFM of additional airflow
	Rigorous housekeeping- capital	HEPA vacuum	NA	$1,304	100%	Nilfisk, 15 gallon capacity
	Rigorous housekeeping- labor	Labor costs	NA	$1,019	100%	10 min/wrker/day
Enameling-appliances						
Enamel preparer	Bag dumping station maintenance	Materials plus labor	NA	$240	100%	Annual: $100 materials plus 4 hours maintenance time [a]
	Rigorous housekeeping- capital	HEPA vacuum	NA	$1,304	100%	Nilfisk, 15 gallon capacity
	Rigorous housekeeping- labor	Labor costs	NA	$1,019	100%	10 min/worker/day
	Eliminate compressed air	Included in rigorous housekeeping	NA	NA	NA	No cost estimated
Porcelain applicator	Improved LEV for spray booths and enclosures	Increased airflow¥cfm	1,000	$1,316	100%	Allotment of 1,000 CFM of additional airflow
	Rigorous housekeeping- capital	HEPA vacuum	NA	$1,304	100%	Nilfisk, 15 gallon capacity
	Rigorous housekeeping- labor	Labor costs	NA	$1,019	100%	10 min/wrker/day
Enameling-						
Enamel preparer	Bag dumping station maintenance	Materials plus labor	NA	$240	100%	Annual: $100 materials plus 4 hours maintenance time [a]
	Rigorous housekeeping- capital	HEPA vacuum	NA	$1,304	100%	Nilfisk, 15 gallon capacity
	Rigorous housekeeping- labor	Labor costs	NA	$1,019	100%	10 min/wrker/day
	Eliminate compressed air	Included in rigorous housekeeping	NA	NA	NA	No cost estimated
Porcelain applicator	Improved LEV for spray booths and enclosures	Increased airflow¥cfm	1,000	$1,316	100%	Allotment of 1,000 CFM of additional airflow
	Rigorous housekeeping- capital	HEPA vacuum	NA	$1,304	100%	Nilfisk, 15 gallon capacity
	Rigorous housekeeping- labor	Labor costs	NA	$1,019	100%	10 min/wrker/day
Asphalt						

Table V-A-1: Detailed Exposure Control Requirements, Analytical Assumptions and Sources for the Cost Data Applied in OSHA's Analysis of Control Costs in General Industry and Maritime (continued)

Sector/Job Category - Control Requirements		Control Description	LEV CFM	Annualized Cost (a)	Applicability [b]	Estimate Source
Production operator	Process enclosure	Enclose conveyors and equip	NA	$901	100%	200 ft of conveyor enclosure
	Enhanced ventilation	Conveyor ventilation	700	$3,684	100%	ACGIH LEVestimate
	Rigorous housekeeping- capital	HEPA vacuum	NA	$1,304	100%	Nilfisk, 15 gallon capacity
	Rigorous housekeeping- labor	Incremental labor costs	NA	$1,693	100%	Addit. 10 minutes/day
Material handler	No additional controls required	NA	NA	NA	NA	Controls for production operator suffice
Mineral processing						
Production Worker	Enclosed ventilation equipment (conveyors)	Conveyor cover; 200'	NA	$901	33%	ERG estimates based on discussions with industrial ventilation consultants
	Conveyor ventilation	LEV	4,900	$25,787	33%	ACGIH LEV estimate, conveyor belt ventilation
	Improved maintenance on process equipment enclosures	Additional maintenance	NA	$560	33%	Incremental cost for annual maintenance
	Improved maintenance	Labor costs	NA	$571	33%	0.5 hr additional maintenance time per week per production worker
	Initial thorough cleaning	Cost per square foot, per facility	NA	$0.018	33%	ERG estimate based on docket submissions and industry contacts
	Improved area cleanup with HEPA	Equipment cost	NA	$1,304	33%	15 gal HEPA vacuum; 5 year life
	Enhanced housekeeping with HEPA vacuums	Additional labor time	NA	$997	33%	Additional 20 minutes/day
	Ventilated bag dumping stations with bag compactor	LEV	1,513	$7,962	33%	Bag opening station; (pg. 10-19, ACGIH, 2001)
Dental equipment						
	Ventilated bag dumping stations with bag compactor	LEV	1,513	$7,962	100%	Bag opening station; (pg. 10-19, ACGIH, 2001)

Table V-A-1: Detailed Exposure Control Requirements, Analytical Assumptions and Sources for the Cost Data Applied in OSHA's Analysis of Control Costs in General Industry and Maritime (continued)

Sector/Job Category - Control Requirements		Control Description	LEV CFM	Annualized Cost (a)	Applicability [b]	Estimate Source
Productio	Enclosed and ventilated mixing equipment	LEV	1,050	$5,526	100%	Mixer & muller hood (pg. 10-87, ACGIH, 2001)
	Increased LEV maintenance	Additional cost per operator	NA	$409	100%	Assumes 1 hour additional maintenance time per operator per month
	Workstation modifications to reduce spillage	Judged to be negligible cost	NA	NA	NA	No cost estimated
Asphalt						
Facility Operator	Enclosed and ventilated control booths	LEV	200	$3,123	100%	ERG estimate based on Means, 2003, ACGIH, 2001
	Control dust from adjacent processes	No additional cost	NA	NA	NA	No cost estimated
Front-end loader operator	Enclosed cabs	Retrofit with cab or replacement equip	NA	$7,365	100%	ERG estimate based on vendor interviews.
Mainten-ance worker	No overexposures	Additional controls not needed	NA	NA	NA	No cost estimated
Quality control worker	No overexposures	Additional controls not needed	NA	NA	NA	No cost estimated
Refractory repair						
	Portable exhaust ventilation	LEV	400	$2,105	33%	Moveable exhaust hoods example: pg. 10-93 (ACGIH, 2001)
Refractory Worker	Wet methods for chipping tools	Shop-built water feed	NA	$242	33%	ERG estimate. $200 in annual costs [a]
	LEV for chipping tools	LEV	600	$3,158	33%	Granite cutting and finishing; (pg. 10-94, ACGIH, 2001)
	Improved maintenance for spay guns	Labor costs	NA	$372	100%	Assumes 1 hour additional maintenance time per operator per month

Table V-A-1: Detailed Exposure Control Requirements, Analytical Assumptions and Sources for the Cost Data Applied in OSHA's Analysis of Control Costs in General Industry and Maritime (continued)

Sector/Job Category - Control Requirements		Control Description	LEV CFM	Annualized Cost (a)	Applicability [b]	Estimate Source
	Half mask respirator	Respirator	NA	$520	100%	Annual cost of respirator use
Ready mix						
Material handler	Yard dust suppression	Wetting with yard hose	NA	$5,894	100%	From concrete; 2 year life
	Enclosed cabs	Retrofit with cab or replacement equip	NA	$7,365	100%	From concrete
Batch operator	No overexposures	No controls necessary	NA	NA	NA	No cost estimated
Mainten-ance operator	Wet methods to clean equipment	Additional cleaning time	NA	$1,024	100%	From concrete. 10 mins per day, 250 days
Quality control	No overexposures	No controls necessary	NA	NA	NA	No cost estimated
Truck Driver	Wet methods for drum cleaning	Water fed chipping equipment	NA	$242	100%	ERG estimate of annual retrofit costs
	Ventilation for drum cleaning	Forced ventilation	NA	$386	100%	5 year life
	Half mask respirator	Respirator	NA	$520	100%	Annual cost of respirator use
Iron						
Sand Systems Operator	LEV, mixer & muller hood	LEV	1,050	$7,962	100%	Mixer & muller hood (pg. 10-87, ACGIH, 2001); Formerly required clean-air island, but not called out in techfeas; dropped from costs
	Conveyor enclosures	200 feet, ventilated (7 take-off points)	4,900	$26,273	100%	One take-off point at-least every 30', 7 overall.
	Bin and hopper ventilation	LEV	1,050	$5,526	100%	CFM from Solburg worksheet. (ACGIH, 2001; p. 10-69)
	Bucket elevator ventilation	LEV	1,600	$8,420	100%	Based on Knutson specs
	Screen ventilation	LEV	1,200	$6,315	100%	Based on Knutson specs
	Substitute silica-free materials	Option not costed, other	NA	NA	NA	No cost estimated

Table V-A-1: Detailed Exposure Control Requirements, Analytical Assumptions and Sources for the Cost Data Applied in OSHA's Analysis of Control Costs in General Industry and Maritime (continued)

Sector/Job Category	Control Requirements	Control Description	LEV CFM	Annualized Cost (a)	Applicability [b]	Estimate Source
Molder	Upgraded sand handling equipment - covered elsewhere	No cost	NA	NA	NA	No cost estimated
	Upgrade or install LEV	LEV	1,050	$5,526	100%	ERG estimates based on discussions with industrial ventilation consultants
	Rigorous housekeeping- capital	HEPA vacuum	NA	$1,304	100%	Nilfisk, 15 gallon capacity
	Rigorous housekeeping- labor	Labor costs	NA	$1,041	100%	10 min/wrker/day
	Eliminate compressed air	Included in rigorous housekeeping	NA	NA	NA	No cost estimated
Coremaker	Eliminated compressed air	Additional labor time	NA	$1,041	100%	10 min/wrker/day
	Enclosed conveyors, covered elsewhere	No cost	NA	NA	NA	No cost estimated
	Non-silica cores and core coatings	Option not costed, other controls sufficient	NA	NA	NA	No cost estimated
	Initial thorough cleaning	Costed below	NA	NA	NA	No cost estimated
Furnace operator	Control dust releases from adjacent processes - covered elsewhere		NA	NA	NA	No cost estimated
	Well-maintained furnace emission control system	Maintenance	NA	$650	100%	20 hours addtional maintenance time per year
	Operator booths or cabs	Based on clean-air island costs	2,500	$13,157	100%	Based on clean air island costs for structural clay
	Minimize dust generated by sand contamination of scrap	Option not costed	NA	NA	NA	No cost estimated
Pouring operator	Control dust from adjacent processes - covered elsewhere	No cost	NA	NA	NA	No cost estimated
	Operator booths or cabs	Based on clean-air island costs	2,500	$13,157	100%	Based on clean air island costs for structural clay
	Physical isolation of pouring area (create a pouring room)	Option not costed	NA	NA	NA	No cost estimated
	Modify ventilation system to reduce airflow from other areas into the pouring area	Option not costed	NA	NA	NA	No cost estimated

Table V-A-1: Detailed Exposure Control Requirements, Analytical Assumptions and Sources for the Cost Data Applied in OSHA's Analysis of Control Costs in General Industry and Maritime (continued)

Sector/Job Category	Control Requirements	Control Description	LEV CFM	Annualized Cost (a)	Applicability [b]	Estimate Source
Shakeout Operator	Improve existing ventilation system efficiency (very large castings)	Double-draft shake-out table	28,800	$151,563	100%	Based on Solberg costs for shakeout conveyor
	Improve existing ventilation system efficiency	Shakeout enclosing hood	7,040	$37,049	100%	Based on ACGIH design parameters for ventilated enclosing hood (pg. 10-23, ACGIGH, 2001); 4'x4' openings
	Partially enclose process	Enclosed, ventilated shakeout conveyor	10,000	$52,626	100%	Based on Solberg costs for shakeout conveyor
	Control emissions from associated operations - covered elsewhere	No cost	NA	NA	100%	No cost estimated
	Half mask respirator	Respirator	NA	$520	100%	Annual cost of respirator use
Knockout Operator	Installing and improving LEV	Small knockout table	1,350	$7,105	100%	Based on ACGIH design parameters for hand grinding table (pg. 10-135), ACGIH, 2001), 4'x6'
	Installing and improving LEV	Large knockout table	4,800	$25,261	100%	Based onACGIH design parameters for ventilated cut-off saw (pg. 10-134, ACGIH, 2001, 2'x3' opening)
	Installing and improving LEV	Ventilated abrasive cutoff saw	1,500	$7,894	100%	No cost estimated
	Reduce residual sand on castings	Option not costed	NA	NA	NA	No cost estimated
	Automate knockout process	Option not costed	NA	NA	NA	No cost estimated
	Half mask respirator	Respirator	NA	$520	100%	Annual cost of respirator use
Abrasive Blasting Operator	Improved maintenance for blasting cabinet	Maintenance	NA	$1,287	100%	Assumes 50% increase in maintenance costs (of up to $2,000) and purchase of new cabinets (25%) at $8,000/cabinet (Norton, 2003), or addit. interlocks at $1,800/cabinet (Heastrup, 2003).
	Half mask respirator	Respirator	NA	$520	100%	Annual cost of respirator use
	LEV for workstations	Hand grinding bench	3,750	$19,735	100%	Consultant Solberg estimate for hand grinding bench
	LEV on hand tools	LEV	200	$794	100%	Consultant Solberg estimate for hand tools

Table V-A-1: Detailed Exposure Control Requirements, Analytical Assumptions and Sources for the Cost Data Applied in OSHA's Analysis of Control Costs in General Industry and Maritime (continued)

Sector/Job Category - Control Requirements		Control Description	LEV CFM	Annualized Cost (a)	Applicability [b]	Estimate Source
Cleaning/ Finishing Operator	Eliminate compressed air (switch to vacuum)	HEPA vacuum plus additional time	NA	$1,474	100%	15 gal vacuum and 5 extra minutes per day
	Substitution with non-silica materials	Option not costed	NA	NA	NA	No cost estimated
	Process automation	Option not costed	NA	NA	NA	No cost estimated
	Wet methods	Option not costed	NA	NA	NA	No cost estimated
	Pre-cleaning with automated equipment	Option not costed	NA	NA	NA	No cost estimated
Material Handler	Enclosed, ventilated cab	Retrofit with cab or replace equipment	NA	$7,365	100%	Per machine
Mainten-ance Operator	Use low silica refractory	Option not costed	NA	NA	NA	No cost estimated
	LEV for chipping tools	Dust collector with HEPA vacuum	NA	$988	100%	5 year life
	Pre-wetting lining to be removed	Additional labor	NA	$3,382	100%	2 hours per week
	Maintaining moisture level in the refractory applied	Additional labor	NA	$1,691	100%	1 hour per week
	Also, use of precast refractories and automated equipment for powdered refractory materials	Option not costed	NA	NA	NA	No cost estimated
Housekeeping Worker	Initial thorough cleaning	Cost per square foot, per facility	NA	$0.02	100%	ERG estimate based on docket submissions and industry contacts
Nonferrous sand casting foundries						
Sand Systems Operator	LEV, mixer & muller hood	LEV	1,050	$7,962	100%	Mixer & muller hood (pg. 10-87, ACGIH, 2001); Formerly required clean-air island, but not called out in techfeas; dropped from costs

Table V-A-1: Detailed Exposure Control Requirements, Analytical Assumptions and Sources for the Cost Data Applied in OSHA's Analysis of Control Costs in General Industry and Maritime (continued)

Sector/Job Category	Control Requirements	Control Description	LEV CFM	Annualized Cost (a)	Applicability [b]	Estimate Source
	Conveyor enclosures	200 feet, ventilated (7 take-off points)	4,900	$26,273	100%	One take-off point at-least every 30', 7 overall.
	Bin and hopper ventilation	LEV	1,050	$5,526	100%	CFM from Solburg worksheet. (ACGIH, 2001; p. 10-69)
	Bucket elevator ventilation	LEV	1,600	$8,420	100%	Based on Knutson specs
	Screen ventilation	LEV	1,200	$6,315	100%	Based on Knutson specs
	Substitute silica-free materials	Option not costed, other controls sufficient	NA	NA	NA	No cost estimated
Molder	Upgraded sand handling equipment - covered elsewhere	No cost	NA	NA	NA	No cost estimated
	Upgrade or install LEV	LEV	1,050	$5,526	100%	ERG estimates based on discussions with industrial ventilation consultants
	Rigorous housekeeping- capital	HEPA vacuum	NA	$1,304	100%	Nilfisk, 15 gallon capacity
	Rigorous housekeeping- labor	Labor costs	NA	$1,041	100%	10 min/wrker/day
	Eliminate compressed air	Included in rigorous housekeeping	NA	NA	NA	No cost estimated
Coremaker	Eliminated compressed air	Additional labor time	NA	$1,041	100%	10 min/wrker/day
	Enclosed conveyors, covered elsewhere	No cost	NA	NA	NA	No cost estimated
	Non-silica cores and core coatings	Option not costed, other controls sufficient	NA	NA	NA	No cost estimated
	Initial thorough cleaning	Cost per square foot, per facility	NA	$0.018	100%	ERG estimate based on docket submissions and industry contacts
Furnace operator	No overexposures, controls not needed	No cost	NA	NA	NA	No cost estimated
Pouring operator	No overexposures, controls not needed	No cost	NA	NA	NA	20 hours additional maintenance time per year

Table V-A-1: Detailed Exposure Control Requirements, Analytical Assumptions and Sources for the Cost Data Applied in OSHA's Analysis of Control Costs in General Industry and Maritime (continued)

Sector/Job Category - Control Requirements		Control Description	LEV CFM	Annualized Cost (a)	Applicability [b]	Estimate Source
Shakeout Operator	Improve existing ventilation system efficiency (very large castings)	Double-draft shake-out table	28,800	$151,563	100%	Based on Solberg costs for shakeout conveyor
	Improve existing ventilation system efficiency	Shakeout enclosing hood	7,040	$37,049	100%	Based on ACGIH design parameters for ventilated enclosing hood (pg. 10-23, ACGIGH, 2001); 4'x4' openings
	Partially enclose process	Enclosed, ventilated shakeout conveyor	10,000	$52,626	100%	Based on Solberg costs for shakeout conveyor
	Control emissions from associated operations - covered elsewhere	No cost	NA	NA	100%	No cost estimated
	Half mask respirator	Respirator	NA	$520	100%	Annual cost of respirator use
Knockout Operator	Installing and improving LEV	Small knockout table	1,350	$7,105	100%	Based on ACGIH design parameters for portable grinding table pg. 10-136), ACGIH, 2001), 3'x3' opening
	Installing and improving LEV	Large knockout table	4,800	$25,261	100%	Based on ACGIH design parameters for hand grinding table (pg. 10-135), ACGIH, 2001), 4'x6'
	Installing and improving LEV	Ventilated abrasive cutoff saw	1,500	$7,894	100%	Based on ACGIH design parameters for ventilated cut-off saw (pg. 10-134, ACGIH, 2001, 2'x3' opening)
	Reduce residual sand on castings	Option not costed	NA	NA	NA	No cost estimated
	Automate knockout process	Option not costed	NA	NA	NA	No cost estimated
	Half mask respirator	Respirator	NA	$520	100%	Annual cost of respirator use
Abrasive Blasting Operator	Improved maintenance for blasting cabinet	Maintenance	NA	$1,287	100%	Assumes 50% increase in maintenance costs (of up to $2,000) and purchase of new cabinets (25%) at $8,000/cabinet (Norton, 2003), or addit. interlocks at $1,800/cabinet (Heastrup, 2003).
	Half mask respirator	Respirator	NA	$520	100%	Annual cost of respirator use

Table V-A-1: Detailed Exposure Control Requirements, Analytical Assumptions and Sources for the Cost Data Applied in OSHA's Analysis of Control Costs in General Industry and Maritime (continued)

Sector/Job Category - Control Requirements		Control Description	LEV CFM	Annualized Cost (a)	Applicability [b]	Estimate Source
Cleaning/ Finishing Operator	LEV for workstations	Hand grinding bench	3,750	$19,735	100%	Consultant Solberg estimate for hand grinding bench
	LEV on hand tools	LEV	200	$794	100%	Consultant Solberg estimate for hand tools
	Eliminate compressed air (switch to vacuum)	HEPA vacuum plus additional time	NA	$1,474	100%	15 gal vacuum and 5 extra minutes per day
	Substitution with non-silica materials	Option not costed	NA	NA	NA	No cost estimated
	Process automation	Option not costed	NA	NA	NA	No cost estimated
	Wet methods	Option not costed	NA	NA	NA	No cost estimated
	Pre-cleaning with automated equipment	Option not costed	NA	NA	NA	No cost estimated
Material Handler	No overexposures, controls not needed	Option not costed	NA	NA	NA	No cost estimated
Mainten-ance Operator	No overexposures, controls not needed	Option not costed	NA	NA	NA	No cost estimated
Housekeeping Worker	No overexposures, controls not needed	Option not costed	NA	NA	NA	No cost estimated
Non-sand casting foundries						
Sand Systems Operator	LEV, mixer & muller hood	LEV	1,050	$7,962	100%	Mixer & muller hood (pg. 10-87, ACGIH, 2001); Formerly required clean-air island, but not called out in techfeas; dropped from costs
	Conveyor enclosures	200 feet, ventilated (7 take-off points)	4,900	$26,273	100%	One take-off point at-least every 30', 7 overall.

Table V-A-1: Detailed Exposure Control Requirements, Analytical Assumptions and Sources for the Cost Data Applied in OSHA's Analysis of Control Costs in General Industry and Maritime (continued)

Sector/Job Category	Control Requirements	Control Description	LEV CFM	Annualized Cost (a)	Applicability [b]	Estimate Source
	Bin and hopper ventilation	LEV	1,050	$5,526	100%	CFM from Solburg worksheet. (ACGIH, 2001; p. 10-69)
	Bucket elevator ventilation	LEV	1,600	$8,420	100%	Based on Knutson specs
	Screen ventilation	LEV	1,200	$6,315	100%	Based on Knutson specs
	Substitute silica-free materials	Option not costed, other controls sufficient	NA	NA	NA	No cost estimated
Molder	Upgraded sand handling equipment - covered elsewhere	No cost	NA	NA	NA	No cost estimated
	Upgrade or install LEV	LEV	1,050	$5,526	100%	ERG estimates based on discussions with industrial ventilation consultants
	Rigorous housekeeping- capital	HEPA vacuum	NA	$1,304	100%	Nilfisk, 15 gallon capacity
	Rigorous housekeeping- labor	Labor costs	NA	$1,041	100%	10 min/wrker/day
	Eliminate compressed air	Included in rigorous housekeeping	NA	NA	NA	No cost estimated
Coremaker	No overexposures, controls not needed	No cost	NA	NA	NA	No cost estimated
Furnace operator	No overexposures, controls not needed	No cost	NA	NA	NA	No cost estimated
Pouring operator	Control dust from adjacent processes - covered elsewhere	No cost	NA	NA	NA	No cost estimated
	Operator booths or cabs	Based on clean-air island costs	2,500	$13,157	100%	Based on clean air island costs for structural clay
	Physical isolation of pouring area (create a pouring room)	Option not costed	NA	NA	NA	No cost estimated
	Modify ventilation system to reduce airflow from other areas into the pouring area	Option not costed	NA	NA	NA	

Table V-A-1: Detailed Exposure Control Requirements, Analytical Assumptions and Sources for the Cost Data Applied in OSHA's Analysis of Control Costs in General Industry and Maritime (continued)

Sector/Job Category	Control Requirements	Control Description	LEV CFM	Annualized Cost (a)	Applicability [b]	Estimate Source
Shakeout Operator	Improve existing ventilation system efficiency (very large castings)	Double-draft shake-out table	28,800	$151,563	100%	Based on Solberg costs for shakeout conveyor
	Improve existing ventilation system efficiency	Shakeout enclosing hood	7,040	$37,049	100%	Based on ACGIH design parameters for ventilated enclosing hood (pg. 10-23, ACGIGH, 2001); 4'x4' openings
	Partially enclose process	Enclosed, ventilated shakeout conveyor	10,000	$52,626	100%	Based on Solberg costs for shakeout conveyor
	Control emissions from associated operations - covered elsewhere	No cost	NA	NA	NA	No cost estimated
	Half mask respirator	Respirator	NA	$520	100%	Annual cost of respirator use
Knockout Operator	Installing and improving LEV	Small knockout table	1,350	$7,105	100%	Based on ACGIH design parameters for portable grinding table pg. 10-136), ACGIH, 2001), 3'x3' opening
	Installing and improving LEV	Large knockout table	4,800	$25,261	100%	Based on ACGIH design parameters for hand grinding table (pg. 10-135), ACGIH, 2001), 4'x6' surface
	Installing and improving LEV	Ventilated abrasive cutoff saw	1,500	$7,894	100%	Based onACGIH design parameters for ventilated cut-off saw (pg. 10-134, ACGIH, 2001, 2'x3' opening)
	Reduce residual sand on castings	Option not costed	NA	NA	NA	No cost estimated
	Automate knockout process	Option not costed	NA	NA	NA	No cost estimated
	Half mask respirator	Respirator	NA	$520	100%	Annual cost of respirator use
Abrasive Blasting Operator	Improved maintenance for blasting cabinet	Maintenance	NA	$1,287	100%	Assumes 50% increase in maintenance costs (of up to $2,000) and purchase of new cabinets (25%) at $8,000/cabinet (Norton, 2003), or addit. interlocks at $1,800/cabinet (Heastrup, 2003).
	Half mask respirator	Respirator	NA	$520	100%	Annual cost of respirator use

Table V-A-1: Detailed Exposure Control Requirements, Analytical Assumptions and Sources for the Cost Data Applied in OSHA's Analysis of Control Costs in General Industry and Maritime (continued)

Sector/Job Category - Control Requirements		Control Description	LEV CFM	Annualized Cost (a)	Applicability [b]	Estimate Source
Cleaning/ Finishing Operator	LEV for workstations	Hand grinding bench	3,750	$19,735	100%	Consultant Solberg estimate for hand grinding bench
	LEV on hand tools	LEV	200	$794	100%	Consultant Solberg estimate for hand tools
	Eliminate compressed air (switch to vacuum)	HEPA vacuum plus additional time	NA	$1,474	100%	15 gal vacuum and 5 extra minutes per day
	Substitution with non-silica materials	Option not costed	NA	NA	NA	No cost estimated
	Process automation	Option not costed	NA	NA	NA	No cost estimated
	Wet methods	Option not costed	NA	NA	NA	No cost estimated
	Pre-cleaning with automated equipment	Option not costed	NA	NA	NA	No cost estimated
Material Handler	Enclosed, ventilated cab	Retrofit with cab or replace equipment	NA	$7,365	100%	Per machine
Mainten-ance Operator	No overexposures, controls not needed	No cost	NA	NA	NA	No cost estimated
House-keeping Worker	No overexposures, controls not needed	No cost	NA	NA	NA	No cost estimated
Captive foundries						
Sand Systems Operator	LEV, mixer & muller hood	LEV	1,050	$7,962	100%	Mixer & muller hood (pg. 10-87, ACGIH, 2001); Formerly required clean-air island, but not called out in techfeas; dropped from costs
	Conveyor enclosures	200 feet, ventilated (7 take-off points)	4,900	$26,273	100%	One take-off point at-least every 30', 7 overall.
	Bin and hopper ventilation	LEV	1,050	$5,526	100%	CFM from Solburg worksheet. (ACGIH, 2001; p. 10-69)

Table V-A-1: Detailed Exposure Control Requirements, Analytical Assumptions and Sources for the Cost Data Applied in OSHA's Analysis of Control Costs in General Industry and Maritime (continued)

Sector/Job Category - Control Requirements		Control Description	LEV CFM	Annualized Cost (a)	Applicability [b]	Estimate Source
	Bucket elevator ventilation	LEV	1,600	$8,420	100%	Based on Knutson specs
	Screen ventilation	LEV	1,200	$6,315	100%	Based on Knutson specs
	Substitute silica-free materials	Option not costed, other controls sufficient	NA	NA	NA	No cost estimated
Molder	Upgraded sand handling equipment - covered elsewhere	No cost	NA	NA	NA	No cost estimated
	Upgrade or install LEV	LEV	1,050	$5,526	100%	ERG estimates based on discussions with industrial ventilation consultants
	Rigorous housekeeping- capital	HEPA vacuum	NA	$1,304	100%	Nilfisk, 15 gallon capacity
	Rigorous housekeeping- labor	Labor costs	NA	$1,041	100%	10 min/wrker/day
	Eliminate compressed air	Included in rigorous housekeeping	NA	NA	NA	No cost estimated
Coremaker	Eliminated compressed air	Additional labor time	NA	$1,041	100%	10 min/wrker/day
	Enclosed conveyors, covered elsewhere	No cost	NA	NA	NA	No cost estimated
	Non-silica cores and core coatings	Option not costed, other controls sufficient	NA	NA	NA	No cost estimated
	Initial thorough cleaning	Cost per square foot, per facility	NA	$0.018	100%	ERG estimate based on docket submissions and industry contacts
Furnace operator	Control dust releases from adjacent processes - covered elsewhere		NA	NA	NA	No cost estimated
	Well-maintained furnace emission control system	Maintenance	NA	$650	100%	20 hours addtional maintenance time per year
	Operator booths or cabs	Based on clean-air island costs	2,500	$13,157	100%	Based on clean air island costs for structural clay
	Minimize dust generated by sand contamination of scrap	Option not costed	NA	NA	NA	No cost estimated
Pouring operator	Control dust from adjacent processes - covered elsewhere	No cost	NA	NA	NA	No cost estimated
	Operator booths or cabs	Based on clean-air island costs	2,500	$13,157	100%	Based on clean air island costs for structural clay

Table V-A-1: Detailed Exposure Control Requirements, Analytical Assumptions and Sources for the Cost Data Applied in OSHA's Analysis of Control Costs in General Industry and Maritime (continued)

Sector/Job Category - Control Requirements		Control Description	LEV CFM	Annualized Cost (a)	Applicability [b]	Estimate Source
	Physical isolation of pouring area (create a pouring room)	Option not costed	NA	NA	NA	No cost estimated
	Modify ventilation system to reduce airflow from other areas into the pouring area	Option not costed	NA	NA	NA	No cost estimated
Shakeout Operator	Improve existing ventilation system efficiency (very large castings)	Double-draft shake-out table	28,800	$151,563	100%	Based on Solberg costs for shakeout conveyor
	Improve existing ventilation system efficiency	Shakeout enclosing hood	7,040	$37,049	100%	Based on ACGIH design parameters for ventilated enclosing hood (pg. 10-23, ACGIGH, 2001); 4'x4' openings
	Partially enclose process	Enclosed, ventilated shakeout conveyor	10,000	$52,626	100%	Based on Solberg costs for shakeout conveyor
	Control emissions from associated operations - covered elsewhere	No cost	NA	NA	NA	No cost estimated
	Half mask respirator	Respirator	NA	$520	100%	Annual cost of respirator use
Knockout Operator	Installing and improving LEV	Small knockout table	1,350	$19,735	100%	Based on ACGIH design parameters for portable grinding table pg. 10-136), ACGIH, 2001), 3'x3' opening
	Installing and improving LEV	Large knockout table	4,800	$794	100%	Based on ACGIH design parameters for hand grinding table (pg. 10-135), ACGIH, 2001), 4'x6'
	Installing and improving LEV	Ventilated abrasive cutoff saw	1,500	$1,474	100%	Based onACGIH design parameters for ventilated cut-off saw (pg. 10-134, ACGIH, 2001, 2'x3' opening)
	Reduce residual sand on castings	Option not costed	NA	NA	NA	No cost estimated
	Automate knockout process	Option not costed	NA	NA	NA	No cost estimated
	Half mask respirator	Respirator	NA	$520	100%	Annual cost of respirator use

Table V-A-1: Detailed Exposure Control Requirements, Analytical Assumptions and Sources for the Cost Data Applied in OSHA's Analysis of Control Costs in General Industry and Maritime (continued)

Sector/Job Category	Control Requirements	Control Description	LEV CFM	Annualized Cost (a)	Applicability [b]	Estimate Source
Abrasive Blasting Operator	Improved maintenance for blasting cabinet	Maintenance	NA	$1,287	100%	Assumes 50% increase in maintenance costs (of up to $2,000) and purchase of new cabinets (25%) at $8,000/cabinet (Norton, 2003), or addit. interlocks at $1,800/cabinet (Heastrup, 2003).
	Half mask respirator	Respirator	NA	$520	100%	Annual cost of respirator use
Cleaning/ Finishing Operator	LEV for workstations	Hand grinding bench	3,750	$19,735	100%	Consultant Solberg estimate for hand grinding bench
	LEV on hand tools	LEV	200	$794	100%	Consultant Solberg estimate for hand tools
	Eliminate compressed air (switch to vacuum)	HEPA vacuum plus additional time	NA	$1,474	100%	15 gal vacuum and 5 extra minutes per day
	Substitution with non-silica materials	Option not costed	NA	NA	NA	No cost estimated
	Process automation	Option not costed	NA	NA	NA	No cost estimated
	Wet methods	Option not costed	NA	NA	NA	No cost estimated
	Pre-cleaning with automated equipment	Option not costed	NA	NA	NA	No cost estimated
Material Handler	Enclosed, ventilated cab	Retrofit with cab or replace equipment	NA	$7,365	100%	
Mainten-ance Operator	Use low silica refractory	Option not costed	NA	NA	NA	No cost estimated
	LEV for chipping tools	Dust collector with HEPA vacuum	NA	$988	100%	5 year life
	Pre-wetting lining to be removed	Additional labor	NA	$3,382	100%	2 hours per week
	Maintaining moisture level in the refractory applied	Additional labor	NA	$5,526	100%	1 hour per week
	Also, use of precast refractories and automated equipment for powdered refractory materials	Option not costed	NA	NA	NA	No cost estimated

Table V-A-1: Detailed Exposure Control Requirements, Analytical Assumptions and Sources for the Cost Data Applied in OSHA's Analysis of Control Costs in General Industry and Maritime (continued)

Sector/Job Category - Control Requirements		Control Description	LEV CFM	Annualized Cost (a)	Applicability [b]	Estimate Source
House-keeping Worker	Initial thorough cleaning	Cost per square foot, per facility	NA	$0.018	100%	No cost estimated
Landscaping						
Land-scaping and Grounds-keeping Workers	Wet methods	Labor costs	NA	$468	100%	Assumes 0.25 hours extra time per day for 100 days
Brick and stone-masons	Masonry saw dust control	Labor costs	NA	$749	100%	Assumes 5% productivity penalty for using wet methods for 100 days per year
Railroads						
Ballast Dumper	Spray system for right-of-way maintenance vehicles	Costs estimated per rail car.	NA	NA	NA	
Machine Operator	Spray system for right-of-way maintenance vehicles	Costs estimated per rail car.	NA	NA	NA	
Captive cut stone I						
Fabricator	Use water fed equipment	No cost, most tools have water capability	NA	NA	NA	No cost estimated
	Manage slurry-assumed included in housekeeping costs	No incremental costs	NA	NA		No cost estimated
	Rigorous housekeeping- capital	HEPA vacuum	NA	$937	100%	Nilfisk, 15 gallon capacity
	Rigorous housekeeping- labor	Labor costs	NA	$997	100%	10 min/wrker/day

Table V-A-1: Detailed Exposure Control Requirements, Analytical Assumptions and Sources for the Cost Data Applied in OSHA's Analysis of Control Costs in General Industry and Maritime (continued)

Sector/Job Category - Control Requirements		Control Description	LEV CFM	Annualized Cost (a)	Applicability [b]	Estimate Source
Captive cut stone II						
Fabricator	Masonry saw dust control	Labor costs	NA	$749	100%	Assumes 5% productivity penalty for using wet methods for 100 days per year
	Use water fed equipment	No cost, most tools have water capability	NA	NA	NA	No cost estimated
	Manage slurry-assumed included in housekeeping costs	No incremental costs	NA	NA	NA	No cost estimated
	Rigorous housekeeping- capital	HEPA vacuum	NA	$937	100%	Nilfisk, 15 gallon capacity
	Rigorous housekeeping- labor	Labor costs	NA	$997	100%	10 min/wrker/day

(a) Costs are annualized using a 3 percent discount rate over the lifetime of the equipment, typically 10 years.

(b) Indicates the percentage of establishments for which the control is applied.

Source: OSHA, Directorate of Standards and Guidance, Office of Regulatory Analysis, based on OSHA (2016)

Table V-A-2: Unit and Annualized Costs and Model Specifications for Silica Engineering Controls Applied in OSHA's Cost Analysis for General Industry and Maritime

Sector/Job Category - Control Requirements	Control Description	LEV CFM	Unit Cost	Operating Cost	Annualized Cost (a)	Workers per	Cost per worker	Workers per Control	Cost per worker	Estimate Source
Cut Stone										
Sawyer										
Control other dust sources in area	Addressed by other controls	NA	NA	NA	NA	NA	NA	NA	NA	No cost estimated
Rigorous housekeeping- capital	HEPA vacuum	NA	$3,633	$511	$937	4	$234	2	$469	Nilfisk, 15 gallon capacity
Rigorous housekeeping- labor	Labor costs	NA	NA	$997	$997	1	$997	1	$997	Additional 10 minutes/day
Manage slurry- assumed included in housekeeping costs		NA	NA	NA	NA	NA	NA	NA	NA	No cost estimated
Pre-wash stone to be cut	Incremental labor	NA	NA	$499	$499	1	$499	1	$499	5 min/wrkr/day
Improve drainage	Plumbing enhancements	NA	$36,412	$3,324	$7,592	4	$1,898	2	$3,796	ERG estimate based on discussions with contractors
Increase water use at saw blade	Extra saw maintenance	NA	NA	$499	$499	1	$499	1	$499	5 min/worker/day;Equipment has water capabilties
Enclose saw	Build enclosure	NA	$527	$115	$230	4	$58	2	$115	8x8x8 dust partition, with plastic sheeting, assumes 5 year life (Means, 2003)
Exhaust saw	LEV	645	$8,603	$2,386	$3,394	4	$849	2	$1,697	Based on saw LEV (e.g., pg. 10-158, 159, 160, ACGIH, 2001)
Fabricator										
Use water fed equipment	No cost, most tools have water	NA	NA	NA	NA	NA	NA	NA	NA	No cost estimated
Manage slurry- assumed included in housekeeping costs	No incremental costs	NA	NA	NA	NA	NA	NA	NA	NA	Assumes no incremental costs

Table V-A-2: Unit and Annualized Costs and Model Specifications for Silica Engineering Controls Applied in OSHA's Cost Analysis for General Industry and Maritime (continued)

Sector/Job Category - Control Requirements	Control Description	LEV CFM	Unit Cost	Operating Cost	Annualized Cost (a)	Workers per	Cost per worker	Workers per Control	Cost per worker	Estimate Source
Rigorous housekeeping- capital	HEPA vacuum	NA	$3,633	$511	$937	4	$234	2	$469	Nilfisk, 15 gallon capacity
Rigorous housekeeping- labor	Labor costs	NA	NA	$997	$997	1	$997	1	$997	10 min/wrkr/day
Splitter/chipper										
Use work practices to position work near	Judged to be a negligible cost	NA	NA	NA	NA	NA	NA	NA	NA	Work practices adjustments judged to be negligible cost.
Rigorous housekeeping- capital	HEPA vacuum	NA	$3,633	$511	$937	4	$234	2	$469	Nilfisk, 15 gallon capacity
Rigorous housekeeping- labor	Labor costs	NA	NA	$997	$997	1	$997	1	$997	Additional 10 minutes/day
Pre-wash stone	Labor	NA	NA	$997	$997	1	$997	1	$997	10 min/wrkr/day
Use flexible trunk LEV for hand chipping	Flexible trunk LEV	600	$8,002	$2,219	$3,158	2	$1,579	2	$1,579	Granite cutting and finishing;pg. 10-94 (ACGIH, 2001)
Tool-mounted LEV for hand-held chipping tools	Shroud and vacuum	NA	$1,738	$608	$812	2	$406	2	$406	Proventilation.com
Keep floors wet; washdown with high pressure hose	Already costed (see sawyers)	NA	NA	NA	NA	NA	NA	NA	NA	High-pressure hose and floor trough installation
Machine operator										
Control other dust sources in area	Addressed by other controls	NA	NA	NA	NA	NA	NA	NA	NA	No cost estimated
Rigorous housekeeping- capital	HEPA vacuum	NA	$3,633	$511	$1,304	4	$326	2	$652	Nilfisk, 15 gallon capacity
Rigorous housekeeping- labor	Labor costs	NA	NA	$997	$997	1	$997	1	$997	Additional 10 minutes/day

Table V-A-2: Unit and Annualized Costs and Model Specifications for Silica Engineering Controls Applied in OSHA's Cost Analysis for General Industry and Maritime (continued)

Sector/Job Category - Control Requirements	Control Description	LEV CFM	Unit Cost	Operating Cost	Annualized Cost (a)	Workers per	Cost per worker	Workers per Control	Cost per worker	Estimate Source
Wash stone before and after each	Add misters to conveyor line	NA	$451	$45	$281	2	$140	2	$140	Judged to require 8 hrs of shop labor,$200 in materials to fabricate;
Keep conveyor clean and damp	Addressed in other	NA	NA	NA	NA	NA	NA	NA	NA	No cost estimated
Management of dust-carrying water	Included in housekeeping	NA	NA	NA	NA	NA	NA	NA	NA	No cost estimated
Enclose machinery	Build enclosure in machine shop	NA	$527	$53	$168	4	$42	2	$84	8x8x8 enclosure, plastic sheeting, from Means, 2003. Five-year life.
Exhaust trimming machine	LEV	500	$6,669	$1,850	$2,631	4	$658	2	$1,316	Based on abrasive cut-off saw; (pg. 10-134) (ACGIH, 2001)
Abrasive Blaster										
For use of maintained, interlocked, ventilated glove-box cabinet	Cost of maintaining blast cabinet	NA	$2,450	$1,000	$1,287	4	$322	2	$644	Assumes 50% increase in maintenance costs (of up to $2,000) and purchase of new cabinets (25%) at $8,000/cabinet (Norton, 2003), or addit. interlocks at $1,800/cabinet (Heastrup, 2003).
Use only non-silica blasting media	Neglible incremental cost	NA	NA	NA	NA	NA	NA	NA	NA	Manufacturer calls indicted no use of sand, and neglible cost difference
Increase blasting cabinet ventilation	Incremental LEV	1,225	$16,338	$4,531	$6,447	4	$1,612	2	$3,223	Judged to require an increase in CFM for a 7x7 booth, approximately 25% of ACGIH recommended 100 cfm per square ft of opening, or 4900 cfm in total.

Table V-A-2: Unit and Annualized Costs and Model Specifications for Silica Engineering Controls Applied in OSHA's Cost Analysis for General Industry and Maritime (continued)

Sector/Job Category - Control Requirements	Control Description	LEV CFM	Unit Cost	Operating Cost	Annualized Cost (a)	Workers per	Cost per worker	Workers per Control	Cost per worker	Estimate Source
Use HEPA vacuums for machine cleaning	Vacuum replaces compressed air cleaning	NA	$3,633	$511	$937	4	$234	2	$469	Judged to create a negligible impact on labor requirements for cleaning
Flat glass										
Material handler										
Automated and ventilated unloading equipment	Not costed	NA	NA	NA	NA	NA	NA	NA	NA	No cost estimated
Conveyor enclosures	Limit dust and spills	NA	$4,147	$415	$901	4	225	4	225	ERG estimates based on discussions with industrial ventilation
Conveyor ventilation	LEV	4900	$65,354	$18,125	$25,787	4	6447	4	6447	Per 200 ft of conveyor enclosure (Pg. 10-70, ACGIH)
Batch operator										
Conveyor enclosures	Limit dust and spills	NA	$4,147	$415	$901	4	$225	4	$225	ERG estimates based on discussions with industrial ventilation
Conveyor ventilation	LEV	4900	$65,354	$18,125	$25,787	4	6447	4	6447	Per 200 ft of conveyor enclosure (Pg. 10-70, ACGIH)
LEV for batch operator workstation	LEV	1,050	$14,004	$3,884	$5,526	4	$1,381	2	$2,763	Bin & hopper ventilation and unvented mixers (pg. 10-69, ACGIH,
Dust suppressants	Use commercial dry suppressants	NA	NA	$676	$676	4	$169	2	$338	Oil-based sawdust sweeping compound
Substitute wider HEPA vacuum use for compressed air	HEPA available, requires more labor	NA	NA	$1,010	$1,010	1	$1,010	1	$1,010	10min/wrker/day
HEPA vacuums	Small HEPA needed	NA	$3,633	$511	$1,304	4	$326	2	$652	Nilfisk, 15 gallon capacity
Other glass										

Table V-A-2: Unit and Annualized Costs and Model Specifications for Silica Engineering Controls Applied in OSHA's Cost Analysis for General Industry and Maritime (continued)

Sector/Job Category - Control Requirements	Control Description	LEV CFM	Unit Cost	Operating Cost	Annualized Cost (a)	Workers per	Cost per worker	Workers per Control	Cost per worker	Estimate Source
Material handler										
Automated and ventilated unloading equipment	Not costed	NA	NA	NA	NA	NA	NA	NA	NA	No cost estimated
Conveyor enclosures	Limit dust and spills	NA	$4,147	$415	$901	4	$225	$4	$225	ERG estimates based on discussions with industrial ventilation
Conveyor ventilation	LEV	4,900	$65,354	$18,125	$25,787	4	$6,447	$4	$6,447	Per 200 ft of conveyor enclosure (Pg. 10-70, ACGIH)
Batch operator										
Conveyor enclosures	Limit dust and spills	NA	$4,147	$415	$901	4	$225	4	$225	ERG estimates based on discussions with industrial ventilation
LEV for batch operator workstation	LEV	1,050	$14,004	$3,884	$5,526	4	$1,381	2	$2,763	$0.22/lb, from www.fastenal.com; Assumed rate of use of 1 lb/day.; 5 minutes per day.
Dust suppressants	Use commercial dry suppressants	NA	NA	$676	$676	4	$169	2	$338	Oil-based sawdust sweeping compound
Substitute wider HEPA vacuum use for compressed air	HEPA available, requires more labor	NA	NA	$1,010	$1,010	1	$1,010	1	$1,010	10 min/wrker/day
HEPA vacuums	Small HEPA needed	NA	$3,633	$511	$937	5	$187	2	$469	Nilfisk, 15 gallon capacity
Conveyor ventilation	LEV	4,900	$65,354	$18,125	$25,787	4	$6,447	4	$6,447	Per 200 ft of conveyor enclosure (Pg. 10-70, ACGIH)
Half mask respirator		NA	NA	NA	$520	1	$520	1	$520	Annual cost of respirator use
Mineral Wool										
Material handler										

Table V-A-2: Unit and Annualized Costs and Model Specifications for Silica Engineering Controls Applied in OSHA's Cost Analysis for General Industry and Maritime (continued)

Sector/Job Category - Control Requirements	Control Description	LEV CFM	Unit Cost	Operating Cost	Annualized Cost (a)	Workers per	Cost per worker	Workers per Control	Cost per worker	Estimate Source
Automated and ventilated unloading equipment	Not costed	NA	NA	NA	NA	NA	NA	NA	NA	No cost estimated
Conveyor ventilation	LEV	4900	$65,354	$18,125	$25,787	4	$6,447	4	$6,447	ERG estimates based on discussions with industrial ventilation
Conveyor enclosures	Limit dust and spills	NA	$4,147	$415	$901	4	$225	4	$225	Per 200 ft of conveyor enclosure (Pg. 10-70, ACGIH)
Batch operator										
Conveyor enclosures	Limit dust and spills	NA	$4,147	$415	$901	4	$225	4	$225	Per 200 ft of conveyor enclosure (Pg. 10-70, ACGIH)
LEV for batch operator workstation	LEV	1,050	$14,004	$3,884	$5,526	4	$1,381	2	$2,763	Bin & hopper ventilation and unvented mixers (pg. 10-69, ACGIH,
Dust suppressants	Use commercial dry suppressants	NA	NA	$676	$676	4	$169	2	$338	Oil-based sawdust sweeping compound
Substitute wider HEPA vacuum use for compressed air	HEPA available, requires more labor	NA	NA	$1,096	$1,096	1	$1,096	1	$1,096	10 min/wrker/day
HEPA vacuums	Small HEPA needed	NA	$3,633	$511	$1,304	5	$261	2	$652	Nilfisk, 15 gallon capacity
Concrete Products										
Material handlers										
Yard dust suppression	Wetting with yard hose	NA	$212	$1,536	$1,647	4	$412	2	$823	Per facility; 2 year life. .25 hour of labor time per day per worker
Enclosed cabs	Retrofit with cab or replacement equip	NA	$15,762	$5,517	$7,365	4	$1,841	2	$3,682	Per machine. Assumes 35% annual maintenance costs

Table V-A-2: Unit and Annualized Costs and Model Specifications for Silica Engineering Controls Applied in OSHA's Cost Analysis for General Industry and Maritime (continued)

Sector/Job Category - Control Requirements	Control Description	LEV CFM	Unit Cost	Operating Cost	Annualized Cost (a)	Workers per	Cost per worker	Workers per Control	Cost per worker	Estimate Source
LEV for blender and hoppers	LEV	1,050	$14,004	$3,884	$5,526	4	$1,381	2	$2,763	Per ACGIH design parameters (pg. 10-69; ACGIH, 2001)
Improved housekeeping - HEPA vacuum	HEPA vacuum cost	NA	$3,633	$511	$1,304	4	$326	2	$652	Nilfisk, 15 gallon capacity
Improved housekeeping - additional labor	Labor cost	NA	NA	$1,024	$1,024	1	$1,024	1	$1,024	10 min/wrker/day
Mixer operators										
Wet methods to clean equipment	Additional cleaning time	NA	NA	$1,024	$1,024	1	$1,024	1	$1,024	Per day/per operator
LEV for bag opening stations	LEV with bag dumping station	1,513	$20,180	$5,597	$7,962	4	$1,991	2	$3,981	Bag opening station; pg. 10-19) (ACGIH, 2001)
Ventilated control room and HEPA filter	LEV	200	$20,328	$740	$3,123	4	$781	2	$1,561	ERG estimates based on Means and ACGIH
Forming operators										
Dust control for adjacent operations	Addressed by other controls	NA	NA	NA	NA	NA	NA	NA	NA	No cost estimated
LEV for forming operator workstations	Moveable LEV duct	600	$8,002	$2,219	$3,158	4	$789	2	$1,579	See similar control for granite cutting and finishing; p.10-94
Initial thorough cleaning	Cost per square foot, per facility	NA	$0	$0	$0	NA	NA	NA	NA	ERG estimate. One time cleaning
Improve housekeeping -	HEPA vacuum cost	NA	$3,633	$511	$1,304	4	$326	2	$652	Nilfisk, 15 gallon capacity
Improve housekeeping - labor	Additional cleaning time	NA	NA	$1,024	$1,024	1	$1,024	1	$1,024	10 min/wrker/day
Abrasive blasting										
Use wet process	Shop built	NA	$213	$21	$133	4	$33	2	$66	Assumes 2-year life

Table V-A-2: Unit and Annualized Costs and Model Specifications for Silica Engineering Controls Applied in OSHA's Cost Analysis for General Industry and Maritime (continued)

Sector/Job Category - Control Requirements	Control Description	LEV CFM	Unit Cost	Operating Cost	Annualized Cost (a)	Workers per	Cost per worker	Workers per Control	Cost per worker	Estimate Source
Use alternative blast media	Use of more expensive non-silica media	NA	NA	$5,156	$5,156	1	$5,156	1	$5,156	Based on 220,000 square feet of coverage per year per crew of 4
Finishing operators										
Work concrete green	Penalty for overall	NA	NA	$2,393	$2,393	1	$2,393	1	$2,393	Assumes 5% productivity penalty per worker
Use wet process	Shop built	NA	$213	$21	$133	4	$33	2	$66	Assumes 2-year life
LEV where wet methods are	Shroud and vacuum	NA	$1,738	$608	$988	2	$494	2	$494	Proventilation.com
Packaging operators										
LEV for bag filling stations	LEV with bag filling station	1,500	$20,006	$5,549	$7,894	4	$1,973	2	$3,947	Bag filling station (pg. 10-15, ACGIH, 2001)
Extended polyethylene bag valves to reduce dust release	Use bags with dust-control feature	NA	NA	$4,915	$4,915	1	$4,915	1	$4,915	Assumes 5 bags per minute; 200 days a year
Pottery										
Material Handler										
Well-ventilated bag dumping stations	LEV	1,513	$20,180	$5,597	$7,962	4	$1,991	2	$3,981	Bag opening station; (pg. 10-19) (ACGIH, 2001)
Ventilated cab enclosures	Retrofit with cab or replacement equip	NA	$15,762	$5,517	$7,365	4	$1,841	2	$3,682	Per machine
Apply LEV to conveyors in material handling area	LEV	10,000	$133,375	$36,990	$52,626	4	$13,157	4	$13,157	ERG estimates based on discussions with industrial ventilation consultants

Table V-A-2: Unit and Annualized Costs and Model Specifications for Silica Engineering Controls Applied in OSHA's Cost Analysis for General Industry and Maritime (continued)

Sector/Job Category - Control Requirements	Control Description	LEV CFM	Unit Cost	Operating Cost	Annualized Cost (a)	Workers per	Cost per worker	Workers per Control	Cost per worker	Estimate Source
Initial thorough cleaning	Cost per square foot, per facility	NA	$0.150	$0.000	$0.018	NA	NA	NA	NA	ERG estimate. One time cleaning
Improve housekeeping -	HEPA vacuum cost	NA	$3,633	$511	$1,304	4	$326	2	$652	Nilfisk, 15 gallon capacity
Improve housekeeping - labor	Additional cleaning time	NA	NA	$961	$961	1	$961	1	$961	10 min/wrker/day
Forming Line Operator										
LEV- hand grinding bench controls	LEV	1,400	$18,672	$5,179	$7,368	4	$1,842	2	$3,684	Welding ventilation bench hood (pg. 10-149, ACGIH
Eliminate compressed air (switch to vacuum)	HEPA vacuum plus additional time	NA	$3,633	$1,048	$1,474	4	$368	2	$737	Includes 5 incremental minutes per day.
Reduce dust generation during mold parting (redesign talc bag)	Cost judged negligible	NA	NA	NA	NA	NA	NA	NA	NA	No cost estimated
Finishing operator										
LEV- hand grinding bench controls	LEV	2,400	$32,010	$8,878	$12,630	4	$3,158	2	$6,315	Hand grinding bench (pg. 10-135, ACGIH, 2001)
Wet finishing	Option not	NA	NA	NA	NA	NA	NA	NA	NA	Assume 5% penalty
Coatings preparer										
Well-ventilated bag dumping stations	LEV	1,513	$20,180	$5,597	$7,962	4	$1,991	2	$3,981	Bag opening station; pg. 10-19) (ACGIH, 2001)

Table V-A-2: Unit and Annualized Costs and Model Specifications for Silica Engineering Controls Applied in OSHA's Cost Analysis for General Industry and Maritime (continued)

Sector/Job Category - Control Requirements	Control Description	LEV CFM	Unit Cost	Operating Cost	Annualized Cost (a)	Workers per	Cost per worker	Workers per Control	Cost per worker	Estimate Source
Well-ventilated or enclosed, automated systems for charging mixing equipment with glaze materials	LEV	1,050	$14,004	$3,884	$5,526	4	$1,381	2	$2,763	Bin & hopper ventilation and unvented mixers (pg. 10-69, ACGIH, 2001)
Eliminate compressed air	Covered by improved housekeeping	NA	NA	NA	NA	5	NA	2	NA	No cost estimated
Improve housekeeping -	HEPA vacuum cost	NA	$3,633	$511	$1,304	4	$326	2	$652	Nilfisk, 15 gallon capacity
Improve housekeeping - labor	Additional cleaning time	NA	NA	$961	$961	1	$961	1	$961	10 min/wrker/day
Coatings Operator										
Substitute low silica content inputs	Option not costed	NA	NA	NA	NA	NA	NA	NA	NA	No cost estimated
Improved LEV for spray booths and enclosures	Increased airflow, additional CFM	250	$3,334	$231	$622	4	$156	2	$311	Increment judged adequate for spray booth
Spray booth maintenance	Booth repairs	NA	NA	$240	$240	4	$60	2	$120	Annual incremental costs of $100 materials plus 4 hours maintenance time [a]
Paint										
Material handler										
No overexposure	No control needed	NA	NA	NA	NA	NA	NA	NA	NA	No cost estimated
Mixer operator										

Table V-A-2: Unit and Annualized Costs and Model Specifications for Silica Engineering Controls Applied in OSHA's Cost Analysis for General Industry and Maritime (continued)

Sector/Job Category - Control Requirements	Control Description	LEV CFM	Unit Cost	Operating Cost	Annualized Cost (a)	Workers per	Cost per worker	Workers per Control	Cost per worker	Estimate Source
Ventilated bag dumping stations with bag compactor	LEV	1,513	$20,180	$5,597	$7,962	4	$1,991	2	$3,981	Bag opening station; pg. 10-19) (ACGIH, 2001)
Structural Clay										
Material Handler (Loader Operators)										
Enclosed, ventilated cab	Retrofit with cab or replace equipment	NA	$15,762	$5,517	$7,365	4	$1,841	2	$3,682	Per machine
Rigorous housekeeping- capital	HEPA Vacuum	NA	$3,633	$511	$1,304	4	$326	2	$652	Nilfisk, 15 gallon capacity
Rigorous housekeeping- labor	Housekeeping - labor	NA	NA	$961	$961	1	$961	1	$961	10 min/wrker/day
Improve cab maintenance and keep windows closed	Use existing cabs for dust control	NA	NA	$788	$788	4	$197	2	$394	Judged to be incremental cost equal to one-half normal maintenance cost
Cover conveyors in material handling area	Conveyor covers	NA	$4,147	$415	$901	4	$225	4	$225	ERG estimates based on discussions with industrial ventilation
Apply LEV to conveyors in material handling area	LEV	10,000	$133,375	$36,990	$52,626	4	$13,157	4	$13,157	ERG estimate of CFM requirements.
Material Handler (Production Line Handlers)										
Use low-silica gravel	Option not costed; substitutes available	NA	NA	NA	NA	NA	NA	NA	NA	No cost estimated

Table V-A-2: Unit and Annualized Costs and Model Specifications for Silica Engineering Controls Applied in OSHA's Cost Analysis for General Industry and Maritime (continued)

Sector/Job Category - Control Requirements	Control Description	LEV CFM	Unit Cost	Operating Cost	Annualized Cost (a)	Workers per	Cost per worker	Workers per Control	Cost per worker	Estimate Source
Misters on conveyor line	Water spray to suppress dust	NA	$10,609	$1,061	$2,305	4	$576	4	$576	Assumes 100 ft. length of conveyor in this area
Exhaust LEV and clean air island (CAI)	LEV	4,000	$53,350	$14,796	$21,050	4	$5,263	2	$10,525	Assumes clean air island plus 1500 cfm.
Material Handler (Post-Production										
Misters on conveyor line	Water spray to suppress dust	NA	$10,609	$1,061	$2,305	4	$576	4	$576	Assumes 100 ft. length of conveyor in this area
Improved dust suppression	hose spraying 0.25/hr/day 250 days/yr	NA	$212	$1,536	$1,647	1	$1,647	1	$1,647	Per facility; 2 year life. .25 hour of labor time per day per worker
Improve housekeeping -	HEPA vacuum cost	NA	$3,633	$511	$1,304	4	$326	2	$652	Nilfisk, 15 gallon capacity
Improve housekeeping - labor	Additional cleaning time	NA	NA	$961	$961	1	$961	1	$961	10 min/wrker/day
Grinding Operators										
Ventilated control room and HEPA filter	LEV	200	$20,328	$740	$3,123	4	$781	2	$1,561	ERG estimates based on Means and ACGIH
Control room improvements and repairs	In-house repairs	NA	$2,240	NA	$263	4	$66	2	$131	ERG estimate
Enclosures with LEV for grinding equipment	LEV	17,000	$226,737	$62,884	$89,464	4	$22,366	2	$44,732	One half of the total 34,000 cfm estimated by Knutson for a medium sized brick facility
Purchase additional HEPA vacuums	HEPA vacuum	NA	$3,633	$511	$1,304	4	$326	2	$652	Nilfisk, 15 gallon capacity

Table V-A-2: Unit and Annualized Costs and Model Specifications for Silica Engineering Controls Applied in OSHA's Cost Analysis for General Industry and Maritime (continued)

Sector/Job Category - Control Requirements	Control Description	LEV CFM	Unit Cost	Operating Cost	Annualized Cost (a)	Workers per	Cost per worker	Workers per Control	Cost per worker	Estimate Source
Enhanced housekeeping with HEPA vacuums	Labor costs	NA	NA	$961	$961	1	$961	1	$961	10 min/wrker/day
Cover conveyors in grinding area	Conveyor covers	NA	$4,147	$415	$901	4	$225	4	$225	ERG estimates based on discussions with industrial ventilation
Dust suppression for raw materials	Dust suppression activity	NA	NA	$676	$676	1	$676	1	$676	Use of oil-based sawdust dust suppressant
Tightly sealed storage units	Option not costed	NA	NA	NA	NA	NA	NA	NA	NA	No incremental costs estimated
Initial thorough cleaning	Cost per square foot, per facility	NA	$0	$0	$0	NA	NA	NA	NA	ERG estimate of costs per square foot of floorspace
Half mask respirator	Respirator	NA	NA	NA	$520	1	$520	1	$520	Annual cost of respirator use
Forming Line operators (Pug mill operators)										
Enclosed and ventilated pug mill equipment	LEV	6,000	$80,025	$22,194	$31,576	4	$7,894	2	$15,788	Estimated by Knutson.
Initial thorough cleaning	See grinding operator	NA	NA	NA	NA	NA	NA	NA	NA	No cost estimated
Misters on conveyor line	Misting	NA	$10,609	$1,061	$2,305	4	$576	4	$576	National Environmental Services Company (Kestner, 2003). [a]
Improve housekeeping -	HEPA vacuum cost	NA	$3,633	$511	$1,304	4	$326	2	$652	Nilfisk, 15 gallon capacity
Improve housekeeping - labor	Additional cleaning time	NA	NA	$961	$961	1	$961	1	$961	10 min/wrker/day
Half mask respirator	Respirator	NA	NA	NA	$520	1	$520	1	$520	Annual cost of respirator use
Forming Line Operators (Coatings Blenders)										
Initial thorough cleaning	See grinding operator	NA	NA	NA	NA	NA	NA	NA	NA	No cost estimated

Table V-A-2: Unit and Annualized Costs and Model Specifications for Silica Engineering Controls Applied in OSHA's Cost Analysis for General Industry and Maritime (continued)

Sector/Job Category - Control Requirements	Control Description	LEV CFM	Unit Cost	Operating Cost	Annualized Cost (a)	Workers per	Cost per worker	Workers per Control	Cost per worker	Estimate Source
Well-ventilated bag dumping stations	LEV	1,513	$20,180	$5,597	$7,962	4	$1,991	2	$3,981	Based on ACGIH design parameters for bag opening station; (pg. 10-19, ACGIH, 2001)
Enclosed and ventilated feed hopper, conveyors, tumble tote charging, and transfer to	Best judgment	9,000	$120,037	$33,291	$47,363	4	$11,841	4	$11,841	Estimated by Knutson. See "Brick Manufacturing.xls" (10,000 cfm typical, including bag dumping)
Improve housekeeping -	HEPA vacuum cost	NA	$3,633	$511	$1,304	4	$326	2	$652	Nilfisk, 15 gallon capacity
Improve housekeeping - labor	Additional cleaning time	NA	NA	$961	$961	1	$961	1	$961	10 min/wrker/day
Forming Line Operators										
Initial thorough cleaning	See grinding operator	NA	NA	NA	NA	NA	NA	NA	NA	No cost estimated
Improve housekeeping -	HEPA vacuum cost	NA	$3,633	$511	$1,304	4	$326	2	$652	Nilfisk, 15 gallon capacity
Improve housekeeping - labor	Additional cleaning time	NA	NA	$961	$961	1	$961	1	$961	10 min/wrker/day
Well-ventilated bag dumping stations	LEV	1,513	$20,180	$5,597	$7,962	4	$1,991	2	$3,981	Based on ACGIH design parameters for bag opening station; (pg. 10-19, ACGIH, 2001)
Enclosed and ventilated	LEV plus clean air island	3,550	$47,348	$13,132	$18,682	4	$4,671	2	$9,341	From Knutson estimates; avg for several production workers
Half mask respirator	Respirator	NA	NA	NA	$520	1	$520	1	$520	Annual cost of respirator use
Dental laboratories										
Dental Technicians										

Table V-A-2: Unit and Annualized Costs and Model Specifications for Silica Engineering Controls Applied in OSHA's Cost Analysis for General Industry and Maritime (continued)

Sector/Job Category - Control Requirements	Control Description	LEV CFM	Unit Cost	Operating Cost	Annualized Cost (a)	Workers per	Cost per worker	Workers per Control	Cost per worker	Estimate Source
Improved LEV in grinding, blasting	Dental lab dust control systems	NA	$800	$80	$174	2	$87	2	$87	Self-contained dust collection system. Darby Dental Lab Supply, 2005 (www.darbylab.com)
Improve housekeeping -	HEPA vacuum cost	NA	$3,633	$511	$1,304	2	$652	2	$652	Nilfisk, 15 gallon capacity
Improve housekeeping - labor	Additional cleaning time	NA	NA	$1,118	$1,118	2	$559	2	$559	10 min/wrker/day
Fine jewelry										
Jewelry workers										
Substitution of low-silica modeling/investment materials	Not costed	NA	NA	NA	NA	NA	NA	NA	NA	Judged that LEV controls will be favored method
LEV for abrasive blasting and finishing	Small-scale jewelry bench LEV	100	$1,334	$370	$526	2	$263	2	$263	Small-scale LEV should be adequate
Costume Jewelry										
Jewelry workers										
Substitution of low-silica modeling/investment materials	Not costed	NA	NA	NA	NA	NA	NA	NA	NA	Judged that LEV controls will be favored method
LEV for abrasive blasting and finishing	Small-scale jewelry bench LEV	100	$1,334	$370	$526	2	$263	2	$263	Small-scale LEV should be adequate
Refractories										
Material handler										

Table V-A-2: Unit and Annualized Costs and Model Specifications for Silica Engineering Controls Applied in OSHA's Cost Analysis for General Industry and Maritime (continued)

Sector/Job Category - Control Requirements	Control Description	LEV CFM	Unit Cost	Operating Cost	Annualized Cost (a)	Workers per	Cost per worker	Workers per Control	Cost per worker	Estimate Source
Ventilated bag dumping stations with bag compactor	LEV	1,513	$20,180	$5,597	$7,962	4	$1,991	2	$3,981	ACGIH-based estimate. See "orig sources"
Enclosed and ventilated mixing equipment	LEV	1,050	$14,004	$3,884	$5,526	4	$1,381	2	$2,763	ACGIH-based estimate. See "orig sources"
Forming Operator										
Increased LEV maintenance	Additional cost per operator	NA	NA	$355	$355	1	$355	1	$355	Assumes 1 hour additional maintenance time per operator per month
Wet methods for mold cleaning	Additional cleaning time	NA	NA	$961	$961	1	$961	1	$961	Assumes 10 additional minutes of cleaning time
Finishing operator										
No overexposures	NA	NA	NA	NA	NA	NA	NA	NA	NA	No cost estimated
Ceramic fiber furnace operator										
No overexposures	NA	NA	NA	NA	NA	NA	NA	NA	NA	No cost estimated
Packaging operator										
LEV for bag filling stations	LEV/ per cfm	1,500	$20,006	$5,549	$7,894	4	$1,973	2	$3,947	ACGIH-based estimate. See "orig sources"
Bag valves to reduce dust release	Per operator	NA	NA	$4,915	$4,915	1	$4,915	1	$4,915	Assumes 5 bags per minute; 200 days a year
Enameling-services										
Enamel preparer										
Bag dumping station maintenance	Materials plus labor	NA	NA	$240	$240	4	$60	2	$120	Annual: $100 materials plus 4 hours maintenance time [a]

Table V-A-2: Unit and Annualized Costs and Model Specifications for Silica Engineering Controls Applied in OSHA's Cost Analysis for General Industry and Maritime (continued)

Sector/Job Category - Control Requirements	Control Description	LEV CFM	Unit Cost	Operating Cost	Annualized Cost (a)	Workers per	Cost per worker	Workers per Control	Cost per worker	Estimate Source
Rigorous housekeeping- capital	HEPA vacuum	NA	$3,633	$511	$1,304	4	$326	2	$652	Nilfisk, 15 gallon capacity
Rigorous housekeeping- labor	Labor costs	NA	NA	$1,019	$1,019	1	$1,019	1	$1,019	10 min/wrker/day
Eliminate compressed air	Included in rigorous housekeeping	NA	NA	NA	NA	10	NA	2	NA	No cost estimated
Porcelain applicator										
Improved LEV for spray booths and enclosures	Increased airflow¥cfm	1,000	$3,334	$925	$1,316	4	$329	2	$658	Allotment of 1,000 CFM of additional airflow
Rigorous housekeeping- capital	HEPA vacuum	NA	$3,633	$511	$1,304	4	$326	2	$652	Nilfisk, 15 gallon capacity
Rigorous housekeeping- labor	Labor costs	NA	NA	$1,019	$1,019	1	$1,019	1	$1,019	10 min/wrker/day
Enameling-iron										
Enamel preparer										
Bag dumping station maintenance	Materials plus labor	NA	NA	$240	$240	4	$60	2	$120	Annual: $100 materials plus 4 hours maintenance time [a]
Rigorous housekeeping- capital	HEPA vacuum	NA	$3,633	$511	$1,304	4	$326	2	$652	Nilfisk, 15 gallon capacity
Rigorous housekeeping- labor	Labor costs	NA	NA	$1,019	$1,019	1	$1,019	1	$1,019	10 min/wrker/day
Eliminate compressed air	Included in rigorous housekeeping	NA	NA	NA	NA	10	NA	2	NA	No cost estimated
Porcelain applicator										

Table V-A-2: Unit and Annualized Costs and Model Specifications for Silica Engineering Controls Applied in OSHA's Cost Analysis for General Industry and Maritime (continued)

Sector/Job Category - Control Requirements	Control Description	LEV CFM	Unit Cost	Operating Cost	Annualized Cost (a)	Workers per	Cost per worker	Workers per Control	Cost per worker	Estimate Source
Improved LEV for spray booths and enclosures	Increased airflow¥cfm	1,000	$3,334	$925	$1,316	4	$329	2	$658	Allotment of 1,000 CFM of additional airflow
Rigorous housekeeping- capital	HEPA vacuum	NA	$3,633	$511	$1,304	4	$326	2	$652	Nilfisk, 15 gallon capacity
Rigorous housekeeping- labor	Labor costs	NA	NA	$1,019	$1,019	1	$1,019	1	$1,019	10 min/wrker/day
Enameling-architecture										
Enamel preparer										
Bag dumping station maintenance	Materials plus labor	NA	NA	$240	$240	4	$60	2	$120	Annual: $100 materials plus 4 hours maintenance time [a]
Rigorous housekeeping- capital	HEPA vacuum	NA	$3,633	$511	$1,304	4	$326	2	$652	Nilfisk, 15 gallon capacity
Rigorous housekeeping- labor	Labor costs	NA	NA	$1,019	$1,019	1	$1,019	1	$1,019	10 min/wrker/day
Eliminate compressed air	Included in rigorous housekeeping	NA	NA	NA	NA	10	NA	2	NA	No cost estimated
Porcelain applicator										
Improved LEV for spray booths and enclosures	Increased airflow¥cfm	1,000	$3,334	$925	$1,316	4	$329	2	$658	Allotment of 1,000 CFM of additional airflow
Rigorous housekeeping- capital	HEPA vacuum	NA	$3,633	$511	$1,304	4	$326	2	$652	Nilfisk, 15 gallon capacity
Rigorous housekeeping- labor	Labor costs	NA	NA	$1,019	$1,019	1	$1,019	1	$1,019	10 min/wrker/day
Enameling-appliances										

Table V-A-2: Unit and Annualized Costs and Model Specifications for Silica Engineering Controls Applied in OSHA's Cost Analysis for General Industry and Maritime (continued)

Sector/Job Category - Control Requirements	Control Description	LEV CFM	Unit Cost	Operating Cost	Annualized Cost (a)	Workers per	Cost per worker	Workers per Control	Cost per worker	Estimate Source
Enamel preparer										
Bag dumping station maintenance	Materials plus labor	NA	NA	$240	$240	4	$60	2	$120	Annual: $100 materials plus 4 hours maintenance time [a]
Rigorous housekeeping- capital	HEPA vacuum	NA	$3,633	$511	$1,304	4	$326	2	$652	Nilfisk, 15 gallon capacity
Rigorous housekeeping- labor	Labor costs	NA	NA	$1,019	$1,019	1	$1,019	1	$1,019	10 min/wrker/day
Eliminate compressed air	Included in rigorous housekeeping	NA	NA	NA	NA	10	NA	2	NA	No cost estimated
Porcelain applicator										
Improved LEV for spray booths and enclosures	Increased airflow¥cfm	1,000	$3,334	$925	$1,316	4	$329	2	$658	Allotment of 1,000 CFM of additional airflow
Rigorous housekeeping- capital	HEPA vacuum	NA	$3,633	$511	$1,304	4	$326	2	$652	Nilfisk, 15 gallon capacity
Rigorous housekeeping- labor	Labor costs	NA	NA	$1,019	$1,019	1	$1,019	1	$1,019	10 min/wrker/day
Enameling-signs										
Enamel preparer										
Bag dumping station maintenance	Materials plus labor	NA	NA	$240	$240	4	$60	2	$120	Annual: $100 materials plus 4 hours maintenance time [a]
Rigorous housekeeping- capital	HEPA vacuum	NA	$3,633	$511	$1,304	4	$326	2	$652	Nilfisk, 15 gallon capacity
Rigorous housekeeping- labor	Labor costs	NA	NA	$1,019	$1,019	1	$1,019	1	$1,019	10 min/wrker/day

Table V-A-2: Unit and Annualized Costs and Model Specifications for Silica Engineering Controls Applied in OSHA's Cost Analysis for General Industry and Maritime (continued)

Sector/Job Category - Control Requirements	Control Description	LEV CFM	Unit Cost	Operating Cost	Annualized Cost (a)	Workers per	Cost per worker	Workers per Control	Cost per worker	Estimate Source
Eliminate compressed air	Included in rigorous housekeeping	NA	NA	NA	NA	10	NA	2	NA	No cost estimated
Porcelain applicator										
Improved LEV for spray booths and enclosures	Increased airflow¥cfm	1,000	$3,334	$925	$1,316	4	$329	2	$658	Allotment of 1,000 CFM of additional airflow
Rigorous housekeeping- capital	HEPA vacuum	NA	$3,633	$511	$1,304	4	$326	2	$652	Nilfisk, 15 gallon capacity
Rigorous housekeeping- labor	Labor costs	NA	NA	$1,019	$1,019	1	$1,019	1	$1,019	10 min/wrker/day
Ready-Mix Concrete										
Material handler										
Yard dust suppression	Wetting with yard hose	NA	$212	$5,784	$5,894	2	$2,947	2	$2,947	From concrete; 2 year life
Enclosed cabs	Retrofit with cab or replacement equip	NA	$15,762	$5,517	$7,365	2	$3,682	2	$3,682	From concrete
Batch operator										
No overexposures	No controls necessary	NA	NA	NA	NA	NA	NA	NA	NA	No cost estimated
Maintenance operator										
Wet methods to clean equipment	Additional cleaning time	NA	NA	1,024	1,024	1	$1,024	1	$1,024	From concrete. 10 mins per day, 250 days
Quality control technician										
No overexposures	No controls necessary	NA	NA	NA	NA	NA	NA	NA	NA	No cost estimated
Truck Driver										

Table V-A-2: Unit and Annualized Costs and Model Specifications for Silica Engineering Controls Applied in OSHA's Cost Analysis for General Industry and Maritime (continued)

Sector/Job Category - Control Requirements	Control Description	LEV CFM	Unit Cost	Operating Cost	Annualized Cost (a)	Workers per	Cost per worker	Workers per Control	Cost per worker	Estimate Source
Wet methods for drum cleaning	Water fed chipping equipment	NA	$242	0	242	4	$61	2	$121	ERG estimate of annual retrofit costs
Ventilation for drum cleaning	Forced ventilation	NA	$824	206	386	4	$96	2	$193	5 year life
Half mask respirator	Respirator	NA	NA	NA	520	1	$520	1	$520	Annual cost of respirator use
Iron Foundries										
Sand Systems Operator										
LEV, mixer & muller hood	LEV	1,050	$20,180	$5,597	$7,962	4	$1,991	2	$3,981	Mixer & muller hood (pg. 10-87, ACGIH, 2001); Formerly required clean-air island, but not called out in techfeas; dropped from costs
Conveyor enclosures	200 feet, ventilated (7 take-off points)	4,900	$69,500	$18,125	$26,273	4	$6,568	4	$6,568	One take-off point at-least every 30', 7 overall.
Bin and hopper ventilation	LEV	1,050	$14,004	$3,884	$5,526	4	$1,381	2	$2,763	CFM from Solburg worksheet. (ACGIH, 2001; p. 10-69)
Bucket elevator ventilation	LEV	1,600	$21,340	$5,918	$8,420	4	$2,105	2	$4,210	Based on Knutson specs
Screen ventilation	LEV	1,200	$16,005	$4,439	$6,315	4	$1,579	2	$3,158	Based on Knutson specs
Substitute silica-free materials	Option not costed, other controls	NA	NA	NA	NA	NA	NA	NA	NA	No cost estimated
Molder										
Upgraded sand handling equipment - covered elsewhere	No cost	NA	NA	NA	NA	NA	NA	NA	NA	No cost estimated

Table V-A-2: Unit and Annualized Costs and Model Specifications for Silica Engineering Controls Applied in OSHA's Cost Analysis for General Industry and Maritime (continued)

Sector/Job Category - Control Requirements	Control Description	LEV CFM	Unit Cost	Operating Cost	Annualized Cost (a)	Workers per	Cost per worker	Workers per Control	Cost per worker	Estimate Source
Upgrade or install LEV	LEV	1,050	$14,004	$3,884	$5,526	4	$1,381	2	$2,763	ERG estimates based on discussions with industrial ventilation
Rigorous housekeeping- capital	HEPA vacuum	NA	$3,633	$511	$1,304	5	$261	2	$652	Nilfisk, 15 gallon capacity
Rigorous housekeeping- labor	Labor costs	NA	NA	$1,041	$1,041	1	$1,041	1	$1,041	10 min/wrker/day
Eliminate compressed air	Included in rigorous housekeeping	NA	NA	NA	NA	NA	NA	NA	NA	No cost estimated
Coremaker										
Eliminated compressed air	Additional labor time	NA	NA	$1,041	$1,041	1	$1,041	1	$1,041	10 min/wrker/day
Enclosed conveyors, covered elsewhere	No cost	NA	NA	NA	NA	NA	NA	NA	NA	No cost estimated
Non-silica cores and core coatings	Option not costed, other controls	NA	NA	NA	NA	NA	NA	NA	NA	No cost estimated
Initial thorough cleaning	Costed below	NA	NA	NA	NA	NA	NA	NA	NA	No cost estimated
Furnace operator										
Control dust releases from adjacent processes - covered elsewhere		NA	NA	NA	NA	NA	NA	NA	NA	No cost estimated
Well-maintained furnace emission control system	Maintenance	NA	NA	$650	$650	4	$163	2	$325	20 hours addtional maintenance time per year

Table V-A-2: Unit and Annualized Costs and Model Specifications for Silica Engineering Controls Applied in OSHA's Cost Analysis for General Industry and Maritime (continued)

Sector/Job Category - Control Requirements	Control Description	LEV CFM	Unit Cost	Operating Cost	Annualized Cost (a)	Workers per	Cost per worker	Workers per Control	Cost per worker	Estimate Source
Operator booths or cabs	Based on clean-air island costs	2,500	$33,344	$9,248	$13,157	4	$3,289	2	$6,578	Based on clean air island costs for structural clay
Minimize dust generated by sand contamination of	Option not costed	NA	NA	NA	NA	NA	NA	NA	NA	No cost estimated
Pouring operator										
Control dust from adjacent processes - covered elsewhere	No cost	NA	NA	NA	NA	NA	NA	NA	NA	No cost estimated
Operator booths or cabs	Based on clean-air island costs	2,500	$33,344	$9,248	$13,157	4	$3,289	2	$6,578	Based on clean air island costs for structural clay
Physical isolation of pouring area (create a pouring room)	Option not costed	NA	NA	NA	NA	NA	NA	NA	NA	No cost estimated
Modify ventilation system to reduce airflow from other areas into the pouring area	Option not costed	NA	NA	NA	NA	NA	NA	NA	NA	No cost estimated
Shakeout Operator										
Improve existing ventilation system efficiency (very large castings)	Double-draft shake-out table	28,800	$384,119	$106,533	$151,563	4	$37,891	2	$75,782	Based on Solberg costs for shakeout conveyor
Improve existing ventilation system efficiency	Shakeout enclosing hood	7,040	$93,896	$26,041	$37,049	4	$9,262	2	$18,524	Based on ACGIH design parameters for ventilated enclosing hood (pg. 10-23, ACGIGH, 2001); 4'x4'

Table V-A-2: Unit and Annualized Costs and Model Specifications for Silica Engineering Controls Applied in OSHA's Cost Analysis for General Industry and Maritime (continued)

Sector/Job Category - Control Requirements	Control Description	LEV CFM	Unit Cost	Operating Cost	Annualized Cost (a)	Workers per	Cost per worker	Workers per Control	Cost per worker	Estimate Source
Partially enclose process	Enclosed, ventilated shakeout conveyor	10,000	$133,375	$36,990	$52,626	4	$13,157	2	$26,313	Based on Solberg costs for shakeout conveyor
Control emissions from associated operations - covered	No cost	NA	NA	NA	NA	NA	NA	NA	NA	No cost estimated
Knockout Operator										
Installing and improving LEV	Small knockout table	1,350	$18,006	$4,994	$7,105	4	$1,776	2	$3,552	Based on ACGIH design parameters for hand grinding table (pg. 10-135), ACGIH, 2001), 4'x6' surface
Installing and improving LEV	Large knockout table	4,800	$64,020	$17,755	$25,261	4	$6,315	2	$12,630	Based onACGIH design parameters for ventilated cut-off saw (pg. 10-134, ACGIH, 2001, 2'x3' opening)
Installing and improving LEV	Ventilated abrasive cutoff saw	1,500	$20,006	$5,549	$7,894	4	$1,973	2	$3,947	No cost estimated
Reduce residual sand on castings	Option not costed	NA	NA	NA	NA	NA	NA	NA	NA	No cost estimated
Automate knockout process	Option not costed	NA	NA	NA	NA	NA	NA	NA	NA	No cost estimated
Abrasive Blasting										

Table V-A-2: Unit and Annualized Costs and Model Specifications for Silica Engineering Controls Applied in OSHA's Cost Analysis for General Industry and Maritime (continued)

Sector/Job Category - Control Requirements	Control Description	LEV CFM	Unit Cost	Operating Cost	Annualized Cost (a)	Workers per	Cost per worker	Workers per Control	Cost per worker	Estimate Source
Improved maintenance for blasting cabinet	Maintenance	NA	$2,450	$1,000	$1,287	2	$644	2	$644	Assumes 50% increase in maintenance costs (of up to $2,000) and purchase of new cabinets (25%) at $8,000/cabinet (Norton, 2003), or addit. interlocks at $1,800/cabinet (Heastrup, 2003).
Cleaning/Finishing										
LEV for workstations	Hand grinding bench	3,750	$50,016	$13,871	$19,735	4	$4,934	2	$9,867	Consultant Solberg estimate for hand grinding bench
LEV on hand tools	LEV	200	$464	$740	$794	2	$397	2	$397	Consultant Solberg estimate for hand tools
Eliminate compressed air (switch to vacuum)	HEPA vacuum plus additional time	NA	$3,633	$1,048	$1,474	4	$368	2	$737	15 gal vacuum and 5 extra minutes per day
Substitution with non-silica materials	Option not costed	NA	NA	NA	NA	NA	NA	NA	NA	No cost estimated
Process automation	Option not	NA	NA	NA	NA	NA	NA	NA	NA	No cost estimated
Wet methods	Option not	NA	NA	NA	NA	NA	NA	NA	NA	No cost estimated
Pre-cleaning with automated equipment	Option not costed	NA	NA	NA	NA	NA	NA	NA	NA	No cost estimated
Material Handler										
Enclosed, ventilated cab	Retrofit with cab or replace equipment	NA	$15,762	$5,517	$7,365	4	$1,841	2	$3,682	Per machine
Maintenance Operator										
Use low silica refractory	Option not costed	NA	NA	NA	NA	NA	NA	NA	NA	No cost estimated

Table V-A-2: Unit and Annualized Costs and Model Specifications for Silica Engineering Controls Applied in OSHA's Cost Analysis for General Industry and Maritime (continued)

Sector/Job Category - Control Requirements	Control Description	LEV CFM	Unit Cost	Operating Cost	Annualized Cost (a)	Workers per	Cost per worker	Workers per Control	Cost per worker	Estimate Source
LEV for chipping tools	Dust collector with HEPA vacuum	NA	$1,738	$608	$988	4	$247	2	$494	5 year life
Pre-wetting lining to be removed	Additional labor	NA	NA	$3,382	$3,382	8	$423	2	$1,691	2 hours per week
Maintaining moisture level in the refractory applied	Additional labor	NA	NA	$1,691	$1,691	8	$211	2	$845	1 hour per week
Also, use of precast refractories and automated equipment for powdered refractory materials	Option not costed	NA	NA	NA	NA	NA	NA	NA	NA	No cost estimated
Housekeeping Worker										
Initial thorough cleaning	Cost per square foot, per facility	NA	0.15	0	$0.02	NA	NA	NA	NA	ERG estimate based on docket submissions and industry contacts
Nonferrous sand										
Sand Systems Operator										
LEV, mixer & muller hood	LEV	1050	$20,180	$5,597	$7,962	4	$1,991	2	$3,981	Mixer & muller hood (pg. 10-87, ACGIH, 2001); Formerly required clean-air island, but not called out in techfeas; dropped from costs
Conveyor enclosures	200 feet, ventilated (7 take-off points)	4900	$69,500	$18,125	$26,273	4	$6,568	4	$6,568	One take-off point at-least every 30', 7 overall.
Bin and hopper ventilation	LEV	1050	$14,004	$3,884	$5,526	4	$1,381	2	$2,763	CFM from Solburg worksheet. (ACGIH, 2001; p. 10-69)

Table V-A-2: Unit and Annualized Costs and Model Specifications for Silica Engineering Controls Applied in OSHA's Cost Analysis for General Industry and Maritime (continued)

Sector/Job Category - Control Requirements	Control Description	LEV CFM	Unit Cost	Operating Cost	Annualized Cost (a)	Workers per	Cost per worker	Workers per Control	Cost per worker	Estimate Source
Bucket elevator ventilation	LEV	1600	$21,340	$5,918	$8,420	4	$2,105	2	$4,210	Based on Knutson specs
Screen ventilation	LEV	1200	$16,005	$4,439	$6,315	4	$1,579	2	$3,158	Based on Knutson specs
Substitute silica-free materials	Option not costed, other controls	NA	NA	NA	NA	NA	NA	NA	NA	No cost estimated
Molder										
Upgraded sand handling equipment - covered elsewhere	No cost	NA	NA	NA	NA	NA	NA	NA	NA	No cost estimated
Upgrade or install LEV	LEV	1050	$14,004	$3,884	$5,526	4	$1,381	2	$2,763	ERG estimates based on discussions with industrial ventilation
Rigorous housekeeping- capital	HEPA vacuum	NA	$3,633	$511	$1,304	5	$261	2	$652	Nilfisk, 15 gallon capacity
Rigorous housekeeping- labor	Labor costs	NA	NA	$1,041	$1,041	1	$1,041	1	$1,041	10 min/wrker/day
Eliminate compressed air	Included in rigorous housekeeping	NA	NA	NA	NA	NA	NA	NA	NA	No cost estimated
Coremaker										
Eliminated compressed air	Additional labor time	NA	NA	$1,041	$1,041	1	$1,041	1	$1,041	10 min/wrker/day
Enclosed conveyors, covered elsewhere		NA	NA	NA	NA	NA	NA	NA	NA	No cost estimated
Non-silica cores and core coatings	Option not costed, other controls	NA	NA	NA	NA	NA	NA	NA	NA	No cost estimated

Table V-A-2: Unit and Annualized Costs and Model Specifications for Silica Engineering Controls Applied in OSHA's Cost Analysis for General Industry and Maritime (continued)

Sector/Job Category - Control Requirements	Control Description	LEV CFM	Unit Cost	Operating Cost	Annualized Cost (a)	Workers per	Cost per worker	Workers per Control	Cost per worker	Estimate Source
Initial thorough cleaning	Cost per square foot, per facility	NA	$0	$0	$0	NA	NA	NA	NA	ERG estimate based on docket submissions and industry contacts
Furnace operator										
No overexposures, controls not needed	No cost	NA	NA	NA	NA	NA	NA	NA	NA	No cost estimated
Pouring operator										
No overexposures, controls not needed	No cost	NA	NA	NA	NA	NA	NA	NA	NA	No cost estimated
Shakeout operator										
Improve existing ventilation system efficiency (very large castings)	Double-draft shake-out table	28800	$384,119	$106,533	$151,563	4	$37,891	2	$75,782	Based on Solberg costs for shakeout conveyor
Improve existing ventilation system efficiency	Shakeout enclosing hood	7040	$93,896	$26,041	$37,049	4	$9,262	2	$18,524	Based on ACGIH design parameters for ventilated enclosing hood (pg. 10-23, ACGIGH, 2001); 4'x4'
Partially enclose process	Enclosed, ventilated shakeout conveyor	10000	$133,375	$36,990	$52,626	4	$13,157	2	$26,313	Based on Solberg costs for shakeout conveyor
Control emissions from associated operations - covered	No cost	NA	NA	NA	NA	NA	NA	NA	NA	No cost estimated
Half mask respirator	Respirator	NA	NA	NA	$520	1	$520	1	$520	Annual cost of respirator use
Installing and improving LEV	Small knockout table	$1,350	$18,006	$4,994	$7,105	$4	$1,776	$2	$3,552	Based on ACGIH design parameters for portable grinding table pg. 10-136), ACGIH, 2001), 3'x3' opening

Table V-A-2: Unit and Annualized Costs and Model Specifications for Silica Engineering Controls Applied in OSHA's Cost Analysis for General Industry and Maritime (continued)

Sector/Job Category - Control Requirements	Control Description	LEV CFM	Unit Cost	Operating Cost	Annualized Cost (a)	Workers per	Cost per worker	Workers per Control	Cost per worker	Estimate Source
Knockout operator										
Reduce residual sand on castings	Option not costed	NA	NA	NA	NA	NA	NA	NA	NA	No cost estimated
Automate knockout process	Option not costed	NA	NA	NA	NA	NA	NA	NA	NA	No cost estimated
Half mask respirator	Respirator	NA	NA	NA	$520	$1	$520	$1	$520	Annual cost of respirator use
Abrasive blasting operator										
Improved maintenance for blasting cabinet	Maintenance	NA	$2,450	$1,000	$1,287	$2	$644	$2	$644	Assumes 50% increase in maintenance costs (of up to $2,000) and purchase of new cabinets (25%) at $8,000/cabinet (Norton, 2003), or addit. interlocks at $1,800/cabinet (Heastrup, 2003).
Half mask respirator	Respirator	NA	NA	NA	$520	$1	$520	$1	$520	Annual cost of respirator use
Cleaning/finishing										
LEV for workstations	Hand grinding bench	$3,750	$50,016	$13,871	$19,735	$4	$4,934	$2	$9,867	Consultant Solberg estimate for hand grinding bench
LEV on hand tools	LEV	$200	$464	$740	$794	$2	$397	$2	$397	Consultant Solberg estimate for hand tools
Eliminate compressed air (switch to vacuum)	HEPA vacuum plus additional time	NA	$3,633	$1,048	$1,474	$4	$368	$2	$737	15 gal vacuum and 5 extra minutes per day
Substitution with non-silica materials	Option not costed	NA	NA	NA	NA	NA	NA	NA	NA	No cost estimated
Process automation	Option not	NA	NA	NA	NA	NA	NA	NA	NA	No cost estimated
Wet methods	Option not	NA	NA	NA	NA	NA	NA	NA	NA	No cost estimated

Table V-A-2: Unit and Annualized Costs and Model Specifications for Silica Engineering Controls Applied in OSHA's Cost Analysis for General Industry and Maritime (continued)

Sector/Job Category - Control Requirements	Control Description	LEV CFM	Unit Cost	Operating Cost	Annualized Cost (a)	Workers per	Cost per worker	Workers per Control	Cost per worker	Estimate Source
Pre-cleaning with automated equipment	Option not costed	NA	NA	NA	NA	NA	NA	NA	NA	No cost estimated
Material handler										
No overexposures, controls not needed	Option not costed	NA	NA	NA	NA	NA	NA	NA	NA	No cost estimated
Maintenance operator										
No overexposures, controls not needed	Option not costed	NA	NA	NA	NA	NA	NA	NA	NA	No cost estimated
Housekeeping worker										
No overexposures, controls not needed	Option not costed	NA	NA	NA	NA	NA	NA	NA	NA	No cost estimated
Nonferrous Sand Casting Foundries										
Sand Systems Operator										
LEV, mixer & muller hood	LEV	1,050	$20,180	$5,597	$7,962	4	$1,991	2	$3,981	Mixer & muller hood (pg. 10-87, ACGIH, 2001); Formerly required clean-air island, but not called out in techfeas; dropped from costs
Conveyor enclosures	200 feet, ventilated (7 take-off points)	4,900	$69,500	$18,125	$26,273	4	$6,568	4	$6,568	One take-off point at-least every 30', 7 overall.
Bin and hopper ventilation	LEV	1,050	$14,004	$3,884	$5,526	4	$1,381	2	$2,763	CFM from Solburg worksheet. (ACGIH, 2001; p. 10-69)
Bucket elevator ventilation	LEV	1,600	$21,340	$5,918	$8,420	4	$2,105	2	$4,210	Based on Knutson specs
Screen ventilation	LEV	1,200	$16,005	$4,439	$6,315	4	$1,579	2	$3,158	Based on Knutson specs

Table V-A-2: Unit and Annualized Costs and Model Specifications for Silica Engineering Controls Applied in OSHA's Cost Analysis for General Industry and Maritime (continued)

Sector/Job Category - Control Requirements	Control Description	LEV CFM	Unit Cost	Operating Cost	Annualized Cost (a)	Workers per	Cost per worker	Workers per Control	Cost per worker	Estimate Source
Substitute silica-free materials	Option not costed, other controls	NA	NA	NA	NA	NA	NA	NA	NA	No cost estimated
Molder										
Upgraded sand handling equipment - covered elsewhere	No cost	NA	NA	NA	NA	NA	NA	NA	NA	No cost estimated
Upgrade or install LEV	LEV	1,050	$14,004	$3,884	$5,526	4	$1,381	2	$2,763	ERG estimates based on discussions with industrial ventilation
Rigorous housekeeping- capital	HEPA vacuum	NA	$3,633	$511	$1,304	5	$261	2	$652	Nilfisk, 15 gallon capacity
Rigorous housekeeping- labor	Labor costs	NA	NA	$1,041	$1,041	1	$1,041	1	$1,041	10 min/wrker/day
Eliminate compressed air	Included in rigorous housekeeping	NA	NA	NA	NA	NA	NA	NA	NA	No cost estimated
Coremaker										
Eliminated compressed air	Additional labor time	NA	NA	$1,041	$1,041	1	$1,041	1	$1,041	No cost estimated
Enclosed conveyors, covered elsewhere	No cost	NA	NA	NA	NA	NA	NA	NA	NA	No cost estimated
Non-silica cores and core coatings	Option not costed, other controls	NA	NA	NA	NA	NA	NA	NA	NA	No cost estimated
Initial thorough cleaning	Cost per square foot, per facility	NA	$0.15	$0.00	$0.02	NA	NA	NA	NA	Based on clean air island costs for structural clay
Furnace operator										

Table V-A-2: Unit and Annualized Costs and Model Specifications for Silica Engineering Controls Applied in OSHA's Cost Analysis for General Industry and Maritime (continued)

Sector/Job Category - Control Requirements	Control Description	LEV CFM	Unit Cost	Operating Cost	Annualized Cost (a)	Workers per	Cost per worker	Workers per Control	Cost per worker	Estimate Source
No overexposures, controls not needed	No cost	NA	NA	NA	NA	NA	NA	NA	NA	No cost estimated
Pouring operator										
No overexposures, controls not needed	No cost	NA	NA	NA	NA	NA	NA	NA	NA	No cost estimated
Shakeout Operator										
Improve existing ventilation system efficiency (very large castings)	Double-draft shake-out table	28,800	$384,119	$106,533	$151,563	4	$37,891	2	$75,782	Based on Solberg costs for shakeout conveyor
Improve existing ventilation system efficiency	Shakeout enclosing hood	7,040	$93,896	$26,041	$37,049	4	$9,262	2	$18,524	Based on ACGIH design parameters for ventilated enclosing hood (pg. 10-23, ACGIGH, 2001); 4'x4'
Partially enclose process	Enclosed, ventilated shakeout conveyor	10,000	$133,375	$36,990	$52,626	4	$13,157	2	$26,313	Based on Solberg costs for shakeout conveyor
Control emissions from associated operations - covered	No cost	NA	NA	NA	NA	NA	NA	NA	NA	No cost estimated
Knockout Operator										
Installing and improving LEV	Small knockout table	1,350	$18,006	$4,994	$7,105	4	$1,776	2	$3,552	Based on ACGIH design parameters for portable grinding table pg. 10-136), ACGIH, 2001), 3'x3' opening

Table V-A-2: Unit and Annualized Costs and Model Specifications for Silica Engineering Controls Applied in OSHA's Cost Analysis for General Industry and Maritime (continued)

Sector/Job Category - Control Requirements	Control Description	LEV CFM	Unit Cost	Operating Cost	Annualized Cost (a)	Workers per	Cost per worker	Workers per Control	Cost per worker	Estimate Source
Installing and improving LEV	Large knockout table	4,800	$64,020	$17,755	$25,261	4	$6,315	2	$12,630	Based on ACGIH design parameters for hand grinding table (pg. 10-135), ACGIH, 2001), 4'x6' surface
Installing and improving LEV	Ventilated abrasive cutoff saw	1,500	$20,006	$5,549	$7,894	4	$1,973	2	$3,947	Based on ACGIH design parameters for ventilated cut-off saw (pg. 10-134, ACGIH, 2001, 2'x3' opening)
Reduce residual sand on castings	Option not costed	NA	NA	NA	NA	NA	NA	NA	NA	No cost estimated
Automate knockout process	Option not costed	NA	NA	NA	NA	NA	NA	NA	NA	No cost estimated
Half mask respirator	Respirator	NA	NA	NA	$520	1	$520	1	$520	Annual cost of respirator use
Abrasive Blasting										
Half mask respirator	Respirator	NA	NA	NA	$520	1	$520	1	$520	Annual cost of respirator use
Improved maintenance for blasting cabinet	Maintenance	NA	$2,450	$1,000	$1,287	2	$644	2	$644	Assumes 50% increase in maintenance costs (of up to $2,000) and purchase of new cabinets (25%) at $8,000/cabinet (Norton, 2003), or addit. interlocks at $1,800/cabinet (Heastrup, 2003).
Cleaning/Finishing										
LEV for workstations	Hand grinding bench	3,750	$50,016	$13,871	$19,735	4	$4,934	2	$9,867	Consultant Solberg estimate for hand grinding bench
LEV on hand tools	LEV	200	$464	$740	$794	2	$397	2	$397	Consultant Solberg estimate for hand tools

Table V-A-2: Unit and Annualized Costs and Model Specifications for Silica Engineering Controls Applied in OSHA's Cost Analysis for General Industry and Maritime (continued)

Sector/Job Category - Control Requirements	Control Description	LEV CFM	Unit Cost	Operating Cost	Annualized Cost (a)	Workers per	Cost per worker	Workers per Control	Cost per worker	Estimate Source
Eliminate compressed air (switch to vacuum)	HEPA vacuum plus additional time	NA	$3,633	$1,048	$1,474	4	$368	2	$737	15 gal vacuum and 5 extra minutes per day
Substitution with non-silica materials	Option not costed	NA	NA	NA	NA	NA	NA	NA	NA	No cost estimated
Process automation	Option not	NA	NA	NA	NA	NA	NA	NA	NA	No cost estimated
Wet methods	Option not	NA	NA	NA	NA	NA	NA	NA	NA	No cost estimated
Pre-cleaning with automated equipment	Option not costed	NA	NA	NA	NA	NA	NA	NA	NA	No cost estimated
Material Handler										
No overexposures, controls not needed	Option not costed	NA	NA	NA	NA	NA	NA	NA	NA	No cost estimated
Maintenance Operator										
No overexposures, controls not needed	Option not costed	NA	NA	NA	NA	NA	NA	NA	NA	No cost estimated
Housekeeping Worker										
No overexposures, controls not needed	Option not costed	NA	NA	NA	NA	NA	NA	NA	NA	No cost estimated
Non-Sand Casting										
Sand Systems Operator										
LEV, mixer & muller hood	LEV	1,050	$20,180	$5,597	$7,962	4	$1,991	2	$3,981	Mixer & muller hood (pg. 10-87, ACGIH, 2001); Formerly required clean-air island, but not called out in techfeas; dropped from costs
Conveyor enclosures	200 feet, ventilated (7 take-off points)	4,900	$69,500	$18,125	$26,273	4	$6,568	4	$6,568	One take-off point at-least every 30', 7 overall.

Table V-A-2: Unit and Annualized Costs and Model Specifications for Silica Engineering Controls Applied in OSHA's Cost Analysis for General Industry and Maritime (continued)

Sector/Job Category - Control Requirements	Control Description	LEV CFM	Unit Cost	Operating Cost	Annualized Cost (a)	Workers per	Cost per worker	Workers per Control	Cost per worker	Estimate Source
Bin and hopper ventilation	LEV	1,050	$14,004	$3,884	$5,526	4	$1,381	2	$2,763	CFM from Solburg worksheet. (ACGIH, 2001; p. 10-69)
Bucket elevator ventilation	LEV	1,600	$21,340	$5,918	$8,420	4	$2,105	2	$4,210	Based on Knutson specs
Screen ventilation	LEV	1,200	$16,005	$4,439	$6,315	4	$1,579	2	$3,158	Based on Knutson specs
Substitute silica-free materials	Option not costed, other controls sufficient	NA	NA	NA	NA	NA	NA	NA	NA	No cost estimated
Molder										
Upgraded sand handling equipment - covered elsewhere	No cost	NA	NA	NA	NA	NA	NA	NA	NA	No cost estimated
Upgrade or install LEV	LEV	1,050	$14,004	$3,884	$5,526	4	$1,381	2	$2,763	ERG estimates based on discussions with industrial ventilation
Rigorous housekeeping- capital	HEPA vacuum	NA	$3,633	$511	$1,304	5	$261	2	$652	Nilfisk, 15 gallon capacity
Rigorous housekeeping- labor	Labor costs	NA	NA	$1,041	$1,041	1	$1,041	1	$1,041	10 min/wrker/day
Eliminate compressed air	Included in rigorous housekeeping	NA	NA	NA	NA	NA	NA	NA	NA	No cost estimated
Coremaker										
No overexposures, controls not needed	No cost	NA	NA	NA	NA	NA	NA	NA	NA	No cost estimated
Furnace operator										

Table V-A-2: Unit and Annualized Costs and Model Specifications for Silica Engineering Controls Applied in OSHA's Cost Analysis for General Industry and Maritime (continued)

Sector/Job Category - Control Requirements	Control Description	LEV CFM	Unit Cost	Operating Cost	Annualized Cost (a)	Workers per	Cost per worker	Workers per Control	Cost per worker	Estimate Source
No overexposures, controls not needed	No cost	NA	NA	NA	NA	NA	NA	NA	NA	No cost estimated
Pouring operator										
Control dust from adjacent processes - covered elsewhere	No cost	NA	NA	NA	NA	NA	NA	NA	NA	No cost estimated
Operator booths or cabs	Based on clean-air island costs	2,500	$33,344	$9,248	$13,157	4	$3,289	2	$6,578	Based on clean air island costs for structural clay
Physical isolation of pouring area (create a pouring room)	Option not costed	NA	NA	NA	NA	NA	NA	NA	NA	No cost estimated
Modify ventilation system to reduce airflow from other areas into the pouring area	Option not costed	NA	NA	NA	NA	NA	NA	NA	NA	No cost estimated
Shakeout Operator										
Improve existing ventilation system efficiency (very large castings)	Double-draft shake-out table	28,800	$384,119	$106,533	$151,563	4	$37,891	2	$75,782	Based on Solberg costs for shakeout conveyor
Improve existing ventilation system efficiency	Shakeout enclosing hood	7,040	$93,896	$26,041	$37,049	4	$9,262	2	$18,524	Based on ACGIH design parameters for ventilated enclosing hood (pg. 10-23, ACGIGH, 2001); 4'x4' openings

Table V-A-2: Unit and Annualized Costs and Model Specifications for Silica Engineering Controls Applied in OSHA's Cost Analysis for General Industry and Maritime (continued)

Sector/Job Category - Control Requirements	Control Description	LEV CFM	Unit Cost	Operating Cost	Annualized Cost (a)	Workers per	Cost per worker	Workers per Control	Cost per worker	Estimate Source
Partially enclose process	Enclosed, ventilated shakeout conveyor	10,000	$133,375	$36,990	$52,626	4	$13,157	2	$26,313	Based on Solberg costs for shakeout conveyor
Control emissions from associated operations - covered elsewhere	No cost	NA	NA	NA	NA	NA	NA	NA	NA	No cost estimated
Half mask respirator	Respirator	NA	NA	NA	$520	1	$520	1	$520	Annual cost of respirator use
Knockout Operator										
Installing and improving LEV	Small knockout table	1,350	$18,006	$4,994	$7,105	4	$1,776	2	$3,552	Based on ACGIH design parameters for portable grinding table pg. 10-136), ACGIH, 2001), 3'x3' opening
Installing and improving LEV	Large knockout table	4,800	$64,020	$17,755	$25,261	4	$6,315	2	$12,630	Based on ACGIH design parameters for hand grinding table (pg. 10-135), ACGIH, 2001), 4'x6' surface
Installing and improving LEV	Ventilated abrasive cutoff saw	1,500	$20,006	$5,549	$7,894	4	$1,973	2	$3,947	Based onACGIH design parameters for ventilated cut-off saw (pg. 10-134, ACGIH, 2001, 2'x3' opening)
Reduce residual sand on castings	Option not costed	NA	NA	NA	NA	NA	NA	NA	NA	No cost estimated
Automate knockout process	Option not costed	NA	NA	NA	NA	NA	NA	NA	NA	No cost estimated
Half mask respirator	Respirator	NA	NA	NA	$520	1	$520	1	$520	Annual cost of respirator use
Abrasive Blasting										

Table V-A-2: Unit and Annualized Costs and Model Specifications for Silica Engineering Controls Applied in OSHA's Cost Analysis for General Industry and Maritime (continued)

Sector/Job Category - Control Requirements	Control Description	LEV CFM	Unit Cost	Operating Cost	Annualized Cost (a)	Workers per	Cost per worker	Workers per Control	Cost per worker	Estimate Source
Improved maintenance for blasting cabinet	Maintenance	NA	$2,450	$1,000	$1,287	2	$644	2	$644	Assumes 50% increase in maintenance costs (of up to $2,000) and purchase of new cabinets (25%) at $8,000/cabinet (Norton, 2003), or addit. interlocks at $1,800/cabinet (Heastrup, 2003).
Half mask respirator	Respirator	NA	NA	NA	$520	1	$520	1	$520	Annual cost of respirator use
Cleaning/Finishing										
LEV for workstations	Hand grinding bench	3,750	$50,016	$13,871	$19,735	4	$4,934	2	$9,867	Consultant Solberg estimate for hand grinding bench
LEV on hand tools	LEV	200	$464	$740	$794	2	$397	2	$397	Consultant Solberg estimate for hand tools
Eliminate compressed air (switch to vacuum)	HEPA vacuum plus additional time	NA	$3,633	$1,048	$1,474	4	$368	2	$737	15 gal vacuum and 5 extra minutes per day
Substitution with non-silica materials	Option not costed	NA	NA	NA	NA	NA	NA	NA	NA	No cost estimated
Process automation	Option not costed	NA	NA	NA	NA	NA	NA	NA	NA	No cost estimated
Wet methods	Option not costed	NA	NA	NA	NA	NA	NA	NA	NA	No cost estimated
Pre-cleaning with automated equipment	Option not costed	NA	NA	NA	NA	NA	NA	NA	NA	No cost estimated
Material Handler										

Table V-A-2: Unit and Annualized Costs and Model Specifications for Silica Engineering Controls Applied in OSHA's Cost Analysis for General Industry and Maritime (continued)

Sector/Job Category - Control Requirements	Control Description	LEV CFM	Unit Cost	Operating Cost	Annualized Cost (a)	Workers per	Cost per worker	Workers per Control	Cost per worker	Estimate Source
Enclosed, ventilated cab	Retrofit with cab or replace equipment	NA	$15,762	$5,517	$7,365	4	$1,841	2	$3,682	Per machine
Maintenance Operator										
No overexposures, controls not needed	No cost	NA	NA	NA	NA	NA	NA	NA	NA	No cost estimated
Housekeeping Worker										
No overexposures, controls not needed	No cost	NA	NA	NA	NA	NA	NA	NA	NA	No cost estimated
Captive Foundries										
Sand Systems Operator										
LEV, mixer & muller hood	LEV	1,050	$20,180	$5,597	$7,962	4	$1,991	2	$3,981	Mixer & muller hood (pg. 10-87, ACGIH, 2001); Formerly required clean-air island, but not called out in techfeas; dropped from costs
Conveyor enclosures	200 feet, ventilated (7 take-off points)	4,900	$69,500	$18,125	$26,273	4	$6,568	4	$6,568	One take-off point at-least every 30', 7 overall.
Bin and hopper ventilation	LEV	1,050	$14,004	$3,884	$5,526	4	$1,381	2	$2,763	CFM from Solburg worksheet. (ACGIH, 2001; p. 10-69)
Bucket elevator ventilation	LEV	1,600	$21,340	$5,918	$8,420	4	$2,105	2	$4,210	Based on Knutson specs
Screen ventilation	LEV	1,200	$16,005	$4,439	$6,315	4	$1,579	2	$3,158	Based on Knutson specs

Table V-A-2: Unit and Annualized Costs and Model Specifications for Silica Engineering Controls Applied in OSHA's Cost Analysis for General Industry and Maritime (continued)

Sector/Job Category - Control Requirements	Control Description	LEV CFM	Unit Cost	Operating Cost	Annualized Cost (a)	Workers per	Cost per worker	Workers per Control	Cost per worker	Estimate Source
Substitute silica-free materials	Option not costed, other controls sufficient	NA	NA	NA	NA	NA	NA	NA	NA	No cost estimated
Molder										
Upgraded sand handling equipment - covered elsewhere	No cost	NA	NA	NA	NA	NA	NA	NA	NA	No cost estimated
Upgrade or install LEV	LEV	1,050	$14,004	$3,884	$5,526	4	$1,381	2	$2,763	ERG estimates based on discussions with industrial ventilation
Rigorous housekeeping- capital	HEPA vacuum	NA	$3,633	$511	$1,304	5	$261	2	$652	Nilfisk, 15 gallon capacity
Rigorous housekeeping- labor	Labor costs	NA	NA	$1,041	$1,041	1	$1,041	1	$1,041	10 min/wrker/day
Eliminate compressed air	Included in rigorous housekeeping	NA	NA	NA	NA	NA	NA	NA	NA	No cost estimated
Coremaker										
Eliminated compressed air	Additional labor time	NA	NA	$1,041	$1,041	1	$1,041	1	$1,041	10 min/wrker/day
Enclosed conveyors, covered elsewhere		NA	NA	NA	NA	NA	NA	NA	NA	No cost estimated
Non-silica cores and core coatings	Option not costed, other controls sufficient	NA	NA	NA	NA	NA	NA	NA	NA	No cost estimated

Table V-A-2: Unit and Annualized Costs and Model Specifications for Silica Engineering Controls Applied in OSHA's Cost Analysis for General Industry and Maritime (continued)

Sector/Job Category - Control Requirements	Control Description	LEV CFM	Unit Cost	Operating Cost	Annualized Cost (a)	Workers per	Cost per worker	Workers per Control	Cost per worker	Estimate Source
Initial thorough cleaning	Cost per square foot, per facility	NA	$0.15	$0.00	$0.02	NA	NA	NA	NA	ERG estimate based on docket submissions and industry contacts
Furnace operator										
Control dust releases from adjacent processes - covered elsewhere	0	NA	NA	NA	NA	NA	NA	NA	NA	No cost estimated
Well-maintained furnace emission control system	Maintenance	NA	NA	$650	$650	4	$163	2	$325	20 hours addtional maintenance time per year
Operator booths or cabs	Based on clean-air island costs	2,500	$33,344	$9,248	$13,157	4	$3,289	2	$6,578	Based on clean air island costs for structural clay
Minimize dust generated by sand contamination of scrap	Option not costed	NA	NA	NA	NA	NA	NA	NA	NA	No cost estimated
Pouring operator										
Control dust from adjacent processes - covered elsewhere	No cost	NA	NA	NA	NA	NA	NA	NA	NA	No cost estimated
Operator booths or cabs	Based on clean-air island costs	2,500	$33,344	$9,248	$13,157	4	$3,289	2	$6,578	Based on clean air island costs for structural clay
Physical isolation of pouring area (create a pouring room)	Option not costed	NA	NA	NA	NA	NA	NA	NA	NA	No cost estimated

Table V-A-2: Unit and Annualized Costs and Model Specifications for Silica Engineering Controls Applied in OSHA's Cost Analysis for General Industry and Maritime (continued)

Sector/Job Category - Control Requirements	Control Description	LEV CFM	Unit Cost	Operating Cost	Annualized Cost (a)	Workers per	Cost per worker	Workers per Control	Cost per worker	Estimate Source
Modify ventilation system to reduce airflow from other areas into the pouring area	Option not costed	NA	NA	NA	NA	NA	NA	NA	NA	No cost estimated
Shakeout Operator										
Improve existing ventilation system efficiency (very large castings)	Double-draft shake-out table	28,800	$384,119	$106,533	$151,563	4	$37,891	2	$75,782	Based on Solberg costs for shakeout conveyor
Improve existing ventilation system efficiency	Shakeout enclosing hood	7,040	$93,896	$26,041	$37,049	4	$9,262	2	$18,524	Based on ACGIH design parameters for ventilated enclosing hood (pg. 10-23, ACGIGH, 2001); 4'x4'
Partially enclose process	Enclosed, ventilated	10,000	$133,375	$36,990	$52,626	4	$13,157	2	$26,313	Based on Solberg costs for shakeout conveyor
Control emissions from associated operations - covered	No cost	NA	NA	NA	NA	NA	NA	NA	NA	No cost estimated
Half mask respirator	Respirator	NA	NA	NA	$520	1	$520	1	$520	Annual cost of respirator use
Knockout Operator										
Installing and improving LEV	Small knockout table	1,350	$50,016	$13,871	$19,735	4	$4,934	2	$9,867	Based on Solberg costs for shakeout conveyor
Installing and improving LEV	Large knockout table	4,800	$464	$740	$794	2	$397	2	$397	Based on ACGIH design parameters for ventilated enclosing hood (pg. 10-23, ACGIGH, 2001); 4'x4'

Table V-A-2: Unit and Annualized Costs and Model Specifications for Silica Engineering Controls Applied in OSHA's Cost Analysis for General Industry and Maritime (continued)

Sector/Job Category - Control Requirements	Control Description	LEV CFM	Unit Cost	Operating Cost	Annualized Cost (a)	Workers per	Cost per worker	Workers per Control	Cost per worker	Estimate Source
Installing and improving LEV	Ventilated abrasive cutoff saw	1,500	$3,633	$1,048	$1,474	4	$368	2	$737	Based on Solberg costs for shakeout conveyor
Reduce residual sand on castings	Option not costed	NA	NA	NA	NA	NA	NA	NA	NA	No cost estimated
Automate knockout process	Option not costed	NA	NA	NA	NA	NA	NA	NA	NA	
Half mask respirator	Respirator	NA	NA	NA	$520	1	$520	1	$520	Annual cost of respirator use
Abrasive Blasting										
Improved maintenance for blasting cabinet	Maintenance	NA	$2,450	$1,000	$1,287	2	NA	2	NA	Assumes 50% increase in maintenance costs (of up to $2,000) and purchase of new cabinets (25%) at $8,000/cabinet (Norton, 2003), or addit. interlocks at $1,800/cabinet (Heastrup, 2003).
Half mask respirator	Respirator	NA	NA	NA	$520	1	$520	1	$520	Annual cost of respirator use
Cleaning/Finishing										
LEV for workstations	Hand grinding bench	3,750	$50,016	$13,871	$19,735	4	$4,934	2	$9,867	Consultant Solberg estimate for hand grinding bench
LEV on hand tools	LEV	200	$464	$740	$794	2	$397	2	$397	Consultant Solberg estimate for hand tools
Eliminate compressed air (switch to vacuum)	HEPA vacuum plus additional time	NA	$3,633	$1,048	$1,474	4	$368	2	$737	15 gal vacuum and 5 extra minutes per day
Substitution with non-silica materials	Option not costed	NA	NA	NA	NA	NA	NA	NA	NA	No cost estimated
Process automation	Option not	NA	NA	NA	NA	NA	NA	NA	NA	No cost estimated

Table V-A-2: Unit and Annualized Costs and Model Specifications for Silica Engineering Controls Applied in OSHA's Cost Analysis for General Industry and Maritime (continued)

Sector/Job Category - Control Requirements	Control Description	LEV CFM	Unit Cost	Operating Cost	Annualized Cost (a)	Workers per	Cost per worker	Workers per Control	Cost per worker	Estimate Source
Wet methods	Option not	NA	NA	NA	NA	NA	NA	NA	NA	No cost estimated
Pre-cleaning with automated equipment	Option not costed	NA	NA	NA	NA	NA	NA	NA	NA	No cost estimated
Material Handler										
Enclosed, ventilated cab	Retrofit with cab or replace equipment	NA	$15,762	$5,517	$7,365	4	$1,841	2	$3,682	0
Maintenance Operator										
Use low silica refractory	Option not costed	NA	NA	NA	NA	NA	NA	NA	NA	No cost estimated
LEV for chipping tools	Dust collector with HEPA vacuum	NA	$1,738	$608	$988	4	$247	2	$494	5 year life
Pre-wetting lining to be removed	Additional labor	NA	NA	$3,382	$3,382	8	$423	2	$1,691	2 hours per week
Maintaining moisture level in the refractory applied	Additional labor	NA	$14,004	$3,884	$5,526	4	$1,381	2	$2,763	1 hour per week
Use of precast refractories and automated equipment for powdered refractory materials	Option not costed	NA	NA	NA	NA	NA	NA	NA	NA	No cost estimated
Housekeeping Worker										
Initial thorough cleaning	Cost per square foot, per facility	NA	$0.15	$0.00	$0.02	NA	NA	NA	NA	ERG estimate of costs per square foot of floorspace
Landscaping										

Table V-A-2: Unit and Annualized Costs and Model Specifications for Silica Engineering Controls Applied in OSHA's Cost Analysis for General Industry and Maritime (continued)

Sector/Job Category - Control Requirements	Control Description	LEV CFM	Unit Cost	Operating Cost	Annualized Cost (a)	Workers per	Cost per worker	Workers per Control	Cost per worker	Estimate Source
Landscaping and Groundskeeping Workers										
Wet methods	Labor costs	NA	NA	$468	$468	4	$117	2	$234	Assumes 0.25 hours extra time per day for 100 days
Brick and stonemasons										
Masonry saw dust control	Labor costs	NA	NA	$749	$749	1	$749	1	$749	Assumes 5% productivity penalty for using wet methods for 100 days per year
Asphalt Roofing Materials										
Production operator										
Process enclosure	Enclose conveyors and equip	NA	$4,147	$415	$901	4	$225	2	$450	200 ft of conveyor enclosure
Enhanced ventilation	Conveyor ventilation	700	$9,336	$2,589	$3,684	4	$921	2	$1,842	ACGIH LEV estimate
Rigorous housekeeping- capital	HEPA vacuum	NA	$3,633	$511	$1,304	4	$326	2	$652	Nilfisk, 15 gallon capacity
Rigorous housekeeping- labor	Incremental labor costs	NA	NA	$1,693	$1,693	1	$1,693	1	$1,693	Addit. 10 minutes/day
Material handler										
No additional controls required	NA	NA	NA	NA	NA	NA	NA	NA	NA	No cost estimated
Porcelain Enameling										
Enamel preparer										
Bag dumping station maintenance	Materials plus labor	NA	NA	$240	$240	4	$60	2	$120	Annual: $100 materials plus 4 hours maintenance time [a]
Rigorous housekeeping- capital	HEPA vacuum	NA	$3,633	$511	$1,304	4	$326	2	$652	Nilfisk, 15 gallon capacity

Table V-A-2: Unit and Annualized Costs and Model Specifications for Silica Engineering Controls Applied in OSHA's Cost Analysis for General Industry and Maritime (continued)

Sector/Job Category - Control Requirements	Control Description	LEV CFM	Unit Cost	Operating Cost	Annualized Cost (a)	Workers per	Cost per worker	Workers per Control	Cost per worker	Estimate Source
Rigorous housekeeping- labor	Labor costs	NA	NA	$1,019	$1,019	1	$1,019	1	$1,019	10 min/wrker/day
Eliminate compressed air	Included in rigorous housekeeping	NA	NA	NA	NA	10	NA	2	NA	No cost estimated
Porcelain applicator										
Improved LEV for spray booths and enclosures	Increased airflow¥cfm	1000	$3,334	$925	$1,316	4	$329	2	$658	Allotment of 1,000 CFM of additional airflow
Rigorous housekeeping- capital	HEPA vacuum	NA	$3,633	$511	$1,304	4	$326	2	$652	Nilfisk, 15 gallon capacity
Rigorous housekeeping- labor	Labor costs	NA	NA	$1,019	$1,019	1	$1,019	1	$1,019	10 min/wrker/day
Bag dumping station maintenance	Materials plus labor	NA	NA	$240	$240	4	$60	2	$120	Annual: $100 materials plus 4 hours maintenance time [a]
Rigorous housekeeping- capital	HEPA vacuum	NA	$3,633	$511	$1,304	4	$326	2	$652	Nilfisk, 15 gallon capacity
Rigorous housekeeping- labor	Labor costs	NA	NA	$1,019	$1,019	1	$1,019	1	$1,019	10 min/wrker/day
Eliminate compressed air	Included in rigorous housekeeping	NA	NA	NA	NA	10	NA	2	NA	No cost estimated
Mineral Processing										
Production Worker										
Enclosed ventilation equipment	Conveyor cover; 200'	NA	$4,147	$415	$901	4	$225	4	$225	ERG estimates based on discussions with industrial ventilation
Conveyor ventilation	LEV	4,900	$65,354	$18,125	$25,787	4	$6,447	4	$6,447	ACGIH LEV estimate, conveyor belt ventilation

Table V-A-2: Unit and Annualized Costs and Model Specifications for Silica Engineering Controls Applied in OSHA's Cost Analysis for General Industry and Maritime (continued)

Sector/Job Category - Control Requirements	Control Description	LEV CFM	Unit Cost	Operating Cost	Annualized Cost (a)	Workers per	Cost per worker	Workers per Control	Cost per worker	Estimate Source
Improved maintenance on process equipment	Additional maintenance	NA	NA	$560	$560	1	$560	1	$560	Incremental cost for annual maintenance
Improved maintenance	Labor costs	NA	NA	$571	$571	1	$571	1	$571	0.5 hr additional maintenance time per week per production worker
Initial thorough cleaning	Cost per square foot, per facility	NA	$0.15	$0.00	$0.02	NA	NA	NA	NA	ERG estimate based on docket submissions and industry contacts
Improved area cleanup with HEPA	Equipment cost	NA	$3,633	$511	$1,304	4	$326	2	$652	15 gal HEPA vacuum; 5 year life
Enhanced housekeeping with HEPA vacuums	Additional labor time	NA	NA	$997	$997	1	$997	1	$997	Additional 20 minutes/day
Ventilated bag dumping stations with bag compactor	LEV	1,513	$20,180	$5,597	$7,962	4	$1,991	2	$3,981	Bag opening station; (pg. 10-19, ACGIH, 2001)
Dental Equipment and Supplies										
Production operator										
Ventilated bag dumping stations with bag compactor	LEV	1,513	$20,180	$5,597	$7,962	4	$1,991	2	$3,981	Bag opening station; (pg. 10-19, ACGIH, 2001)
Enclosed and ventilated mixing equipment	LEV	1,050	$14,004	$3,884	$5,526	4	$1,381	2	$2,763	Bag opening station; (pg. 10-19, ACGIH, 2001)
Increased LEV maintenance	Additional cost per operator	NA	NA	$409	$409	1	$409	1	$409	Mixer & muller hood (pg. 10-87, ACGIH, 2001)

Table V-A-2: Unit and Annualized Costs and Model Specifications for Silica Engineering Controls Applied in OSHA's Cost Analysis for General Industry and Maritime (continued)

Sector/Job Category - Control Requirements	Control Description	LEV CFM	Unit Cost	Operating Cost	Annualized Cost (a)	Workers per	Cost per worker	Workers per Control	Cost per worker	Estimate Source
Workstation modifications to reduce spillage	Judged to be negligible cost	NA	NA	NA	NA	NA	NA	NA	NA	Assumes 1 hour additional maintenance time per operator per month
Asphalt Paving Products										
Facility Operator										
Enclosed and ventilated control booths	LEV	200	$20,328	$740	$3,123	4	$781	2	$1,561	ERG estimate based on Means, 2003, ACGIH, 2001
Control dust from adjacent processes	No additional cost	NA	NA	NA	NA	NA	NA	NA	NA	No cost estimated
Front-end loader operator										
Enclosed cabs	Retrofit with cab or replacement equip	NA	$15,762	$5,517	$7,365	2	$3,682	2	$3,682	ERG estimate based on vendor interviews.
Maintenance worker										
No overexposures	Additional controls not needed	NA	NA	NA	NA	NA	NA	NA	NA	No cost estimated
Quality control worker										
No overexposures	Additional controls not needed	NA	NA	NA	NA	NA	NA	NA	NA	No cost estimated
Refractory Repair										
Refractory Worker										
Portable exhaust ventilation	LEV	400	$5,335	$1,480	$2,105	2	$1,053	2	$1,053	Moveable exhaust hoods example: pg. 10-93 (ACGIH, 2001)

Table V-A-2: Unit and Annualized Costs and Model Specifications for Silica Engineering Controls Applied in OSHA's Cost Analysis for General Industry and Maritime (continued)

Sector/Job Category - Control Requirements	Control Description	LEV CFM	Unit Cost	Operating Cost	Annualized Cost (a)	Workers per	Cost per worker	Workers per Control	Cost per worker	Estimate Source
Wet methods for chipping tools	Shop-built water feed equipment	NA	$242	$0.00	$242	1	$242	1	$242	ERG estimate. $200 in annual costs [a]
LEV for chipping tools	LEV	600	$8,002	$2,219	$3,158	2	$1,579	2	$1,579	Granite cutting and finishing; (pg. 10-94, ACGIH, 2001)
Improved maintenance for spay guns	Labor costs	NA	NA	$372	$372	1	$372	1	$372	Assumes 1 hour additional maintenance time per operator per month
Half mask respirator	Respirator	NA	NA	NA	$520	1	$520	1	$520	Annual cost of respirator use

(a) Costs are annualized using a 3 percent discount rate over the lifetime of the equipment, typically 10 years.
Source: OSHA, Directorate of Standards and Guidance, Office of Regulatory Analysis, Based on OSHA (2016)

Table V-A-3: Total Control Costs by Sector, Job Category, and Control for General Industry and Maritime Employers Affected by the Final Silica PEL and an Alternative Silica PEL of 100 μg/m³

Sector/Job Category - Control Requirements	At-Risk Workers 50 μg/m³	At-Risk Workers 100 μg/m³	Cost per Worker Estabs w/ >19	Cost per Worker Estabs w/ <20	Percent Applicability	Total Cost 50 μg/m³
Cut Stone						
Sawyer	1,281	694				
Control other dust sources in			NA	NA	NA	$0
Rigorous housekeeping- capital			$234	$469	100.0%	$412,139
Rigorous housekeeping- labor			$997	$997	100.0%	$1,277,386
Manage slurry-assumed included in housekeeping costs			NA	NA	NA	$0
Pre-wash stone to be cut			$499	$499	100.0%	$638,693
Improve drainage			$1,898	$3,796	100.0%	$3,339,232
Increase water use at saw blade			$499	$499	100.0%	$638,693
Enclose saw			$58	$115	100.0%	$101,205
Exhaust saw			$849	$1,697	100.0%	$1,492,937
Fabricator	734	508				
Use water fed equipment			NA	NA	NA	$0
Manage slurry-assumed included in housekeeping costs			NA	NA	NA	$0
Rigorous housekeeping- capital			$234	$469	100.0%	$236,025
Rigorous housekeeping- labor			$997	$997	100.0%	$731,537
Splitter/chipper	435	304				
Use work practices to position work near duct			NA	NA	NA	$0
Rigorous housekeeping- capital			$234	$469	100.0%	$139,861
Rigorous housekeeping- labor			$997	$997	100.0%	$433,486
Pre-wash stone			$997	$997	100.0%	$433,486
Use flexible trunk LEV for hand chipping			$1,579	$1,579	100.0%	$480,474
Tool-mounted LEV for hand-held chipping tools			$406	$406	100.0%	$123,531
Keep floors wet; wash down with high pressure hose			NA	NA	NA	$0
Machine operator	2,513	1,675				
Control other dust sources in			NA	NA	NA	$0
Rigorous housekeeping- capital			$326	$652	100.0%	$1,125,150
Rigorous housekeeping- labor			$997	$997	100.0%	$2,505,209
Wash stone before and after each process			$140	$140	100.0%	$352,399
Keep conveyor clean and damp			NA	NA	NA	$0
Management of dust-carrying water			NA	NA	NA	$0

Table V-A-3: Total Control Costs by Sector, Job Category, and Control for General Industry and Maritime Employers Affected by the Final Silica PEL and an Alternative Silica PEL of 100 μg/m³ (continued)

Sector/Job Category - Control Requirements	At-Risk Workers 50 μg/m³	At-Risk Workers 100 μg/m³	Cost per Worker Estabs w/ >19	Cost per Worker Estabs w/ <20	Percent Applicability	Total Cost 50 μg/m³
Enclose machinery			$42	$84	100.0%	$144,692
Exhaust trimming machine			$658	$1,316	100.0%	$2,269,726
Abrasive Blaster	281	225				
For use of maintained, interlocked, ventilated glove-box			$322	$644	100.0%	$124,298
Use only non-silica blasting			NA	NA	100.0%	$0
Increase blasting cabinet ventilation			$1,612	$3,223	100.0%	$622,513
Use HEPA vacuums for machine cleaning			$234	$469	100.0%	$90,485
Flat glass						
Material handler	39	24				
Automated and ventilated unloading equipment			NA	NA	NA	$0
Conveyor enclosures			$225	$225	100.0%	$8,849
Conveyor ventilation			$6,447	$6,447	100.0%	$253,317
Batch operator	87	43				
Conveyor enclosures			$225	$225	100.0%	$19,578
Conveyor ventilation			$6,447	$6,447	100.0%	$560,464
LEV for batch operator			$1,381	$2,763	100.0%	$122,019
Dust suppressants			$169	$338	100.0%	$14,938
Substitute wider HEPA vacuum use for compressed air			$1,010	$1,010	100.0%	$87,796
HEPA vacuums			$326	$652	100.0%	$28,804
Other glass						
Material handler	249	150				
Automated and ventilated unloading equipment			NA	NA	NA	$0
Conveyor ventilation			$6,447	$6,447	100.0%	$1,607,710
Conveyor enclosures			$225	$225	100.0%	$56,162
Batch operator	530	265				
Conveyor enclosures			$225	$225	100.0%	$119,461
LEV for batch operator			$1,381	$2,763	100.0%	$777,399
Dust suppressants			$169	$338	100.0%	$95,170
Substitute wider HEPA vacuum use for compressed air			$1,010	$1,010	100.0%	$535,699
HEPA vacuums			$187	$469	100.0%	$108,490
Mineral Wool						

Table V-A-3: Total Control Costs by Sector, Job Category, and Control for General Industry and Maritime Employers Affected by the Final Silica PEL and an Alternative Silica PEL of 100 μg/m³ (continued)

Sector/Job Category - Control Requirements	At-Risk Workers 50 μg/m³	At-Risk Workers 100 μg/m³	Cost per Worker Estabs w/ >19	Cost per Worker Estabs w/ <20	Percent Applicability	Total Cost 50 μg/m³
Material handler	157	94				
Automated and ventilated unloading equipment			NA	NA	NA	$0
Conveyor ventilation			$6,447	$6,447	100.0%	$1,008,964
Conveyor enclosures			$225	$225	100.0%	$35,246
Batch operator	301	150				
Conveyor enclosures			$225	$225	100.0%	$67,715
LEV for batch operator			$1,381	$2,763	100.0%	$447,809
Dust suppressants			$169	$338	100.0%	$54,821
Substitute wider HEPA vacuum use for compressed air			$1,096	$1,096	100.0%	$329,644
HEPA vacuums			$261	$652	100.0%	$87,629
Concrete Products						
Material handlers	3,235	1,618				
Yard dust suppression			$412	$823	100.0%	$1,628,412
Enclosed cabs			$1,841	$3,682	100.0%	$7,281,823
LEV for blender and hoppers			$1,381	$2,763	100.0%	$5,463,547
Improved housekeeping - HEPA vacuum			$326	$652	100.0%	$1,289,711
Improved housekeeping - additional labor			$1,024	$1,024	100.0%	$3,313,005
Mixer operators	626	536				
Wet methods to clean equipment			$1,024	$1,024	100.0%	$640,558
LEV for bag opening stations			$1,991	$3,981	75.0%	$1,141,622
Ventilated control room and HEPA filter			$781	$1,561	25.0%	$149,248
Forming operators	594	119				
Dust control for adjacent operations			NA	NA	NA	$0
LEV for forming operator workstations			$789	$1,579	100.0%	$573,631
Initial thorough cleaning			NA	NA	100.0%	$340,568
Improve housekeeping - capital			$326	$652	100.0%	$236,967
Improve housekeeping - labor			$1,024	$1,024	100.0%	$608,721
Abrasive blasting operators	2,211	1,579				
Use wet process			$33	$66	80.0%	$71,825
Use alternative blast media			$5,156	$5,156	20.0%	$2,279,914
Finishing operators	1,611	1,181				
Work concrete green			$2,393	$2,393	100.0%	$3,854,456

Table V-A-3: Total Control Costs by Sector, Job Category, and Control for General Industry and Maritime Employers Affected by the Final Silica PEL and an Alternative Silica PEL of 100 μg/m³ (continued)

Sector/Job Category - Control Requirements	At-Risk Workers 50 μg/m³	At-Risk Workers 100 μg/m³	Cost per Worker Estabs w/ >19	Cost per Worker Estabs w/ <20	Percent Applicability	Total Cost 50 μg/m³
Use wet process			$33	$66	50.0%	$32,706
LEV where wet methods are infeasible			$494	$494	50.0%	$397,661
Packaging operators	1,113	557				
LEV for bag filling stations			$1,973	$3,947	100.0%	$2,685,994
Extended polyethylene bag valves to reduce dust release			$4,915	$4,915	100.0%	$5,471,794
Pottery						
Material Handler	379	152				
Well-ventilated bag dumping stations			$1,991	$3,981	100.0%	$878,885
Ventilated cab enclosures			$1,841	$3,682	100.0%	$812,920
Apply LEV to conveyors in material handling area			$13,157	$13,157	100.0%	$4,984,811
Forming Line Operator	1,022	186				
LEV- hand grinding bench			$1,842	$3,684	100.0%	$2,194,352
Eliminate compressed air (switch to vacuum)			$368	$737	100.0%	$438,867
Reduce dust generation during mold parting (redesign talc bag)			NA	NA	NA	$0
Finishing operator	88	0				
LEV- hand grinding bench			$3,158	$6,315	100.0%	$322,401
Wet finishing			NA	NA	NA	$0
Coatings preparer	268	134				
Well-ventilated bag dumping stations			$1,991	$3,981	100.0%	$622,032
Well-ventilated or enclosed, automated systems for charging mixing equipment with glaze materials			$1,381	$2,763	100.0%	$431,681
Eliminate compressed air			NA	NA	0.0%	$0
Improve housekeeping - capital			$326	$652	100.0%	$101,902
Improve housekeeping - labor			$961	$961	100.0%	$257,729
Coatings Operator	739	296				
Substitute low silica content			NA	NA	NA	$0
Improved LEV for spray booths and enclosures			$156	$311	100.0%	$133,889
Spray booth maintenance			$60	$120	100.0%	$51,583
Paint						

Table V-A-3: Total Control Costs by Sector, Job Category, and Control for General Industry and Maritime Employers Affected by the Final Silica PEL and an Alternative Silica PEL of 100 μg/m³ (continued)

Sector/Job Category - Control Requirements	At-Risk Workers 50 μg/m³	At-Risk Workers 100 μg/m³	Cost per Worker Estabs w/ >19	Cost per Worker Estabs w/ <20	Percent Applicability	Total Cost 50 μg/m³
Material handler	0	0				
No overexposure			NA	NA	NA	$0
Mixer operator	386	386				
Ventilated bag dumping stations with bag compactor			$1,991	$3,981	100.0%	$881,545
Structural Clay						
Material Handler (Loader Operators)	372	248				
Enclosed, ventilated cab			$1,841	$3,682	100.0%	$154,618
Rigorous housekeeping- capital			$326	$652	100.0%	$27,385
Rigorous housekeeping- labor			$961	$961	100.0%	$73,360
Improve cab maintenance and keep windows closed			$197	$394	100.0%	$16,546
Cover conveyors in material handling area			$225	$225	100.0%	$17,189
Apply LEV to conveyors in material handling area			$13,157	$13,157	100.0%	$1,004,218
Material Handler (Production Line Handlers)	104	21				
Use low-silica gravel			NA	NA	NA	$0
Misters on conveyor line			$576	$576	100.0%	$508,803
Exhaust LEV and clean air island (CAI)			$5,263	$10,525	100.0%	$5,113,025
Material Handler (Post-Production Handlers)	76	38				
Misters on conveyor line			$576	$576	100.0%	$60,090
Improved dust suppression			$1,647	$1,647	100.0%	$171,765
Improve housekeeping - capital			$326	$652	100.0%	$37,418
Improve housekeeping - labor			$961	$961	100.0%	$100,237
Grinding Operators	178	148				
Ventilated control room and HEPA filter			$781	$1,561	100.0%	$319,453
Control room improvements and repairs			$66	$131	100.0%	$26,863
Enclosures with LEV for grinding equipment			$22,366	$44,732	100.0%	$9,151,885
Purchase additional HEPA vacuums			$326	$652	100.0%	$133,435
Enhanced housekeeping with HEPA vacuums			$961	$961	100.0%	$357,452

Table V-A-3: Total Control Costs by Sector, Job Category, and Control for General Industry and Maritime Employers Affected by the Final Silica PEL and an Alternative Silica PEL of 100 μg/m³ (continued)

Sector/Job Category - Control Requirements	At-Risk Workers 50 μg/m³	At-Risk Workers 100 μg/m³	Cost per Worker Estabs w/ >19	Cost per Worker Estabs w/ <20	Percent Applicability	Total Cost 50 μg/m³
Cover conveyors in grinding area			$225	$225	100.0%	$83,755
Dust suppression for raw			$676	$676	100.0%	$251,589
Tightly sealed storage units			NA	NA	NA	$0
Initial thorough cleaning			NA	NA	100.0%	$165,944
Half mask respirator			$520	$520	100.0%	$0
Forming Line operators (Pug mill operators)	1,057	755				
Enclosed and ventilated pug mill equipment			$7,894	$15,788	100.0%	$1,546,797
Initial thorough cleaning			NA	NA	NA	$0
Misters on conveyor line			$576	$576	100.0%	$102,616
Improve housekeeping - capital			$326	$652	100.0%	$63,898
Improve housekeeping - labor			$961	$961	100.0%	$171,174
Half mask respirator			$520	$520	100.0%	$0
Forming Line Operators (Coatings Blenders)	2,295	1,530				
Initial thorough cleaning			NA	NA	NA	$0
Well-ventilated bag dumping stations			$1,991	$3,981	100.0%	$364,047
Enclosed and ventilated feed hopper, conveyors, tumble tote charging, and transfer to transfer tote			$11,841	$11,841	100.0%	$1,968,268
Improve housekeeping - capital			$326	$652	100.0%	$59,638
Improve housekeeping - labor			$961	$961	100.0%	$159,762
Forming Line Operators	166	62				
Initial thorough cleaning			NA	NA	NA	$0
Improve housekeeping - capital			$326	$652	100.0%	$379,288
Improve housekeeping - labor			$961	$961	100.0%	$1,016,056
Well-ventilated bag dumping stations			$1,991	$3,981	100.0%	$2,315,268
Enclosed and ventilated workstations			$4,671	$9,341	100.0%	$5,432,386
Half mask respirator			$520	$520	100.0%	$0
Dental laboratories						
Dental Technicians	1,101	0				
Improved LEV in grinding,			$87	$87	100.0%	$95,652
Improve housekeeping - capital			$652	$652	100.0%	$717,945
Improve housekeeping - labor			$559	$559	100.0%	$615,380

Table V-A-3: Total Control Costs by Sector, Job Category, and Control for General Industry and Maritime Employers Affected by the Final Silica PEL and an Alternative Silica PEL of 100 μg/m³ (continued)

Sector/Job Category - Control Requirements	At-Risk Workers 50 μg/m³	At-Risk Workers 100 μg/m³	Cost per Worker Estabs w/ >19	Cost per Worker Estabs w/ <20	Percent Applicability	Total Cost 50 μg/m³
Fine jewelry						
Jewelry workers	2,154	2,154				
Substitution of low-silica modeling/investment materials			NA	NA	NA	$0
LEV for abrasive blasting and finishing			$263	$263	100.0%	$566,760
Costume Jewelry						
Jewelry workers	258	258				
Substitution of low-silica modeling/investment materials			NA	NA	NA	$0
LEV for abrasive blasting and finishing			$263	$263	100.0%	$67,937
Refractories						
Material handler	211	105				
Ventilated bag dumping stations with bag compactor			$1,991	$3,981	100.0%	$461,664
Enclosed and ventilated mixing equipment			$1,381	$2,763	100.0%	$320,388
Forming Operator	125	0				
Increased LEV maintenance			$355	$355	100.0%	$44,421
Wet methods for mold cleaning			$961	$961	100.0%	$120,175
Finishing operator	0	0				
No overexposures			NA	NA	NA	$0
Ceramic fiber furnace operator	0	0				
No overexposures			NA	NA	NA	$0
Packaging operator	25	25				
LEV for bag filling stations			$1,973	$3,947	100.0%	$54,306
Bag valves to reduce dust			$4,915	$4,915	100.0%	$122,923
Enameling-services						
Enamel preparer	26	9				
Bag dumping station			$60	$120	100.0%	$1,901
Rigorous housekeeping- capital			$326	$652	100.0%	$10,347
Rigorous housekeeping- labor			$1,019	$1,019	100.0%	$26,521
Eliminate compressed air			NA	NA	NA	$0
Porcelain applicator	1,628	814				
Improved LEV for spray booths			$329	$658	100.0%	$652,919
Rigorous housekeeping- capital			$326	$652	100.0%	$647,331
Rigorous housekeeping- labor			$1,019	$1,019	100.0%	$1,659,291
Enameling-iron						

Table V-A-3: Total Control Costs by Sector, Job Category, and Control for General Industry and Maritime Employers Affected by the Final Silica PEL and an Alternative Silica PEL of 100 μg/m³ (continued)

Sector/Job Category - Control Requirements	At-Risk Workers 50 μg/m³	At-Risk Workers 100 μg/m³	Cost per Worker Estabs w/ >19	Cost per Worker Estabs w/ <20	Percent Applicability	Total Cost 50 μg/m³
Enamel preparer	1	0				
Bag dumping station			$60	$120	100.0%	$77
Rigorous housekeeping- capital			$326	$652	100.0%	$418
Rigorous housekeeping- labor			$1,019	$1,019	100.0%	$1,079
Eliminate compressed air			NA	NA	NA	$0
Porcelain applicator	6	3				
Improved LEV for spray booths and enclosures			$329	$658	100.0%	$2,412
Rigorous housekeeping- capital			$326	$652	100.0%	$2,391
Rigorous housekeeping- labor			$1,019	$1,019	100.0%	$6,166
Enameling-architecture						
Enamel preparer	0	0				
Bag dumping station			$60	$120	100.0%	$14
Rigorous housekeeping- capital			$326	$652	100.0%	$76
Rigorous housekeeping- labor			$1,019	$1,019	100.0%	$180
Eliminate compressed air			NA	NA	NA	$0
Porcelain applicator	16	8				
Improved LEV for spray booths and enclosures			$329	$658	100.0%	$6,871
Rigorous housekeeping- capital			$326	$652	100.0%	$6,812
Rigorous housekeeping- labor			$1,019	$1,019	100.0%	$16,217
Enameling-appliances						
Enamel preparer	0	0				
Bag dumping station			$60	$120	100.0%	$0
Rigorous housekeeping- capital			$326	$652	100.0%	$0
Rigorous housekeeping- labor			$1,019	$1,019	100.0%	$0
Eliminate compressed air			NA	NA	NA	$0
Porcelain applicator	48	24				
Improved LEV for spray booths and enclosures			$329	$658	100.0%	$16,245
Rigorous housekeeping- capital			$326	$652	100.0%	$16,106
Rigorous housekeeping- labor			$1,019	$1,019	100.0%	$49,343
Enameling-signs						
Enamel preparer	28	9				
Bag dumping station			$60	$120	100.0%	$2,224
Rigorous housekeeping- capital			$326	$652	100.0%	$12,105
Rigorous housekeeping- labor			$1,019	$1,019	100.0%	$28,852
Eliminate compressed air			NA	NA	NA	$0
Porcelain applicator	135	67				

Table V-A-3: Total Control Costs by Sector, Job Category, and Control for General Industry and Maritime Employers Affected by the Final Silica PEL and an Alternative Silica PEL of 100 μg/m³ (continued)

Sector/Job Category - Control Requirements	At-Risk Workers 50 μg/m³	100 μg/m³	Cost per Worker Estabs w/ >19	Estabs w/ <20	Percent Applicability	Total Cost 50 μg/m³
Improved LEV for spray booths and enclosures			$329	$658	100.0%	$58,044
Rigorous housekeeping- capital			$326	$652	100.0%	$57,547
Rigorous housekeeping- labor			$1,019	$1,019	100.0%	$137,167
Ready-Mix Concrete						
Material handler	1,129	376				
Yard dust suppression			$2,947	$2,947	100.0%	$3,327,513
Enclosed cabs			$3,682	$3,682	100.0%	$4,157,530
Batch operator	206	0				
No overexposures			NA	NA	NA	$0
Maintenance operator	372	0				
Wet methods to clean equipment			$1,024	$1,024	100.0%	$381,355
Quality control technician	0	0				
No overexposures			NA	NA	NA	$0
Truck Driver	18,234	18,234				
Wet methods for drum cleaning			$61	$121	100.0%	$1,591,493
Ventilation for drum cleaning			$96	$193	100.0%	$2,532,700
Half mask respirator			$520	$520	100.0%	$0
Iron Foundries						
Sand Systems Operator	262	157				
LEV, mixer & muller hood			$1,991	$3,981	100.0%	$536,401
Conveyor enclosures			$6,568	$6,568	100.0%	$1,723,213
Bin and hopper ventilation			$1,381	$2,763	100.0%	$372,255
Bucket elevator ventilation			$2,105	$4,210	100.0%	$567,245
Screen ventilation			$1,579	$3,158	100.0%	$425,434
Substitute silica-free materials			NA	NA	NA	$0
Molder	1,806	691				
Upgraded sand handling equipment - covered elsewhere			NA	NA	NA	$0
Upgrade or install LEV			$1,381	$2,763	100.0%	$2,562,909
Rigorous housekeeping- capital			$261	$652	100.0%	$490,384
Rigorous housekeeping- labor			$1,041	$1,041	100.0%	$1,879,979
Eliminate compressed air			NA	NA	NA	$0
Coremaker	1,788	544				
Eliminated compressed air			$1,041	$1,041	100.0%	$1,860,524
Enclosed conveyors, covered elsewhere			NA	NA	NA	$0
Non-silica cores and core			NA	NA	NA	$0
Initial thorough cleaning			NA	NA	NA	$0

Table V-A-3: Total Control Costs by Sector, Job Category, and Control for General Industry and Maritime Employers Affected by the Final Silica PEL and an Alternative Silica PEL of 100 μg/m³ (continued)

Sector/Job Category - Control Requirements	At-Risk Workers 50 μg/m³	At-Risk Workers 100 μg/m³	Cost per Worker Estabs w/ >19	Cost per Worker Estabs w/ <20	Percent Applicability	Total Cost 50 μg/m³
Furnace operator	343	343				
Control dust releases from adjacent processes - covered elsewhere			NA	NA	NA	$0
Well-maintained furnace emission control system			$163	$325	100.0%	$57,348
Operator booths or cabs			$3,289	$6,578	100.0%	$1,160,134
Pouring operator	630	378				
Control dust from adjacent processes - covered elsewhere			NA	NA	NA	$0
Operator booths or cabs			$3,289	$6,578	100.0%	$2,126,913
Physical isolation of pouring area (create a pouring room)			NA	NA	NA	$0
Modify ventilation system to reduce airflow from other areas into the pouring area			NA	NA	NA	$0
Shakeout Operator	238	93				
Improve existing ventilation system efficiency (very large castings)			$37,891	$75,782	100.0%	$9,257,445
Improve existing ventilation system efficiency			$9,262	$18,524	100.0%	$2,262,931
Partially enclose process			$13,157	$26,313	100.0%	$3,214,391
Control emissions from associated operations - covered			NA	NA	100.0%	$0
Knockout Operator	204	108				
Installing and improving LEV			$1,776	$3,552	100.0%	$371,951
Installing and improving LEV			$1,776	$3,552	100.0%	$371,951
Installing and improving LEV			$1,776	$3,552	100.0%	$371,951
Reduce residual sand on castings			NA	NA	NA	$0
Automate knockout process			NA	NA	NA	$0
Abrasive Blasting Operator	1,269	774				
Improved maintenance for blasting cabinet			$644	$644	100.0%	$816,979
Cleaning/Finishing Operator	2,452	1,740				
LEV for workstations			$4,934	$9,867	100.0%	$12,425,145
LEV on hand tools			$397	$397	100.0%	$973,702

Table V-A-3: Total Control Costs by Sector, Job Category, and Control for General Industry and Maritime Employers Affected by the Final Silica PEL and an Alternative Silica PEL of 100 μg/m³ (continued)

Sector/Job Category - Control Requirements	At-Risk Workers 50 μg/m³	100 μg/m³	Cost per Worker Estabs w/ >19	Estabs w/ <20	Percent Applicability	Total Cost 50 μg/m³
Eliminate compressed air (switch to vacuum)			$368	$737	100.0%	$658,192
Substitution with non-silica materials			NA	NA	NA	$0
Process automation			NA	NA	NA	$0
Wet methods			NA	NA	NA	$0
Pre-cleaning with automated equipment			NA	NA	NA	$0
Material Handler	734	286				
Enclosed, ventilated cab			$1,841	$3,682	100.0%	$1,388,980
Maintenance Operator	290	156				
Use low silica refractory			NA	NA	NA	$0
LEV for chipping tools			$247	$494	100.0%	$73,621
Pre-wetting lining to be removed			$423	$1,691	100.0%	$132,717
Maintaining moisture level in the refractory applied			$211	$845	100.0%	$66,358
Also, use of precast refractories and automated equipment for powdered refractory materials			NA	NA	NA	$0
Housekeeping Worker	134	19				
Initial thorough cleaning			NA	NA	100.0%	$181,413
Initial thorough cleaning			NA	NA	100.0%	$181,413
Nonferrous Sand Casting Foundries						
Sand Systems Operator	38	0				
LEV, mixer & muller hood			$1,991	$3,981	100.0%	$83,771
Conveyor enclosures			$6,568	$6,568	100.0%	$246,545
Bin and hopper ventilation			$1,381	$2,763	100.0%	$58,136
Bucket elevator ventilation			$2,105	$4,210	100.0%	$88,588
Screen ventilation			$1,579	$3,158	100.0%	$66,441
Substitute silica-free materials			NA	NA	NA	$0
Molder	277	62				
Upgraded sand handling equipment - covered elsewhere			NA	NA	NA	$0
Upgrade or install LEV			$1,381	$2,763	100.0%	$428,793
Rigorous housekeeping- capital			$261	$652	100.0%	$85,351
Rigorous housekeeping- labor			$1,041	$1,041	100.0%	$288,151
Eliminate compressed air			NA	NA	NA	$0
Coremaker	71	0				
Eliminated compressed air			$1,041	$1,041	100.0%	$73,699

Table V-A-3: Total Control Costs by Sector, Job Category, and Control for General Industry and Maritime Employers Affected by the Final Silica PEL and an Alternative Silica PEL of 100 μg/m³ (continued)

Sector/Job Category - Control Requirements	At-Risk Workers 50 μg/m³	At-Risk Workers 100 μg/m³	Cost per Worker Estabs w/ >19	Cost per Worker Estabs w/ <20	Percent Applicability	Total Cost 50 μg/m³
Enclosed conveyors, covered elsewhere			NA	NA	NA	$0
Non-silica cores and core			NA	NA	NA	$0
Initial thorough cleaning			NA	NA	100.0%	$37,233
Furnace operator	0	0				
No overexposures, controls not needed			NA	NA	NA	$0
Pouring operator	80	80				
No overexposures, controls not needed			NA	NA	NA	$0
Shakeout Operator	67	24				
Improve existing ventilation system efficiency (very large castings)			$37,891	$75,782	100.0%	$2,829,097
Improve existing ventilation system efficiency			$9,262	$18,524	100.0%	$691,557
Partially enclose process			$13,157	$26,313	100.0%	$982,325
Control emissions from associated operations - covered			NA	NA	100.0%	$0
Knockout Operator	29	0				
Installing and improving LEV			$1,776	$3,552	100.0%	$57,497
Installing and improving LEV			$1,776	$3,552	100.0%	$57,497
Installing and improving LEV			$1,776	$3,552	100.0%	$57,497
Reduce residual sand on castings			NA	NA	NA	$0
Automate knockout process			NA	NA	NA	$0
Abrasive Blasting Operator	77	0				
Improved maintenance for blasting cabinet			$644	$644	100.0%	$49,405
Cleaning/Finishing Operator	422	38				
LEV for workstations			$4,934	$9,867	100.0%	$2,335,436
LEV on hand tools			$397	$397	100.0%	$167,666
Eliminate compressed air (switch to vacuum)			$368	$737	100.0%	$15,853
Substitution with non-silica materials			NA	NA	NA	$0
Process automation			NA	NA	NA	$0
Wet methods			NA	NA	NA	$0
Pre-cleaning with automated equipment			NA	NA	NA	$0

Table V-A-3: Total Control Costs by Sector, Job Category, and Control for General Industry and Maritime Employers Affected by the Final Silica PEL and an Alternative Silica PEL of 100 μg/m³ (continued)

Sector/Job Category - Control Requirements	At-Risk Workers 50 μg/m³	At-Risk Workers 100 μg/m³	Cost per Worker Estabs w/ >19	Cost per Worker Estabs w/ <20	Percent Applicability	Total Cost 50 μg/m³
Material Handler	0	0				
No overexposures, controls not needed			NA	NA	NA	$0
Maintenance Operator	0	0				
No overexposures, controls not needed			NA	NA	NA	$0
Housekeeping Worker	0	0				
No overexposures, controls not needed			NA	NA	NA	$0
Non-Sand Casting Foundries						
Sand Systems Operator	23	0				
LEV, mixer & muller hood			$1,991	$3,981	100.0%	$46,085
Conveyor enclosures			$6,568	$6,568	100.0%	$149,446
Bin and hopper ventilation			$1,381	$2,763	100.0%	$31,983
Bucket elevator ventilation			$2,105	$4,210	100.0%	$48,735
Screen ventilation			$1,579	$3,158	100.0%	$36,551
Substitute silica-free materials			NA	NA	NA	$0
Molder	275	118				
Upgraded sand handling equipment - covered elsewhere			NA	NA	NA	$0
Upgrade or install LEV			$1,381	$2,763	100.0%	$385,926
Rigorous housekeeping- capital			$261	$652	100.0%	$73,508
Rigorous housekeeping- labor			$1,041	$1,041	100.0%	$285,758
Eliminate compressed air			NA	NA	NA	$0
Coremaker	0	0				
No overexposures, controls not needed			NA	NA	NA	$0
Furnace operator	0	0				
No overexposures, controls not needed			NA	NA	NA	$0
Pouring operator	43	43				
Control dust from adjacent processes - covered elsewhere			NA	NA	NA	$0
Operator booths or cabs			$3,289	$6,578	100.0%	$142,762
Physical isolation of pouring area (create a pouring room)			NA	NA	NA	$0
Modify ventilation system to reduce airflow from other areas into the pouring area			NA	NA	NA	$0

Table V-A-3: Total Control Costs by Sector, Job Category, and Control for General Industry and Maritime Employers Affected by the Final Silica PEL and an Alternative Silica PEL of 100 μg/m³ (continued)

Sector/Job Category - Control Requirements	At-Risk Workers 50 μg/m³	At-Risk Workers 100 μg/m³	Cost per Worker Estabs w/ >19	Cost per Worker Estabs w/ <20	Percent Applicability	Total Cost 50 μg/m³
Shakeout Operator	81	65				
Improve existing ventilation system efficiency (very large castings)			$37,891	$75,782	100.0%	$3,132,980
Improve existing ventilation system efficiency			$9,262	$18,524	100.0%	$765,840
Partially enclose process			$13,157	$26,313	100.0%	$1,087,840
Control emissions from associated operations - covered			NA	NA	NA	$0
Knockout Operator	61	23				
Installing and improving LEV			$1,776	$3,552	100.0%	$109,654
Installing and improving LEV			$1,776	$3,552	100.0%	$109,654
Installing and improving LEV			$1,776	$3,552	100.0%	$109,654
Reduce residual sand on castings			NA	NA	NA	$0
Automate knockout process			NA	NA	NA	$0
Abrasive Blasting Operator	197	118				
Improved maintenance for blasting cabinet			$644	$644	100.0%	$126,701
Cleaning/Finishing Operator	151	90				
LEV for workstations			$4,934	$9,867	100.0%	$755,767
LEV on hand tools			$397	$397	100.0%	$59,784
Eliminate compressed air (switch to vacuum)			$368	$737	100.0%	$33,858
Substitution with non-silica materials			NA	NA	NA	$0
Process automation			NA	NA	NA	$0
Wet methods			NA	NA	NA	$0
Pre-cleaning with automated equipment			NA	NA	NA	$0
Material Handler	133	133				
Enclosed, ventilated cab			$1,841	$3,682	100.0%	$248,615
Maintenance Operator	0	0				
No overexposures, controls not needed			NA	NA	NA	$0
Housekeeping Worker	0	NA				
No overexposures, controls not needed			NA	NA	NA	$0
Captive Foundries						
Sand Systems Operator	46	0				

Table V-A-3: Total Control Costs by Sector, Job Category, and Control for General Industry and Maritime Employers Affected by the Final Silica PEL and an Alternative Silica PEL of 100 μg/m³ (continued)

Sector/Job Category - Control Requirements	At-Risk Workers 50 μg/m³	At-Risk Workers 100 μg/m³	Cost per Worker Estabs w/ >19	Cost per Worker Estabs w/ <20	Percent Applicability	Total Cost 50 μg/m³
LEV, mixer & muller hood			$1,991	$3,981	100.0%	$92,549
Conveyor enclosures			$6,568	$6,568	100.0%	$305,381
Bin and hopper ventilation			$1,381	$2,763	100.0%	$64,228
Bucket elevator ventilation			$2,105	$4,210	100.0%	$97,871
Screen ventilation			$1,579	$3,158	100.0%	$73,403
Substitute silica-free materials			NA	NA	NA	$0
Molder	396	124				
Upgraded sand handling equipment - covered elsewhere			NA	NA	NA	$0
Upgrade or install LEV			$1,381	$2,763	100.0%	$546,522
Rigorous housekeeping- capital			$261	$652	100.0%	$103,208
Rigorous housekeeping- labor			$1,041	$1,041	100.0%	$411,762
Eliminate compressed air			NA	NA	NA	$0
Coremaker	82	0				
Eliminated compressed air			$1,041	$1,041	100.0%	$84,881
Enclosed conveyors, covered elsewhere			NA	NA	NA	$0
Non-silica cores and core			NA	NA	NA	$0
Initial thorough cleaning			NA	NA	100.0%	$0
Furnace operator	58	0				
Control dust releases from adjacent processes - covered elsewhere			NA	NA	NA	$0
Well-maintained furnace emission control system			$163	$325	100.0%	$9,448
Operator booths or cabs			$3,289	$6,578	100.0%	$191,131
Pouring operator	93	93				
Control dust from adjacent processes - covered elsewhere			NA	NA	NA	$0
Operator booths or cabs			$3,289	$6,578	100.0%	$305,810
Physical isolation of pouring area (create a pouring room)			NA	NA	NA	$0
Modify ventilation system to reduce airflow from other areas into the pouring area			NA	NA	NA	$0
Shakeout Operator	109	59				
Improve existing ventilation system efficiency (very large castings)			$37,891	$75,782	100.0%	$4,145,133

Table V-A-3: Total Control Costs by Sector, Job Category, and Control for General Industry and Maritime Employers Affected by the Final Silica PEL and an Alternative Silica PEL of 100 μg/m³ (continued)

Sector/Job Category - Control Requirements	At-Risk Workers 50 μg/m³	At-Risk Workers 100 μg/m³	Cost per Worker Estabs w/ >19	Cost per Worker Estabs w/ <20	Percent Applicability	Total Cost 50 μg/m³
Improve existing ventilation system efficiency			$9,262	$18,524	100.0%	$1,013,255
Partially enclose process			$13,157	$26,313	100.0%	$1,439,282
Control emissions from associated operations - covered			NA	NA	NA	$0
Knockout Operator	63	16				
Installing and improving LEV			$4,934	$9,867	100.0%	$312,799
Installing and improving LEV			$4,934	$9,867	100.0%	$312,799
Installing and improving LEV			$4,934	$9,867	100.0%	$312,799
Reduce residual sand on castings			NA	NA	NA	$0
Automate knockout process			NA	NA	NA	$0
Abrasive Blasting Operator	304	169				
Improved maintenance for blasting cabinet			NA	NA	100.0%	$0
Cleaning/Finishing Operator	428	95				
LEV for workstations			$4,934	$9,867	100.0%	$2,111,049
LEV on hand tools			$397	$397	100.0%	$169,919
Eliminate compressed air (switch to vacuum)			$368	$737	100.0%	$35,028
Substitution with non-silica materials			NA	NA	NA	$0
Process automation			NA	NA	NA	$0
Wet methods			NA	NA	NA	$0
Pre-cleaning with automated equipment			NA	NA	NA	$0
Material Handler	163	163				
Enclosed, ventilated cab			$1,841	$3,682	100.0%	$299,564
Maintenance Operator	79	79				
Use low silica refractory			NA	NA	NA	$0
LEV for chipping tools			$247	$494	100.0%	$19,542
Pre-wetting lining to be removed			$423	$1,691	100.0%	$33,462
Maintaining moisture level in the refractory applied			$1,381	$2,763	100.0%	$109,350
Also, use of precast refractories and automated equipment for powdered refractory materials			NA	NA	NA	$0
Housekeeping Worker	NA	NA				
Initial thorough cleaning			NA	NA	100.0%	$1,391,378
Landscaping						

Table V-A-3: Total Control Costs by Sector, Job Category, and Control for General Industry and Maritime Employers Affected by the Final Silica PEL and an Alternative Silica PEL of 100 μg/m³ (continued)

Sector/Job Category - Control Requirements	At-Risk Workers 50 μg/m³	At-Risk Workers 100 μg/m³	Cost per Worker Estabs w/ >19	Cost per Worker Estabs w/ <20	Percent Applicability	Total Cost 50 μg/m³
Landscaping and Grounds keeping Workers	883	353				
Wet methods			$117	$234	100.0%	$2,085,294
Brick and stonemasons	11,989	0				
Masonry saw dust control			$749	$749	100.0%	$467,360
Asphalt Roofing Materials						
Production operator	1,076	538				
Process enclosure			$225	$450	100.0%	$262,810
Enhanced ventilation			$921	$1,842	100.0%	$1,074,763
Rigorous housekeeping- capital			$326	$652	100.0%	$380,559
Rigorous housekeeping- labor			$1,693	$1,693	100.0%	$1,821,089
Material handler	335	134				
No additional controls required			NA	NA	NA	$0
Porcelain Enameling						
Enamel preparer	26	9				
Bag dumping station			$60	$120	100.0%	$1,901
Rigorous housekeeping- capital			$326	$652	100.0%	$10,347
Rigorous housekeeping- labor			$1,019	$1,019	100.0%	$26,521
Eliminate compressed air			NA	NA	NA	$0
Porcelain applicator	1,628	814				
Improved LEV for spray booths and enclosures			$329	$658	100.0%	$652,919
Rigorous housekeeping- capital			$326	$652	100.0%	$647,331
Rigorous housekeeping- labor			$1,019	$1,019	100.0%	$1,659,291
Mineral Processing						
Production Worker	1,479	423				
Enclosed ventilation equipment (conveyors)			$225	$225	33.3%	$111,048
Conveyor ventilation			$6,447	$6,447	33.3%	$3,178,928
Improved maintenance on process equipment enclosures			$560	$560	33.3%	$276,244
Improved maintenance			$571	$571	33.3%	$281,583
Initial thorough cleaning			NA	NA	33.3%	$61,173
Improved area cleanup with			$326	$652	33.3%	$189,733
Dental Equipment and Supplies						
Production operator	1,983	991				
Ventilated bag dumping stations with bag compactor			$1,991	$3,981	100.0%	$4,663,290

Table V-A-3: Total Control Costs by Sector, Job Category, and Control for General Industry and Maritime Employers Affected by the Final Silica PEL and an Alternative Silica PEL of 100 μg/m³ (continued)

Sector/Job Category - Control Requirements	At-Risk Workers 50 μg/m³	100 μg/m³	Cost per Worker Estabs w/ >19	Estabs w/ <20	Percent Applicability	Total Cost 50 μg/m³
Enclosed and ventilated mixing equipment			$1,381	$2,763	100.0%	$3,236,256
Increased LEV maintenance			$409	$409	100.0%	$810,472
Asphalt Paving Products						
Facility Operator	0	0				
Enclosed and ventilated control booths			$781	$1,561	100.0%	$0
Front-end loader operator	48	0				
Enclosed cabs			$3,682	$3,682	100.0%	$175,221
Maintenance worker	0	0				
No overexposures			NA	NA	NA	$0
Quality control worker	0	0				
No overexposures			NA	NA	NA	$0
Refractory Repair						
Refractory Worker	591	591				
Portable exhaust ventilation			$1,053	$1,053	33.3%	$207,393
Wet methods for chipping tools			$242	$242	33.3%	$47,783
LEV for chipping tools			$1,579	$1,579	33.3%	$311,089
Improved maintenance for spay guns			$372	$372	100.0%	$219,654
All Workers [a]	100,375	58,779				$238,094,052

[a] Excludes abrasive blasters in shipyards (NAICS 336611; 336612)

Source: OSHA, Directorate of Standards and Guidance, Office of Regulatory Analysis, Based on OSHA (2016).

APPENDIX V-B

Compliance Costs for Small Entities (as defined by SBA) and Very Small Entities (fewer than twenty employees) Affected by the Final Silica Standard

Table V-B-1: Annualized Compliance Costs by Provision for Small Entities Affected by OSHA's Final Silica Standard (2012 dollars)

NAICS	Industry	Control Costs	Respirators	Exposure Assessment	Medical Surveillance	Control Plan	Regulated Area	Training & Familiarization	Total
213112	Support Activities for Oil and Gas	$21,249,502	$95,821	$3,530,444	$540,824	$6,053	$167,115	$52,566	**$25,642,324**
324121	Asphalt Paving Mixture and Block Manufacturing	$100,340	$1,094	$80,200	$5,065	$23,211	$335	$47,366	**$257,611**
324122	Asphalt Shingle and Coating Materials Manufacturing	$597,247	$21,374	$410,379	$218,916	$4,866	$4,003	$15,458	**$1,272,241**
325510	Paint and Coating Manufacturing	$285,822	$9,942	$150,895	$60,789	$31,356	$1,884	$31,914	**$572,603**
327110	Pottery, Ceramics, and Plumbing Fixture Manufacturing	$3,428,870	$65,401	$1,005,018	$478,146	$15,337	$12,275	$54593	**$5,059,640**
327120	Clay Building Material and Refractories Manufacturing	$10,546,584	$594,108	$1,623,710	$656,276	$47,378	$94,559	$84,978	**$13,647,591**
327211	Flat Glass Manufacturing	$99,454	$8,540	$13,205	$4,947	$1,035	$1,427	$877	**$129,486**
327212	Other Pressed and Blown Glass and Glassware Manufacturing	$737,102	$63,780	$109,772	$37,443	$5,706	$10,244	$6,160	**$970,207**
327213	Glass Container Manufacturing	$1,632,303	$140,865	$218,018	$82,642	$5,996	$22,907	$10,361	**$2,113,092**
327320	Ready-Mix Concrete Manufacturing	$4,165,484	$2,389,549	$9,868,273	$2,959,572	$146,919	$384,473	$335,916	**$20,250,184**
327331	Concrete Block and Brick Manufacturing	$2,692,085	$212,442	$1,115,282	$395,091	$25,993	$34,549	$75,124	**$4,550,565**
327332	Concrete Pipe Manufacturing	$1,144,230	$90,166	$442,370	$167,294	$10,375	$14,952	$30,680	**$1,900,067**
327390	Other Concrete Product Manufacturing	$8,793,130	$692,730	$3,356,160	$1,284,747	$67,670	$112,752	$232,516	**$14,539,705**
327991	Cut Stone and Stone Product	$7,952,941	$214,233	$3,397,457	$1,282,336	$67,270	$39,283	$153,325	**$13,106,845**
327992	Ground or Treated Mineral and Earth Manufacturing	$1,111,380	$25,379	$608,213	$282,738	$6,291	$4,838	$37,096	**$2,075,935**
327993	Mineral Wool Manufacturing	$759,210	$63,094	$108,362	$38,352	$5,241	$10,091	$5,901	**$990,251**
327999	All Other Miscellaneous Nonmetallic Mineral Product Manufacturing	$4,353,079	$38,878	$951,067	$433,388	$24,356	$7,422	$64,073	**$5,872,264**
331110	Iron and Steel Mills and Ferroalloy Manufacturing	$105,411	$1,562	$14,845	$8,604	$9,960	$302	$5,607	**$146,290**

Table V-B-1: Annualized Compliance Costs by Provision for Small Entities Affected by OSHA's Final Silica Standard (2012 dollars) (continued)

NAICS	Industry	Control Costs	Respirators	Exposure Assessment	Medical Surveillance	Control Plan	Regulated Area	Training & Familiarization	Total
331210	Iron and Steel Pipe and Tube Manufacturing from Purchased Steel	$58,174	$861	$8,701	$4,771	$7,158	$342	$3,658	**$83,666**
331221	Rolled Steel Shape Manufacturing	$29,271	$433	$4,540	$2,408	$3,873	$561	$1,903	**$42,989**
331222	Steel Wire Drawing	$45,922	$679	$7,180	$3,780	$6,106	$485	$2,977	**$67,130**
331314	Secondary Smelting and Alloying of Aluminum	$13,243	$196	$2,087	$1,091	$1,754	$370	$849	**$19,590**
331420	Copper Rolling, Drawing, Extruding, and Alloying	$47,111	$697	$7,257	$3,873	$6,059	$336	$3,002	**$68,335**
331492	Secondary Smelting, Refining, and Alloying of Nonferrous Metal (except Copper and Aluminum)	$25,820	$382	$4,015	$2,124	$3,379	$355	$1,658	**$37,734**
331511	Iron Foundries	$8,532,938	$449,524	$2,168,755	$1,099,781	$19,363	$74,701	$97,214	**$12,442,276**
331512	Steel Investment Foundries	$1,959,002	$98,686	$381,993	$173,619	$7,249	$16,157	$35,969	**$2,672,675**
331513	Steel Foundries (except Investment)	$3,768,848	$197,262	$966,802	$484,430	$9,286	$33,064	$43,336	**$5,503,027**
331524	Aluminum Foundries (except Die-	$2,112,333	$57,159	$598,117	$272,765	$17,813	$9,616	$62,307	**$3,130,109**
331529	Other Nonferrous Metal Foundries (except Die-Casting)	$1,130,663	$29,953	$338,116	$144,192	$11,092	$5,193	$34,249	**$1,693,459**
332111	Iron and Steel Forging	$54,869	$812	$8,648	$4,519	$7,266	$343	$3,517	**$79,975**
332112	Nonferrous Forging	$9,259	$137	$1,459	$763	$1,226	$226	$594	**$13,664**
332117	Powder Metallurgy Part Manufacturing	$20,345	$301	$3,207	$1,676	$2,694	$376	$1,304	**$29,903**
332119	Metal Crown, Closure, and Other Metal Stamping (except Automotive)	$183,167	$2,710	$28,870	$15,087	$24,256	$521	$11,741	**$266,352**
332215	Metal Kitchen Cookware, Utensil, Cutlery, and Flatware (except Precious) Manufacturing	$18,480	$273	$2,913	$1,522	$2,447	$377	$1,185	**$27,196**
332216	Saw Blade and Handtool Manufacturing	$82,594	$1,222	$13,018	$6,803	$10,937	$446	$5,294	**$120,315**
332323	Ornamental and Architectural Metal Work Manufacturing	$16,635	$600	$9,584	$3,692	$2,538	$544	$1,474	**$35,067**
332439	Other Metal Container Manufacturing	$28,909	$428	$4,557	$2,381	$3,828	$371	$1,853	**$42,327**

NAICS	Industry	Control Costs	Respirators	Exposure Assessment	Medical Surveillance	Control Plan	Regulated Area	Training & Familiarization	Total
332510	Hardware Manufacturing	$62,849	$930	$9,906	$5,177	$8,323	$356	$4,029	**$91,570**
332613	Spring Manufacturing	$43,180	$639	$6,806	$3,557	$5,718	$439	$2,768	**$63,105**
332618	Other Fabricated Wire Product Manufacturing	$86,978	$1,287	$13,709	$7,164	$11,518	$531	$5,575	**$126,762**
332710	Machine Shops	$1,006,095	$14,883	$158,578	$82,869	$133,231	$3,084	$64,492	**$1,463,233**
332812	Metal Coating, Engraving (except Jewelry and Silverware), and Allied Services to Manufacturers	$1,300,193	$60,277	$857,332	$369,286	$78,250	$11,194	$78,580	**$2,755,111**
332911	Industrial Valve Manufacturing	$68,796	$1,018	$10,843	$5,667	$9,110	$291	$4,410	**$100,135**
332912	Fluid Power Valve and Hose Fitting Manufacturing	$60,489	$895	$9,534	$4,982	$8,010	$263	$3,877	**$88,050**
332913	Plumbing Fixture Fitting and Trim Manufacturing	$20,077	$297	$3,165	$1,654	$2,659	$399	$1,287	**$29,537**
332919	Other Metal Valve and Pipe Fitting Manufacturing	$32,946	$487	$5,193	$2,714	$4,363	$348	$2,112	**$48,163**
332991	Ball and Roller Bearing Manufacturing	$19,213	$284	$2,864	$1,575	$2,636	$128	$1,336	**$28,037**
332996	Fabricated Pipe and Pipe Fitting Manufacturing	$79,876	$1,182	$12,590	$6,579	$10,577	$402	$5,120	**$116,327**
332999	All Other Miscellaneous Fabricated Metal Product Manufacturing	$271,048	$4,178	$44,877	$23,402	$36,283	$1,154	$17,721	**$398,663**
333318	Other Commercial and Service Industry Machinery Manufacturing	$152,589	$2,259	$23,184	$12,530	$19,715	$421	$9,887	**$220,586**
333413	Industrial and Commercial Fan and Blower and Air Purification Equipment Manufacturing	$51,835	$767	$8,170	$4,270	$6,864	$323	$3,323	**$75,552**
333414	Heating Equipment (except Warm Air Furnaces) Manufacturing	$52,193	$772	$8,227	$4,299	$6,912	$437	$3,346	**$76,185**
333511	Industrial Mold Manufacturing	$134,905	$1,996	$21,263	$11,112	$17,865	$577	$8,648	**$196,365**

Table V-B-1: Annualized Compliance Costs by Provision for Small Entities Affected by OSHA's Final Silica Standard (2012 dollars) (continued)

Table V-B-1: Annualized Compliance Costs by Provision for Small Entities Affected by OSHA's Final Silica Standard (2012 dollars) (continued)

NAICS	Industry	Control Costs	Respirators	Exposure Assessment	Medical Surveillance	Control Plan	Regulated Area	Training & Familiarization	Total
333514	Special Die and Tool, Die Set, Jig, and Fixture Manufacturing	$164,461	$2,433	$25,922	$13,546	$21,779	$579	$10,542	**$239,261**
333515	Cutting Tool and Machine Tool Accessory Manufacturing	$101,801	$1,506	$16,046	$8,385	$13,481	$539	$6,526	**$148,284**
333517	Machine Tool Manufacturing	$82,565	$1,221	$13,014	$6,801	$10,934	$511	$5,293	**$120,338**
333519	Rolling Mill and Other Metalworking Machinery Manufacturing	$36,060	$533	$5,684	$2,970	$4,775	$465	$2,312	**$52,800**
333612	Speed Changer, Industrial High-Speed Drive, and Gear Manufacturing	$33,269	$492	$5,244	$2,740	$4,406	$311	$2,133	**$48,595**
333613	Mechanical Power Transmission Equipment Manufacturing	$30,033	$444	$4,734	$2,474	$3,977	$291	$1,925	**$43,878**
333911	Pump and Pumping Equipment Manufacturing	$54,601	$808	$8,606	$4,497	$7,231	$243	$3,500	**$79,486**
333912	Air and Gas Compressor Manufacturing	$42,029	$622	$6,625	$3,462	$5,566	$298	$2,694	**$61,295**
333991	Power-Driven Handtool Manufacturing	$11,091	$164	$1,748	$914	$1,469	$188	$711	**$16,285**
333992	Welding and Soldering Equipment Manufacturing	$33,540	$496	$5,286	$2,763	$4,441	$319	$2,150	**$48,996**
333993	Packaging Machinery Manufacturing	$56,309	$833	$8,875	$4,638	$7,457	$424	$3,610	**$82,146**
333994	Industrial Process Furnace and Oven Manufacturing	$35,534	$526	$5,601	$2,927	$4,706	$486	$2,278	**$52,056**
333995	Fluid Power Cylinder and Actuator Manufacturing	$44,336	$656	$6,988	$3,652	$5,871	$276	$2,842	**$64,620**
333996	Fluid Power Pump and Motor Manufacturing	$15,050	$223	$2,372	$1,240	$1,993	$215	$965	**$22,056**
333997	Scale and Balance Manufacturing	$7,778	$115	$1,226	$641	$1,030	$315	$499	**$11,603**
333999	All Other Miscellaneous General Purpose Machinery Manufacturing	$135,881	$2,010	$21,417	$11,192	$17,994	$397	$8,710	**$197,602**
334519	Other Measuring and Controlling Device Manufacturing	$79,638	$1,178	$12,552	$6,560	$10,546	$345	$5,105	**$115,924**

Table V-B-1: Annualized Compliance Costs by Provision for Small Entities Affected by OSHA's Final Silica Standard (2012 dollars) (continued)

NAICS	Industry	Control Costs	Respirators	Exposure Assessment	Medical Surveillance	Control Plan	Regulated Area	Training & Familiarization	Total
335210	Small Electrical Appliance Manufacturing	$8,121	$319	$3,532	$1,935	$2,395	$489	$1,207	**$17,998**
335221	Household Cooking Appliance Manufacturing	$6,484	$255	$2,554	$1,534	$1,398	$308	$764	**$13,297**
335222	Household Refrigerator and Home Freezer Manufacturing	$2,276	$90	$849	$537	$541	$120	$295	**$4,707**
335224	Household Laundry Equipment Manufacturing	$75	$3	$27	$18	$16	$8	$9	**$157**
335228	Other Major Household Appliance Manufacturing	$1,766	$69	$854	$423	$369	$96	$187	**$3,765**
336111	Automobile Manufacturing	$15,680	$233	$2,058	$1,273	$651	$75	$512	**$20,482**
336112	Light Truck and Utility Vehicle Manufacturing	$5,955	$88	$778	$483	$223	$16	$185	**$7,727**
336120	Heavy Duty Truck Manufacturing	$27,224	$404	$3,638	$2,213	$1,962	$133	$1,244	**$36,819**
336211	Motor Vehicle Body Manufacturing	$113,278	$1,677	$17,144	$9,299	$14,988	$421	$7,526	**$164,332**
336212	Truck Trailer Manufacturing	$67,041	$992	$10,567	$5,522	$8,878	$356	$4,297	**$97,653**
336213	Motor Home Manufacturing	$7,744	$115	$1,069	$631	$691	$158	$402	**$10,810**
336310	Motor Vehicle Gasoline Engine and Engine Parts Manufacturing	$81,299	$1,204	$11,852	$6,654	$9,896	$232	$5,181	**$116,317**
336320	Motor Vehicle Electrical and Electronic Equipment Manufacturing	$110,734	$1,640	$16,383	$9,073	$13,048	$333	$6,769	**$157,980**
336330	Motor Vehicle Steering and Suspension Components (except Spring) Manufacturing	$41,238	$611	$6,042	$3,376	$4,745	$217	$2,491	**$58,720**
336340	Motor Vehicle Brake System Manufacturing	$41,440	$613	$6,238	$3,400	$5,498	$285	$2,773	**$60,248**
336350	Motor Vehicle Transmission and Power Train Parts Manufacturing	$91,842	$1,360	$13,253	$7,510	$10,126	$237	$5,424	**$129,753**
336370	Motor Vehicle Metal Stamping	$213,250	$3,155	$33,612	$17,565	$28,239	$793	$13,670	**$310,283**
336390	Other Motor Vehicle Parts Manufacturing	$254,128	$3,763	$37,722	$20,828	$32,197	$940	$16,515	**$366,093**

Table V-B-1: Annualized Compliance Costs by Provision for Small Entities Affected by OSHA's Final Silica Standard (2012 dollars) (continued)

NAICS	Industry	Control Costs	Respirators	Exposure Assessment	Medical Surveillance	Control Plan	Regulated Area	Training & Familiarization	Total
336611	Ship Building and Repairing	$2,008,291	$20,776	$213,837	$135,231	$9,947	$3,844	$12,834	**$2,404,761**
336612	Boat Building	$1,577,177	$16,575	$223,918	$109,703	$22,193	$3,087	$16,667	**$1,969,321**
336992	Military Armored Vehicle, Tank, and Tank Component Manufacturing	$16,684	$247	$2,342	$1,361	$1,964	$228	$1,067	**$23,894**
337110	Wood Kitchen Cabinet and Countertop Manufacturing	$60,274	$3,058	$52,300	$18,761	$12,401	$1,038	$7,601	**$155,433**
337215	Showcase, Partition, Shelving, and Locker Manufacturing	$107,215	$1,586	$16,899	$8,831	$14,198	$483	$6,873	**$156,085**
339114	Dental Equipment and Supplies Manufacturing	$3,164,628	$63,689	$714,398	$292,661	$24,708	$11,745	$59,760	**$4,331,589**
339116	Dental Laboratories	$949,355	$32,076	$3,183,225	$894,048	$177,669	$5,924	$477,387	**$5,719,685**
339910	Jewelry and Silverware Manufacturing	$307,004	$84,101	$1,056,341	$389,052	$94,941	$15,545	$118,840	**$2,065,825**
339950	Sign Manufacturing	$165,143	$6,410	$101,516	$39,416	$25,718	$1,722	$14,898	**$354,823**
423840	Industrial Supplies Merchant	$293,977	$176,873	$539,055	$140,452	$66,544	$27,587	$42,616	**$1,287,104**
444110	Home Centers	$3,242	$102	$1,156	$619	$596	$36	$292	**$6,043**
482110	Rail transportation	$0	$0	$0	$0	$0	$0	$0	**$0**
561730	Landscaping Services	$981,387	$423,361	$11,206,941	$3,852,384	$814,923	$77,035	$893,070	**$18,249,100**
621210	Offices of Dentists	$288,447	$10,282	$1,260,886	$289,420	$287,404	$1,876	$294,166	**$2,432,481**
Total--General Industry and Maritime		**$100,708,106**	**$103,311,396**	**$6,533,409**	**$51,652,657**	**$18,056,898**	**$2,832,091**	**$1,249,714**	**$3,852,419**
236100	Residential Building Construction	$21,438,463	$2,404,840	$565,303	$7,307,218	$7,281,058	$0	$10,802,066	**$49,798,948**
236200	Nonresidential Building Construction	$20,403,909	$1,443,597	$302,783	$4,377,779	$2,021,424	$0	$5,808,478	**$34,357,970**
237100	Utility System Construction	$22,031,365	$1,128,688	$133,196	$3,475,077	$769,084	$0	$2,724,938	**$30,262,348**
237200	Land Subdivision	$511,345	$52,791	$6,156	$169,266	$92,037	$0	$134,988	**$966,584**
237300	Highway, Street, and Bridge Construction	$15,180,881	$790,520	$351,298	$2,111,649	$478,134	$0	$2,487,444	**$21,399,925**
237900	Other Heavy and Civil Engineering Construction	$3,543,169	$253,280	$31,225	$799,414	$174,215	$0	$614,308	**$5,415,610**
238100	Foundation, Structure, and Building Exterior Contractors	$77,635,627	$4,249,657	$625,169	$11,583,215	$4,578,106	$0	$11,540,533	**$110,212,308**
238200	Building Equipment Contractors	$22,069,025	$300,416	$513,378	$840,550	$6,559,449	$0	$10,805,056	**$41,087,873**

Table V-B-1: Annualized Compliance Costs by Provision for Small Entities Affected by OSHA's Final Silica Standard (2012 dollars) (continued)

NAICS	Industry	Control Costs	Respirators	Exposure Assessment	Medical Surveillance	Control Plan	Regulated Area	Training & Familiarization	Total
238300	Building Finishing Contractors	$22,377,976	$1,216,852	$6,376,866	$4,328,205	$4,335,359	$0	$5,864,209	**$44,499,467**
238900	Other Specialty Trade Contractors	$54,766,815	$1,605,713	$3,577,046	$4,851,898	$3,354,028	$0	$8,718,329	**$76,873,828**
221100	Electric Utilities	$313,352	$3,903	$1,892	$12,334	$178,370	$0	$0	**$509,851**
999200	State Governments	$0	$0	$0	$0	$0	$0	$0	**$0**
999300	Local Governments	$0	$0	$0	$0	$0	$0	$0	**$0**
Total -- Construction		**$260,271,927**	**$13,450,258**	**$12,484,311**	**$39,856,606**	**$29,821,264**	**$0**	**$59,500,348**	**$415,384,713**
	Total	**$363,583,323**	**$19,983,667**	**$64,136,968**	**$57,913,503**	**$32,653,355**	**$1,249,714**	**$63,352,767**	**$602,873,297**

Source: OSHA, Directorate of Standards and Guidance, Office of Regulatory Analysis, based on OSHA (2016)

Table V-B-2: Annualized Compliance Costs by Provision for Very Small Entities (<20 employees) Affected by OSHA's Final Silica Standard (2012 Dollars)

NAICS	Industry	Control Costs	Respirators	Exposure Assessment	Medical Surveillance	Control Plan	Regulated Area	Training & Familiarization	Total
213112	Support Activities for Oil and Gas Operations	$10,024,588	$41,066	$1,513,047	$231,782	$2,594	$71,621	$22,528	$11,907,226
324121	Asphalt Paving Mixture and Block	$16,261	$205	$21,986	$965	$6,630	$62	$11,811	$57,921
324122	Asphalt Shingle and Coating Materials Manufacturing	$111,320	$2,922	$117,521	$30,809	$1,499	$535	$3,329	$267,935
325510	Paint and Coating Manufacturing	$0	$2,133	$62,307	$13,395	$7,748	$396	$10,392	$96,372
327110	Pottery, Ceramics, and Plumbing Fixture Manufacturing	$1,660,830	$17,851	$534,966	$134,359	$13,032	$3,285	$24,832	$2,389,156
327120	Clay Building Material and Refractories Manufacturing	$1,282,703	$57,947	$327,166	$66,056	$8,595	$9,052	$13,968	$1,765,486
327211	Flat Glass Manufacturing	$7,767	$630	$2,268	$378	$74	$103	$99	$11,319
327212	Other Pressed and Blown Glass and Glassware Manufacturing	$189,096	$15,457	$56,077	$9,398	$1,828	$2,439	$2,452	$276,747
327213	Glass Container Manufacturing	$16,200	$1,324	$4,804	$805	$157	$211	$210	$23,711
327320	Ready-Mix Concrete Manufacturing	$773,218	$857,780	$3,126,719	$651,101	$37,130	$82,005	$89,018	$5,616,970
327331	Concrete Block and Brick Manufacturing	$759,787	$49,576	$440,791	$94,493	$7,854	$7,940	$22,697	$1,383,138
327332	Concrete Pipe Manufacturing	$185,239	$12,087	$107,465	$23,037	$1,596	$1,971	$5,301	$336,697
327390	Other Concrete Product Manufacturing	$2,507,401	$163,608	$1,454,673	$311,839	$28,424	$26,182	$76,732	$4,568,859
327991	Cut Stone and Stone Product Manufacturing	$2,878,699	$84,349	$2,055,979	$514,764	$37,023	$15,241	$78,844	$5,664,898
327992	Ground or Treated Mineral and Earth Manufacturing	$232,373	$3,211	$146,261	$36,727	$1,521	$600	$6,282	$426,975
327993	Mineral Wool Manufacturing	$96,648	$7,634	$28,285	$4,801	$920	$1,198	$1,234	$140,721
327999	All Other Miscellaneous Nonmetallic Mineral Product Manufacturing	$1,910,274	$8,458	$385,261	$96,740	$8,695	$1,583	$19,969	$2,430,981
331110	Iron and Steel Mills and Ferroalloy	$0	$0	$0	$0	$0	$0	$0	$0
331210	Iron and Steel Pipe and Tube Manufacturing from Purchased Steel	$0	$0	$0	$0	$0	$0	$0	$0
331221	Rolled Steel Shape Manufacturing	$0	$0	$0	$0	$0	$0	$0	$0

Table V-B-2: Annualized Compliance Costs by Provision for Very Small Entities (<20 employees) Affected by OSHA's Final Silica Standard (2012 Dollars) (continued)

NAICS	Industry	Control Costs	Respirators	Exposure Assessment	Medical Surveillance	Control Plan	Regulated Area	Training & Familiarization	Total
331222	Steel Wire Drawing	$0	$0	$0	$0	$0	$0	$0	$0
331314	Secondary Smelting and Alloying of Aluminum	$0	$0	$0	$0	$0	$0	$0	$0
331420	Copper Rolling, Drawing, Extruding, and	$0	$0	$0	$0	$0	$0	$0	$0
331492	Secondary Smelting, Refining, and Alloying of Nonferrous Metal (except Copper and	$0	$0	$0	$0	$0	$0	$0	$0
331511	Iron Foundries	$658,431	$7,119	$232,211	$54,206	$3,907	$3,488	$8,145	$967,507
331512	Steel Investment Foundries	$81,390	$641	$32,556	$6,744	$819	$594	$2,150	$124,895
331513	Steel Foundries (except Investment)	$380,645	$4,116	$134,242	$31,337	$2,379	$2,027	$4,797	$559,542
331524	Aluminum Foundries (except Die-Casting)	$639,052	$2,509	$148,128	$33,828	$5,485	$1,134	$11,961	$842,096
331529	Other Nonferrous Metal Foundries (except Die-Casting)	$621,044	$2,436	$143,869	$32,856	$4,583	$1,129	$11,075	$816,991
332111	Iron and Steel Forging	$0	$0	$0	$0	$0	$0	$0	$0
332112	Nonferrous Forging	$0	$0	$0	$0	$0	$0	$0	$0
332117	Powder Metallurgy Part Manufacturing	$0	$0	$0	$0	$0	$0	$0	$0
332119	Metal Crown, Closure, and Other Metal Stamping (except Automotive)	$0	$0	$0	$0	$0	$0	$0	$0
332215	Metal Kitchen Cookware, Utensil, Cutlery, and Flatware (except Precious) Manufacturing	$0	$0	$0	$0	$0	$0	$0	$0
332216	Saw Blade and Handtool Manufacturing	$0	$0	$0	$0	$0	$0	$0	$0
332323	Ornamental and Architectural Metal Work Manufacturing	$5,599	$223	$5,713	$1,401	$311	$199	$416	$13,862
332439	Other Metal Container Manufacturing	$0	$0	$0	$0	$0	$0	$0	$0
332510	Hardware Manufacturing	$0	$0	$0	$0	$0	$0	$0	$0
332613	Spring Manufacturing	$0	$0	$0	$0	$0	$0	$0	$0
332618	Other Fabricated Wire Product Manufacturing	$0	$0	$0	$0	$0	$0	$0	$0
332710	Machine Shops	$0	$0	$0	$0	$0	$0	$0	$0
332812	Metal Coating, Engraving (except Jewelry and Silverware), and Allied Services to	$388,052	$15,459	$395,877	$97,078	$21,485	$2,818	$28,818	$949,586
332911	Industrial Valve Manufacturing	$0	$0	$0	$0	$0	$0	$0	$0

Table V-B-2: Annualized Compliance Costs by Provision for Very Small Entities (<20 employees) Affected by OSHA's Final Silica Standard (2012 Dollars) (continued)

NAICS	Industry	Control Costs	Respirators	Exposure Assessment	Medical Surveillance	Control Plan	Regulated Area	Training & Familiarization	Total
332912	Fluid Power Valve and Hose Fitting Manufacturing	$0	$0	$0	$0	$0	$0	$0	$0
332913	Plumbing Fixture Fitting and Trim	$0	$0	$0	$0	$0	$0	$0	$0
332919	Other Metal Valve and Pipe Fitting	$0	$0	$0	$0	$0	$0	$0	$0
332991	Ball and Roller Bearing Manufacturing	$0	$0	$0	$0	$0	$0	$0	$0
332996	Fabricated Pipe and Pipe Fitting Manufacturing	$0	$0	$0	$0	$0	$0	$0	$0
332999	All Other Miscellaneous Fabricated Metal Product Manufacturing	$0	$0	$0	$0	$0	$0	$0	$0
333318	Other Commercial and Service Industry Machinery Manufacturing	$0	$0	$0	$0	$0	$0	$0	$0
333413	Industrial and Commercial Fan and Blower and Air Purification Equipment Manufacturing	$0	$0	$0	$0	$0	$0	$0	$0
333414	Heating Equipment (except Warm Air Furnaces) Manufacturing	$0	$0	$0	$0	$0	$0	$0	$0
333511	Industrial Mold Manufacturing	$0	$0	$0	$0	$0	$0	$0	$0
333514	Special Die and Tool, Die Set, Jig, and Fixture Manufacturing	$0	$0	$0	$0	$0	$0	$0	$0
333515	Cutting Tool and Machine Tool Accessory Manufacturing	$0	$0	$0	$0	$0	$0	$0	$0
333517	Machine Tool Manufacturing	$0	$0	$0	$0	$0	$0	$0	$0
333519	Rolling Mill and Other Metalworking Machinery Manufacturing	$0	$0	$0	$0	$0	$0	$0	$0
333612	Speed Changer, Industrial High-Speed Drive, and Gear Manufacturing	$0	$0	$0	$0	$0	$0	$0	$0
333613	Mechanical Power Transmission Equipment Manufacturing	$0	$0	$0	$0	$0	$0	$0	$0
333911	Pump and Pumping Equipment Manufacturing	$0	$0	$0	$0	$0	$0	$0	$0
333912	Air and Gas Compressor Manufacturing	$0	$0	$0	$0	$0	$0	$0	$0
333991	Power-Driven Handtool Manufacturing	$0	$0	$0	$0	$0	$0	$0	$0

Table V-B-2: Annualized Compliance Costs by Provision for Very Small Entities (<20 employees) Affected by OSHA's Final Silica Standard (2012 Dollars) (continued)

NAICS	Industry	Control Costs	Respirators	Exposure Assessment	Medical Surveillance	Control Plan	Regulated Area	Training & Familiarization	Total
333992	Welding and Soldering Equipment	$0	$0	$0	$0	$0	$0	$0	$0
333993	Packaging Machinery Manufacturing	$0	$0	$0	$0	$0	$0	$0	$0
333994	Industrial Process Furnace and Oven Manufacturing	$0	$0	$0	$0	$0	$0	$0	$0
333995	Fluid Power Cylinder and Actuator	$0	$0	$0	$0	$0	$0	$0	$0
333996	Fluid Power Pump and Motor Manufacturing	$0	$0	$0	$0	$0	$0	$0	$0
333997	Scale and Balance Manufacturing	$0	$0	$0	$0	$0	$0	$0	$0
333999	All Other Miscellaneous General Purpose Machinery Manufacturing	$0	$0	$0	$0	$0	$0	$0	$0
334519	Other Measuring and Controlling Device Manufacturing	$0	$0	$0	$0	$0	$0	$0	$0
335210	Small Electrical Appliance Manufacturing	$520	$21	$531	$130	$29	$31	$39	$1,302
335221	Household Cooking Appliance Manufacturing	$0	$0	$0	$0	$0	$0	$0	$0
335222	Household Refrigerator and Home Freezer Manufacturing	$0	$0	$0	$0	$0	$0	$0	$0
335224	Household Laundry Equipment Manufacturing	$0	$0	$0	$0	$0	$0	$0	$0
335228	Other Major Household Appliance	$0	$0	$0	$0	$0	$0	$0	$0
336111	Automobile Manufacturing	$0	$0	$0	$0	$0	$0	$0	$0
336112	Light Truck and Utility Vehicle Manufacturing	$0	$0	$0	$0	$0	$0	$0	$0
336120	Heavy Duty Truck Manufacturing	$0	$0	$0	$0	$0	$0	$0	$0
336211	Motor Vehicle Body Manufacturing	$0	$0	$0	$0	$0	$0	$0	$0
336212	Truck Trailer Manufacturing	$0	$0	$0	$0	$0	$0	$0	$0
336213	Motor Home Manufacturing	$0	$0	$0	$0	$0	$0	$0	$0
336310	Motor Vehicle Gasoline Engine and Engine Parts Manufacturing	$0	$0	$0	$0	$0	$0	$0	$0
336320	Motor Vehicle Electrical and Electronic Equipment Manufacturing	$0	$0	$0	$0	$0	$0	$0	$0
336330	Motor Vehicle Steering and Suspension Components (except Spring) Manufacturing	$0	$0	$0	$0	$0	$0	$0	$0

Table V-B-2: Annualized Compliance Costs by Provision for Very Small Entities (<20 employees) Affected by OSHA's Final Silica Standard (2012 Dollars) (continued)

NAICS	Industry	Control Costs	Respirators	Exposure Assessment	Medical Surveillance	Control Plan	Regulated Area	Training & Familiarization	Total
336340	Motor Vehicle Brake System Manufacturing	$0	$0	$0	$0	$0	$0	$0	$0
336350	Motor Vehicle Transmission and Power Train Parts Manufacturing	$0	$0	$0	$0	$0	$0	$0	$0
336370	Motor Vehicle Metal Stamping	$0	$0	$0	$0	$0	$0	$0	$0
336390	Other Motor Vehicle Parts Manufacturing	$0	$0	$0	$0	$0	$0	$0	$0
336611	Ship Building and Repairing	$46,380	$1,730	$46,186	$11,771	$1,612	$313	$2,162	$110,154
336612	Boat Building	$65,727	$2,452	$65,453	$16,682	$2,284	$447	$3,063	$156,109
336992	Military Armored Vehicle, Tank, and Tank Component Manufacturing	$0	$0	$0	$0	$0	$0	$0	$0
337110	Wood Kitchen Cabinet and Countertop Manufacturing	$13,592	$1,399	$35,817	$8,743	$2,030	$468	$2,723	$64,773
337215	Showcase, Partition, Shelving, and Locker Manufacturing	$0	$0	$0	$0	$0	$0	$0	$0
339114	Dental Equipment and Supplies Manufacturing	$1,252,884	$16,260	$327,787	$76,583	$15,041	$2,943	$24,867	$1,716,366
339116	Dental Laboratories	$907,845	$19,896	$2,629,140	$562,238	$158,235	$3,636	$360,205	$4,641,195
339910	Jewelry and Silverware Manufacturing	$0	$32,955	$677,937	$156,640	$51,262	$6,028	$68,757	$993,578
339950	Sign Manufacturing	$57,829	$2,295	$58,488	$14,409	$3,020	$607	$4,051	$140,698
423840	Industrial Supplies Merchant Wholesalers	$0	$79,435	$346,287	$64,246	$11,435	$12,256	$15,338	$528,996
444110	Home Centers	$481	$33	$839	$205	$48	$11	$64	$1,681
482110	Rail transportation	$0	$0	$0	$0	$0	$0	$0	$0
561730	Landscaping Services	$1,367,307	$275,740	$10,130,933	$2,548,202	$525,780	$49,585	$705,218	$15,602,766
621210	Offices of Dentists	$243,314	$8,870	$1,172,128	$250,658	$178,457	$1,613	$239,361	$2,094,401
Total-General Industry and Maritime		**$29,382,495**	**$29,382,495**	**$1,799,826**	**$26,969,700**	**$6,189,407**	**$1,153,520**	**$313,755**	**$1,882,907**
236100	Residential Building Construction	$16,482,914	$1,919,993	$521,181	$5,710,927	$7,193,658	$0	$9,464,322	$41,292,996
236200	Nonresidential Building Construction	$10,147,946	$780,587	$239,032	$2,259,082	$1,701,450	$0	$3,664,305	$18,792,402
237100	Utility System Construction	$9,345,735	$530,736	$102,682	$1,541,983	$717,522	$0	$1,563,938	$13,802,596
237200	Land Subdivision	$302,305	$34,119	$5,813	$103,870	$81,055	$0	$105,825	$632,988
237300	Highway, Street, and Bridge Construction	$4,859,798	$278,715	$217,368	$709,497	$352,138	$0	$1,063,113	$7,480,629
237900	Other Heavy and Civil Engineering Construction	$1,694,032	$133,430	$25,450	$398,320	$175,087	$0	$387,138	$2,813,457

Table V-B-2: Annualized Compliance Costs by Provision for Very Small Entities (<20 employees) Affected by OSHA's Final Silica Standard (2012 Dollars) (continued)

NAICS	Industry	Control Costs	Respirators	Exposure Assessment	Medical Surveillance	Control Plan	Regulated Area	Training & Familiarization	Total
238100	Foundation, Structure, and Building Exterior Contractors	$43,126,684	$2,517,874	$507,754	$6,639,803	$4,035,644	$0	$7,899,471	$64,727,230
238200	Building Equipment Contractors	$12,248,188	$179,164	$434,249	$482,742	$5,983,868	$0	$7,905,171	$27,233,382
238300	Building Finishing Contractors	$13,961,759	$806,920	$5,501,968	$2,775,586	$3,800,225	$0	$4,544,619	$31,391,077
238900	Other Specialty Trade Contractors	$31,640,631	$989,660	$3,001,766	$2,891,234	$3,036,184	$0	$6,161,614	$47,721,089
221100	Electric Utilities	$15,012	$211	$190	$623	$2,620	$0	$3,457	$22,113
999200	State Governments	$0	$0	$0	$0	$0	$0	$0	$0
999300	Local Governments	$0	$0	$0	$0	$0	$0	$0	$0
Total -- Construction		**$143,825,004**	**$8,171,410**	**$10,557,453**	**$23,513,668**	**$27,079,451**	**$0**	**$42,762,974**	**$255,909,961**
	Total	**$173,207,499**	**$9,971,236**	**$37,527,153**	**$29,703,074**	**$28,232,972**	**$313,755**	**$44,645,881**	**$323,601,570**

Source: OSHA, Directorate of Standards and Guidance, Office of Regulatory Analysis, based on OSHA (2016)

APPENDIX V-C

Compliance Costs for Entities in General Industry, Maritime, and Construction Affected by the Alternative Permissible Exposure Limit of 100 μg/m^3

Table V-C-1: Annualized Compliance Costs for Employers in General Industry, Maritime, and Construction Affected by OSHA's Final Silica Standard, OSHA's 100 μg/m³ PEL Alternative (2012 Dollars)

Industry	Engineering Controls	Respirators	Exposure Assessment	Medical Surveillance	Exposure Control Plan	Regulated Areas	Training & Familiarization	Total
General Industry	$16,220,542	$0	$46,583,119	$20,052,427	$4,065,164	$0	$5,945,116	**$92,866,368**
Maritime	$0	$0	$911,668	$596,410	$66,922	$0	$72,112	**$1,647,111**
Construction	$404,342,599	$1,035,678	$16,387,093	$2,921,273	$40,141,004	Not Applicable	$89,918,502	**$554,746,150**
Total	**$420,563,141**	**$1,035,678**	**$63,881,880**	**$23,570,110**	**$44,273,091**	**$0**	**$95,935,731**	**$649,259,630**

Source: OSHA, Directorate of Standards and Guidance, Office of Regulatory Analysis, based on OSHA (2016).

Table V-C-2: Annualized Costs, by Industry, for All General Industry and Maritime Entities Affected by the Alternative Silica PEL of 100 μg/m³ (2012 dollars)

NAICS	Industry	All Establishments	Small Firms (SBA-Defined)	Very Small Entities (<20 Employees)
213112	Support Activities for Oil and Gas Operations	$7,115,229	$2,316,063	$992,599
324121	Asphalt Paving Mixture and Block Manufacturing	$308,446	$275,522	$196,586
324122	Asphalt Shingle and Coating Materials Manufacturing	$927,975	$822,141	$143,453
325510	Paint and Coating Manufacturing	$389,059	$353,220	$94,115
327110	Pottery, Ceramics, and Plumbing Fixture Manufacturing	$1,748,967	$1,500,221	$504,087
327120	Clay Building Material and Refractories Manufacturing	$2,211,135	$2,066,156	$395,702
327211	Flat Glass Manufacturing	$82,182	$64,683	$2,396
327212	Other Pressed and Blown Glass and Glassware Manufacturing	$260,593	$202,287	$52,211
327213	Glass Container Manufacturing	$238,965	$178,922	$4,361
327320	Ready-Mix Concrete Manufacturing	$16,065,211	$15,548,329	$9,531,702
327331	Concrete Block and Brick Manufacturing	$1,680,456	$1,586,809	$715,883
327332	Concrete Pipe Manufacturing	$883,824	$821,312	$300,830
327390	Other Concrete Product Manufacturing	$4,804,670	$4,645,492	$1,589,442
327991	Cut Stone and Stone Product Manufacturing	$4,162,866	$4,020,530	$2,209,362
327992	Ground or Treated Mineral and Earth Manufacturing	$908,227	$724,697	$256,292
327993	Mineral Wool Manufacturing	$301,470	$256,997	$42,505
327999	All Other Miscellaneous Nonmetallic Mineral Product Manufacturing	$1,390,804	$1,266,575	$429,486
331110	Iron and Steel Mills and Ferroalloy Manufacturing	$123,810	$52,223	$0
331210	Iron and Steel Pipe and Tube Manufacturing from Purchased Steel	$35,038	$22,416	$0
331221	Rolled Steel Shape Manufacturing	$11,253	$9,263	$0
331222	Steel Wire Drawing	$20,489	$17,904	$0
331314	Secondary Smelting and Alloying of Aluminum	$7,741	$6,456	$0
331420	Copper Rolling, Drawing, Extruding, and Alloying	$29,668	$23,315	$0
331492	Secondary Smelting, Refining, and Alloying of Nonferrous Metal (except Copper and Aluminum)	$15,580	$13,002	$0
331511	Iron Foundries	$4,103,330	$2,990,484	$224,762
331512	Steel Investment Foundries	$677,546	$445,277	$25,625
331513	Steel Foundries (except Investment)	$1,948,642	$1,313,620	$126,313
331524	Aluminum Foundries (except Die-Casting)	$595,955	$573,547	$112,065
331529	Other Nonferrous Metal Foundries (except Die-Casting)	$382,654	$346,329	$101,225
332111	Iron and Steel Forging	$34,149	$27,618	$0
332112	Nonferrous Forging	$8,774	$4,862	$0
332117	Powder Metallurgy Part Manufacturing	$11,691	$10,012	$0

Table V-C-2: Annualized Costs, by Industry, for All General Industry and Maritime Entities Affected by the Alternative Silica PEL of 100 μg/m³ (2012 dollars) (continued)

NAICS	Industry	All Establishments	Small Firms (SBA-Defined)	Very Small Entities (<20 Employees)
332119	Metal Crown, Closure, and Other Metal Stamping (except Automotive)	$76,083	$69,528	$0
332215	Metal Kitchen Cookware, Utensil, Cutlery, and Flatware (except Precious) Manufacturing	$10,693	$8,214	$0
332216	Saw Blade and Handtool Manufacturing	$40,186	$35,327	$0
332323	Ornamental and Architectural Metal Work Manufacturing	$18,063	$15,467	$6,207
332439	Other Metal Container Manufacturing	$17,063	$14,273	$0
332510	Hardware Manufacturing	$38,726	$30,652	$0
332613	Spring Manufacturing	$21,437	$19,622	$0
332618	Other Fabricated Wire Product Manufacturing	$35,424	$33,236	$0
332710	Machine Shops	$352,424	$348,006	$0
332812	Metal Coating, Engraving (except Jewelry and Silverware), and Allied Services to Manufacturers	$1,334,397	$1,293,761	$453,039
332911	Industrial Valve Manufacturing	$51,028	$38,618	$0
332912	Fluid Power Valve and Hose Fitting Manufacturing	$46,818	$29,163	$0
332913	Plumbing Fixture Fitting and Trim Manufacturing	$11,132	$7,769	$0
332919	Other Metal Valve and Pipe Fitting Manufacturing	$20,871	$15,694	$0
332991	Ball and Roller Bearing Manufacturing	$32,861	$18,490	$0
332996	Fabricated Pipe and Pipe Fitting Manufacturing	$42,869	$37,366	$0
332999	All Other Miscellaneous Fabricated Metal Product Manufacturing	$105,494	$99,947	$952
333318	Other Commercial and Service Industry Machinery Manufacturing	$76,852	$59,774	$0
333413	Industrial and Commercial Fan and Blower and Air Purification Equipment Manufacturing	$35,090	$29,802	$0
333414	Heating Equipment (except Warm Air Furnaces) Manufacturing	$25,810	$24,376	$0
333511	Industrial Mold Manufacturing	$50,722	$47,702	$0
333514	Special Die and Tool, Die Set, Jig, and Fixture	$61,855	$58,138	$0
333515	Cutting Tool and Machine Tool Accessory Manufacturing	$40,807	$40,052	$0
333517	Machine Tool Manufacturing	$34,919	$30,473	$0
333519	Rolling Mill and Other Metalworking Machinery	$17,061	$14,462	$0
333612	Speed Changer, Industrial High-Speed Drive, and Gear Manufacturing	$22,195	$16,517	$0
333613	Mechanical Power Transmission Equipment Manufacturing	$22,368	$17,697	$0
333911	Pump and Pumping Equipment Manufacturing	$48,963	$35,504	$0
333912	Air and Gas Compressor Manufacturing	$29,526	$21,447	$0
333991	Power-Driven Handtool Manufacturing	$11,640	$7,924	$0
333992	Welding and Soldering Equipment Manufacturing	$19,615	$13,177	$0
333993	Packaging Machinery Manufacturing	$28,783	$25,419	$0
333994	Industrial Process Furnace and Oven Manufacturing	$15,806	$15,123	$0

Table V-C-2: Annualized Costs, by Industry, for All General Industry and Maritime Entities Affected by the Alternative Silica PEL of 100 µg/m³ (2012 dollars) (continued)

NAICS	Industry	All Establishments	Small Firms (SBA-Defined)	Very Small Entities (<20 Employees)
333995	Fluid Power Cylinder and Actuator Manufacturing	$32,194	$22,659	$0
333996	Fluid Power Pump and Motor Manufacturing	$15,151	$11,021	$0
333997	Scale and Balance Manufacturing	$5,329	$4,921	$0
333999	All Other Miscellaneous General Purpose Machinery Manufacturing	$71,981	$61,226	$0
334519	Other Measuring and Controlling Device Manufacturing	$47,998	$37,006	$0
335210	Small Electrical Appliance Manufacturing	$10,449	$6,100	$574
335221	Household Cooking Appliance Manufacturing	$11,253	$3,697	$382
335222	Household Refrigerator and Home Freezer Manufacturing	$10,355	$1,629	$101
335224	Household Laundry Equipment Manufacturing	$4,612	$52	$35
335228	Other Major Household Appliance Manufacturing	$11,591	$776	$127
336111	Automobile Manufacturing	$51,812	$3,569	$0
336112	Light Truck and Utility Vehicle Manufacturing	$45,174	$1,416	$0
336120	Heavy Duty Truck Manufacturing	$31,507	$5,172	$0
336211	Motor Vehicle Body Manufacturing	$57,958	$42,977	$0
336212	Truck Trailer Manufacturing	$38,673	$27,460	$0
336213	Motor Home Manufacturing	$8,432	$2,755	$0
336310	Motor Vehicle Gasoline Engine and Engine Parts Manufacturing	$71,543	$40,706	$0
336320	Motor Vehicle Electrical and Electronic Equipment Manufacturing	$66,671	$43,879	$0
336330	Motor Vehicle Steering and Suspension Components (except Spring) Manufacturing	$37,671	$21,972	$0
336340	Motor Vehicle Brake System Manufacturing	$31,268	$19,957	$0
336350	Motor Vehicle Transmission and Power Train Parts Manufacturing	$74,627	$39,702	$0
336370	Motor Vehicle Metal Stamping	$112,868	$78,196	$0
336390	Other Motor Vehicle Parts Manufacturing	$169,694	$108,558	$0
336611	Ship Building and Repairing	$1,250,658	$404,624	$60,206
336612	Boat Building	$396,453	$346,714	$75,787
336992	Military Armored Vehicle, Tank, and Tank Component Manufacturing	$14,609	$5,241	$0
337110	Wood Kitchen Cabinet and Countertop Manufacturing	$95,746	$79,505	$37,921
337215	Showcase, Partition, Shelving, and Locker Manufacturing	$48,460	$42,675	$0
339114	Dental Equipment and Supplies Manufacturing	$1,414,665	$1,199,301	$443,607
339116	Dental Laboratories	$2,372,163	$2,285,315	$1,672,992
339910	Jewelry and Silverware Manufacturing	$2,037,526	$1,887,513	$906,192
339950	Sign Manufacturing	$165,726	$155,339	$61,851
423840	Industrial Supplies Merchant Wholesalers	$670,464	$607,462	$338,877
444110	Home Centers	$40,481	$39,924	$1,277
482110	Rail transportation	$16,562,059	$0	$0

Table V-C-2: Annualized Costs, by Industry, for All General Industry and Maritime Entities Affected by the Alternative Silica PEL of 100 μg/m³ (2012 dollars) (continued)

NAICS	Industry	All Establishments	Small Firms (SBA-Defined)	Very Small Entities (<20 Employees)
561730	Landscaping Services	$12,974,323	$12,547,193	$8,164,124
621210	Offices of Dentists	$1,167,353	$1,163,548	$962,629
Total – General Industry and Maritime		**$94,513,479**	**$66,428,766**	**$31,237,879**

Source: OSHA, Directorate of Standards and Guidance, Office of Regulatory Analysis, based on OSHA (2016).

Table V-C-3: Annualized Costs, by Industry, for All Construction Entities Affected by the Alternative Silica PEL of 100 μg/ m^3

NAICS	Industry	All Establishments	Small Firms (SBA Defined)	Very Small Entities (<20 Employees)
236100	Residential Building Construction	$44,201,254	$43,518,090	$31,287,321
236200	Nonresidential Building Construction	$43,750,729	$39,095,419	$19,460,361
237100	Utility System Construction	$70,673,855	$47,522,721	$6,086,430
237200	Land Subdivision	$1,503,981	$438,491	$224,275
237300	Highway, Street, and Bridge Construction	$41,937,681	$34,905,656	$6,968,170
237900	Other Heavy and Civil Engineering Construction	$10,729,965	$7,081,995	$1,095,235
238100	Foundation, Structure, and Building Exterior Contractors	$119,212,593	$114,650,672	$2,408,990
238200	Building Equipment Contractors	$58,370,588	$45,810,293	$7,011,641
238300	Building Finishing Contractors	$38,612,644	$28,106,025	$6,807,187
238900	Other Specialty Trade Contractors	$87,700,663	$82,723,423	$39,594,885
221100	Electric Utilities	$3,108,681	$734,554	$23,496
999200	State Governments	$6,138,565	NA	NA
999300	Local Governments	$28,804,951	NA	NA
Total -- Construction		**$554,746,150**	**$444,587,337**	**$120,967,991**

Source: OSHA, Directorate of Standards and Guidance, Office of Regulatory Analysis, based on OSHA (2016).

APPENDIX V-D

Compliance Costs at the Alternative Discount Rates of 7 Percent and 0 Percent for Entities in General Industry, Maritime, and Construction Affected by the Final Silica Standard

Table V-D-1: Annualized Compliance Costs for Employers in General Industry, Maritime, and Construction Affected by OSHA's Final Silica Standard

(7% discount rate; 2012 dollars)

Industry	Engineering Controls	Respirators	Exposure Assessment	Medical Surveillance	Exposure Control Plan	Regulated Areas	Training & Familiarization	Total
General Industry	$237,478,609	$10,412,041	$80,054,343	$30,017,230	$4,065,164	$2,645,743	$6,625,341	**$371,298,471**
Maritime	$10,107,279	$104,346	$1,143,692	$704,780	$66,922	$19,528	$80,814	**$12,227,361**
Construction	$426,312,347	$22,390,518	$16,499,801	$69,137,947	$43,365,065	Not Applicable	$94,896,910	**$672,602,589**
Total	**$673,898,234**	**$32,906,905**	**$97,697,836**	**$99,859,958**	**$47,497,152**	**$2,665,271**	**$101,603,066**	**$1,056,128,421**

Source: OSHA, Directorate of Standards and Guidance, Office of Regulatory Analysis, based on OSHA (2016).

Table V-D-2: Annualized Costs, by Industry, for All General Industry and Maritime and Construction Entities Affected by the Final Silica Standard (7% discount rate; 2012 dollars)

NAICS	Industry	All Establishments	Small Firms (SBA-Definec	Very Small Entities (<20 Employees)
General Industry and Maritime				
213112	Support Activities for Oil and Gas Operations	$100,244,816	$24,837,535	$12,225,589
324121	Asphalt Paving Mixture and Block Manufacturing	$566,638	$284,523	$64,186
324122	Asphalt Shingle and Coating Materials Manufacturing	$3,918,614	$1,307,860	$275,898
325510	Paint and Coating Manufacturing	$1,073,862	$609,451	$101,026
327110	Pottery, Ceramics, and Plumbing Fixture Manufacturing	$9,226,002	$5,311,614	$2,510,713
327120	Clay Building Material and Refractories Manufacturing	$22,380,068	$14,371,875	$1,855,958
327211	Flat Glass Manufacturing	$762,468	$136,093	$11,834
327212	Other Pressed and Blown Glass and Glassware Manufacturing	$2,318,605	$1,018,541	$289,444
327213	Glass Container Manufacturing	$2,323,649	$2,219,075	$24,798
327320	Ready-Mix Concrete Manufacturing	$30,602,177	$20,653,557	$5,709,223
327331	Concrete Block and Brick Manufacturing	$7,242,954	$4,694,597	$1,430,321
327332	Concrete Pipe Manufacturing	$3,930,957	$1,960,343	$348,151
327390	Other Concrete Product Manufacturing	$21,541,018	$15,001,271	$4,724,961
327991	Cut Stone and Stone Product Manufacturing	$15,227,229	$13,643,490	$5,902,452
327992	Ground or Treated Mineral and Earth Manufacturing	$4,474,496	$2,166,010	$444,920
327993	Mineral Wool Manufacturing	$2,745,877	$1,039,656	$147,108
327999	All Other Miscellaneous Nonmetallic Mineral Product Manufacturing	$12,150,544	$6,152,128	$2,551,974
331110	Iron and Steel Mills and Ferroalloy Manufacturing	$706,128	$159,807	$0
331210	Iron and Steel Pipe and Tube Manufacturing from Purchased Steel	$177,829	$91,256	$0
331221	Rolled Steel Shape Manufacturing	$55,620	$46,828	$0
331222	Steel Wire Drawing	$100,472	$73,147	$0
331314	Secondary Smelting and Alloying of Aluminum	$38,442	$21,326	$0
331420	Copper Rolling, Drawing, Extruding, and Alloying	$147,505	$74,494	$0
331492	Secondary Smelting, Refining, and Alloying of Nonferrous Metal (except Copper and Aluminum)	$77,133	$41,115	$0
331511	Iron Foundries	$24,444,332	$13,015,148	$1,013,007
331512	Steel Investment Foundries	$5,735,697	$2,811,858	$131,237
331513	Steel Foundries (except Investment)	$11,633,497	$5,756,277	$585,865

Table V-D-2: Annualized Costs, by Industry, for All General Industry and Maritime and Construction Entities Affected by the Final Silica Standard (7% discount rate; 2012 dollars) (continued)

NAICS	Industry	All Establishments	Small Firms (SBA-Defined)	Very Small Entities (<20 Employees)
331524	Aluminum Foundries (except Die-Casting)	$4,339,248	$3,296,154	$888,795
331529	Other Nonferrous Metal Foundries (except Die-Casting)	$2,705,355	$1,783,000	$862,254
332111	Iron and Steel Forging	$168,554	$87,156	$0
332112	Nonferrous Forging	$43,685	$14,877	$0
332117	Powder Metallurgy Part Manufacturing	$57,711	$32,568	$0
332119	Metal Crown, Closure, and Other Metal Stamping (except Automotive)	$371,208	$290,314	$0
332215	Metal Kitchen Cookware, Utensil, Cutlery, and Flatware (except Precious) Manufacturing	$52,388	$29,617	$0
332216	Saw Blade and Handtool Manufacturing	$195,957	$131,122	$0
332323	Ornamental and Architectural Metal Work Manufacturing	$46,401	$36,918	$14,294
332439	Other Metal Container Manufacturing	$82,934	$46,112	$0
332510	Hardware Manufacturing	$187,018	$99,794	$0
332613	Spring Manufacturing	$104,609	$68,758	$0
332618	Other Fabricated Wire Product Manufacturing	$173,220	$138,144	$0
332710	Machine Shops	$1,722,691	$1,594,857	$0
332812	Metal Coating, Engraving (except Jewelry and Silverware), and Allied Services to Manufacturers	$3,563,926	$2,851,227	$979,407
332911	Industrial Valve Manufacturing	$249,885	$109,136	$0
332912	Fluid Power Valve and Hose Fitting Manufacturing	$239,779	$95,964	$0
332913	Plumbing Fixture Fitting and Trim Manufacturing	$53,910	$32,168	$0
332919	Other Metal Valve and Pipe Fitting Manufacturing	$100,768	$52,476	$0
332991	Ball and Roller Bearing Manufacturing	$158,660	$30,571	$0
332996	Fabricated Pipe and Pipe Fitting Manufacturing	$209,818	$126,778	$0
332999	All Other Miscellaneous Fabricated Metal Product Manufacturing	$501,163	$434,020	$0
333318	Other Commercial and Service Industry Machinery Manufacturing	$380,391	$240,558	$0
333413	Industrial and Commercial Fan and Blower and Air Purification Equipment Manufacturing	$170,080	$82,335	$0
333414	Heating Equipment (except Warm Air Furnaces) Manufacturing	$126,594	$83,017	$0
333511	Industrial Mold Manufacturing	$247,390	$214,016	$0
333514	Special Die and Tool, Die Set, Jig, and Fixture Manufacturing	$300,713	$260,778	$0

Table V-D-2: Annualized Costs, by Industry, for All General Industry and Maritime and Construction Entities Affected by the Final Silica Standard (7% discount rate; 2012 dollars) (continued)

NAICS	Industry	All Establishments	Small Firms (SBA-Defined)	Very Small Entities (<20 Employees)
333515	Cutting Tool and Machine Tool Accessory Manufacturing	$199,757	$161,604	$0
333517	Machine Tool Manufacturing	$170,796	$131,143	$0
333519	Rolling Mill and Other Metalworking Machinery Manufacturing	$82,643	$57,521	$0
333612	Speed Changer, Industrial High-Speed Drive, and Gear Manufacturing	$112,169	$52,950	$0
333613	Mechanical Power Transmission Equipment Manufacturing	$109,467	$47,809	$0
333911	Pump and Pumping Equipment Manufacturing	$237,550	$86,630	$0
333912	Air and Gas Compressor Manufacturing	$148,118	$66,796	$0
333991	Power-Driven Handtool Manufacturing	$61,549	$17,738	$0
333992	Welding and Soldering Equipment Manufacturing	$107,787	$53,386	$0
333993	Packaging Machinery Manufacturing	$140,706	$89,515	$0
333994	Industrial Process Furnace and Oven Manufacturing	$77,786	$56,709	$0
333995	Fluid Power Cylinder and Actuator Manufacturing	$167,148	$70,422	$0
333996	Fluid Power Pump and Motor Manufacturing	$74,477	$24,027	$0
333997	Scale and Balance Manufacturing	$26,672	$12,624	$0
333999	All Other Miscellaneous General Purpose Machinery Manufacturing	$358,995	$215,379	$0
334519	Other Measuring and Controlling Device Manufacturing	$241,844	$126,344	$0
335210	Small Electrical Appliance Manufacturing	$25,876	$18,991	$1,342
335221	Household Cooking Appliance Manufacturing	$30,360	$14,042	$0
335222	Household Refrigerator and Home Freezer Manufacturing	$27,591	$4,974	$0
335224	Household Laundry Equipment Manufacturing	$13,095	$165	$0
335228	Other Major Household Appliance Manufacturing	$28,372	$3,960	$0
336111	Automobile Manufacturing	$396,898	$22,422	$0
336112	Light Truck and Utility Vehicle Manufacturing	$355,594	$8,462	$0
336120	Heavy Duty Truck Manufacturing	$201,124	$40,264	$0
336211	Motor Vehicle Body Manufacturing	$283,933	$179,199	$0
336212	Truck Trailer Manufacturing	$196,480	$106,425	$0
336213	Motor Home Manufacturing	$49,872	$11,802	$0
336310	Motor Vehicle Gasoline Engine and Engine Parts Manufacturing	$364,536	$126,932	$0

Table V-D-2: Annualized Costs, by Industry, for All General Industry and Maritime and Construction Entities Affected by the Final Silica Standard (7% discount rate; 2012 dollars) (continued)

NAICS	Industry	All Establishments	Small Firms (SBA-Defined)	Very Small Entities (<20 Employees)
336320	Motor Vehicle Electrical and Electronic Equipment Manufacturing	$344,603	$172,381	$0
336330	Motor Vehicle Steering and Suspension Components (except Spring) Manufacturing	$197,157	$64,077	$0
336340	Motor Vehicle Brake System Manufacturing	$153,326	$65,692	$0
336350	Motor Vehicle Transmission and Power Train Parts Manufacturing	$397,651	$141,650	$0
336370	Motor Vehicle Metal Stamping	$563,827	$338,184	$0
336390	Other Motor Vehicle Parts Manufacturing	$848,777	$399,355	$0
336611	Ship Building and Repairing	$9,643,639	$2,419,123	$112,615
336612	Boat Building	$2,583,723	$1,982,736	$159,598
336992	Military Armored Vehicle, Tank, and Tank Component Manufacturing	$76,220	$26,074	$0
337110	Wood Kitchen Cabinet and Countertop Manufacturing	$215,226	$163,195	$66,617
337215	Showcase, Partition, Shelving, and Locker Manufacturing	$235,091	$170,113	$0
339114	Dental Equipment and Supplies Manufacturing	$6,227,075	$4,548,134	$1,805,532
339116	Dental Laboratories	$7,199,860	$6,005,910	$4,877,970
	Jewelry and Silverware Manufacturing	$2,795,368	$2,145,334	$1,026,992
339950	Sign Manufacturing	$428,930	$372,159	$144,933
423840	Industrial Supplies Merchant Wholesalers	$2,375,893	$1,332,618	$537,809
444110	Home Centers	$116,539	$6,380	$1,724
482110	Rail transportation	$16,596,146	$0	$0
561730	Landscaping Services	$25,101,018	$18,709,921	$15,980,354
621210	Offices of Dentists	$2,733,888	$2,565,432	$2,209,839
Totals – General Industry and Maritime		**$383,525,832**	**$193,198,008**	**$58,760,031**
Construction				
236100	Residential Building Construction	$57,073,084	$51,739,170	$43,820,237
236200	Nonresidential Building Construction	$53,890,151	$35,132,521	$20,146,733
237100	Utility System Construction	$84,338,755	$30,633,419	$14,971,555
237200	Land Subdivision	$2,008,050	$991,414	$693,388
237300	Highway, Street, and Bridge Construction	$48,978,092	$21,699,668	$8,340,024
237900	Other Heavy and Civil Engineering Construction	$13,525,085	$5,497,283	$3,020,623

Table V-D-2: Annualized Costs, by Industry, for All General Industry and Maritime and Construction Entities Affected by the Final Silica Standard (7% discount rate; 2012 dollars) (continued)

NAICS	Industry	All Establishments	Small Firms (SBA-Defined)	Very Small Entities (<20 Employees)
238100	Foundation, Structure, and Building Exterior Contractors	$141,876,932	$112,326,737	$67,291,663
238200	Building Equipment Contractors	$62,392,817	$42,724,665	$29,541,159
238300	Building Finishing Contractors	$56,658,011	$45,573,912	$32,931,008
238900	Other Specialty Trade Contractors	$103,292,586	$77,996,744	$49,753,522
221100	Electric Utilities	$3,324,686	$0	$205,436
999200	State Governments	$8,734,017	$0	$0
999300	Local Governments	$36,510,322	$0	$0
Totals -- Construction		**$672,602,589**	**$424,315,532**	**$270,715,347**

Source: U.S. Department of Labor, Directorate of Standards and Guidance, Office of Regulatory Analysis, Based on OSHA (2016).

Table V-D-3: Annualized Compliance Costs for Employers in General Industry, Maritime, and Construction Affected by OSHA's Final Silica Standard (0% discount rate; 2012 dollars)

Industry	Engineering Controls	Respirators	Exposure Assessment	Medical Surveillance	Exposure Control Plan	Regulated Areas	Training & Familiarization	Total
General Industry	$221,516,491	$10,373,918	$77,638,041	$28,341,475	$4,065,164	$2,598,678	$5,479,032	**$350,012,800**
Maritime	$10,059,629	$104,247	$1,121,014	$664,943	$66,922	$19,181	$66,149	**$12,102,085**
Construction	$421,189,390	$22,390,518	$16,484,305	$65,017,946	$37,931,905	Not Applicable	$86,507,340	**$649,521,403**
Total	**$652,765,510**	**$32,868,684**	**$95,243,360**	**$94,024,363**	**$42,063,992**	**$2,617,859**	**$92,052,521**	**$1,011,636,288**

Source: OSHA, Directorate of Standards and Guidance, Office of Regulatory Analysis, based on OSHA (2016).

Table V-D-4: Annualized Costs, by Industry, for All General Industry and Maritime Entities Affected by the Final Silica Standard (0% discount rate; 2012 dollars)

NAICS	Industry	All Establishments	Small Firms (SBA-Defined)	Very Small Entities (<20 Employees)
213112	Support Activities for Oil and Gas Operations	$96,343,128	$23,843,927	$11,689,325
324121	Asphalt Paving Mixture and Block Manufacturing	$476,328	$239,176	$53,629
324122	Asphalt Shingle and Coating Materials Manufacturing	$3,739,001	$1,247,913	$262,473
325510	Paint and Coating Manufacturing	$964,040	$547,418	$93,197
327110	Pottery, Ceramics, and Plumbing Fixture Manufacturing	$8,489,025	$4,887,320	$2,305,917
327120	Clay Building Material and Refractories Manufacturing	$20,479,615	$13,151,456	$1,703,496
327211	Flat Glass Manufacturing	$700,083	$124,958	$10,966
327212	Other Pressed and Blown Glass and Glassware Manufacturing	$2,133,278	$937,128	$268,057
327213	Glass Container Manufacturing	$2,136,722	$2,040,560	$22,966
327320	Ready-Mix Concrete Manufacturing	$29,597,121	$19,975,240	$5,554,409
327331	Concrete Block and Brick Manufacturing	$6,868,579	$4,451,942	$1,350,781
327332	Concrete Pipe Manufacturing	$3,727,325	$1,858,793	$328,842
327390	Other Concrete Product Manufacturing	$20,424,409	$14,223,659	$4,461,807
327991	Cut Stone and Stone Product Manufacturing	$14,216,988	$12,738,490	$5,501,935
327992	Ground or Treated Mineral and Earth Manufacturing	$4,161,359	$2,014,427	$414,691
327993	Mineral Wool Manufacturing	$2,525,985	$956,400	$136,339
327999	All Other Miscellaneous Nonmetallic Mineral Product Manufacturing	$11,219,292	$5,680,612	$2,347,958
331110	Iron and Steel Mills and Ferroalloy Manufacturing	$605,511	$137,036	$0
331210	Iron and Steel Pipe and Tube Manufacturing from Purchased Steel	$152,911	$78,469	$0
331221	Rolled Steel Shape Manufacturing	$47,938	$40,361	$0
331222	Steel Wire Drawing	$86,547	$63,009	$0
331314	Secondary Smelting and Alloying of Aluminum	$33,170	$18,401	$0
331420	Copper Rolling, Drawing, Extruding, and Alloying	$126,960	$64,118	$0
331492	Secondary Smelting, Refining, and Alloying of Nonferrous Metal (except Copper and Aluminum)	$66,449	$35,419	$0
331511	Iron Foundries	$22,623,753	$12,050,671	$936,356
331512	Steel Investment Foundries	$5,255,262	$2,577,448	$120,552
331513	Steel Foundries (except Investment)	$10,766,235	$5,329,908	$541,521
331524	Aluminum Foundries (except Die-Casting)	$3,971,194	$3,016,575	$810,115
331529	Other Nonferrous Metal Foundries (except Die-Casting)	$2,476,637	$1,632,232	$785,993
332111	Iron and Steel Forging	$145,091	$75,059	$0
332112	Nonferrous Forging	$37,647	$12,833	$0
332117	Powder Metallurgy Part Manufacturing	$49,755	$28,079	$0
332119	Metal Crown, Closure, and Other Metal Stamping (except Automotive)	$319,536	$249,946	$0

Table V-D-4: Annualized Costs, by Industry, for All General Industry and Maritime Entities Affected by the Final Silica Standard (0% discount rate; 2012 dollars) (continued)

NAICS	Industry	All Establishments	Small Firms (SBA-Defined)	Very Small Entities (<20 Employees)
332215	Metal Kitchen Cookware, Utensil, Cutlery, and Flatware (except Precious) Manufacturing	$45,148	$25,539	$0
332216	Saw Blade and Handtool Manufacturing	$168,695	$112,915	$0
332323	Ornamental and Architectural Metal Work Manufacturing	$42,376	$33,796	$13,563
332439	Other Metal Container Manufacturing	$71,449	$39,735	$0
332510	Hardware Manufacturing	$160,982	$85,939	$0
332613	Spring Manufacturing	$90,116	$59,236	$0
332618	Other Fabricated Wire Product Manufacturing	$149,165	$118,970	$0
332710	Machine Shops	$1,483,162	$1,373,117	$0
332812	Metal Coating, Engraving (except Jewelry and Silverware), and Allied Services to Manufacturers	$3,361,164	$2,689,012	$928,992
332911	Industrial Valve Manufacturing	$215,030	$93,972	$0
332912	Fluid Power Valve and Hose Fitting Manufacturing	$206,078	$82,631	$0
332913	Plumbing Fixture Fitting and Trim Manufacturing	$46,452	$27,737	$0
332919	Other Metal Valve and Pipe Fitting Manufacturing	$86,795	$45,210	$0
332991	Ball and Roller Bearing Manufacturing	$136,503	$26,302	$0
332996	Fabricated Pipe and Pipe Fitting Manufacturing	$180,629	$109,171	$0
332999	All Other Miscellaneous Fabricated Metal Product Manufacturing	$432,383	$374,454	$0
333318	Other Commercial and Service Industry Machinery Manufacturing	$327,187	$206,912	$0
333413	Industrial and Commercial Fan and Blower and Air Purification Equipment Manufacturing	$146,455	$70,908	$0
333414	Heating Equipment (except Warm Air Furnaces) Manufacturing	$109,045	$71,508	$0
333511	Industrial Mold Manufacturing	$212,997	$184,280	$0
333514	Special Die and Tool, Die Set, Jig, and Fixture	$258,893	$224,530	$0
333515	Cutting Tool and Machine Tool Accessory Manufacturing	$172,018	$139,164	$0
333517	Machine Tool Manufacturing	$147,046	$112,941	$0
333519	Rolling Mill and Other Metalworking Machinery Manufacturing	$71,203	$49,567	$0
333612	Speed Changer, Industrial High-Speed Drive, and Gear Manufacturing	$96,527	$45,614	$0
333613	Mechanical Power Transmission Equipment	$94,276	$41,186	$0
333911	Pump and Pumping Equipment Manufacturing	$204,417	$74,595	$0
333912	Air and Gas Compressor Manufacturing	$127,434	$57,529	$0
333991	Power-Driven Handtool Manufacturing	$52,959	$15,290	$0
333992	Welding and Soldering Equipment Manufacturing	$92,605	$45,990	$0
333993	Packaging Machinery Manufacturing	$121,165	$77,100	$0
333994	Industrial Process Furnace and Oven Manufacturing	$67,034	$48,871	$0
333995	Fluid Power Cylinder and Actuator Manufacturing	$143,714	$60,648	$0

Table V-D-4: Annualized Costs, by Industry, for All General Industry and Maritime Entities Affected by the Final Silica Standard (0% discount rate; 2012 dollars) (continued)

NAICS	Industry	All Establishments	Small Firms (SBA-Defined)	Very Small Entities (<20 Employees)
333996	Fluid Power Pump and Motor Manufacturing	$64,139	$20,707	$0
333997	Scale and Balance Manufacturing	$23,039	$10,904	$0
333999	All Other Miscellaneous General Purpose Machinery Manufacturing	$308,863	$185,431	$0
334519	Other Measuring and Controlling Device Manufacturing	$208,014	$108,790	$0
335210	Small Electrical Appliance Manufacturing	$23,596	$17,318	$1,274
335221	Household Cooking Appliance Manufacturing	$27,642	$12,785	$0
335222	Household Refrigerator and Home Freezer Manufacturing	$25,095	$4,524	$0
335224	Household Laundry Equipment Manufacturing	$11,929	$151	$0
335228	Other Major Household Appliance Manufacturing	$25,771	$3,632	$0
336111	Automobile Manufacturing	$339,056	$19,154	$0
336112	Light Truck and Utility Vehicle Manufacturing	$303,608	$7,225	$0
336120	Heavy Duty Truck Manufacturing	$172,135	$34,460	$0
336211	Motor Vehicle Body Manufacturing	$244,250	$154,154	$0
336212	Truck Trailer Manufacturing	$168,934	$91,647	$0
336213	Motor Home Manufacturing	$42,810	$10,131	$0
336310	Motor Vehicle Gasoline Engine and Engine Parts Manufacturing	$313,180	$109,049	$0
336320	Motor Vehicle Electrical and Electronic Equipment Manufacturing	$296,107	$148,122	$0
336330	Motor Vehicle Steering and Suspension Components (except Spring) Manufacturing	$169,393	$55,053	$0
336340	Motor Vehicle Brake System Manufacturing	$131,921	$56,521	$0
336350	Motor Vehicle Transmission and Power Train Parts Manufacturing	$341,386	$121,608	$0
336370	Motor Vehicle Metal Stamping	$484,813	$291,181	$0
336390	Other Motor Vehicle Parts Manufacturing	$729,685	$343,321	$0
336611	Ship Building and Repairing	$9,546,978	$2,394,876	$108,440
336612	Boat Building	$2,555,107	$1,960,090	$153,681
336992	Military Armored Vehicle, Tank, and Tank Component Manufacturing	$65,486	$22,401	$0
337110	Wood Kitchen Cabinet and Countertop Manufacturing	$197,097	$150,135	$63,518
337215	Showcase, Partition, Shelving, and Locker Manufacturing	$202,382	$146,480	$0
339114	Dental Equipment and Supplies Manufacturing	$5,728,131	$4,183,520	$1,655,349
339116	Dental Laboratories	$6,622,460	$5,523,354	$4,478,447
339910	Jewelry and Silverware Manufacturing	$2,619,795	$2,011,750	$970,844
339950	Sign Manufacturing	$394,667	$342,913	$137,771
423840	Industrial Supplies Merchant Wholesalers	$2,236,322	$1,256,065	$523,024
444110	Home Centers	$106,182	$5,813	$1,652
482110	Rail transportation	$16,538,702	$0	$0
561730	Landscaping Services	$24,063,157	$17,937,350	$15,346,665

Table V-D-4: Annualized Costs, by Industry, for All General Industry and Maritime Entities Affected by the Final Silica Standard (0% discount rate; 2012 dollars) (continued)

NAICS	Industry	All Establishments	Small Firms (SBA-Defined)	Very Small Entities (<20 Employees)
621210	Offices of Dentists	$2,495,078	$2,341,336	$2,015,269
Total – General Industry and Maritime		**$362,114,885**	**$181,235,308**	**$66,099,815**
236100	Residential Building Construction	$53,479,897	$48,463,250	$40,708,911
236200	Nonresidential Building Construction	$51,930,990	$33,821,234	$19,195,888
237100	Utility System Construction	$82,747,185	$30,006,324	$14,536,135
237200	Land Subdivision	$1,928,509	$949,584	$655,597
237300	Highway, Street, and Bridge Construction	$47,852,805	$21,191,292	$8,078,836
237900	Other Heavy and Civil Engineering Construction	$13,216,441	$5,359,535	$2,916,649
238100	Foundation, Structure, and Building Exterior Contractors	$137,375,126	$108,734,831	$64,715,423
238200	Building Equipment Contractors	$58,433,935	$39,948,978	$27,088,869
238300	Building Finishing Contractors	$54,432,194	$43,759,273	$31,372,879
238900	Other Specialty Trade Contractors	$100,816,280	$76,094,608	$48,229,176
221100	Electric Utilities	$3,119,632	$0	$196,012
999200	State Governments	$8,543,573	$0	$0
999300	Local Governments	$35,644,833	$0	$0
Total -- Construction		**$649,521,403**	**$408,328,910**	**$257,694,374**

Source: OSHA, Directorate of Standards and Guidance, Office of Regulatory Analysis, Based on OSHA (2016).

CHAPTER VI: ECONOMIC FEASIBILITY ANALYSIS AND REGULATORY FLEXIBILITY DETERMINATION

INTRODUCTION

In this chapter, OSHA investigates the economic impacts of its silica rule on affected employers in general industry, maritime, and construction. This impact investigation has two overriding objectives: (1) to establish whether the rule is economically feasible for all affected industries, and (2) to determine if the Agency can certify that the rule will not have a significant economic impact on a substantial number of small entities.

First, OSHA presents its approach for establishing economic feasibility and making the determination of whether the rule will have a significant economic impact on a substantial number of small entities. OSHA next applies this approach to industries with affected employers in general industry and maritime and then to industries with affected employers in construction. Finally, OSHA examines the employment effects of the silica rule. This will include a review of estimates of employment effects that commenters provided and a summary of a report prepared for the Agency by Inforum—a not-for-profit corporation (based at the University of Maryland) specializing in the design and application of macroeconomic models of the United States (and other countries)—to estimate the industry and aggregate employment effects of the silica rule.

Many commenters questioned OSHA's preliminary conclusions concerning economic feasibility, but did so for reasons that OSHA has responded to in previous chapters.

A variety of commenters raised issues concerning industries with possible silica exposure that were not covered in the Preliminary Economic and Initial Regulatory Feasibility Analysis (PEA). A full discussion of these comments and of industries added for this Final Economic and Regulatory Feasibility Analysis (FEA) appears in Chapters III (Profile of Affected Industries) and IV (Technological Feasibility Analysis) of this FEA.

Many commenters questioned why OSHA used no data after 2006 (see comments by the Brick Industry Association (BIA) (Document ID 2300, p. 5), the American Fuel & Petrochemical Manufacturers (AFPM) (Document ID 2350, p. 6), The Belden Brick Company (Document ID 3260, p. 3), Basalite Concrete Products, LLC (Document ID 2083, p. 1), SBG Consulting (Document ID 2222, p. 1), Acme Brick (Document ID 2182, p. 4), Erie Bronze & Aluminum (Document ID 1780, p. 1), Calstone (Document ID 3391, p. 2), the Chamber of Commerce (Document ID 1782, p. 1), the Mason Contractors Association of America (MCAA) (Document ID 1767, p. 2), Scango Consulting LLC d.b.a. Capitol Hardscapes (Document ID 2241, p. 3), the National Concrete Masonry Association (NCMA) (Document ID 3585, p. 2944), the American Road and Transportation Builders Association (ARTBA) (Document ID 2245, p. 4), and the Construction Industry Safety Coalition (CISC) (Document ID 4217, Attachment 1, pp. 4 and 49-52)). As discussed in Chapter III of this FEA, OSHA is using revenue data from 2012 and profit data averaged across the years 2000 through 2012. The revenue data from 2012 represent a reasonable choice because this year was neither a peak growth year nor a recession year and was the most up-to-date data available at the time this analysis was developed. The range of years for profits assures the use of profit rates from throughout the business cycle—including two recessions and two sustained growth periods.

One commenter questioned OSHA's sources and methodology for estimating revenues (Document ID 2308, Attachment 9, pp. 7-8 and 14-16). This commenter questioned the methodology used to update revenue estimates between Economic Census years. This is no longer an issue as OSHA is using 2012 Economic Census data and using 2012 as the base year for the analysis. Therefore, there is no need for a methodology to update Economic Census revenues.

OSHA also received criticism on the choice of the data source and the methodology for estimating profits of the construction industry. These include comments from the National Association of Home Builders (NAHB) and the CISC (Document ID 2296, Attachment 1, pp. 20–22; 2308, Attachment 9, pp. 7-12).

Stuart Sessions, submitting on behalf of the CISC, criticized OSHA for using the Internal Revenue Service's (IRS) *Corporation Source Book* (CSB) as the source for industry profits since those data are only presented at the four-digit NAICS level instead of the five- or six-digit NAICS level. Mr. Sessions recommended that OSHA use an alternative data source for profit data and recommended Bizminer or RMA (Document ID 4231, Attachment 1, pp.12-13). OSHA investigated these sources and determined that these data were private data sources and that their publishers would not allow the data to be made publicly available. These other sources of profit data also suffered from the disadvantage of not representing adequate and random samples of the affected industries. A further discussion on this issue appears in Chapter III of this FEA.

In the PEA, OSHA used IRS data to calculate profit rates as the ratio of net income to total receipts (with the numerator including only firms with positive net income and the denominator including firms with and without net income) by NAICS industry. In response to comments criticizing this ratio as an inappropriate method to calculate industry profitability (Document ID 2308, Attachment 9, pp. 11-12; 4209, pp. 115-116), OSHA has revised the way that estimated profits are calculated. In this FEA, OSHA calculates profit rates using the method recommended by Mr. Sessions, which is discussed more fully in Chapter III. This method includes unprofitable firms and divides the “net income” from all firms (profitable and unprofitable) by total receipts from all firms (profitable and unprofitable), resulting in somewhat lower profit rates.

Similarly, Mr. Sessions criticized OSHA for using data that he believed were at a level that was too aggregated to show economic impacts of the costs of the rule accurately (Document ID 2319, Attachment 1, p. 71). The Portland Cement Association likewise disagreed with OSHA’s presentation of costs as averages across industries. It said that “a more focused explanation of individual plant and facility costs is relevant to those industries with significant compliance responsibilities” (Document ID 2284, p. 6). OSHA’s data sources for profile data are presented in Chapter III of this FEA. In general, OSHA has disaggregated industries to the extent that the source data will allow.

The most common criticism of OSHA’s preliminary conclusions on economic feasibility was that the conclusions were based on costs that were underestimated or inaccurate (see, e.g., Document ID 2023, p. 1; 2299, p. 15; 2379, Attachment 3, pp. 2 and 10; 2388, pp. 2 and 10; 2296, Attachment 1, p. 17; 2116, Attachment 1, p. 22; and 3378, Attachment 2). For example, Wayne D’Angelo of the American Petroleum Institute (API) and the Independent Petroleum Association of America (IPAA) (API/IPAA or “the Associations”) critiqued OSHA’s feasibility analysis for the hydraulic fracturing industry, stating that OSHA had not met its obligations due to inaccurate cost data and an industry profile that, they asserted, did not “reasonably represent the typical firms in the various segments of the industry, given varying operations, exposure levels, and processes” (Document ID 2301, Attachment 1, pp. 62-63).

OSHA responded to comments on its preliminary cost estimates in Chapter V. In the aggregate, OSHA increased its cost estimate by approximately 46 percent, in part as a result of changes in cost estimates made in response to comments and in part as a result of changes in the rule.

Some commenters argued that OSHA had not adequately considered the possibility that smaller establishments might have higher costs or that the costs have a greater impact on small businesses (Document ID 4231, Attachment 1, p. 11; 2379, Attachment 2, p. 7; 3582, Tr. 2107 – 2109; 2203, p. 1; 2351, p. 8; 3433, p. 9; 3580, Tr. 1398). As discussed in Chapter V, OSHA has made a number of changes to the costs analysis to reflect higher costs for small establishments.

LEGAL INTERPETATIONS AND ANALYTIC APPROACH

Economic Feasibility

Section 6(b)(5) of the OSH Act states:

> The Secretary . . . shall set the standard which most adequately assures, *to the extent feasible*, on the basis of the best available evidence, that no employee will suffer material impairment of health or functional capacity . . . .[1] [Emphasis added.]

OSHA has interpreted the phrase "to the extent feasible" to encompass economic feasibility and was supported in this view by the U.S. Court of Appeals for the D.C. Circuit in its 1974 asbestos decision.[2] The court noted that "Congress does not appear to have intended to protect employees by putting their employers out of business,"[3] and then proceeded to define the concept of economic feasibility and to indicate its boundaries:

> Standards may be economically feasible even though, from the standpoint of employers, they are financially burdensome and affect profit margins adversely. Nor does the concept of economic feasibility necessarily guarantee the continued existence of individual employers. It would appear to be consistent with the purposes of the Act to envisage the economic demise of an employer who has lagged behind the rest of the industry in protecting the health and safety of employees and is consequently financially unable to comply with new standards as quickly as other employers. As the effect becomes more widespread within an industry, the problem of economic feasibility becomes more pressing.[4]

Thus, according to the court, OSHA standards would satisfy the economic feasibility criterion even if they imposed significant costs on regulated industries and forced some marginal firms out of business, so long as they did not cause massive economic dislocations within a particular industry or imperil the existence of the industry.[5]

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[1] 29 U.S.C. 655(b)(5).

[2] *Indus Union Dep't v. Hodgson*, 499 F.2d 467 (D.C. Cir. 1974).

[3] *Id.* at 478.

[4] *Id*.

[5] *Id*.; *see also Am. Iron and Steel Inst. v. OSHA*, 939 F.2d 975, 980 (D.C. Cir. 1991); *United Steelworkers of Am., AFL-CIO-CLC v. Marshall*, 647 F.2d 1189, 1265 (D.C. Cir. 1980)

The implication, for analysis of economic impacts, is that OSHA is required to determine whether its standards will eliminate or alter the competitive structure of an industry, not to determine whether any individual plants will close, or whether some marginal plants may close earlier than they otherwise might have. OSHA thus has an obligation to examine industries, and to consider industry definitions carefully. However, OSHA does not have an obligation to conduct a facility-by-facility analysis of the thousands of facilities in the dozens of industries covered by a major standard.

In practice, the economic burden of an OSHA standard on an industry—and whether the standard is economically feasible for that industry—depends on the magnitude of compliance costs incurred by establishments in that industry and the extent to which they are able to pass those costs on to their customers. That, in turn, depends, to a significant degree, on the price elasticity of demand for the products sold by establishments in that industry.

The price elasticity of demand refers to the relationship between the price charged for a product and the demand for that product: the more elastic the relationship, the less an establishment's compliance costs can be passed through to customers in the form of a price increase and the more it has to absorb compliance costs in the form of reduced profits. When demand is inelastic, establishments can recover most of the variable costs of compliance (i.e., costs that are highly correlated with the amount of output) by raising the prices they charge; under this scenario, if costs are variable rather than fixed, profit rates are largely unchanged and the industry remains largely unaffected. Any impacts are primarily on those customers using the relevant product. On the other hand, when demand is elastic, establishments cannot recover all compliance costs simply by passing the cost increase through in the form of a price increase; instead, they must absorb some of the increase from their profits. Commonly, this will mean reductions both in the quantity of goods and services produced and in total profits, though the profit rate may remain unchanged. Other things being equal, higher fixed costs mean that the optimal scale of the typical establishment will be larger than it would be if fixed costs were lower. This in turn means that, where there are higher fixed costs, there will be fewer plants for the same level of production. Whether an increase in fixed costs results in closures of existing plants depends on several factors. If demand regularly increases (such as due to economic growth) or the industry regularly experiences plant closures, the optimal scale may be arrived at by reduced entry rather than premature closures. If plants are not part of a simple homogeneous market, it may not be possible to shift the scale of production. For example, if a plant provides foundry products to others in the same city, it may not be able to readily expand its scale of production.

In general, "[w]hen an industry is subjected to a higher cost, it does not simply swallow it; it raises its price and reduces its output, and in this way shifts a part of the cost to its consumers and a part to its suppliers." *Am. Dental Ass'n v. Sec'y of Labor*, 984 F.2d 823, 829 (7th Cir. 1993). This summary by the court is in accord with microeconomic theory. In the long run, an industry can remain viable only if its profits are adequate to provide a return on investment that ensures that investment in the industry will continue. As technology and costs change, the long-run demand for some products naturally increases and the long-run demand for other products naturally decreases. In the face of additional compliance costs (or other external costs), firms that otherwise have a profitable line of business may have to increase prices to stay viable. Increases in prices typically result in reduced quantity demanded, but rarely eliminate all demand for the product. Whether this decrease in the total production of goods and services results in smaller output for each establishment within the industry; the closure of some plants within the industry; a reduced number of new establishments entering the industry; or a combination of the three, is dependent on the cost and profit structure of individual firms within the industry.

If demand is perfectly inelastic (i.e., the price elasticity of demand is zero), then the impact of compliance costs that are one percent of revenues for each firm in the industry would result in a one percent increase in the price of the product, with the quantity demanded constant. (This outcome would hold in the long run, regardless of type of costs, but in the short run would only hold with certainty if compliance costs are strictly variable.) Such a scenario represents an extreme case, but might be observed in situations in which there were few if any substitutes for the product in question, or if the products of the affected sector account for only a very small portion of the revenue or income of its customers. Under this scenario, both profits and output of the industry would be unaffected, but customers would be worse off.

If the demand is perfectly elastic (i.e., the price elasticity of demand is infinitely large), then no increase in price is possible and before-tax profits would be reduced by an amount equal to the costs of compliance (net of any cost savings—such as reduced workers' compensation insurance premiums—resulting from the standard) if the industry attempted to maintain production at the same level. Under this scenario, if the costs of compliance are such a large percentage of profits that some or all plants in the industry could no longer operate with hope of an adequate return on investment, then some or all of the firms would close. Similarly, if compliance costs are fixed, such costs may result in premature closures or reduced entry into the market in some circumstances.

A commonly discussed intermediate case would be a price elasticity of demand of one.[6] In this scenario, if the costs of compliance amount to one percent of revenues, then

[6] Here and throughout this chapter, the price elasticity of demand is reported as an absolute value.

production would decline by one percent and prices would rise by one percent. (As before, this outcome would hold in the long run, regardless of type of costs, but in the short run would hold with certainty only if compliance costs are variable.) Under this scenario, and if marginal costs of the regulation fall proportionally with output, then industry revenues would remain the same, with somewhat lower production, but with similar profit rates. Customers would, however, receive less of the product for their (same) expenditures, and firms would have lower total profits; this, as the court described in *Am. Dental Ass'n v. Sec'y of Labor*, is the more typical case.

A decline in output as a result of an increase in price may occur in a variety of ways: individual establishments could each reduce their levels of production; some marginal plants could close; or, in the case of an industry with high turnover of establishments, new entry may be delayed until demand equals supply. In many cases a decrease in overall output for an industry will be a combination of all three kinds of reductions. Which possibility is most likely depends on the rate of turnover in the industry and on the form that the costs of the regulation take.

When turnover in an industry is high, or an industry is expanding rapidly, then the key issue is the long run costs as determined by the cost of entry into the industry. For example, if there is annual turnover in an industry of ten percent per year, and a price elasticity of one, then a single year without new entry would result in a price rise of ten percent. Such a rise would be more than enough to compensate existing employers for a cost increase of one percent of revenues.

If the costs are variable costs (i.e., costs that vary with the level of production at a facility), then economic theory suggests that any reductions in output will take the form of reductions in output at each affected facility, with few, if any, plant closures. If the costs of a regulation primarily take the form of fixed costs (i.e., costs that do not vary with the level of production at a facility), and assuming perfect competition, then reductions in overall output can only take the form of plant closures or delays in new entry. Most of the costs of this regulation, as estimated in Chapter V of this FEA, are variable costs. Almost all of the major costs of program elements, such as medical surveillance and training, will vary in proportion to the number of employees (which is a rough proxy for the amount of production). Exposure monitoring costs will vary with the number of employees, but do have some economies of scale to the extent that a larger firm need only conduct representative sampling rather than sample every employee. The costs of engineering controls in construction also vary by level of production because almost all necessary equipment can readily be rented and the productivity costs of using some of these controls vary proportionally to the level of production. Finally, the costs of operating engineering controls in general industry (the majority of the annualized costs of engineering controls are in general industry) vary by the number of hours the establishment works, and thus vary by the level of production and are not fixed costs in the strictest sense.

This leaves two kinds of costs that are, in some sense, fixed costs—capital costs of engineering controls in general industry and certain initial costs that new entrants to the industry will not have to bear.

Fixed costs in the form of capital costs of engineering controls in general industry and maritime due to this standard are relatively small as compared to the total costs, representing less than 21 percent of total annualized costs and approximately $1,019 per year per affected establishment in general industry.

There are some initial fixed costs in the sense that they might only be borne by firms in the industry today. For example, costs for general training not currently required and initial costs of medical surveillance may not be borne by establishments new to the industry to the extent they can hire from a workforce that may have already had this training and/or initial medical surveillance. An initial thorough facility cleaning is not a cost a new establishment would need to bear. These costs will disappear after the initial year of the standard and thus would be difficult to pass on. These costs, however, represent less than two percent of total costs and less than $58 per affected establishment. These initial fixed costs that may be borne by firms in the affected industries today, together with capital costs, gives a total fixed cost of approximately 22 percent of total annual costs.

Because the remaining three-fourths of the total annual costs are variable, OSHA expects it is somewhat more likely that reductions in industry output resulting from the increase in costs associated with this rule will be met by reductions in output at each affected facility rather than as a result of plant closures or reduced new entry. However, closures of some marginal plants or poorly performing facilities are always possible.

To determine whether a rule is economically feasible, OSHA begins with two screening tests to consider minimum threshold effects of the rule under two extreme cases: (1) all costs are passed through to customers in the form of higher prices (consistent with a price elasticity of demand of zero), and (2) all costs are absorbed by the firm in the form of reduced profits (consistent with an infinite price elasticity of demand).

In the former case, the immediate impact of the rule would be observed in increased industry revenues. While there is no hard and fast rule, in the absence of evidence to the contrary, OSHA generally considers a standard to be economically feasible for an industry when the annualized costs of compliance are less than a threshold level of one percent of annual revenues. Retrospective studies of previous OSHA regulations have shown that potential impacts of such a small magnitude are unlikely to eliminate an industry or significantly alter its competitive structure,[7] particularly since most industries have at least some ability to raise prices to reflect increased costs and, as shown in the FEA, normal price variations for products typically exceed three percent a year.[8] Of course, OSHA recognizes that even when costs are within this range, there could be unusual circumstances requiring further analysis.

In the latter case, the immediate impact of the rule would be observed in reduced industry profits. OSHA uses the ratio of annualized costs to annual profits as a second check on economic feasibility. Again, while there is no hard and fast rule, in the absence of evidence to the contrary, OSHA generally considers a standard to be economically feasible for an industry when the annualized costs of compliance are less than a threshold level of ten percent of annual profits. In the context of economic feasibility, the Agency believes this threshold level to be fairly modest, given that normal year-to-year variations in profit rates in an industry can exceed 40 percent or more.[9] OSHA's choice of a threshold level of ten percent of annual profits is low enough that even if, in a hypothetical worst case, all compliance costs were upfront costs, then upfront costs would still equal 88.5 percent of profits using a three percent discount rate (See section Normal Year-to-Year Variations in Prices and Profit Rates below) and thus would be affordable from profits alone without the need for an employer to resort to credit markets. If the threshold level were *first-year* costs of ten percent of annual profits, firms could even more easily expect to cover first-year costs at the threshold level out of current profits without having to access capital (including credit markets) markets and otherwise being threatened with short-term insolvency.

In general, it is usually the case that firms would be able to pass on some or all of the costs of the rule to their customers in the form of higher prices. OSHA therefore will tend to give much more weight to the ratio of industry costs to industry revenues than to the ratio of industry costs to industry profits. However, if costs exceed either the threshold percentage of revenue or the threshold percentage of profits for an industry, or if there is other evidence of a threat to the viability of an industry because of the standard, OSHA will examine the effect of the rule on that industry more closely. Such an examination

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[7] See OSHA's web page, http://www.osha.gov/dea/lookback.html#Completed, for a link to all completed OSHA lookback reviews.

[8] See, for example, Table VI-3 and the accompanying text presented later in this chapter.

[9] See, for example, Table VI-5 and the accompanying text presented later in this chapter.

would include market factors specific to the industry, such as normal variations in prices and profits, international trade and foreign competition, and any special circumstances, such as close domestic substitutes of equal cost, which might make the industry particularly vulnerable to a regulatory cost increase.

The preceding discussion focused on the economic viability of the affected industries in their entirety. However, even if OSHA found that a standard did not threaten the survival of affected industries, there is still the question of whether the industries' competitive structure would be significantly altered. For example, if the annualized costs of an OSHA standard were equal to ten percent of an industry's annual profits, and the price elasticity of demand for the products in that industry were equal to one, then OSHA would not expect the industry to go out of business. However, if the increase in costs were such that most or all small firms in that industry would have to close, it could reasonably be concluded that the competitive structure of the industry had been altered. For this reason, OSHA also examines the differential costs by size of establishment.

Public Comments on OSHA Approach to Economic Feasibility

Some commenters were concerned that reductions of profits of less than ten percent could still represent major losses to an employer. For example, one commenter said:

> The proposed rule states that in no cases will the amount of revenue or profits exceed 8.8% noting that this number is easily passed to consumers in the form of increased product and service costs. For a rule as specific and slight as one affecting only silica dust inhalation, a reduction in profits by 8.8% should give the government pause (Document ID 2189, p. 1).

Another commenter expressed similar concerns about a reduction in profits of 4.8 percent (Document ID 1882, Attachment 1, p. 2). OSHA is not dismissive of losses in profits of less than ten percent. However, such losses need to be weighed against the OSH Act's objectives of occupational safety and health. For purposes of assessing economic feasibility, OSHA needs to be concerned with major dislocating effects on entire industries, which will not be the result of relatively small changes in profits. Further, as will be discussed below, these costs can likely be passed on to consumers.

API/IPAA, while disagreeing with OSHA's cost estimates, acknowledged that OSHA's use of the rules of thumb of ten percent of profits or one percent of revenues has been upheld in court (Document ID 2301, Attachment 1, pp. 62-63).

Some commenters were also concerned that OSHA's screening analysis methodology did not give adequate consideration to upfront costs (Document ID 2379, Attachment 3, p.

39; 2119, Attachment 3, p. 22). As will be discussed below, OSHA's choice of a threshold level of ten percent of annual profits is low enough that even if, in a hypothetical worst case, all compliance costs were upfront costs, then upfront costs would still equal 88.5 percent of profits and thus would be affordable from profits alone without needing to resort to credit markets. (If the cost exceeds 100 percent of profits then the company would have to borrow to pay the balance. Otherwise the firm will not have to borrow but could finance the cost internally.)

While not specifically addressed to the issue of the screening analysis, Mr. Sessions provided some estimates of how various percentage cost increases might interact with demand and supply elasticities to produce estimates of declines in total industry output. His estimates show that the decline in total revenues (and, in this situation, total production) associated with increased costs of one percent of revenues ranges from zero to 0.83 percent of total production (the range depending on the elasticities of supply and demand, with the highest impact on total revenues associated with a very unlikely price elasticity of ten) (Document ID 4231, Attachment 1, p. 31). Even the largest decline in revenues would result in only a 0.83 percent decline in revenues, which would not represent a major dislocation of any affected industry.[10] While OSHA does not necessarily endorse this particular approach to calculating changes in total revenue for given percentage change in costs, the calculation confirms OSHA's general view that increases of less than one percent of costs do not render a standard economically infeasible.

After reviewing these comments, OSHA has decided to retain its screening test of ten percent of profits and one percent of revenues as levels below which significant dislocation of an industry is extremely unlikely.

Regulatory Flexibility Screening Analysis

The Regulatory Flexibility Act (RFA), Pub. L. No. 96-354, 94 Stat. 1164 (codified at 5 U.S.C. 601), requires Federal agencies to consider the economic impact that a rulemaking will have on small entities. The RFA states that whenever an agency promulgates a final rule under section 553 of this title, after being required by that section or any other law to publish a general notice of proposed rulemaking the agency shall prepare a final regulatory flexibility analysis (FRFA). 5 U.S.C. 604(a). Pursuant to section 605(b), in lieu of an FRFA, the head of an agency may certify that the final rule will not have a significant economic impact on a substantial number of small entities. A certification

[10] Mr. Sessions's analysis assumes that profits will remain sufficient to assure the viability of the remaining firms in the industry. This is a common assumption in analyzing long run economic effects of a cost change.

must be supported by a factual basis. If the head of an agency makes a certification, the agency shall publish such certification in the Federal Register at the time of publication of the final rule. 5 U.S.C. 605(b). Thus, if OSHA cannot issue the required certification, it must prepare a FRFA.

OSHA makes its determination about whether it can issue the required certification by applying screening tests to consider minimum threshold effects of the rule on small entities. These screening tests are similar in concept to those OSHA described above to identify minimum threshold effects for the purposes of demonstrating economic feasibility and are discussed below.

There are, however, two differences. First, for each affected industry, the screening tests are applied, not to all establishments, but to small entities (defined as "small business concerns" by the Small Business Administration (SBA)) and also to very small entities (as defined by OSHA as small businesses with fewer than 20 employees). Second, although OSHA's regulatory flexibility screening test for revenues also uses a minimum threshold level of annualized costs equal to one percent of annual revenues, OSHA has established a minimum threshold level of annualized costs equal to five percent of annual profits for the average small entity or very small entity (rather than the ten percent threshold applicable for general economic feasibility screening). The Agency has chosen a lower minimum threshold level for the profitability screening analysis and has applied its screening tests to both small entities and very small entities in order to ensure that certification will be made, and an FRFA will not be prepared, only if OSHA can be highly confident that a final rule will not have a significant economic impact on a substantial number of small entities or very small entities in any affected industry.

OSHA has prepared separate regulatory flexibility screening tests for general industry, maritime, and construction.

IMPACTS IN GENERAL INDUSTRY AND MARITIME

In this section, OSHA will determine whether (1) the rule is economically feasible for all affected industries in general industry and maritime, and (2) the Agency can certify that the rule will not have a significant economic impact on a substantial number of small entities in general industry and maritime. OSHA concludes that the rule is economically feasible, but the Agency is unable to certify that it will not have a significant economic impact on a substantial number of small entities.

Economic Feasibility Screening Analysis: All Establishments

Earlier chapters of this FEA identified the general industry and maritime sectors potentially affected by the final rule; presented summary profile data for affected industries, including the number of affected entities and establishments, the number of at-risk workers, and the average revenue for affected entities and establishments; and developed estimates, by affected industry, of the costs of the rule. The economic impacts of the final rule on general industry and maritime are driven, in part, by the costs of additional dust control measures, respirators, and silica program activities needed to comply with the rule.

To determine whether the final rule's projected costs of compliance would threaten the economic viability of affected industries; OSHA first compared, for each affected industry, annualized compliance costs to annual revenues and profits per (average) affected establishment. The results for all affected establishments in all affected industries in general industry and maritime are presented in Table VI-1, using annualized costs per establishment for the PEL of 50 $\mu g/m^3$. Shown in the table for each affected industry are total annualized costs, the total number of affected establishments, annualized costs per affected establishment, annual revenues per establishment, the profit rate, annual profits per establishment, annualized compliance costs as a percentage of annual revenues, and annualized compliance costs as a percentage of annual profits.

The annualized costs per affected establishment for each affected industry were calculated by distributing the industry-level (incremental) annualized compliance costs among all affected establishments in the industry, where annualized compliance costs reflect a three percent discount rate.[11] Dividing the total compliance cost from Table VI-1 by the total number of affected establishments gives the annualized cost for the average establishment, $4,939 (370,810,530 / 75,074) in 2012 dollars.[12] It is clear from Table VI-1 that the estimates of the annualized costs per affected establishment in general industry and maritime vary widely from industry to industry. These estimates range from $220,558 for NAICS 213112 (Support Activities for Oil and Gas Operations) and $57,403 for NAICS 331511 (Iron Foundries) to $377 for NAICS 324121 (Asphalt Paving Mixture and Block Manufacturing) and $304 for NAICS 621210 (Offices of Dentists).

[11] Tables VI-A-1 and VI-A-2 in Appendix VI-A show per-establishment annualized costs and ratios of annualized cost to annual revenue and annualized costs to annual profit using discount rates of seven percent and zero percent, respectively, to annualize costs.

[12] This estimate excludes NAICS 482110 (Railroad transportation) because the number of railroad establishments was not provided in the Census data.

Additionally, OSHA estimated before-tax profit rates using corporate balance sheet data from the IRS's *Corporation Source Book* (IRS, 2012). For each of the years 2000 through 2012, OSHA calculated profit rates as the ratio of total receipts for all firms (profitable and unprofitable) to net income of all firms (profitable and unprofitable) by NAICS group and averaged profit rates across the 13-year (2000 through 2012) period.[13] Since some data provided by the IRS were not available at disaggregated levels for all industries and profit rates, data at more highly aggregated levels were used as proxy for such industries, that is, where data were not available for each six-digit NAICS code, corresponding four- and five-digit NAICS codes were used as appropriate.

As previously discussed, OSHA has established a minimum threshold level of annualized costs equal to one percent of annual revenues—and, secondarily, annualized costs equal to ten percent of annual profits—below which the Agency has concluded that costs are unlikely to threaten the economic viability of an affected industry. Table VI-1 shows that there are eight industries in which the annualized costs of the rule exceed ten percent of annual profits and none where annualized costs exceed one percent of annual revenues. NAICS 213112 (Support Activities for Oil and Gas Operations), has the highest cost impact as a percentage of revenues, of 0.56 percent. NAICS 327110 (Clay Building Materials and Refractories Manufacturing) has the highest cost impact as a percentage of profits, of 31.08 percent. For all affected establishments in general industry and maritime, the estimated annualized cost of the rule is, on average, equal to 0.06 percent of annual revenue and 2.43 percent of annual profits.

The industries with costs that exceed ten percent of profits are: NAICS 327120 - Clay Building Material and Refractories Manufacturing, 31 percent; NAICS 327110 - Pottery, Ceramics, and Plumbing Fixture Manufacturing, 31 percent; NAICS 327991 - Cut Stone and Stone Product Manufacturing, 24 percent; NAICS 327390 - Other Concrete Product Manufacturing, 17 percent; NAICS 327999 - All Other Miscellaneous Nonmetallic Mineral Product Manufacturing, 16 percent; NAICS 327332 – Concrete Pipe Manufacturing, 13 percent; NAICS 327331 Concrete Block and Brick Manufacturing, 13 percent; and NAICS 327320 Ready-Mix Concrete Manufacturing, 10 percent.

Based on the analysis that follows in the discussions of year-to-year variations and of international trade, OSHA finds that the final rule is economically feasible in these industries.

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[13] During the recession some industries had a negative "net income." The NAICS code 3361, Motor Vehicle Manufacturing, had a large negative "net income" for 2008 and 2009, pulling the average profit rate down to -0.05 percent, resulting in a negative cost to profit ratio.

Table VI-1 Screening Analysis for Establishments in General Industry and Maritime Affected by OSHA's Silica Standard

NAICS	Industry	Total Compliance Costs	Total Affected Establishments	Annual Cost per Affected Establishment	Annual Revenues per Establishment ($1000)	Percent Profit	Annual Profit per Establishment	Cost to Revenue	Cost to Profit
213112	Support Activities for Oil and Gas Operations	$97,927,752	16,960	$220,558	$39,182	7.09%	$2,777,295	0.56%	7.94%
324121	Asphalt Paving Mixture and Block Manufacturing	$513,042	4,737	$377	$9,646	5.96%	$574,834	0.00%	0.07%
324122	Asphalt Shingle and Coating Materials Manufacturing	$3,811,893	3,158	$17,094	$47,115	5.96%	$2,807,740	0.04%	0.61%
325510	Paint and Coating Manufacturing	$1,008,627	2,511	$1,306	$20,352	3.86%	$786,325	0.01%	0.17%
327110	Pottery, Ceramics, and Plumbing Fixture Manufacturing	$8,788,336	6,269	$13,417	$3,255	1.34%	$43,558	0.41%	30.80%
327120	Clay Building Material and Refractories Manufacturing	$21,252,204	7,893	$36,267	$8,720	1.34%	$116,694	0.42%	31.08%
327211	Flat Glass Manufacturing	$725,452	221	$13,063	$37,273	2.63%	$978,432	0.04%	1.34%
327212	Other Pressed and Blown Glass and Glassware Manufacturing	$2,208,578	674	$12,935	$7,550	2.63%	$198,200	0.17%	6.53%
327213	Glass Container Manufacturing	$2,212,672	686	$35,667	$51,795	2.63%	$1,359,618	0.07%	2.62%
327320	Ready-Mix Concrete Manufacturing	$30,004,503	27,123	$5,580	$3,787	1.43%	$54,169	0.15%	10.30%
327331	Concrete Block and Brick Manufacturing	$7,020,737	7,182	$8,593	$4,763	1.43%	$68,135	0.18%	12.61%
327332	Concrete Pipe Manufacturing	$3,810,088	3,967	$10,824	$5,720	1.43%	$81,834	0.19%	13.23%
327390	Other Concrete Product Manufacturing	$20,878,235	21,832	$10,582	$4,379	1.43%	$62,650	0.24%	16.89%
327991	Cut Stone and Stone Product Manufacturing	$14,628,182	9,429	$7,869	$1,890	1.75%	$33,122	0.42%	23.76%
327992	Ground or Treated Mineral and Earth Manufacturing	$4,288,421	5,432	$17,223	$13,360	1.75%	$234,143	0.13%	7.36%
327993	Mineral Wool Manufacturing	$2,615,391	789	$15,065	$17,671	1.75%	$309,697	0.09%	4.86%
327999	All Other Miscellaneous Nonmetallic Mineral Product Manufacturing	$11,597,806	7,952	$25,659	$8,951	1.75%	$156,869	0.29%	16.36%
331110	Iron and Steel Mills and Ferroalloy Manufacturing	$646,402	594	$2,307	$201,471	1.35%	$2,728,087	0.00%	0.08%
331210	Iron and Steel Pipe and Tube Manufacturing from Purchased Steel	$163,038	145	$1,476	$54,855	2.14%	$1,175,284	0.00%	0.13%
331221	Rolled Steel Shape Manufacturing	$51,060	44	$1,235	$35,875	2.14%	$768,643	0.00%	0.16%
331222	Steel Wire Drawing	$92,206	81	$1,185	$19,233	2.14%	$412,064	0.01%	0.29%
331314	Secondary Smelting and Alloying of Aluminum	$35,312	30	$1,159	$49,325	2.52%	$1,243,421	0.00%	0.09%
331420	Copper Rolling, Drawing, Extruding, and Alloying	$135,310	119	$1,269	$93,805	2.14%	$2,009,801	0.00%	0.06%
331492	Secondary Smelting, Refining, and Alloying of Nonferrous Metal (except Copper and Aluminum)	$70,791	62	$1,218	$55,758	2.14%	$1,194,643	0.00%	0.10%
331511	Iron Foundries	$23,362,955	13,583	$57,403	$26,576	4.36%	$1,157,952	0.22%	4.96%
331512	Steel Investment Foundries	$5,450,435	5,487	$42,582	$29,129	4.36%	$1,269,196	0.15%	3.35%
331513	Steel Foundries (except Investment)	$11,118,366	6,469	$53,454	$21,811	4.36%	$950,345	0.25%	5.62%
331524	Aluminum Foundries (except Die-Casting)	$4,120,657	5,601	$10,149	$6,972	4.36%	$303,783	0.15%	3.34%
331529	Other Nonferrous Metal Foundries (except Die-Casting)	$2,569,518	3,451	$8,565	$8,043	4.36%	$350,441	0.11%	2.44%
332111	Iron and Steel Forging	$154,626	136	$1,239	$29,983	3.81%	$1,141,045	0.00%	0.11%

Table VI-1 Screening Analysis for Establishments in General Industry and Maritime Affected by OSHA's Silica Standard (Continued)

NAICS	Industry	Total Compliance Costs	Total Affected Establishments	Annual Cost per Affected Establishment	Annual Revenues per Establishment ($1000)	Percent Profit	Annual Profit per Establishment	Cost to Revenue	Cost to Profit
332112	Nonferrous Forging	$40,101	35	$1,404	$38,519	3.81%	$1,465,896	0.00%	0.10%
332117	Powder Metallurgy Part Manufacturing	$52,988	46	$1,152	$15,217	3.81%	$579,097	0.01%	0.20%
332119	Metal Crown, Closure, and Other Metal Stamping (except Automotive)	$340,536	299	$1,182	$7,883	3.81%	$300,003	0.01%	0.39%
332215	Metal Kitchen Cookware, Utensil, Cutlery, and Flatware (except Precious) Manufacturing	$48,090	42	$1,315	$19,914	4.12%	$820,139	0.01%	0.16%
332216	Saw Blade and Handtool Manufacturing	$179,774	157	$1,223	$6,670	4.12%	$274,708	0.02%	0.45%
332323	Ornamental and Architectural Metal Work Manufacturing	$44,015	40	$1,098	$2,623	2.70%	$70,844	0.04%	1.55%
332439	Other Metal Container Manufacturing	$76,117	66	$1,228	$10,764	2.93%	$315,184	0.01%	0.39%
332510	Hardware Manufacturing	$171,563	150	$1,283	$12,347	4.63%	$572,156	0.01%	0.22%
332613	Spring Manufacturing	$96,006	84	$1,172	$9,172	4.63%	$425,023	0.01%	0.28%
332618	Other Fabricated Wire Product Manufacturing	$158,941	139	$1,163	$5,920	4.63%	$274,353	0.02%	0.42%
332710	Machine Shops	$1,580,507	1,387	$1,142	$2,015	4.63%	$93,386	0.06%	1.22%
332812	Metal Coating, Engraving (except Jewelry and Silverware), and Allied Services to Manufacturers	$3,443,786	4,113	$2,126	$5,226	2.96%	$154,661	0.04%	1.37%
332911	Industrial Valve Manufacturing	$229,195	201	$1,292	$23,997	5.95%	$1,428,175	0.01%	0.09%
332912	Fluid Power Valve and Hose Fitting Manufacturing	$219,774	196	$1,579	$27,901	5.95%	$1,660,504	0.01%	0.10%
332913	Plumbing Fixture Fitting and Trim Manufacturing	$49,483	43	$1,383	$32,065	5.95%	$1,908,358	0.00%	0.07%
332919	Other Metal Valve and Pipe Fitting Manufacturing	$92,474	80	$1,240	$19,968	5.95%	$1,188,418	0.01%	0.10%
332991	Ball and Roller Bearing Manufacturing	$145,507	127	$1,472	$38,700	5.95%	$2,303,203	0.00%	0.06%
332996	Fabricated Pipe and Pipe Fitting Manufacturing	$192,491	169	$1,203	$11,163	5.95%	$664,344	0.01%	0.18%
332999	All Other Miscellaneous Fabricated Metal Product Manufacturing	$460,336	405	$1,163	$4,158	5.95%	$247,481	0.03%	0.47%
333318	Other Commercial and Service Industry Machinery Manufacturing	$348,809	308	$1,350	$12,612	3.05%	$384,822	0.01%	0.35%
333413	Industrial and Commercial Fan and Blower and Air Purification Equipment Manufacturing	$156,056	136	$1,195	$12,256	3.00%	$367,965	0.01%	0.32%
333414	Heating Equipment (except Warm Air Furnaces) Manufacturing	$116,177	102	$1,144	$11,241	3.00%	$337,472	0.01%	0.34%
333511	Industrial Mold Manufacturing	$226,974	199	$1,168	$3,653	3.82%	$139,525	0.03%	0.84%
333514	Special Die and Tool, Die Set, Jig, and Fixture Manufacturing	$275,889	242	$1,170	$3,106	3.82%	$118,634	0.04%	0.99%
333515	Cutting Tool and Machine Tool Accessory Manufacturing	$183,291	161	$1,141	$3,474	3.82%	$132,676	0.03%	0.86%
333517	Machine Tool Manufacturing	$156,698	137	$1,216	$10,853	3.82%	$414,454	0.01%	0.29%
333519	Rolling Mill and Other Metalworking Machinery Manufacturing	$75,852	66	$1,220	$8,534	3.82%	$325,928	0.01%	0.37%
333612	Speed Changer, Industrial High-Speed Drive, and Gear Manufacturing	$102,884	91	$1,346	$20,704	1.99%	$411,587	0.01%	0.33%
333613	Mechanical Power Transmission Equipment Manufacturing	$100,450	88	$1,219	$19,069	1.99%	$379,071	0.01%	0.32%
333911	Pump and Pumping Equipment Manufacturing	$217,882	191	$1,321	$28,279	3.80%	$1,074,041	0.00%	0.12%

Table VI-1 Screening Analysis for Establishments in General Industry and Maritime Affected by OSHA's Silica Standard (Continued)

NAICS	Industry	Total Compliance Costs	Total Affected Establishments	Annual Cost per Affected Establishment	Annual Revenues per Establishment ($1000)	Percent Profit	Annual Profit per Establishment	Cost to Revenue	Cost to Profit
333912	Air and Gas Compressor Manufacturing	$135,840	120	$1,367	$34,028	3.80%	$1,292,380	0.00%	0.11%
333991	Power-Driven Handtool Manufacturing	$56,450	50	$1,515	$28,169	3.80%	$1,069,870	0.01%	0.14%
333992	Welding and Soldering Equipment Manufacturing	$98,775	89	$1,706	$17,097	3.80%	$649,359	0.01%	0.26%
333993	Packaging Machinery Manufacturing	$129,107	113	$1,199	$9,812	3.80%	$372,657	0.01%	0.32%
333994	Industrial Process Furnace and Oven Manufacturing	$71,404	62	$1,148	$7,795	3.80%	$296,067	0.01%	0.39%
333995	Fluid Power Cylinder and Actuator Manufacturing	$153,238	137	$1,448	$20,250	3.80%	$769,086	0.01%	0.19%
333996	Fluid Power Pump and Motor Manufacturing	$68,340	60	$1,341	$27,468	3.80%	$1,043,257	0.00%	0.13%
333997	Scale and Balance Manufacturing	$24,516	21	$1,169	$11,016	3.80%	$418,388	0.01%	0.28%
333999	All Other Miscellaneous General Purpose Machinery Manufacturing	$329,237	291	$1,261	$9,113	3.80%	$346,116	0.01%	0.36%
334519	Other Measuring and Controlling Device Manufacturing	$221,763	196	$1,354	$12,673	4.51%	$571,009	0.01%	0.24%
335210	Small Electrical Appliance Manufacturing	$24,524	24	$1,207	$26,870	4.01%	$1,078,458	0.00%	0.11%
335221	Household Cooking Appliance Manufacturing	$28,748	30	$1,956	$45,715	4.01%	$1,834,780	0.00%	0.11%
335222	Household Refrigerator and Home Freezer Manufacturing	$26,111	27	$2,363	$117,769	4.01%	$4,726,688	0.00%	0.05%
335224	Household Laundry Equipment Manufacturing	$12,403	13	$3,929	$101,337	4.01%	$4,067,200	0.00%	0.10%
335228	Other Major Household Appliance Manufacturing	$26,829	26	$2,273	$125,405	4.01%	$5,033,174	0.00%	0.05%
336111	Automobile Manufacturing	$362,562	354	$9,291	$600,655	-0.50%	-$3,026,184	0.00%	-0.31%
336112	Light Truck and Utility Vehicle Manufacturing	$324,735	319	$11,927	$1,521,927	-0.50%	-$7,667,681	0.00%	-0.16%
336120	Heavy Duty Truck Manufacturing	$183,916	174	$4,548	$354,849	-0.50%	-$1,787,779	0.00%	-0.25%
336211	Motor Vehicle Body Manufacturing	$260,377	229	$1,371	$15,229	1.30%	$197,621	0.01%	0.69%
336212	Truck Trailer Manufacturing	$180,129	160	$1,486	$19,658	1.30%	$255,102	0.01%	0.58%
336213	Motor Home Manufacturing	$45,680	42	$2,828	$39,044	1.30%	$506,657	0.01%	0.56%
336310	Motor Vehicle Gasoline Engine and Engine Parts Manufacturing	$334,051	298	$1,705	$37,520	1.30%	$486,887	0.00%	0.35%
336320	Motor Vehicle Electrical and Electronic Equipment Manufacturing	$315,816	283	$1,576	$30,162	1.30%	$391,403	0.01%	0.40%
336330	Motor Vehicle Steering and Suspension Components (except Spring) Manufacturing	$180,676	162	$1,677	$48,080	1.30%	$623,914	0.00%	0.27%
336340	Motor Vehicle Brake System Manufacturing	$140,620	123	$1,411	$51,448	1.30%	$667,628	0.00%	0.21%
336350	Motor Vehicle Transmission and Power Train Parts Manufacturing	$364,252	329	$1,859	$68,201	1.30%	$885,017	0.00%	0.21%
336370	Motor Vehicle Metal Stamping	$516,924	458	$1,457	$40,671	1.30%	$527,778	0.00%	0.28%
336390	Other Motor Vehicle Parts Manufacturing	$778,085	689	$1,527	$38,534	1.30%	$500,038	0.00%	0.31%
336611	Ship Building and Repairing	$9,586,384	3,038	$27,183	$36,357	6.06%	$2,204,764	0.07%	1.23%

Table VI-1 Screening Analysis for Establishments in General Industry and Maritime Affected by OSHA's Silica Standard (Continued)

NAICS	Industry	Total Compliance Costs	Total Affected Establishments	Annual Cost per Affected Establishment	Annual Revenues per Establishment ($1000)	Percent Profit	Annual Profit per Establishment	Cost to Revenue	Cost to Profit
336612	Boat Building	$2,566,768	787	$8,195	$8,054	6.06%	$488,437	0.10%	1.68%
336992	Military Armored Vehicle, Tank, and Tank Component Manufacturing	$69,849	62	$2,229	$81,906	4.03%	$3,304,704	0.00%	0.07%
337110	Wood Kitchen Cabinet and Countertop Manufacturing	$204,454	223	$993	$1,555	2.77%	$43,087	0.06%	2.31%
337215	Showcase, Partition, Shelving, and Locker Manufacturing	$215,675	189	$1,215	$5,949	2.77%	$164,853	0.02%	0.74%
339114	Dental Equipment and Supplies Manufacturing	$5,930,743	4,956	$8,158	$7,145	7.32%	$523,086	0.11%	1.56%
339116	Dental Laboratories	$6,857,347	31,105	$1,006	$676	7.32%	$49,470	0.15%	2.03%
339910	Jewelry and Silverware Manufacturing	$2,690,864	6,772	$1,270	$3,549	3.92%	$139,242	0.04%	0.91%
339950	Sign Manufacturing	$408,620	384	$1,124	$1,925	3.92%	$75,524	0.06%	1.49%
423840	Industrial Supplies Merchant Wholesalers	$2,292,917	1,773	$1,362	$8,430	2.98%	$251,560	0.02%	0.54%
444110	Home Centers	$110,386	107	$1,033	$2,122	6.05%	$128,360	0.05%	0.80%
482110	Rail transportation	$16,562,059	16,895	NA	NA	6.23%	NA	NA	NA
561730	Landscaping Services	$24,481,907	43,033	$942	$566	2.96%	$16,767	0.17%	5.62%
621210	Offices of Dentists	$2,592,207	8,525	$304	$787	7.78%	$61,216	0.04%	0.50%
	Totals	**$370,810,530**	**75,074**						

Source: OSHA, Directorate of Standards and Guidance, Office of Regulatory Analysis, based on ERG, 2015

Normal Year-to-Year Variations in Prices and Profit Rates

The United States has a dynamic and constantly changing economy in which an annual percentage changes in industry revenues or prices of one percent or more is common. Examples of year-to-year changes in an industry that could cause such variations in revenues or prices include increases in fuel, material, real estate, or other costs; tax increases; and shifts in demand.

Methodology

To demonstrate the normal year-to-year variation in prices for all the manufacturers in general industry and maritime affected by the rule, OSHA developed Table VI-2 and Table VI-3, which show, respectively, year-to-year producer price indices and year-to-year percentage changes in producer prices, by industry, for the years 2004 through 2014. For the combined affected manufacturing industries in general industry and maritime over the 11-year period, Table VI-3 shows an average change in producer prices of 2.7 percent a year. For the industries in general industry and maritime with the largest estimated potential annual cost impact as a percentage of revenue—NAICS 213112 – Support Activities for Oil and Gas Operations, 0.56 percent; and NAICS 327991 - Cut Stone and Stone Product Manufacturing, 0.42 percent—the average annual changes in producer prices in these industries over the 12-year period were, respectively, 3.8 percent, and 0.5 percent.

Based on these data, it is clear that the potential cost impacts of the rule in general industry and maritime are all well within normal year-to-year variations in prices in those industries. The maximum cost impact of the rule as a percentage of revenue in any affected industry is 0.56 percent, while the average annual change in producer prices for affected industries was 2.7 percent for the period 2004 through 2014 (changed from 1998 to 2009 in the PEA). Furthermore, even a casual examination of Table VI-3 reveals that annual changes in producer prices in excess of five or even ten percent are possible without threatening an industry's economic viability. Thus, OSHA concludes that the potential price impacts of the rule would not threaten the economic viability of any industries in general industry and maritime.

Changes in profit rates are also subject to the dynamics of the U.S. economy. A recession, a downturn in a particular industry, foreign competition, or the increased competitiveness of producers of close domestic substitutes are all easily capable of causing a decline in profit rates in an industry of well in excess of ten percent in one year or for several years in succession.

To demonstrate the normal year-to-year variation in profit rates for all the manufacturers in general industry and maritime affected by the rule, OSHA developed Table VI-4 and Table VI-5, which show, respectively, year-to-year profit rates and year-to-year percentage changes in profit rates, by industry, for the years 2000 through 2012. For the combined affected manufacturing industries in general industry and maritime over the thirteen-year period, OSHA calculated an average change in profit rates of 138.5 percent a year (average for all industries calculated from the per-NAICS averages shown in Table VI-5). For the industries in general industry and maritime with the largest estimated potential annual cost impacts as a percentage of profit— NAICS 327120 - Clay Building Material and Refractories Manufacturing, 31 percent; NAICS 327110 - Pottery, Ceramics, and Plumbing Fixture Manufacturing, 31 percent; NAICS 327991 - Cut Stone and Stone Product Manufacturing, 24 percent—the average annual percentage changes in profit rates in these industries over the 13-year period were, respectively, 951 percent, 951 percent, and 113 percent.

One complicating factor is that the annualized costs of the rule, if absorbed in lost profits, would involve not just a temporary loss of profits but a longer term negative effect on profits relative to the baseline. To address this issue, the Agency compared the effect of a longer term reduction in profits to much larger reductions in profits but over shorter periods. Assuming a three-percent discount rate, the Agency determined a ten percent decline in profit rates relative to the original baseline, which remains constant at that lower level over a ten-year period, would be equivalent to:[14]

- an 88.5 percent decline in profit rates for one year;
- a 44.5 percent decline in profit rates that remains constant at the lower level for two years; or
- a 30 percent decline in profit rates that remains constant at the lower level for three years.[15]

[14] Note that the reduction in profits rates over time, as a result of the rule, is being measured here relative to the baseline. If the reduction in profit rates were made relative to the previous year, as is done in Table VI-5 below, then there would be only a one-time reduction in the profit rate in year one as a result of the rule, after which the profit rate would reach a new (lower) level but would not change from year to year.

[15] Assuming a seven-percent discount rate, a ten-percent decline in profit rates over the ten-year annualization period would be equivalent to: a 75-percent decline in profit rates for one year; a 39-percent decline in profit rates that remains constant at the lower level for two years; or a 27-percent decline in profit rates that remains constant at the lower level for three years.

An examination of Table VI-5, for the thirteen year period from 2000 to 2012, clearly shows that short-run changes in average industry profit rates of the above magnitudes have occurred on numerous occasions in general industry and maritime, without threatening the economic viability of the affected industries. For this reason, OSHA is confident that potential profit rate impacts of ten percent or less as a result of the rule would not threaten the economic viability of the affected industries in general industry and maritime.

A longer-term loss of profits in excess of ten percent a year could be more problematic for some affected industries and might conceivably, under sufficiently adverse circumstances, threaten an industry's economic viability. In OSHA's view, however, affected industries would generally be able to pass on most or all of the costs of the rule in the form of higher prices rather than bear the costs of the rule in reduced profits. In other words, the demand for the goods and services produced by affected industries in general industry and maritime do not appear to be perfectly elastic or close to it. While there are substitutes for these products, there are no perfect substitutes that would lead the price elasticity to be extremely high. As a result, the demand for quantities of brick and structural clay, vitreous china, ceramic wall and floor tile, other structural clay products (such as clay sewer pipe), and the various other products manufactured by affected industries would not significantly contract in response to a 0.48 percent (or lower) price increase for these products. It is of course possible that such price changes will result in some reduction in output, and the reduction in output might be met through the closure of a small percentage of the plants in the industry. However, the only realistic circumstance under which an entire industry would be significantly affected by small price increases would be the availability in the market of a very close or perfect substitute product not subject to OSHA regulation. The classic example, in theory, would be foreign competition. In the following discussion, OSHA examines the threat of foreign competition for affected U.S. establishments in general industry and maritime, and concludes that it is unlikely to threaten the viability of any affected industry.

Public Comments on Year-to-Year Variations in Prices and Profit Rates

The American Chemistry Council (ACC) stated, with respect to a similar analysis in the PEA, that short-term volatility within an industry sector is of little value in projecting what will happen when a new regulation resets the baseline for profits and revenue because OSHA is comparing short-term changes to long-term changes (Document ID 2307, Attachment 2, p. 196). Another commenter made the similar point that year-to-year fluctuations cannot be compared to long-term changes (Document ID 2308, Attachment 9, p. 7).

OSHA first examines the issue of changes in prices over time. Such changes, on the whole, represent pass through of changes in costs, since profits are not continually rising. These changes in costs are not "fluctuations" with upward and downward shifts in prices.

For almost all industries these changes in costs are continuing upward shifts that average each year much larger changes than the maximum price change any industry will need to incur in order to comply with the silica rule.

For variations in profits, these are indeed fluctuations and profits do indeed both rise and fall. However, if, as the commenters argue only long-term average profits matter, then we could reach the very counterintuitive result that there should be no excess plant closures during recessions. This is not the case because long-term profits are, in fact, nothing more than a prediction and the present value of long term profits will be different at the beginning than at the end of a recession. Recognizing these timing effects is why OSHA examined the annualized value of losses in profits associated with the recession beginning 2008 and compared it to the annualized value of the loss in profits as result of costs of this standard. While temporary and permanent losses are different, the use of discounting enables us to compare short- and long-term losses.

Table VI-2: Time Series of Producer Prices for Industries in General Industry and Maritime Affected by OSHA's Final Silica Standard

NAICS	Industry	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
213112	Support Activities for Oil and Gas Operations	141.8	161.3	187.6	194.3	196.9	181.5	178.3	190.3	196.5	199.3	199.3
324121	Asphalt Paving Mixture and Block Manufacturing	149.9	162.3	203.7	221.6	269.1	271.2	282.1	298.5	318.1	319.1	325.5
324122	Asphalt Shingle and Coating Materials Manufacturing	121.6	133.9	147.5	149.2	185.4	219.2	220.4	231.4	232.2	237.7	233.2
325314	Fertilizer (Mixing Only) Manufacturing	156.7	169	174.5	191.3	274.9	237.5	209.8	230.8	235.1	223.9	226.4
325510	Paint and Coating Manufacturing	174.7	187.2	200.8	209	223.2	236.8	237.3	249.5	269.8	273.2	275.4
327110	Pottery, Ceramics, and Plumbing Fixture Manufacturing	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	101.6	103	104.8
327120	Clay Building Material and Refractories Manufacturing	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	100.6	102.4	103.3
327211	Flat Glass Manufacturing	93.9	96.3	96.7	96.2	98.6	94.8	91.1	90.1	89	91.3	94.1
327212	Other Pressed and Blown Glass and Glassware Manufacturing	127.4	128.1	127.6	128.5	130.7	132.7	133.7	132	133.8	133.9	132.2
327213	Glass Container Manufacturing	142	143.9	150.2	159.3	169.5	176.7	179.2	182.2	185.6	187.8	190.8
327320	Ready-Mix Concrete Manufacturing	162.1	181.9	202.5	210.3	216.7	222.1	216.6	215.2	220.1	226.9	236.8
327331	Concrete Block and Brick Manufacturing	173.4	186.6	200	208.6	213.7	217.6	215.9	216.5	218.2	221.9	227.8
327332	Concrete Pipe Manufacturing	103	108.3	115.3	118.4	131.3	129.2	124.5	127.6	130.5	135.2	139.8
327390	Other Concrete Product Manufacturing	104.7	111.3	121	126.6	132.2	131.4	132.4	133.8	135.9	139	143
327991	Cut Stone and Stone Product Manufacturing	149.5	151.6	153.9	154.3	155.7	154.5	154.5	154.3	154.4	155.3	158.9
327992	Ground or Treated Mineral and Earth Manufacturing	141.9	149.6	162.1	168.5	179.6	204	211.1	221.6	231.6	239.8	252.7
327993	Mineral Wool Manufacturing	140.8	146.7	154.7	150	144.8	145.8	149	169	180	189.6	200.8

Table VI-2: Time Series of Producer Prices for Industries in General Industry and Maritime Affected by OSHA's Final Silica Standard (continued)

NAICS	Industry	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
327999	All Other Miscellaneous Nonmetallic Mineral Product Manufacturing	102.2	107.3	115.5	123	126.5	128.2	127.7	131.9	135.2	137.3	140.9
331110	Iron and Steel Mills and Ferroalloy Manufacturing	136.4	145.9	161.5	172	202.5	147.8	175.1	197	188.2	176.8	183
331210	Iron and Steel Pipe and Tube Manufacturing from Purchased Steel	211.1	228.9	234.6	240.1	295.2	235.5	272.5	315.3	314.1	295.1	294.2
331221	Rolled Steel Shape Manufacturing	148.8	168.6	168.9	171.7	222	183.7	187.5	206.9	199.3	189.5	193.9
331222	Steel Wire Drawing	153.8	164.8	167.3	169.8	215.9	190.1	188.3	199.8	200.4	197.1	196.1
331314	Secondary Smelting and Alloying of Aluminum	108.9	112.2	137.2	144.1	148.5	108.6	133.5	145.5	130.4	128.3	132.4
331420	Copper Rolling, Drawing, Extruding, and Alloying	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	99	94.1	90.9
331492	Secondary Smelting, Refining, and Alloying of Nonferrous Metal (except Copper and Aluminum)	109.5	123.2	155.7	188.4	194.8	178.3	202.8	238.8	231.3	218.2	206.6
331511	Iron Foundries	158.7	173.4	181.2	188.5	218.6	210.9	222.3	237.8	247.5	248.4	249.8
331512	Steel Investment Foundries	197.7	204.8	216	235.4	235.4	235.4	234.6	242.5	245.1	246.9	249.3
331513	Steel Foundries (except Investment)	146.2	160.1	170.5	183.7	193.4	191.4	198.2	205.1	213.5	217.1	218
331524	Aluminum Foundries (except Die-Casting)	119.9	124.3	133.1	140.8	150.5	152.2	155.9	157.1	158	157.8	157.4
331529	Other Nonferrous Metal Foundries (except Die-Casting)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	101.7	102	101.6
332111	Iron and Steel Forging	117.5	128.1	133.9	140.4	150.9	148.6	150.6	157.5	159.1	158.2	160.6
332112	Nonferrous Forging	145.8	149.3	158.1	163	165.7	164.2	156.8	158.1	154.9	152.1	151.4
332117	Powder Metallurgy Part Manufacturing	100.6	101.8	104.4	106.2	110.8	N/A	115.4	120.7	121.5	120.4	120.3
332119	Metal Crown, Closure, and Other Metal Stamping (except Automotive)	142	149.2	154.2	162.9	175.9	172.6	173.9	183.4	182.9	183	183.8

Table VI-2: Time Series of Producer Prices for Industries in General Industry and Maritime Affected by OSHA's Final Silica Standard (continued)

NAICS	Industry	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
332215	Metal Kitchen Cookware, Utensil, Cutlery, and Flatware (except Precious) Manufacturing	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	101.4	102.6	104.3
332216	Saw Blade and Handtool Manufacturing	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	101.3	103.1	103.9
332323	Ornamental and Architectural Metal Work Manufacturing	173.3	185.1	191.9	199.6	224.4	230.8	230.3	239.4	243.6	246.6	251.7
332439	Other Metal Container Manufacturing	111.7	120.2	127	128.1	145.1	138.8	135.7	140	141.4	141.1	142.6
332510	Hardware Manufacturing	138.7	143.8	148.5	154.7	164.2	167.8	169.9	175.5	177.8	178.3	181.2
332613	Spring Manufacturing	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	101.3	102	103.3
332618	Other Fabricated Wire Product Manufacturing	148.2	154.7	161.4	167.1	197.1	199.5	208.3	218.5	223.1	224.3	226.3
332710	Machine Shops	136.1	142.8	146.1	149.5	158.9	163.2	163	167.2	169.9	170.4	170.5
332812	Metal Coating, Engraving (except Jewelry and Silverware), and Allied Services to Manufacturers	126.7	129.5	140.7	149	151.9	145.9	150.3	155.4	158.4	159	161
332911	Industrial Valve Manufacturing	135.5	145.1	158.2	172.8	182.9	187.2	190	200.2	209.8	215.7	223
332912	Fluid Power Valve and Hose Fitting Manufacturing	136.7	146.1	154.9	162.3	168.7	175.7	178.8	186.1	191.9	194.7	196.5
332913	Plumbing Fixture Fitting and Trim Manufacturing	192.4	200	209.6	225.2	234.7	236.3	238.1	246.7	252	259.2	263.7
332919	Other Metal Valve and Pipe Fitting Manufacturing	173.6	187.6	205.4	216.5	225.9	235.9	235.2	237.2	241.9	243.8	247
332991	Ball and Roller Bearing Manufacturing	177.3	186.9	194.4	202.2	214	225.3	230	238.5	246.7	252.7	258.5
332996	Fabricated Pipe and Pipe Fitting Manufacturing	187.4	206.1	217.3	214.3	230.5	242.5	268.7	286.1	297.2	300.5	305.9
332999	All Other Miscellaneous Fabricated Metal Product Manufacturing	102.5	106.1	111.1	114	118.8	123.4	125	129	130.6	131.2	132.7

Table VI-2: Time Series of Producer Prices for Industries in General Industry and Maritime Affected by OSHA's Final Silica Standard (continued)

NAICS	Industry	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
333318	Other Commercial and Service Industry Machinery Manufacturing	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	100.9	102.4	105
333413	Industrial and Commercial Fan and Blower and Air Purification Equipment Manufacturing	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	101.6	102.9	105.5
333414	Heating Equipment (except Warm Air Furnaces) Manufacturing	206.2	215.4	222.3	231.2	245.7	255.3	257.2	264.3	271.9	276	280.1
333511	Industrial Mold Manufacturing	99.3	101.6	103.5	103.3	103.2	102.4	101.8	102.2	102.9	103.8	104.3
333514	Special Die and Tool, Die Set, Jig, and Fixture Manufacturing	100.4	100.2	100.6	101.2	103	102.5	102.1	104.7	106.5	107.7	108.4
333515	Cutting Tool and Machine Tool Accessory Manufacturing	144.5	150.5	156.9	158.9	161.6	164.9	166.3	172.7	175.9	177	180.2
333517	Machine Tool Manufacturing	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	102.1	105.4	107.3
333519	Rolling Mill and Other Metalworking Machinery Manufacturing	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	99.7	99.9	100.5
333612	Speed Changer, Industrial High-Speed Drive, and Gear Manufacturing	182.6	193.3	201.1	211.2	225.8	233.6	233.2	247.6	258.1	266	268.8
333613	Mechanical Power Transmission Equipment Manufacturing	168.4	177.9	185.8	192.6	206.4	222.4	224.6	232.6	239.1	243.9	244.8
333911	Pump and Pumping Equipment Manufacturing	179.5	190.1	199.5	210.7	219.8	224.6	227.4	232.4	239.2	241.6	246.9
333912	Air and Gas Compressor Manufacturing	151.2	161	165.8	171.7	181	188.3	190.1	200.2	205.7	212.4	217.6
333991	Power-Driven Handtool Manufacturing	174.5	176.1	175.2	176.3	179	180	178.7	179.8	184.5	185.7	188.3
333992	Welding and Soldering Equipment Manufacturing	171.2	182.7	191.5	203.6	217.5	222.4	225	236.4	244.3	248.3	252.2
333993	Packaging Machinery Manufacturing	141.6	145	147.9	150.1	162.4	172.5	177.1	180.7	185.4	189.5	197.2
333994	Industrial Process Furnace and Oven Manufacturing	170.5	174.6	180.2	185.8	194.6	197.6	199.3	203.5	207	210.3	214.8

Table VI-2: Time Series of Producer Prices for Industries in General Industry and Maritime Affected by OSHA's Final Silica Standard (continued)

NAICS	Industry	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
333995	Fluid Power Cylinder and Actuator Manufacturing	142.8	151.5	158.4	163.9	173.9	177.9	180	184	188.2	189.9	191.7
333996	Fluid Power Pump and Motor Manufacturing	130.8	133.9	140.3	145.1	155.2	161.4	166.6	171	177.3	181	184.4
333997	Scale and Balance Manufacturing	126.9	129	130.1	131.9	136	140.7	142	146.1	151.6	154.4	157.8
333999	All Other Miscellaneous General Purpose Machinery Manufacturing	165.5	169	173.5	178.6	187.3	195.5	197.8	205.3	211	216.4	221.6
334519	Other Measuring and Controlling Device Manufacturing	144	145.8	147.4	149.4	151.3	154	154	155.1	157.5	158.7	160.2
335210	Small Electrical Appliance Manufacturing	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	102.5	103.7	103.9
335221	Household Cooking Appliance Manufacturing	105.7	108.5	111.1	112.4	115.9	122.7	122.9	124.6	131.8	131.9	132
335222	Household Refrigerator and Home Freezer Manufacturing	96.6	99.1	99.8	101.1	105.1	109.4	105.8	106.9	110.7	111.9	110.6
335224	Household Laundry Equipment Manufacturing	129.2	130	128.8	126.7	127.4	130	130.6	130.4	139.4	136.2	135.8
335228	Other Major Household Appliance Manufacturing	150.2	163.4	169	174.5	187.3	201.6	205.1	210.6	215.2	218	220.1
336111	Automobile Manufacturing	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
336112	Light Truck and Utility Vehicle Manufacturing	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
336120	Heavy Duty Truck Manufacturing	102.2	106.4	110.4	115.5	118.9	124.4	128.1	131.2	134.6	136.8	139.3
336211	Motor Vehicle Body Manufacturing	176.7	190.3	200	205	212	216.4	217.7	220.9	225.9	227.7	231.1
336212	Truck Trailer Manufacturing	166.2	176.2	184.5	190.2	199.1	200.9	205.6	215.5	221.5	221	223.2
336213	Motor Home Manufacturing	163.8	169.3	166.6	171.1	174.6	170.7	168.5	170.4	174.9	178.4	179
336310	Motor Vehicle Gasoline Engine and Engine Parts Manufacturing	101.4	102.5	111.5	113.1	116	103.7	108.2	113	114.7	114.8	114.2

Table VI-2: Time Series of Producer Prices for Industries in General Industry and Maritime Affected by OSHA's Final Silica Standard (continued)

NAICS	Industry	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
336320	Motor Vehicle Electrical and Electronic Equipment Manufacturing	99.8	101.7	102.5	103.7	102.9	102.9	103.4	105	106	106	106.8
336330	Motor Vehicle Steering and Suspension Components (except Spring) Manufacturing	101.7	104.9	106.1	104.8	106.3	105.1	105.7	106.5	107.2	106.8	106.6
336340	Motor Vehicle Brake System Manufacturing	99.6	100.3	101.2	101.6	103.4	104.5	104.2	107.1	108.8	108.4	107.6
336350	Motor Vehicle Transmission and Power Train Parts Manufacturing	100.9	101.2	103.2	105.9	108.1	112.7	113.8	114.6	117	118.4	120.1
336370	Motor Vehicle Metal Stamping	118.5	120.4	120.9	124.2	128.1	131.3	129.2	128.8	128.7	128.4	128.1
336390	Other Motor Vehicle Parts Manufacturing	100.6	101.9	102.5	104.4	108.4	109.5	112.4	115.1	116.1	116	115.4
336611	Ship Building and Repairing	159.8	163.9	169.9	177	181.6	187.4	191.1	195	196.4	196.7	200.3
336612	Boat Building	198	206.7	214.1	220.9	228.4	233.4	237.4	241.2	246.7	253.1	259
336992	Military Armored Vehicle, Tank, and Tank Component Manufacturing	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
337110	Wood Kitchen Cabinet and Countertop Manufacturing	170.6	174.3	179.5	183.1	187.7	191.5	191.5	194.5	198.3	204.2	209.4
337215	Showcase, Partition, Shelving, and Locker Manufacturing	110.7	118.8	119.4	120.9	126	128.7	129.3	133.5	136.2	137.2	138.7
339114	Dental Equipment and Supplies Manufacturing	203.2	212	229.8	238	248.9	253.4	271.4	305.4	310.3	322.9	328.9
339116	Dental Laboratories	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
339910	Jewelry and Silverware Manufacturing	0	0	0	0	0	0	0	0	101.3	101.2	94.7
339950	Sign Manufacturing	146.7	152.1	155.4	158.6	161.7	162.2	162.9	163.9	165.6	167.8	169.8
423840	Industrial Supplies Merchant Wholesalers	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
444110	Home Centers	107	109.6	122.5	121.8	115.7	118.4	115.9	115.9	119.2	128.6	125.7
482110	Rail transportation	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

Table VI-2: Time Series of Producer Prices for Industries in General Industry and Maritime Affected by OSHA's Final Silica Standard (continued)

NAICS	Industry	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
621210	Offices of Dentists	N/A	N/A	N/A	N/A	N/A	N/A	N/A	102	103.8	105.7	107.2

Source: OSHA, Directorate of Standards and Guidance, Office of Regulatory Analysis, based on ERG, 2011 and BLS, 2015

Table VI-3: Annual Percentage Change in Producer Prices for Industries in General Industry and Maritime Affected by OSHA's Final Silica Standard

NAICS	Industry	2003-2004	2004-2005	2005-2006	2006-2007	2007-2008	2008-2009	2009-2010	2010-2011	2011-2012	2012-2013	2013-2014	Average Annual Change
213112	Support Activities for Oil and Gas Operations	4.6%	13.8%	16.3%	3.6%	1.3%	-7.8%	-1.8%	6.7%	3.3%	1.4%	0.0%	3.8%
324121	Asphalt Paving Mixture and Block Manufacturing	1.9%	8.3%	25.5%	8.8%	21.4%	0.8%	4.0%	5.8%	6.6%	0.3%	2.0%	7.8%
324122	Asphalt Shingle and Coating Materials Manufacturing	1.1%	10.1%	10.2%	1.2%	24.3%	18.2%	0.5%	5.0%	0.3%	2.4%	-1.9%	6.5%
325314	Fertilizer (Mixing Only) Manufacturing	5.0%	7.8%	3.3%	9.6%	43.7%	-13.6%	-11.7%	10.0%	1.9%	-4.8%	1.1%	4.8%
325510	Paint and Coating Manufacturing	3.3%	7.2%	7.3%	4.1%	6.8%	6.1%	0.2%	5.1%	8.1%	1.3%	0.8%	4.6%
327110	Pottery, Ceramics, and Plumbing Fixture Manufacturing	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1.4%	1.7%	1.6%
327120	Clay Building Material and Refractories Manufacturing	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1.8%	0.9%	1.3%
327211	Flat Glass Manufacturing	-1.9%	2.6%	0.4%	-0.5%	2.5%	-3.9%	-3.9%	-1.1%	-1.2%	2.6%	3.1%	-0.1%
327212	Other Pressed and Blown Glass and Glassware Manufacturing	-2.3%	0.5%	-0.4%	0.7%	1.7%	1.5%	0.8%	-1.3%	1.4%	0.1%	-1.3%	0.1%
327213	Glass Container Manufacturing	3.0%	1.3%	4.4%	6.1%	6.4%	4.2%	1.4%	1.7%	1.9%	1.2%	1.6%	3.0%

Table VI-3: Annual Percentage Change in Producer Prices for Industries in General Industry and Maritime Affected by OSHA's Final Silica Standard (continued)

NAICS	Industry	2003-2004	2004-2005	2005-2006	2006-2007	2007-2008	2008-2009	2009-2010	2010-2011	2011-2012	2012-2013	2013-2014	Average Annual
327320	Ready-Mix Concrete Manufacturing	5.3%	12.2%	11.3%	3.9%	3.0%	2.5%	-2.5%	-0.6%	2.3%	3.1%	4.4%	4.1%
327331	Concrete Block and Brick Manufacturing	3.6%	7.6%	7.2%	4.3%	2.4%	1.8%	-0.8%	0.3%	0.8%	1.7%	2.7%	2.9%
327332	Concrete Pipe Manufacturing	N/A	5.1%	6.5%	2.7%	10.9%	-1.6%	-3.6%	2.5%	2.3%	3.6%	3.4%	3.2%
327390	Other Concrete Product Manufacturing	N/A	6.3%	8.7%	4.6%	4.4%	-0.6%	0.8%	1.1%	1.6%	2.3%	2.9%	3.2%
327991	Cut Stone and Stone Product Manufacturing	-0.1%	1.4%	1.5%	0.3%	0.9%	-0.8%	0.0%	-0.1%	0.1%	0.6%	2.3%	0.5%
327992	Ground or Treated Mineral and Earth Manufacturing	1.9%	5.4%	8.4%	3.9%	6.6%	13.6%	3.5%	5.0%	4.5%	3.5%	5.4%	5.6%
327993	Mineral Wool Manufacturing	6.8%	4.2%	5.5%	-3.0%	-3.5%	0.7%	2.2%	13.4%	6.5%	5.3%	5.9%	4.0%
327999	All Other Miscellaneous Nonmetallic Mineral Product Manufacturing	N/A	5.0%	7.6%	6.5%	2.8%	1.3%	-0.4%	3.3%	2.5%	1.6%	2.6%	3.3%
331110	Iron and Steel Mills and Ferroalloy Manufacturing	N/A	7.0%	10.7%	6.5%	17.7%	-27.0%	18.5%	12.5%	-4.5%	-6.1%	3.5%	3.9%
331210	Iron and Steel Pipe and Tube Manufacturing from Purchased Steel	49.4%	8.4%	2.5%	2.3%	22.9%	-20.2%	15.7%	15.7%	-0.4%	-6.0%	-0.3%	8.2%

Table VI-3: Annual Percentage Change in Producer Prices for Industries in General Industry and Maritime Affected by OSHA's Final Silica Standard (continued)

NAICS	Industry	2003-2004	2004-2005	2005-2006	2006-2007	2007-2008	2008-2009	2009-2010	2010-2011	2011-2012	2012-2013	2013-2014	Average Annual
331221	Rolled Steel Shape Manufacturing	26.1%	13.3%	0.2%	1.7%	29.3%	-17.3%	2.1%	10.3%	-3.7%	-4.9%	2.3%	5.4%
331222	Steel Wire Drawing	26.1%	7.2%	1.5%	1.5%	27.1%	-11.9%	-0.9%	6.1%	0.3%	-1.6%	-0.5%	5.0%
331314	Secondary Smelting and Alloying of Aluminum	N/A	3.0%	22.3%	5.0%	3.1%	-26.9%	22.9%	9.0%	-10.4%	-1.6%	3.2%	3.0%
331420	Copper Rolling, Drawing, Extruding, and Alloying	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	-4.9%	-3.4%	-4.2%
331492	Secondary Smelting, Refining, and Alloying of Nonferrous Metal (except Copper and Aluminum)	N/A	12.5%	26.4%	21.0%	3.4%	-8.5%	13.7%	17.8%	-3.1%	-5.7%	-5.3%	7.2%
331511	Iron Foundries	6.0%	9.3%	4.5%	4.0%	16.0%	-3.5%	5.4%	7.0%	4.1%	0.4%	0.6%	4.9%
331512	Steel Investment Foundries	-1.1%	3.6%	5.5%	9.0%	0.0%	0.0%	-0.3%	3.4%	1.1%	0.7%	1.0%	2.1%
331513	Steel Foundries (except Investment)	6.3%	9.5%	6.5%	7.7%	5.3%	-1.0%	3.6%	3.5%	4.1%	1.7%	0.4%	4.3%
331524	Aluminum Foundries (except Die-Casting)	2.9%	3.7%	7.1%	5.8%	6.9%	1.1%	2.4%	0.8%	0.6%	-0.1%	-0.3%	2.8%
331529	Other Nonferrous Metal Foundries (except Die-Casting)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0.3%	-0.4%	0.0%
332111	Iron and Steel Forging	4.2%	9.0%	4.5%	4.9%	7.5%	-1.5%	1.3%	4.6%	1.0%	-0.6%	1.5%	3.3%
332112	Nonferrous Forging	0.3%	2.4%	5.9%	3.1%	1.7%	-0.9%	-4.5%	0.8%	-2.0%	-1.8%	-0.5%	0.4%

Table VI-3: Annual Percentage Change in Producer Prices for Industries in General Industry and Maritime Affected by OSHA's Final Silica Standard (continued)

NAICS	Industry	2003-2004	2004-2005	2005-2006	2006-2007	2007-2008	2008-2009	2009-2010	2010-2011	2011-2012	2012-2013	2013-2014	Average Annual
332117	Powder Metallurgy Part Manufacturing	N/A	1.2%	2.6%	1.7%	4.3%	N/A	N/A	4.6%	0.7%	-0.9%	-0.1%	1.8%
332119	Metal Crown, Closure, and Other Metal Stamping (except Automotive)	8.1%	5.1%	3.4%	5.6%	8.0%	-1.9%	0.8%	5.5%	-0.3%	0.1%	0.4%	3.2%
332215	Metal Kitchen Cookware, Utensil, Cutlery, and Flatware (except Precious) Manufacturing	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1.2%	1.7%	1.4%
332216	Saw Blade and Handtool Manufacturing	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1.8%	0.8%	1.3%
332323	Ornamental and Architectural Metal Work Manufacturing	15.1%	6.8%	3.7%	4.0%	12.4%	2.9%	-0.2%	4.0%	1.8%	1.2%	2.1%	4.9%
332439	Other Metal Container Manufacturing	N/A	7.6%	5.7%	0.9%	13.3%	-4.3%	-2.2%	3.2%	1.0%	-0.2%	1.1%	2.6%
332510	Hardware Manufacturing	3.7%	3.7%	3.3%	4.2%	6.1%	2.2%	1.3%	3.3%	1.3%	0.3%	1.6%	2.8%
332613	Spring Manufacturing	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0.7%	1.3%	1.0%
332618	Other Fabricated Wire Product Manufacturing	9.7%	4.4%	4.3%	3.5%	18.0%	1.2%	4.4%	4.9%	2.1%	0.5%	0.9%	4.9%
332710	Machine Shops	3.0%	4.9%	2.3%	2.3%	6.3%	2.7%	-0.1%	2.6%	1.6%	0.3%	0.1%	2.4%

Table VI-3: Annual Percentage Change in Producer Prices for Industries in General Industry and Maritime Affected by OSHA's Final Silica Standard (continued)

NAICS	Industry	2003-2004	2004-2005	2005-2006	2006-2007	2007-2008	2008-2009	2009-2010	2010-2011	2011-2012	2012-2013	2013-2014	Average Annual
332812	Metal Coating, Engraving (except Jewelry and Silverware), and Allied Services to Manufacturers	3.2%	2.2%	8.6%	5.9%	1.9%	-3.9%	3.0%	3.4%	1.9%	0.4%	1.3%	2.5%
332911	Industrial Valve Manufacturing	4.4%	7.1%	9.0%	9.2%	5.8%	2.4%	1.5%	5.4%	4.8%	2.8%	3.4%	5.1%
332912	Fluid Power Valve and Hose Fitting Manufacturing	2.9%	6.9%	6.0%	4.8%	3.9%	4.1%	1.8%	4.1%	3.1%	1.5%	0.9%	3.6%
332913	Plumbing Fixture Fitting and Trim Manufacturing	2.2%	4.0%	4.8%	7.4%	4.2%	0.7%	0.8%	3.6%	2.1%	2.9%	1.7%	3.1%
332919	Other Metal Valve and Pipe Fitting Manufacturing	3.3%	8.1%	9.5%	5.4%	4.3%	4.4%	-0.3%	0.9%	2.0%	0.8%	1.3%	3.6%
332991	Ball and Roller Bearing Manufacturing	2.7%	5.4%	4.0%	4.0%	5.8%	5.3%	2.1%	3.7%	3.4%	2.4%	2.3%	3.7%
332996	Fabricated Pipe and Pipe Fitting Manufacturing	20.2%	10.0%	5.4%	-1.4%	7.6%	5.2%	10.8%	6.5%	3.9%	1.1%	1.8%	6.5%
332999	All Other Miscellaneous Fabricated Metal Product Manufacturing	N/A	3.5%	4.7%	2.6%	4.2%	3.9%	1.3%	3.2%	1.2%	0.5%	1.1%	2.6%

Table VI-3: Annual Percentage Change in Producer Prices for Industries in General Industry and Maritime Affected by OSHA's Final Silica Standard (continued)

NAICS	Industry	2003-2004	2004-2005	2005-2006	2006-2007	2007-2008	2008-2009	2009-2010	2010-2011	2011-2012	2012-2013	2013-2014	Average Annual
333318	Other Commercial and Service Industry Machinery Manufacturing	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1.5%	2.5%	2.0%
333413	Industrial and Commercial Fan and Blower and Air Purification Equipment Manufacturing	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1.3%	2.5%	1.9%
333414	Heating Equipment (except Warm Air Furnaces) Manufacturing	3.2%	4.5%	3.2%	4.0%	6.3%	3.9%	0.7%	2.8%	2.9%	1.5%	1.5%	3.1%
333511	Industrial Mold Manufacturing	N/A	2.3%	1.9%	-0.2%	-0.1%	-0.8%	-0.6%	0.4%	0.7%	0.9%	0.5%	0.5%
333514	Special Die and Tool, Die Set, Jig, and Fixture Manufacturing	N/A	-0.2%	0.4%	0.6%	1.8%	-0.5%	-0.4%	2.5%	1.7%	1.1%	0.6%	0.8%
333515	Cutting Tool and Machine Tool Accessory Manufacturing	1.1%	4.2%	4.3%	1.3%	1.7%	2.0%	0.8%	3.8%	1.9%	0.6%	1.8%	2.1%
333517	Machine Tool Manufacturing	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	3.2%	1.8%	2.5%

Table VI-3: Annual Percentage Change in Producer Prices for Industries in General Industry and Maritime Affected by OSHA's Final Silica Standard (continued)

NAICS	Industry	2003-2004	2004-2005	2005-2006	2006-2007	2007-2008	2008-2009	2009-2010	2010-2011	2011-2012	2012-2013	2013-2014	Average Annual
333519	Rolling Mill and Other Metalworking Machinery Manufacturing	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0.2%	0.6%	0.4%
333612	Speed Changer, Industrial High-Speed Drive, and Gear Manufacturing	4.0%	5.9%	4.0%	5.0%	6.9%	3.5%	-0.2%	6.2%	4.2%	3.1%	1.1%	4.0%
333613	Mechanical Power Transmission Equipment Manufacturing	5.3%	5.6%	4.4%	3.7%	7.2%	7.8%	1.0%	3.6%	2.8%	2.0%	0.4%	4.0%
333911	Pump and Pumping Equipment Manufacturing	2.8%	5.9%	4.9%	5.6%	4.3%	2.2%	1.2%	2.2%	2.9%	1.0%	2.2%	3.2%
333912	Air and Gas Compressor Manufacturing	2.5%	6.5%	3.0%	3.6%	5.4%	4.0%	1.0%	5.3%	2.7%	3.3%	2.4%	3.6%
333991	Power-Driven Handtool Manufacturing	0.8%	0.9%	-0.5%	0.6%	1.5%	0.6%	-0.7%	0.6%	2.6%	0.7%	1.4%	0.8%
333992	Welding and Soldering Equipment Manufacturing	5.9%	6.7%	4.8%	6.3%	6.8%	2.3%	1.2%	5.1%	3.3%	1.6%	1.6%	4.1%
333993	Packaging Machinery Manufacturing	2.0%	2.4%	2.0%	1.5%	8.2%	6.2%	2.7%	2.0%	2.6%	2.2%	4.1%	3.3%

Table VI-3: Annual Percentage Change in Producer Prices for Industries in General Industry and Maritime Affected by OSHA's Final Silica Standard (continued)

NAICS	Industry	2003-2004	2004-2005	2005-2006	2006-2007	2007-2008	2008-2009	2009-2010	2010-2011	2011-2012	2012-2013	2013-2014	Average Annual
333994	Industrial Process Furnace and Oven Manufacturing	1.1%	2.4%	3.2%	3.1%	4.7%	1.5%	0.9%	2.1%	1.7%	1.6%	2.1%	2.2%
333995	Fluid Power Cylinder and Actuator Manufacturing	6.3%	6.1%	4.6%	3.5%	6.1%	2.3%	1.2%	2.2%	2.3%	0.9%	0.9%	3.3%
333996	Fluid Power Pump and Motor Manufacturing	0.5%	2.4%	4.8%	3.4%	7.0%	4.0%	3.2%	2.6%	3.7%	2.1%	1.9%	3.2%
333997	Scale and Balance Manufacturing	0.8%	1.7%	0.9%	1.4%	3.1%	3.5%	0.9%	2.9%	3.8%	1.8%	2.2%	2.1%
333999	All Other Miscellaneous General Purpose Machinery Manufacturing	2.0%	2.1%	2.7%	2.9%	4.9%	4.4%	1.2%	3.8%	2.8%	2.6%	2.4%	2.9%
334519	Other Measuring and Controlling Device Manufacturing	0.8%	1.3%	1.1%	1.4%	1.3%	1.8%	0.0%	0.7%	1.5%	0.8%	0.9%	1.1%
335210	Small Electrical Appliance Manufacturing	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1.2%	0.2%	0.7%
335221	Household Cooking Appliance Manufacturing	-2.2%	2.6%	2.4%	1.2%	3.1%	5.9%	0.2%	1.4%	5.8%	0.1%	0.1%	1.9%
335222	Household Refrigerator and Home Freezer Manufacturing	-0.5%	2.6%	0.7%	1.3%	4.0%	4.1%	-3.3%	1.0%	3.6%	1.1%	-1.2%	1.2%

Table VI-3: Annual Percentage Change in Producer Prices for Industries in General Industry and Maritime Affected by OSHA's Final Silica Standard (continued)

NAICS	Industry	2003-2004	2004-2005	2005-2006	2006-2007	2007-2008	2008-2009	2009-2010	2010-2011	2011-2012	2012-2013	2013-2014	Average Annual
335224	Household Laundry Equipment Manufacturing	0.1%	0.6%	-0.9%	-1.6%	0.6%	2.0%	0.5%	-0.2%	6.9%	-2.3%	-0.3%	0.5%
335228	Other Major Household Appliance Manufacturing	4.0%	8.8%	3.4%	3.3%	7.3%	7.6%	1.7%	2.7%	2.2%	1.3%	1.0%	3.9%
336111	Automobile Manufacturing	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
336112	Light Truck and Utility Vehicle Manufacturing	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
336120	Heavy Duty Truck Manufacturing	N/A	4.1%	3.8%	4.6%	2.9%	4.6%	3.0%	2.4%	2.6%	1.6%	1.8%	3.2%
336211	Motor Vehicle Body Manufacturing	5.5%	7.7%	5.1%	2.5%	3.4%	2.1%	0.6%	1.5%	2.3%	0.8%	1.5%	3.0%
336212	Truck Trailer Manufacturing	5.9%	6.0%	4.7%	3.1%	4.7%	0.9%	2.3%	4.8%	2.8%	-0.2%	1.0%	3.3%
336213	Motor Home Manufacturing	3.8%	3.4%	-1.6%	2.7%	2.0%	-2.2%	-1.3%	1.1%	2.6%	2.0%	0.3%	1.2%
336310	Motor Vehicle Gasoline Engine and Engine Parts Manufacturing	N/A	1.1%	8.8%	1.4%	2.6%	-10.6%	4.3%	4.4%	1.5%	0.1%	-0.5%	1.3%
336320	Motor Vehicle Electrical and Electronic Equipment Manufacturing	N/A	1.9%	0.8%	1.2%	-0.8%	0.0%	0.5%	1.5%	1.0%	0.0%	0.8%	0.7%

Table VI-3: Annual Percentage Change in Producer Prices for Industries in General Industry and Maritime Affected by OSHA's Final Silica Standard (continued)

NAICS	Industry	2003-2004	2004-2005	2005-2006	2006-2007	2007-2008	2008-2009	2009-2010	2010-2011	2011-2012	2012-2013	2013-2014	Average Annual
336330	Motor Vehicle Steering and Suspension Components (except Spring) Manufacturing	N/A	3.1%	1.1%	-1.2%	1.4%	-1.1%	0.6%	0.8%	0.7%	-0.4%	-0.2%	0.5%
336340	Motor Vehicle Brake System Manufacturing	N/A	0.7%	0.9%	0.4%	1.8%	1.1%	-0.3%	2.8%	1.6%	-0.4%	-0.7%	0.8%
336350	Motor Vehicle Transmission and Power Train Parts Manufacturing	N/A	0.3%	2.0%	2.6%	2.1%	4.3%	1.0%	0.7%	2.1%	1.2%	1.4%	1.8%
336370	Motor Vehicle Metal Stamping	4.9%	1.6%	0.4%	2.7%	3.1%	2.5%	-1.6%	-0.3%	-0.1%	-0.2%	-0.2%	1.2%
336390	Other Motor Vehicle Parts Manufacturing	N/A	1.3%	0.6%	1.9%	3.8%	1.0%	2.6%	2.4%	0.9%	-0.1%	-0.5%	1.4%
336611	Ship Building and Repairing	5.3%	2.6%	3.7%	4.2%	2.6%	3.2%	2.0%	2.0%	0.7%	0.2%	1.8%	2.6%
336612	Boat Building	2.0%	4.4%	3.6%	3.2%	3.4%	2.2%	1.7%	1.6%	2.3%	2.6%	2.3%	2.7%
336992	Military Armored Vehicle, Tank, and Tank Component Manufacturing	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
337110	Wood Kitchen Cabinet and Countertop Manufacturing	1.8%	2.2%	3.0%	2.0%	2.5%	2.0%	0.0%	1.6%	2.0%	3.0%	2.5%	2.0%
337215	Showcase, Partition, Shelving, and Locker Manufacturing	N/A	7.3%	0.5%	1.3%	4.2%	2.1%	0.5%	3.2%	2.0%	0.7%	1.1%	2.3%

Table VI-3: Annual Percentage Change in Producer Prices for Industries in General Industry and Maritime Affected by OSHA's Final Silica Standard (continued)

NAICS	Industry	2003-2004	2004-2005	2005-2006	2006-2007	2007-2008	2008-2009	2009-2010	2010-2011	2011-2012	2012-2013	2013-2014	Average Annual
339114	Dental Equipment and Supplies Manufacturing	2.3%	4.3%	8.4%	3.6%	4.6%	1.8%	7.1%	12.5%	1.6%	4.1%	1.9%	4.7%
339116	Dental Laboratories	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
339910	Jewelry and Silverware Manufacturing	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	-0.1%	-6.4%	-3.3%
339950	Sign Manufacturing	0.7%	3.7%	2.2%	2.1%	2.0%	0.3%	0.4%	0.6%	1.0%	1.3%	1.2%	1.4%
423840	Industrial Supplies Merchant Wholesalers	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
444110	Home Centers	N/A	2.4%	11.8%	-0.6%	-5.0%	2.3%	-2.1%	0.0%	2.8%	7.9%	-2.3%	1.7%
482110	Rail transportation	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
621210	Offices of Dentists	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1.8%	1.8%	1.4%	1.7%

N/A = Not available.
Source: OSHA, Directorate of Standards and Guidance, Office of Regulatory Analysis, based on ERG, 2015.and BLS, 2015

Table VI-4: Time Series of Annual Profit Rates for Industries in General Industry and Maritime Affected by OSHA's Final Silica Standard

NAICS	Industry	2012	2011	2010	2009	2008	2007	2006	2005	2004	2003	2002	2001	2000	Average
213112	Support Activities for Oil and Gas Operations	7.63%	6.37%	6.53%	1.13%	12.70%	17.59%	19.29%	6.78%	3.37%	-0.95%	0.43%	8.11%	3.16%	**7.09%**
324121	Asphalt Paving Mixture and Block Manufacturing	6.07%	5.20%	6.94%	6.59%	6.22%	7.35%	7.99%	8.57%	7.96%	2.58%	3.42%	4.03%	4.55%	**5.96%**
324122	Asphalt Shingle and Coating Materials Manufacturing	6.07%	5.20%	6.94%	6.59%	6.22%	7.35%	7.99%	8.57%	7.96%	2.58%	3.42%	4.03%	4.55%	**5.96%**
325510	Paint and Coating Manufacturing	3.92%	3.90%	4.01%	3.28%	2.66%	5.15%	5.11%	5.45%	4.85%	0.78%	3.79%	3.69%	3.64%	**3.86%**
327110	Pottery, Ceramics, and Plumbing Fixture Manufacturing	3.50%	3.50%	1.09%	1.77%	2.81%	-5.12%	-2.15%	6.29%	3.40%	-0.03%	-0.38%	0.88%	1.83%	**1.34%**
327120	Clay Building Material and Refractories Manufacturing	3.50%	3.50%	1.09%	1.77%	2.81%	-5.12%	-2.15%	6.29%	3.40%	-0.03%	-0.38%	0.88%	1.83%	**1.34%**
327211	Flat Glass Manufacturing	4.09%	4.75%	7.03%	1.81%	0.22%	8.88%	2.12%	0.22%	-0.34%	0.20%	0.89%	2.63%	1.62%	**2.63%**
327212	Other Pressed and Blown Glass and Glassware Manufacturing	4.09%	4.75%	7.03%	1.81%	0.22%	8.88%	2.12%	0.22%	-0.34%	0.20%	0.89%	2.63%	1.62%	**2.63%**
327213	Glass Container Manufacturing	4.09%	4.75%	7.03%	1.81%	0.22%	8.88%	2.12%	0.22%	-0.34%	0.20%	0.89%	2.63%	1.62%	**2.63%**

Table VI-4: Time Series of Annual Profit Rates for Industries in General Industry and Maritime Affected by OSHA's Final Silica Standard (continued)

NAICS	Industry	2012	2011	2010	2009	2008	2007	2006	2005	2004	2003	2002	2001	2000	Average
327320	Ready-Mix Concrete Manufacturing	-1.15%	-4.26%	-5.71%	-7.44%	-2.69%	4.70%	4.23%	10.26%	5.23%	3.05%	2.77%	3.38%	6.22%	**1.43%**
327331	Concrete Block and Brick Manufacturing	-1.15%	-4.26%	-5.71%	-7.44%	-2.69%	4.70%	4.23%	10.26%	5.23%	3.05%	2.77%	3.38%	6.22%	**1.43%**
327332	Concrete Pipe Manufacturing	-1.15%	-4.26%	-5.71%	-7.44%	-2.69%	4.70%	4.23%	10.26%	5.23%	3.05%	2.77%	3.38%	6.22%	**1.43%**
327390	Other Concrete Product Manufacturing	-1.15%	-4.26%	-5.71%	-7.44%	-2.69%	4.70%	4.23%	10.26%	5.23%	3.05%	2.77%	3.38%	6.22%	**1.43%**
327991	Cut Stone and Stone Product Manufacturing	1.12%	-0.31%	-1.09%	-3.69%	-1.15%	3.88%	2.64%	7.55%	3.65%	1.82%	1.71%	2.68%	3.98%	**1.75%**
327992	Ground or Treated Mineral and Earth Manufacturing	1.12%	-0.31%	-1.09%	-3.69%	-1.15%	3.88%	2.64%	7.55%	3.65%	1.82%	1.71%	2.68%	3.98%	**1.75%**
327993	Mineral Wool Manufacturing	1.12%	-0.31%	-1.09%	-3.69%	-1.15%	3.88%	2.64%	7.55%	3.65%	1.82%	1.71%	2.68%	3.98%	**1.75%**
327999	All Other Miscellaneous Nonmetallic Mineral Product Manufacturing	1.12%	-0.31%	-1.09%	-3.69%	-1.15%	3.88%	2.64%	7.55%	3.65%	1.82%	1.71%	2.68%	3.98%	**1.75%**
331110	Iron and Steel Mills and Ferroalloy Manufacturing	1.79%	0.55%	-0.65%	-6.26%	5.80%	6.43%	8.96%	7.74%	7.34%	-3.92%	-2.58%	-6.39%	-1.23%	**1.35%**
331210	Iron and Steel Pipe and Tube Manufacturing from Purchased Steel	2.36%	1.77%	1.14%	-3.37%	4.38%	7.04%	7.55%	6.44%	5.58%	-1.77%	-1.32%	-2.50%	0.56%	**2.14%**
331221	Rolled Steel Shape Manufacturing	2.36%	1.77%	1.14%	-3.37%	4.38%	7.04%	7.55%	6.44%	5.58%	-1.77%	-1.32%	-2.50%	0.56%	**2.14%**
331222	Steel Wire Drawing	2.36%	1.77%	1.14%	-3.37%	4.38%	7.04%	7.55%	6.44%	5.58%	-1.77%	-1.32%	-2.50%	0.56%	**2.14%**
331314	Secondary Smelting and Alloying of Aluminum	1.33%	2.21%	2.25%	-1.82%	1.81%	7.76%	6.17%	4.88%	3.72%	1.39%	-0.16%	0.74%	2.50%	**2.52%**
331420	Copper Rolling, Drawing, Extruding, and Alloying	2.36%	1.77%	1.14%	-3.37%	4.38%	7.04%	7.55%	6.44%	5.58%	-1.77%	-1.32%	-2.50%	0.56%	**2.14%**

Table VI-4: Time Series of Annual Profit Rates for Industries in General Industry and Maritime Affected by OSHA's Final Silica Standard (continued)

NAICS	Industry	2012	2011	2010	2009	2008	2007	2006	2005	2004	2003	2002	2001	2000	Average
331492	Secondary Smelting, Refining, and Alloying of Nonferrous Metal (except Copper and Aluminum)	2.36%	1.77%	1.14%	-3.37%	4.38%	7.04%	7.55%	6.44%	5.58%	-1.77%	-1.32%	-2.50%	0.56%	**2.14%**
331511	Iron Foundries	9.76%	7.57%	7.09%	3.99%	6.39%	7.11%	5.78%	4.95%	1.65%	-0.44%	0.31%	1.46%	1.03%	**4.36%**
331512	Steel Investment Foundries	9.76%	7.57%	7.09%	3.99%	6.39%	7.11%	5.78%	4.95%	1.65%	-0.44%	0.31%	1.46%	1.03%	**4.36%**
331513	Steel Foundries (except Investment)	9.76%	7.57%	7.09%	3.99%	6.39%	7.11%	5.78%	4.95%	1.65%	-0.44%	0.31%	1.46%	1.03%	**4.36%**
331524	Aluminum Foundries (except Die-Casting)	9.76%	7.57%	7.09%	3.99%	6.39%	7.11%	5.78%	4.95%	1.65%	-0.44%	0.31%	1.46%	1.03%	**4.36%**
331529	Other Nonferrous Metal Foundries (except Die-Casting)	9.76%	7.57%	7.09%	3.99%	6.39%	7.11%	5.78%	4.95%	1.65%	-0.44%	0.31%	1.46%	1.03%	**4.36%**
332111	Iron and Steel Forging	7.16%	4.90%	6.57%	1.66%	3.64%	4.79%	5.03%	4.47%	2.75%	2.35%	2.46%	0.35%	3.35%	**3.81%**
332112	Nonferrous Forging	7.16%	4.90%	6.57%	1.66%	3.64%	4.79%	5.03%	4.47%	2.75%	2.35%	2.46%	0.35%	3.35%	**3.81%**
332117	Powder Metallurgy Part Manufacturing	7.16%	4.90%	6.57%	1.66%	3.64%	4.79%	5.03%	4.47%	2.75%	2.35%	2.46%	0.35%	3.35%	**3.81%**
332119	Metal Crown, Closure, and Other Metal Stamping (except Automotive)	7.16%	4.90%	6.57%	1.66%	3.64%	4.79%	5.03%	4.47%	2.75%	2.35%	2.46%	0.35%	3.35%	**3.81%**
332215	Metal Kitchen Cookware, Utensil, Cutlery, and Flatware (except Precious) Manufacturing	5.70%	4.83%	5.24%	3.49%	4.74%	5.27%	6.09%	5.80%	4.67%	1.09%	0.86%	1.62%	4.15%	**4.12%**
332216	Saw Blade and Handtool Manufacturing	5.70%	4.83%	5.24%	3.49%	4.74%	5.27%	6.09%	5.80%	4.67%	1.09%	0.86%	1.62%	4.15%	**4.12%**
332323	Ornamental and Architectural Metal Work Manufacturing	3.34%	-0.06%	-0.19%	0.78%	3.35%	5.36%	5.37%	4.49%	2.90%	0.49%	1.75%	3.65%	3.88%	**2.70%**
332439	Other Metal Container Manufacturing	6.08%	3.01%	4.74%	2.68%	3.68%	4.41%	0.17%	5.78%	2.45%	1.17%	3.21%	-0.20%	0.90%	**2.93%**
332510	Hardware Manufacturing	6.28%	4.91%	4.68%	2.61%	4.81%	5.98%	5.66%	7.20%	5.08%	2.66%	2.93%	2.49%	4.96%	**4.63%**

Table VI-4: Time Series of Annual Profit Rates for Industries in General Industry and Maritime Affected by OSHA's Final Silica Standard (continued)

NAICS	Industry	2012	2011	2010	2009	2008	2007	2006	2005	2004	2003	2002	2001	2000	Average
332613	Spring Manufacturing	6.28%	4.91%	4.68%	2.61%	4.81%	5.98%	5.66%	7.20%	5.08%	2.66%	2.93%	2.49%	4.96%	**4.63%**
332618	Other Fabricated Wire Product Manufacturing	6.28%	4.91%	4.68%	2.61%	4.81%	5.98%	5.66%	7.20%	5.08%	2.66%	2.93%	2.49%	4.96%	**4.63%**
332710	Machine Shops	6.28%	4.91%	4.68%	2.61%	4.81%	5.98%	5.66%	7.20%	5.08%	2.66%	2.93%	2.49%	4.96%	**4.63%**
332812	Metal Coating, Engraving (except Jewelry and Silverware), and Allied Services to Manufacturers	7.65%	5.86%	5.08%	-4.25%	4.13%	3.16%	4.60%	3.03%	3.32%	0.58%	0.68%	-0.35%	4.97%	**2.96%**
332911	Industrial Valve Manufacturing	7.37%	6.81%	5.79%	3.71%	5.85%	7.38%	6.71%	9.50%	6.49%	4.07%	4.19%	3.31%	6.20%	**5.95%**
332912	Fluid Power Valve and Hose Fitting Manufacturing	7.37%	6.81%	5.79%	3.71%	5.85%	7.38%	6.71%	9.50%	6.49%	4.07%	4.19%	3.31%	6.20%	**5.95%**
332913	Plumbing Fixture Fitting and Trim Manufacturing	7.37%	6.81%	5.79%	3.71%	5.85%	7.38%	6.71%	9.50%	6.49%	4.07%	4.19%	3.31%	6.20%	**5.95%**
332919	Other Metal Valve and Pipe Fitting Manufacturing	7.37%	6.81%	5.79%	3.71%	5.85%	7.38%	6.71%	9.50%	6.49%	4.07%	4.19%	3.31%	6.20%	**5.95%**
332991	Ball and Roller Bearing Manufacturing	7.37%	6.81%	5.79%	3.71%	5.85%	7.38%	6.71%	9.50%	6.49%	4.07%	4.19%	3.31%	6.20%	**5.95%**
332996	Fabricated Pipe and Pipe Fitting Manufacturing	7.37%	6.81%	5.79%	3.71%	5.85%	7.38%	6.71%	9.50%	6.49%	4.07%	4.19%	3.31%	6.20%	**5.95%**
332999	All Other Miscellaneous Fabricated Metal Product Manufacturing	7.37%	6.81%	5.79%	3.71%	5.85%	7.38%	6.71%	9.50%	6.49%	4.07%	4.19%	3.31%	6.20%	**5.95%**
333318	Other Commercial and Service Industry Machinery Manufacturing	3.55%	2.49%	3.61%	1.24%	1.35%	5.69%	5.57%	6.37%	1.50%	0.90%	0.86%	1.00%	5.54%	**3.05%**
333413	Industrial and Commercial Fan and Blower and Air Purification Equipment Manufacturing	2.82%	2.84%	1.84%	0.27%	2.12%	4.33%	5.21%	4.66%	2.64%	2.79%	3.30%	2.31%	3.90%	**3.00%**

Table VI-4: Time Series of Annual Profit Rates for Industries in General Industry and Maritime Affected by OSHA's Final Silica Standard (continued)

NAICS	Industry	2012	2011	2010	2009	2008	2007	2006	2005	2004	2003	2002	2001	2000	Average
333414	Heating Equipment (except Warm Air Furnaces) Manufacturing	2.82%	2.84%	1.84%	0.27%	2.12%	4.33%	5.21%	4.66%	2.64%	2.79%	3.30%	2.31%	3.90%	**3.00%**
333511	Industrial Mold Manufacturing	6.93%	4.73%	3.67%	2.37%	3.67%	5.21%	5.55%	11.24%	2.42%	1.28%	-0.70%	-0.39%	3.68%	**3.82%**
333514	Special Die and Tool, Die Set, Jig, and Fixture Manufacturing	6.93%	4.73%	3.67%	2.37%	3.67%	5.21%	5.55%	11.24%	2.42%	1.28%	-0.70%	-0.39%	3.68%	**3.82%**
333515	Cutting Tool and Machine Tool Accessory Manufacturing	6.93%	4.73%	3.67%	2.37%	3.67%	5.21%	5.55%	11.24%	2.42%	1.28%	-0.70%	-0.39%	3.68%	**3.82%**
333517	Machine Tool Manufacturing	6.93%	4.73%	3.67%	2.37%	3.67%	5.21%	5.55%	11.24%	2.42%	1.28%	-0.70%	-0.39%	3.68%	**3.82%**
333519	Rolling Mill and Other Metalworking Machinery Manufacturing	6.93%	4.73%	3.67%	2.37%	3.67%	5.21%	5.55%	11.24%	2.42%	1.28%	-0.70%	-0.39%	3.68%	**3.82%**
333612	Speed Changer, Industrial High-Speed Drive, and Gear Manufacturing	6.05%	6.09%	1.83%	-0.03%	1.75%	3.87%	3.38%	3.68%	1.78%	-1.55%	1.53%	-2.01%	-0.52%	**1.99%**
333613	Mechanical Power Transmission Equipment Manufacturing	6.05%	6.09%	1.83%	-0.03%	1.75%	3.87%	3.38%	3.68%	1.78%	-1.55%	1.53%	-2.01%	-0.52%	**1.99%**
333911	Pump and Pumping Equipment Manufacturing	5.17%	3.72%	4.69%	2.68%	4.41%	8.02%	4.32%	5.70%	3.60%	0.37%	0.63%	2.27%	3.79%	**3.80%**
333912	Air and Gas Compressor Manufacturing	5.17%	3.72%	4.69%	2.68%	4.41%	8.02%	4.32%	5.70%	3.60%	0.37%	0.63%	2.27%	3.79%	**3.80%**
333991	Power-Driven Handtool Manufacturing	5.17%	3.72%	4.69%	2.68%	4.41%	8.02%	4.32%	5.70%	3.60%	0.37%	0.63%	2.27%	3.79%	**3.80%**
333992	Welding and Soldering Equipment Manufacturing	5.17%	3.72%	4.69%	2.68%	4.41%	8.02%	4.32%	5.70%	3.60%	0.37%	0.63%	2.27%	3.79%	**3.80%**
333993	Packaging Machinery Manufacturing	5.17%	3.72%	4.69%	2.68%	4.41%	8.02%	4.32%	5.70%	3.60%	0.37%	0.63%	2.27%	3.79%	**3.80%**

Table VI-4: Time Series of Annual Profit Rates for Industries in General Industry and Maritime Affected by OSHA's Final Silica Standard (continued)

NAICS	Industry	2012	2011	2010	2009	2008	2007	2006	2005	2004	2003	2002	2001	2000	Average
333994	Industrial Process Furnace and Oven Manufacturing	5.17%	3.72%	4.69%	2.68%	4.41%	8.02%	4.32%	5.70%	3.60%	0.37%	0.63%	2.27%	3.79%	**3.80%**
333995	Fluid Power Cylinder and Actuator Manufacturing	5.17%	3.72%	4.69%	2.68%	4.41%	8.02%	4.32%	5.70%	3.60%	0.37%	0.63%	2.27%	3.79%	**3.80%**
333996	Fluid Power Pump and Motor Manufacturing	5.17%	3.72%	4.69%	2.68%	4.41%	8.02%	4.32%	5.70%	3.60%	0.37%	0.63%	2.27%	3.79%	**3.80%**
333997	Scale and Balance Manufacturing	5.17%	3.72%	4.69%	2.68%	4.41%	8.02%	4.32%	5.70%	3.60%	0.37%	0.63%	2.27%	3.79%	**3.80%**
333999	All Other Miscellaneous General Purpose Machinery Manufacturing	5.17%	3.72%	4.69%	2.68%	4.41%	8.02%	4.32%	5.70%	3.60%	0.37%	0.63%	2.27%	3.79%	**3.80%**
334519	Other Measuring and Controlling Device Manufacturing	7.08%	6.53%	7.64%	5.03%	5.68%	6.02%	7.77%	10.63%	2.59%	-1.36%	-2.89%	0.81%	3.04%	**4.51%**
335210	Small Electrical Appliance Manufacturing	4.90%	6.24%	4.48%	3.49%	4.50%	3.34%	3.77%	5.11%	5.11%	2.36%	1.82%	2.52%	4.53%	**4.01%**
335221	Household Cooking Appliance Manufacturing	4.90%	6.24%	4.48%	3.49%	4.50%	3.34%	3.77%	5.11%	5.11%	2.36%	1.82%	2.52%	4.53%	**4.01%**
335222	Household Refrigerator and Home Freezer Manufacturing	4.90%	6.24%	4.48%	3.49%	4.50%	3.34%	3.77%	5.11%	5.11%	2.36%	1.82%	2.52%	4.53%	**4.01%**
335224	Household Laundry Equipment Manufacturing	4.90%	6.24%	4.48%	3.49%	4.50%	3.34%	3.77%	5.11%	5.11%	2.36%	1.82%	2.52%	4.53%	**4.01%**
335228	Other Major Household Appliance Manufacturing	4.90%	6.24%	4.48%	3.49%	4.50%	3.34%	3.77%	5.11%	5.11%	2.36%	1.82%	2.52%	4.53%	**4.01%**
336111	Automobile Manufacturing	3.58%	1.82%	0.14%	-13.08%	-4.86%	0.35%	0.33%	3.61%	0.16%	0.36%	0.50%	-0.75%	1.28%	**-0.50%**
336112	Light Truck and Utility Vehicle Manufacturing	3.58%	1.82%	0.14%	-13.08%	-4.86%	0.35%	0.33%	3.61%	0.16%	0.36%	0.50%	-0.75%	1.28%	**-0.50%**
336120	Heavy Duty Truck Manufacturing	3.58%	1.82%	0.14%	-13.08%	-4.86%	0.35%	0.33%	3.61%	0.16%	0.36%	0.50%	-0.75%	1.28%	**-0.50%**
336211	Motor Vehicle Body Manufacturing	4.37%	3.01%	2.00%	-5.02%	-0.87%	2.52%	1.87%	4.20%	0.74%	0.44%	1.13%	0.31%	2.17%	**1.30%**

Table VI-4: Time Series of Annual Profit Rates for Industries in General Industry and Maritime Affected by OSHA's Final Silica Standard (continued)

NAICS	Industry	2012	2011	2010	2009	2008	2007	2006	2005	2004	2003	2002	2001	2000	Average
336212	Truck Trailer Manufacturing	4.37%	3.01%	2.00%	-5.02%	-0.87%	2.52%	1.87%	4.20%	0.74%	0.44%	1.13%	0.31%	2.17%	**1.30%**
336213	Motor Home Manufacturing	4.37%	3.01%	2.00%	-5.02%	-0.87%	2.52%	1.87%	4.20%	0.74%	0.44%	1.13%	0.31%	2.17%	**1.30%**
336310	Motor Vehicle Gasoline Engine and Engine Parts Manufacturing	4.37%	3.01%	2.00%	-5.02%	-0.87%	2.52%	1.87%	4.20%	0.74%	0.44%	1.13%	0.31%	2.17%	**1.30%**
336320	Motor Vehicle Electrical and Electronic Equipment Manufacturing	4.37%	3.01%	2.00%	-5.02%	-0.87%	2.52%	1.87%	4.20%	0.74%	0.44%	1.13%	0.31%	2.17%	**1.30%**
336330	Motor Vehicle Steering and Suspension Components (except Spring) Manufacturing	4.37%	3.01%	2.00%	-5.02%	-0.87%	2.52%	1.87%	4.20%	0.74%	0.44%	1.13%	0.31%	2.17%	**1.30%**
336340	Motor Vehicle Brake System Manufacturing	4.37%	3.01%	2.00%	-5.02%	-0.87%	2.52%	1.87%	4.20%	0.74%	0.44%	1.13%	0.31%	2.17%	**1.30%**
336350	Motor Vehicle Transmission and Power Train Parts Manufacturing	4.37%	3.01%	2.00%	-5.02%	-0.87%	2.52%	1.87%	4.20%	0.74%	0.44%	1.13%	0.31%	2.17%	**1.30%**
336370	Motor Vehicle Metal Stamping	4.37%	3.01%	2.00%	-5.02%	-0.87%	2.52%	1.87%	4.20%	0.74%	0.44%	1.13%	0.31%	2.17%	**1.30%**
336390	Other Motor Vehicle Parts Manufacturing	4.37%	3.01%	2.00%	-5.02%	-0.87%	2.52%	1.87%	4.20%	0.74%	0.44%	1.13%	0.31%	2.17%	**1.30%**
336611	Ship Building and Repairing	7.30%	6.81%	8.35%	6.88%	6.61%	7.60%	7.52%	5.89%	5.03%	3.97%	4.65%	4.64%	3.60%	**6.06%**
336612	Boat Building	7.30%	6.81%	8.35%	6.88%	6.61%	7.60%	7.52%	5.89%	5.03%	3.97%	4.65%	4.64%	3.60%	**6.06%**
336992	Military Armored Vehicle, Tank, and Tank Component Manufacturing	7.13%	3.99%	3.26%	1.53%	4.04%	6.45%	7.60%	5.65%	4.82%	5.25%	1.52%	-1.24%	2.45%	**4.03%**
337110	Wood Kitchen Cabinet and Countertop Manufacturing	3.05%	2.23%	2.57%	0.30%	0.58%	3.78%	5.01%	4.87%	3.07%	2.45%	2.57%	1.79%	3.75%	**2.77%**

Table VI-4: Time Series of Annual Profit Rates for Industries in General Industry and Maritime Affected by OSHA's Final Silica Standard (continued)

NAICS	Industry	2012	2011	2010	2009	2008	2007	2006	2005	2004	2003	2002	2001	2000	Average
337215	Showcase, Partition, Shelving, and Locker Manufacturing	3.05%	2.23%	2.57%	0.30%	0.58%	3.78%	5.01%	4.87%	3.07%	2.45%	2.57%	1.79%	3.75%	**2.77%**
339114	Dental Equipment and Supplies Manufacturing	7.40%	7.72%	7.65%	7.65%	5.63%	7.53%	11.07%	15.65%	6.14%	3.98%	5.07%	4.45%	5.23%	**7.32%**
339116	Dental Laboratories	7.40%	7.72%	7.65%	7.65%	5.63%	7.53%	11.07%	15.65%	6.14%	3.98%	5.07%	4.45%	5.23%	**7.32%**
339910	Jewelry and Silverware Manufacturing	6.37%	4.51%	4.68%	2.80%	3.63%	4.26%	5.41%	5.11%	3.19%	3.05%	2.91%	1.81%	3.26%	**3.92%**
339950	Sign Manufacturing	6.37%	4.51%	4.68%	2.80%	3.63%	4.26%	5.41%	5.11%	3.19%	3.05%	2.91%	1.81%	3.26%	**3.92%**
423840	Industrial Supplies Merchant Wholesalers	4.49%	3.70%	3.47%	2.23%	3.42%	3.93%	4.28%	4.31%	2.92%	1.57%	0.82%	1.61%	2.05%	**2.98%**
444110	Home Centers	7.90%	5.99%	6.47%	7.18%	5.59%	8.30%	9.53%	10.73%	8.47%	0.84%	0.92%	1.05%	5.67%	**6.05%**
482110	Rail transportation	12.67%	6.74%	9.72%	4.97%	7.46%	10.72%	11.72%	9.35%	2.68%	0.99%	0.68%	0.48%	2.83%	**6.23%**
561730	Landscaping Services	3.85%	3.35%	3.61%	2.08%	3.03%	3.60%	3.70%	5.02%	2.47%	2.33%	1.43%	2.49%	1.53%	**2.96%**
621210	Offices of Dentists	10.01%	8.60%	9.77%	9.33%	8.47%	9.06%	7.22%	7.51%	7.42%	6.06%	6.16%	6.29%	5.24%	**7.78%**

Source: Based on Internal Revenue Service, *Corporation Source Book*, 2012.

Table VI-5: Annual Percentage Change in Profit Rates for Industries in General Industry and Maritime Affected by OSHA's Final Silica Standard

NAICS	Title	2011-2012	2010-2011	2009-2010	2008-2009	2007-2008	2006-2007	2005-2006	2004-2005	2003-2004	2002-2003	2001-2002	2000-2001	Average Change (Absolute Values)
213112	Support Activities for Oil and Gas Operations	19.85%	-2.57%	476.57%	-91.08%	-27.81%	-8.81%	184.70%	100.98%	-456.38%	-318.92%	-94.67%	156.45%	**161.56%**
324121	Asphalt Paving Mixture and Block Manufacturing	16.83%	-25.14%	5.44%	5.93%	-15.46%	-7.92%	-6.78%	7.60%	208.11%	-24.38%	-15.27%	-11.42%	**29.19%**
324122	Asphalt Shingle and Coating Materials Manufacturing	16.83%	-25.14%	5.44%	5.93%	-15.46%	-7.92%	-6.78%	7.60%	208.11%	-24.38%	-15.27%	-11.42%	**29.19%**
325510	Paint and Coating Manufacturing	0.49%	-2.72%	22.35%	22.97%	-48.29%	0.80%	-6.29%	12.44%	518.92%	-79.32%	2.61%	1.54%	**59.89%**
327110	Pottery, Ceramics, and Plumbing Fixture Manufacturing	0.03%	220.48%	-38.35%	-37.00%	-154.97%	138.43%	-134.15%	85.06%	-10314.06%	-91.28%	-143.47%	-52.13%	**950.78%**
327120	Clay Building Material and Refractories Manufacturing	0.03%	220.48%	-38.35%	-37.00%	-154.97%	138.43%	-134.15%	85.06%	-10314.06%	-91.28%	-143.47%	-52.13%	**950.78%**
327211	Flat Glass Manufacturing	-13.92%	-32.43%	289.47%	711.46%	-97.49%	318.29%	869.52%	-164.20%	-272.18%	-77.82%	-66.03%	61.79%	**247.88%**

Table VI-5: Annual Percentage Change in Profit Rates for Industries in General Industry and Maritime Affected by OSHA's Final Silica Standard (continued)

NAICS	Title	2011-2012	2010-2011	2009-2010	2008-2009	2007-2008	2006-2007	2005-2006	2004-2005	2003-2004	2002-2003	2001-2001	2000-2001	Average Change (Abso-lute Values)
327212	Other Pressed and Blown Glass and Glassware Manufacturing	-13.92%	-32.43%	289.47%	711.46%	-97.49%	318.29%	869.52%	-164.20%	-272.18%	-77.82%	-66.03%	61.79%	**247.88%**
327213	Glass Container Manufacturing	-13.92%	-32.43%	289.47%	711.46%	-97.49%	318.29%	869.52%	-164.20%	-272.18%	-77.82%	-66.03%	61.79%	**247.88%**
327320	Ready-Mix Concrete Manufacturing	-73.11%	-25.42%	-23.19%	175.91%	-157.30%	11.14%	-58.75%	96.30%	71.17%	10.11%	-17.99%	-45.63%	**63.83%**
327331	Concrete Block and Brick Manufacturing	-73.11%	-25.42%	-23.19%	175.91%	-157.30%	11.14%	-58.75%	96.30%	71.17%	10.11%	-17.99%	-45.63%	**63.83%**
327332	Concrete Pipe Manufacturing	-73.11%	-25.42%	-23.19%	175.91%	-157.30%	11.14%	-58.75%	96.30%	71.17%	10.11%	-17.99%	-45.63%	**63.83%**

Table VI-5: Annual Percentage Change in Profit Rates for Industries in General Industry and Maritime Affected by OSHA's Final Silica Standard (continued)

NAICS	Title	2011-2012	2010-2011	2009-2010	2008-2009	2007-2008	2006-2007	2005-2006	2004-2005	2003-2004	2002-2003	2001-2001	2000-2001	Average Change (Absolute Values)
327390	Other Concrete Product Manufacturing	-73.11%	-25.42%	-23.19%	175.91%	-157.30%	11.14%	-58.75%	96.30%	71.17%	10.11%	-17.99%	-45.63%	**63.83%**
327991	Cut Stone and Stone Product Manufacturing	-465.91%	-71.98%	-70.48%	219.51%	-129.73%	47.31%	-65.08%	106.66%	100.57%	6.74%	-36.25%	-32.73%	**112.75%**
327992	Ground or Treated Mineral and Earth Manufacturing	-465.91%	-71.98%	-70.48%	219.51%	-129.73%	47.31%	-65.08%	106.66%	100.57%	6.74%	-36.25%	-32.73%	**112.75%**
327993	Mineral Wool Manufacturing	-465.91%	-71.98%	-70.48%	219.51%	-129.73%	47.31%	-65.08%	106.66%	100.57%	6.74%	-36.25%	-32.73%	**112.75%**
327999	All Other Miscellaneous Nonmetallic Mineral Product Manufacturing	-465.91%	-71.98%	-70.48%	219.51%	-129.73%	47.31%	-65.08%	106.66%	100.57%	6.74%	-36.25%	-32.73%	**112.75%**

Table VI-5: Annual Percentage Change in Profit Rates for Industries in General Industry and Maritime Affected by OSHA's Final Silica Standard (continued)

NAICS	Title	2011-2012	2010-2011	2009-2010	2008-2009	2007-2008	2006-2007	2005-2006	2004-2005	2003-2004	2002-2003	2001-2001	2000-2001	Average Change (Absolute Values)
331110	Iron and Steel Mills and Ferroalloy Manufacturing	223.28%	-185.92%	-89.69%	-207.84%	-9.78%	-28.16%	15.74%	5.36%	-287.39%	51.82%	-59.59%	420.60%	**132.10%**
331210	Iron and Steel Pipe and Tube Manufacturing from Purchased Steel	33.35%	54.50%	-133.93%	-176.90%	-37.72%	-6.77%	17.27%	15.37%	-416.07%	33.41%	-47.00%	-547.90%	**126.68%**
331221	Rolled Steel Shape Manufacturing	33.35%	54.50%	-133.93%	-176.90%	-37.72%	-6.77%	17.27%	15.37%	-416.07%	33.41%	-47.00%	-547.90%	**126.68%**
331222	Steel Wire Drawing	33.35%	54.50%	-133.93%	-176.90%	-37.72%	-6.77%	17.27%	15.37%	-416.07%	33.41%	-47.00%	-547.90%	**126.68%**
331314	Secondary Smelting and Alloying of Aluminum	-39.76%	-1.85%	-223.57%	-200.72%	-76.70%	25.71%	26.37%	31.36%	167.96%	-965.73%	-121.56%	-70.32%	**162.63%**
331420	Copper Rolling, Drawing, Extruding, and Alloying	33.35%	54.50%	-133.93%	-176.90%	-37.72%	-6.77%	17.27%	15.37%	-416.07%	33.41%	-47.00%	-547.90%	**126.68%**

Table VI-5: Annual Percentage Change in Profit Rates for Industries in General Industry and Maritime Affected by OSHA's Final Silica Standard (continued)

NAICS	Title	2011-2012	2010-2011	2009-2010	2008-2009	2007-2008	2006-2007	2005-2006	2004-2005	2003-2004	2002-2003	2001-2001	2000-2001	Average Change (Absolute Values)
331492	Secondary Smelting, Refining, and Alloying of Nonferrous Metal (except Copper and Aluminum)	33.35%	54.50%	-133.93%	-176.90%	-37.72%	-6.77%	17.27%	15.37%	-416.07%	33.41%	-47.00%	-547.90%	**126.68%**
331511	Iron Foundries	28.84%	6.82%	77.69%	-37.52%	-10.17%	23.03%	16.69%	200.54%	-474.01%	-241.80%	-78.74%	42.52%	**103.20%**
331512	Steel Investment Foundries	28.84%	6.82%	77.69%	-37.52%	-10.17%	23.03%	16.69%	200.54%	-474.01%	-241.80%	-78.74%	42.52%	**103.20%**
331513	Steel Foundries (except Investment)	28.84%	6.82%	77.69%	-37.52%	-10.17%	23.03%	16.69%	200.54%	-474.01%	-241.80%	-78.74%	42.52%	**103.20%**
331524	Aluminum Foundries (except Die-Casting)	28.84%	6.82%	77.69%	-37.52%	-10.17%	23.03%	16.69%	200.54%	-474.01%	-241.80%	-78.74%	42.52%	**103.20%**
331529	Other Nonferrous Metal Foundries (except Die-Casting)	28.84%	6.82%	77.69%	-37.52%	-10.17%	23.03%	16.69%	200.54%	-474.01%	-241.80%	-78.74%	42.52%	**103.20%**

Table VI-5: Annual Percentage Change in Profit Rates for Industries in General Industry and Maritime Affected by OSHA's Final Silica Standard (continued)

NAICS	Title	2011-2012	2010-2011	2009-2010	2008-2009	2007-2008	2006-2007	2005-2006	2004-2005	2003-2004	2002-2003	2001-2001	2000-2001	Average Change (Absolute Values)
332111	Iron and Steel Forging	46.06%	-25.32%	295.06%	-54.31%	-24.01%	-4.81%	12.48%	62.65%	17.03%	-4.37%	599.22%	-89.51%	**102.90%**
332112	Nonferrous Forging	46.06%	-25.32%	295.06%	-54.31%	-24.01%	-4.81%	12.48%	62.65%	17.03%	-4.37%	599.22%	-89.51%	**102.90%**
332117	Powder Metallurgy Part Manufacturing	46.06%	-25.32%	295.06%	-54.31%	-24.01%	-4.81%	12.48%	62.65%	17.03%	-4.37%	599.22%	-89.51%	**102.90%**
332119	Metal Crown, Closure, and Other Metal Stamping (except Automotive)	46.06%	-25.32%	295.06%	-54.31%	-24.01%	-4.81%	12.48%	62.65%	17.03%	-4.37%	599.22%	-89.51%	**102.90%**
332215	Metal Kitchen Cookware, Utensil, Cutlery, and Flatware (except Precious) Manufacturing	18.04%	-7.76%	50.26%	-26.40%	-10.13%	-13.53%	5.00%	24.35%	329.72%	26.45%	-47.02%	-60.90%	**51.63%**

Table VI-5: Annual Percentage Change in Profit Rates for Industries in General Industry and Maritime Affected by OSHA's Final Silica Standard (continued)

NAICS	Title	2011-2012	2010-2011	2009-2010	2008-2009	2007-2008	2006-2007	2005-2006	2004-2005	2003-2004	2002-2003	2001-2001	2000-2001	Average Change (Absolute Values)
332216	Saw Blade and Handtool Manufacturing	18.04%	-7.76%	50.26%	-26.40%	-10.13%	-13.53%	5.00%	24.35%	329.72%	26.45%	-47.02%	-60.90%	**51.63%**
332323	Ornamental and Architectural Metal Work Manufacturing	-6151.38%	-70.50%	-123.94%	-76.63%	-37.60%	-0.14%	19.64%	54.92%	489.76%	-71.97%	-52.05%	-5.86%	**596.20%**
332439	Other Metal Container Manufacturing	102.11%	-36.46%	76.66%	-27.17%	-16.51%	2508.03%	-97.08%	136.31%	108.59%	-63.49%	-1672.77%	-122.82%	**414.00%**
332510	Hardware Manufacturing	27.94%	5.03%	78.92%	-45.68%	-19.57%	5.74%	-21.39%	41.58%	90.92%	-9.07%	17.80%	-49.84%	**34.46%**
332613	Spring Manufacturing	27.94%	5.03%	78.92%	-45.68%	-19.57%	5.74%	-21.39%	41.58%	90.92%	-9.07%	17.80%	-49.84%	**34.46%**
332618	Other Fabricated Wire Product Manufacturing	27.94%	5.03%	78.92%	-45.68%	-19.57%	5.74%	-21.39%	41.58%	90.92%	-9.07%	17.80%	-49.84%	**34.46%**
332710	Machine Shops	27.94%	5.03%	78.92%	-45.68%	-19.57%	5.74%	-21.39%	41.58%	90.92%	-9.07%	17.80%	-49.84%	**34.46%**

Table VI-5: Annual Percentage Change in Profit Rates for Industries in General Industry and Maritime Affected by OSHA's Final Silica Standard (continued)

NAICS	Title	2011-2012	2010-2011	2009-2010	2008-2009	2007-2008	2006-2007	2005-2006	2004-2005	2003-2004	2002-2003	2001-2001	2000-2001	Average Change (Absolute Values)
332812	Metal Coating, Engraving (except Jewelry and Silverware), and Allied Services to Manufacturers	30.66%	15.38%	-219.44%	-202.82%	30.87%	-31.32%	51.57%	-8.74%	474.20%	-15.46%	-295.87%	-107.03%	**123.61%**
332911	Industrial Valve Manufacturing	8.22%	17.58%	56.15%	-36.64%	-20.70%	10.00%	-29.39%	46.35%	59.48%	-2.83%	26.74%	-46.68%	**30.06%**
332912	Fluid Power Valve and Hose Fitting Manufacturing	8.22%	17.58%	56.15%	-36.64%	-20.70%	10.00%	-29.39%	46.35%	59.48%	-2.83%	26.74%	-46.68%	**30.06%**
332913	Plumbing Fixture Fitting and Trim Manufacturing	8.22%	17.58%	56.15%	-36.64%	-20.70%	10.00%	-29.39%	46.35%	59.48%	-2.83%	26.74%	-46.68%	**30.06%**

Table VI-5: Annual Percentage Change in Profit Rates for Industries in General Industry and Maritime Affected by OSHA's Final Silica Standard (continued)

NAICS	Title	2011-2012	2010-2011	2009-2010	2008-2009	2007-2008	2006-2007	2005-2006	2004-2005	2003-2004	2002-2003	2001-2001	2000-2001	Average Change (Absolute Values)
332919	Other Metal Valve and Pipe Fitting Manufacturing	8.22%	17.58%	56.15%	-36.64%	-20.70%	10.00%	-29.39%	46.35%	59.48%	-2.83%	26.74%	-46.68%	**30.06%**
332991	Ball and Roller Bearing Manufacturing	8.22%	17.58%	56.15%	-36.64%	-20.70%	10.00%	-29.39%	46.35%	59.48%	-2.83%	26.74%	-46.68%	**30.06%**
332996	Fabricated Pipe and Pipe Fitting Manufacturing	8.22%	17.58%	56.15%	-36.64%	-20.70%	10.00%	-29.39%	46.35%	59.48%	-2.83%	26.74%	-46.68%	**30.06%**
332999	All Other Miscellaneous Fabricated Metal Product Manufacturing	8.22%	17.58%	56.15%	-36.64%	-20.70%	10.00%	-29.39%	46.35%	59.48%	-2.83%	26.74%	-46.68%	**30.06%**
333318	Other Commercial and Service Industry Machinery Manufacturing	42.18%	-30.84%	191.11%	-8.42%	-76.21%	2.08%	-12.62%	324.83%	67.56%	4.11%	-14.09%	-81.92%	**71.33%**

Table VI-5: Annual Percentage Change in Profit Rates for Industries in General Industry and Maritime Affected by OSHA's Final Silica Standard (continued)

NAICS	Title	2011-2012	2010-2011	2009-2010	2008-2009	2007-2008	2006-2007	2005-2006	2004-2005	2003-2004	2002-2003	2001-2001	2000-2001	Average Change (Abso-lute Values)
333413	Industrial and Commercial Fan and Blower and Air Purification Equipment Manufacturing	-0.54%	54.50%	586.58%	-87.38%	-51.07%	-16.88%	11.81%	76.27%	-5.38%	-15.23%	42.74%	-40.74%	**82.43%**
333414	Heating Equipment (except Warm Air Furnaces) Manufacturing	-0.54%	54.50%	586.58%	-87.38%	-51.07%	-16.88%	11.81%	76.27%	-5.38%	-15.23%	42.74%	-40.74%	**82.43%**
333511	Industrial Mold Manufacturing	46.53%	29.00%	54.93%	-35.46%	-29.67%	-5.98%	-50.67%	364.55%	89.29%	-283.59%	76.95%	-110.70%	**98.11%**
333514	Special Die and Tool, Die Set, Jig, and Fixture Manufacturing	46.53%	29.00%	54.93%	-35.46%	-29.67%	-5.98%	-50.67%	364.55%	89.29%	-283.59%	76.95%	-110.70%	**98.11%**

Table VI-5: Annual Percentage Change in Profit Rates for Industries in General Industry and Maritime Affected by OSHA's Final Silica Standard (continued)

NAICS	Title	2011-2012	2010-2011	2009-2010	2008-2009	2007-2008	2006-2007	2005-2006	2004-2005	2003-2004	2002-2003	2001-2001	2000-2001	Average Change (Absolute Values)
333515	Cutting Tool and Machine Tool Accessory Manufacturing	46.53%	29.00%	54.93%	-35.46%	-29.67%	-5.98%	-50.67%	364.55%	89.29%	-283.59%	76.95%	-110.70%	**98.11%**
333517	Machine Tool Manufacturing	46.53%	29.00%	54.93%	-35.46%	-29.67%	-5.98%	-50.67%	364.55%	89.29%	-283.59%	76.95%	-110.70%	**98.11%**
333519	Rolling Mill and Other Metalworking Machinery Manufacturing	46.53%	29.00%	54.93%	-35.46%	-29.67%	-5.98%	-50.67%	364.55%	89.29%	-283.59%	76.95%	-110.70%	**98.11%**
333612	Speed Changer, Industrial High-Speed Drive, and Gear Manufacturing	-0.61%	232.95%	-6710.17%	-101.58%	-54.78%	14.44%	-8.03%	107.33%	-214.29%	-201.73%	-175.86%	286.60%	**675.70%**

Table VI-5: Annual Percentage Change in Profit Rates for Industries in General Industry and Maritime Affected by OSHA's Final Silica Standard (continued)

NAICS	Title	2011-2012	2010-2011	2009-2010	2008-2009	2007-2008	2006-2007	2005-2006	2004-2005	2003-2004	2002-2003	2001-2001	2000-2001	Average Change (Absolute Values)
333613	Mechanical Power Transmission Equipment Manufacturing	-0.61%	232.95%	-6710.17%	-101.58%	-54.78%	14.44%	-8.03%	107.33%	-214.29%	-201.73%	-175.86%	286.60%	**675.70%**
333911	Pump and Pumping Equipment Manufacturing	38.98%	-20.72%	74.98%	-39.28%	-44.99%	85.61%	-24.24%	58.57%	870.29%	-41.25%	-72.25%	-40.02%	**117.60%**
333912	Air and Gas Compressor Manufacturing	38.98%	-20.72%	74.98%	-39.28%	-44.99%	85.61%	-24.24%	58.57%	870.29%	-41.25%	-72.25%	-40.02%	**117.60%**
333991	Power-Driven Handtool Manufacturing	38.98%	-20.72%	74.98%	-39.28%	-44.99%	85.61%	-24.24%	58.57%	870.29%	-41.25%	-72.25%	-40.02%	**117.60%**
333992	Welding and Soldering Equipment Manufacturing	38.98%	-20.72%	74.98%	-39.28%	-44.99%	85.61%	-24.24%	58.57%	870.29%	-41.25%	-72.25%	-40.02%	**117.60%**

Table VI-5: Annual Percentage Change in Profit Rates for Industries in General Industry and Maritime Affected by OSHA's Final Silica Standard (continued)

NAICS	Title	2011-2012	2010-2011	2009-2010	2008-2009	2007-2008	2006-2007	2005-2006	2004-2005	2003-2004	2002-2003	2001-2001	2000-2001	Average Change (Abso-lute Values)
333993	Packaging Machinery Manufacturing	38.98%	-20.72%	74.98%	-39.28%	-44.99%	85.61%	-24.24%	58.57%	870.29%	-41.25%	-72.25%	-40.02%	**117.60%**
333994	Industrial Process Furnace and Oven Manufacturing	38.98%	-20.72%	74.98%	-39.28%	-44.99%	85.61%	-24.24%	58.57%	870.29%	-41.25%	-72.25%	-40.02%	**117.60%**
333995	Fluid Power Cylinder and Actuator Manufacturing	38.98%	-20.72%	74.98%	-39.28%	-44.99%	85.61%	-24.24%	58.57%	870.29%	-41.25%	-72.25%	-40.02%	**117.60%**
333996	Fluid Power Pump and Motor Manufacturing	38.98%	-20.72%	74.98%	-39.28%	-44.99%	85.61%	-24.24%	58.57%	870.29%	-41.25%	-72.25%	-40.02%	**117.60%**
333997	Scale and Balance Manufacturing	38.98%	-20.72%	74.98%	-39.28%	-44.99%	85.61%	-24.24%	58.57%	870.29%	-41.25%	-72.25%	-40.02%	**117.60%**

Table VI-5: Annual Percentage Change in Profit Rates for Industries in General Industry and Maritime Affected by OSHA's Final Silica Standard (continued)

NAICS	Title	2011-2012	2010-2011	2009-2010	2008-2009	2007-2008	2006-2007	2005-2006	2004-2005	2003-2004	2002-2003	2001-2001	2000-2001	Average Change (Absolute Values)
333999	All Other Miscellaneous General Purpose Machinery Manufacturing	38.98%	-20.72%	74.98%	-39.28%	-44.99%	85.61%	-24.24%	58.57%	870.29%	-41.25%	-72.25%	-40.02%	**117.60%**
334519	Other Measuring and Controlling Device Manufacturing	8.38%	-14.51%	52.09%	-11.58%	-5.63%	-22.52%	-26.85%	310.79%	-289.62%	-52.75%	-456.78%	-73.35%	**110.40%**
335210	Small Electrical Appliance Manufacturing	-21.42%	39.21%	28.24%	-22.38%	34.59%	-11.33%	-26.19%	-0.12%	116.80%	29.67%	-27.82%	-44.37%	**33.51%**
335221	Household Cooking Appliance Manufacturing	-21.42%	39.21%	28.24%	-22.38%	34.59%	-11.33%	-26.19%	-0.12%	116.80%	29.67%	-27.82%	-44.37%	**33.51%**

Table VI-5: Annual Percentage Change in Profit Rates for Industries in General Industry and Maritime Affected by OSHA's Final Silica Standard (continued)

NAICS	Title	2011-2012	2010-2011	2009-2010	2008-2009	2007-2008	2006-2007	2005-2006	2004-2005	2003-2004	2002-2003	2001-2001	2000-2001	Average Change (Absolute Values)
335222	Household Refrigerator and Home Freezer Manufacturing	-21.42%	39.21%	28.24%	-22.38%	34.59%	-11.33%	-26.19%	-0.12%	116.80%	29.67%	-27.82%	-44.37%	**33.51%**
335224	Household Laundry Equipment Manufacturing	-21.42%	39.21%	28.24%	-22.38%	34.59%	-11.33%	-26.19%	-0.12%	116.80%	29.67%	-27.82%	-44.37%	**33.51%**
335228	Other Major Household Appliance Manufacturing	-21.42%	39.21%	28.24%	-22.38%	34.59%	-11.33%	-26.19%	-0.12%	116.80%	29.67%	-27.82%	-44.37%	**33.51%**
336111	Automobile Manufacturing	96.69%	1165.24%	-101.10%	169.42%	-1472.83%	6.95%	-90.83%	2114.40%	-54.75%	-28.01%	-166.42%	-158.73%	**468.78%**
336112	Light Truck and Utility Vehicle Manufacturing	96.69%	1165.24%	-101.10%	169.42%	-1472.83%	6.95%	-90.83%	2114.40%	-54.75%	-28.01%	-166.42%	-158.73%	**468.78%**

Table VI-5: Annual Percentage Change in Profit Rates for Industries in General Industry and Maritime Affected by OSHA's Final Silica Standard (continued)

NAICS	Title	2011-2012	2010-2011	2009-2010	2008-2009	2007-2008	2006-2007	2005-2006	2004-2005	2003-2004	2002-2003	2001-2001	2000-2001	Average Change (Absolute Values)
336120	Heavy Duty Truck Manufacturing	96.69%	1165.24%	-101.10%	169.42%	-1472.83%	6.95%	-90.83%	2114.40%	-54.75%	-28.01%	-166.42%	-158.73%	**468.78%**
336211	Motor Vehicle Body Manufacturing	45.22%	50.25%	-139.89%	476.36%	-134.51%	34.61%	-55.40%	465.42%	68.12%	-60.74%	268.37%	-85.89%	**157.06%**
336212	Truck Trailer Manufacturing	45.22%	50.25%	-139.89%	476.36%	-134.51%	34.61%	-55.40%	465.42%	68.12%	-60.74%	268.37%	-85.89%	**157.06%**
336213	Motor Home Manufacturing	45.22%	50.25%	-139.89%	476.36%	-134.51%	34.61%	-55.40%	465.42%	68.12%	-60.74%	268.37%	-85.89%	**157.06%**
336310	Motor Vehicle Gasoline Engine and Engine Parts Manufacturing	45.22%	50.25%	-139.89%	476.36%	-134.51%	34.61%	-55.40%	465.42%	68.12%	-60.74%	268.37%	-85.89%	**157.06%**
336320	Motor Vehicle Electrical and Electronic Equipment Manufacturing	45.22%	50.25%	-139.89%	476.36%	-134.51%	34.61%	-55.40%	465.42%	68.12%	-60.74%	268.37%	-85.89%	**157.06%**

Table VI-5: Annual Percentage Change in Profit Rates for Industries in General Industry and Maritime Affected by OSHA's Final Silica Standard (continued)

NAICS	Title	2011-2012	2010-2011	2009-2010	2008-2009	2007-2008	2006-2007	2005-2006	2004-2005	2003-2004	2002-2003	2001-2001	2000-2001	Average Change (Absolute Values)
336330	Motor Vehicle Steering and Suspension Components (except Spring) Manufacturing	45.22%	50.25%	-139.89%	476.36%	-134.51%	34.61%	-55.40%	465.42%	68.12%	-60.74%	268.37%	-85.89%	**157.06%**
336340	Motor Vehicle Brake System Manufacturing	45.22%	50.25%	-139.89%	476.36%	-134.51%	34.61%	-55.40%	465.42%	68.12%	-60.74%	268.37%	-85.89%	**157.06%**
336350	Motor Vehicle Transmission and Power Train Parts Manufacturing	45.22%	50.25%	-139.89%	476.36%	-134.51%	34.61%	-55.40%	465.42%	68.12%	-60.74%	268.37%	-85.89%	**157.06%**
336370	Motor Vehicle Metal Stamping	45.22%	50.25%	-139.89%	476.36%	-134.51%	34.61%	-55.40%	465.42%	68.12%	-60.74%	268.37%	-85.89%	**157.06%**
336390	Other Motor Vehicle Parts Manufacturing	45.22%	50.25%	-139.89%	476.36%	-134.51%	34.61%	-55.40%	465.42%	68.12%	-60.74%	268.37%	-85.89%	**157.06%**
336611	Ship Building and Repairing	7.25%	-18.51%	21.41%	4.08%	-12.99%	1.01%	27.78%	16.98%	26.75%	-14.64%	0.14%	29.11%	**15.06%**

Table VI-5: Annual Percentage Change in Profit Rates for Industries in General Industry and Maritime Affected by OSHA's Final Silica Standard (continued)

NAICS	Title	2011-2012	2010-2011	2009-2010	2008-2009	2007-2008	2006-2007	2005-2006	2004-2005	2003-2004	2002-2003	2001-2001	2000-2001	Average Change (Absolute Values)
336612	Boat Building	7.25%	-18.51%	21.41%	4.08%	-12.99%	1.01%	27.78%	16.98%	26.75%	-14.64%	0.14%	29.11%	**15.06%**
336992	Military Armored Vehicle, Tank, and Tank Component Manufacturing	78.72%	22.57%	112.43%	-62.05%	-37.37%	-15.11%	34.40%	17.38%	-8.24%	245.73%	-222.50%	-150.56%	**83.92%**
337110	Wood Kitchen Cabinet and Countertop Manufacturing	36.73%	-13.32%	752.05%	-47.58%	-84.80%	-24.51%	2.84%	58.68%	25.29%	-4.71%	43.85%	-52.28%	**95.55%**
337215	Showcase, Partition, Shelving, and Locker Manufacturing	36.73%	-13.32%	752.05%	-47.58%	-84.80%	-24.51%	2.84%	58.68%	25.29%	-4.71%	43.85%	-52.28%	**95.55%**
339114	Dental Equipment and Supplies Manufacturing	-4.24%	0.89%	0.06%	35.98%	-25.28%	-32.01%	-29.26%	154.94%	54.15%	-21.40%	13.99%	-15.06%	**32.27%**
339116	Dental Laboratories	-4.24%	0.89%	0.06%	35.98%	-25.28%	-32.01%	-29.26%	154.94%	54.15%	-21.40%	13.99%	-15.06%	**32.27%**

Table VI-5: Annual Percentage Change in Profit Rates for Industries in General Industry and Maritime Affected by OSHA's Final Silica Standard (continued)

NAICS	Title	2011-2012	2010-2011	2009-2010	2008-2009	2007-2008	2006-2007	2005-2006	2004-2005	2003-2004	2002-2003	2001-2001	2000-2001	Average Change (Absolute Values)
339910	Jewelry and Silverware Manufacturing	41.43%	-3.68%	67.28%	-23.03%	-14.68%	-21.25%	5.84%	60.16%	4.59%	4.75%	61.33%	-44.69%	**29.39%**
339950	Sign Manufacturing	41.43%	-3.68%	67.28%	-23.03%	-14.68%	-21.25%	5.84%	60.16%	4.59%	4.75%	61.33%	-44.69%	**29.39%**
423840	Industrial Supplies Merchant Wholesalers	21.40%	6.76%	55.74%	-34.94%	-12.86%	-8.32%	-0.61%	47.72%	85.88%	91.39%	-49.04%	-21.31%	**36.33%**
444110	Home Centers	31.89%	-7.37%	-9.83%	28.45%	-32.70%	-12.87%	-11.22%	26.77%	910.10%	-8.55%	-12.70%	-81.48%	**97.83%**
482110	Rail transportation	87.85%	-30.63%	95.61%	-33.43%	-30.37%	-8.56%	25.44%	248.51%	169.87%	46.07%	42.25%	-83.07%	**75.14%**
561730	Landscaping Services	14.88%	-7.35%	74.04%	-31.50%	-15.78%	-2.60%	-26.43%	103.69%	5.65%	63.31%	-42.52%	62.97%	**37.56%**
621210	Offices of Dentists	16.38%	-11.95%	4.66%	10.14%	-6.54%	25.52%	-3.80%	1.15%	22.47%	-1.62%	-2.06%	20.03%	**10.53%**

Source: Based on Internal Revenue Service, *Corporation Source Book*, 2012.

International Trade Effects

The magnitude and strength of foreign competition is an important factor in determining the ability of firms in the U.S. to pass on (part or all of) the costs of the rule in the form of higher prices for their products. If firms are unable to do so, they must absorb the costs of the rule out of profits, possibly resulting in the business failure of individual firms or even, if the cost impacts are sufficiently large and pervasive, causing significant dislocations within an affected industry.

Below, OSHA examines the likelihood of significant dislocations. The discussion will begin with some theoretical background and then proceed with empirical evidence and estimated impacts. Throughout, the Agency draws on ERG (2007c) (Document ID 1710), which was prepared specifically to help analyze the international trade impacts of OSHA's silica rule. OSHA concludes, based on the following analysis, that the rule will not result in significant dislocations due to foreign competition within any affected industry.

Theoretical Background

Despite the long history of international economics, there are relatively few tools that are directly applicable to analyzing the projected impacts of a domestic regulation on the international trade of affected industries. Ideally, such impacts would be evaluated using trade elasticities: econometric estimates of the percentage change in a country's imports and exports in response to a given percentage change in price caused by the regulation. Academic international trade economists tend to focus their attention on patterns of trade and factor flows, trade policy, and the implications of exchange rate regimes.[16] The vast amount of theoretical and econometric work performed on these topics tends to be at too high a level of aggregation to be of use in the narrow context of projecting the potential trade impacts on a specific industry.

A second reason trade elasticity estimates tend to be relatively rare in the literature might be attributable to the difficulty of estimating them. Data—including prices and quantities of imports, exports, domestic and foreign consumption and supply, and the myriad of other factors that affect consumption of these products—are often not available at a useful level of detail. For example, data tend to be either too aggregated to be informative or so granular that generating consistent indices of products of interest over several years is costly and difficult. In addition, because trade is rarely bilateral, the elasticity of the change in Japanese demand for U.S. products, for example, will not only depend on the

[16] See, for example, Deardorff (1984), Document ID 0617, and Goldstein and Kahn (1985), Document ID 0709.

U.S. price change, but also on the supply of the same product from Japan's other trading partners.

Because of the difficulty in obtaining useful, reliable trade elasticities, economists sometimes use "synthetic" elasticities to analyze trade impacts. These elasticities are not econometrically estimated, but instead are calculated from available data using relationships derived from the theoretical literature. Thus, a synthetic trade elasticity might be calculated as a function of the domestic price elasticity, transportation costs, and trade shares (Goldstein and Kahn, 1985, Document ID 0709). ERG examined two approaches to estimating trade elasticities using a synthetic approach: (1) one country's traded product is a *perfect* substitute (a good that can be used in the exact same way as the good it replaces) for its trade partner's product, and (2) one country's traded product is an *imperfect* substitute (a product someone can use as a substitute but it is not considered identical) for its trade partner's product.

When traded products are perfect substitutes, there are no models with distinct import demand or export supply relationships. Conceptually, trade is a residual in the perfect substitutes case; that is, a country's imports result from the excess demand for the domestic product. Similarly, exports are a residual resulting from excess supply remaining from domestic consumption. Thus, in the perfect substitutes model, trade can be estimated as the difference between domestic demand and domestic supply.

To simplify the model, the world can be divided into trade between the U.S. and the rest of the world (ROW). The relationship between the ROW price and the U.S. price is a function of the monetary exchange rate and transportation costs. The elasticity of U.S. imports with respect to a change in the U.S. domestic price is subject to key parameters such as transportation costs and relies on the assumption that what the U.S. imports is equal to what the ROW exports.

While this "perfect substitutes" approach to modeling trade elasticities makes intuitive sense, there is a significant methodological inconsistency in applying it to countries that both import and export a specific product because this combination creates opposing conditions. In the perfect substitutes framework, trade is a residual: the difference between domestic demand and supply. And U.S. exports for the same product are also determined as a residual: the difference between domestic supply and demand. Clearly both conditions cannot be true at the same time. Either domestic production exceeds demand and the country exports, or domestic demand exceeds domestic production and the country imports, but not both. This inconsistency suggests that the perfect substitutes framework is unsatisfactory for developing estimates of trade elasticities when a country both imports and exports the same product.

The second model involves imperfect substitutes. If consumers perceive foreign and domestically produced goods to be close, but not perfect, substitutes—that is, if consumers differentiate foreign from domestically produced goods—then a country may both import and export that general class of products simultaneously. This description better matches U.S. trade patterns for many products, including those produced by industries projected to be highly impacted by OSHA's silica rule.

One of the earliest and most frequently used methods for dealing with international trade in differentiated products is the synthetic elasticity model developed by Armington (1969a, Document ID 0533 and 1969b, Document ID 0534).[17] Armington models make two basic assumptions in order to differentiate internationally traded products. First, traded goods can be thought of as "weakly separable." Second, there exists a constant elasticity of substitution between all products in each broad category of goods the country imports.

The first assumption implies that consumption may be modeled using a two-stage decision-making process. In the first stage, consumers allocate their income across the spectrum of broad goods categories that they purchase; in the second stage, consumers allocate that share of income earmarked for a particular goods category among the differentiated products that comprise the category (Armington, 1969a, Document ID 0533). Thus, in the first stage, the Armington specification models consumers as choosing how to allocate their income across broad categories of goods—such as food, clothing, transportation, housing, etc.—given their income and the relative prices of each good. Assuming a consumer chooses fine earthenware in the first stage, in the second stage, the consumer needs to decide how to allocate that share of income among china and pottery products from the U.S., China, Great Britain, and other countries. This second division of income among the differentiated products depends only on the relative price of those products and the consumer's perceived elasticity of substitutability between those products. The second decision is "separable" from the first decision.

The second assumption—identical and constant elasticities of substitution between pairs of different countries' products—allows the Armington model to be estimated with less data and fewer computing requirements than if the demand for each country's product

[17] The Armington framework has become ubiquitous for incorporating trade flows in computable general equilibrium models (CGE). Significant CGE models such as those used by the U.S. International Trade Commission, the World Trade Organization, Australia's Productivity Commission, Trade Canada, and the Global Trade Analysis Project based at Purdue University all use Armington-type specifications to model trade flows. In addition, ERG developed a synthetic model for EPA to estimate trade elasticities for iron and steel products based on the Armington framework (EPA, 2002, Document ID 0656). This approach was revised and further developed to model the potential effects of EPA effluent guideline on trade in the meat and poultry product industries (EPA, 2004, Document ID 0659).

needed to be individually estimated. Although this second assumption is not literally true for all quantities of imports consumed in each country, it is a reasonable assumption for a country at its market equilibrium and for small changes from that equilibrium.

Armington (1969a, Document ID 0533) showed that trade in differentiated products—whether imports or exports—can be expressed as a function of (1) total demand for that product class regardless of source, (2) foreign and domestic market shares, and (3) the willingness of consumers to substitute foreign made for domestically made products (the elasticity of substitution, often referred to as the Armington elasticity). Armington (1969a, Document ID 0533, 1969b, Document ID 0534) derived relationships between certain important elasticities implied by his model, including the partial elasticity of demand in the i^{th} country for the j^{th} country's product; that is, the import price elasticity of demand for the i^{th} country with respect to a change in the j^{th} country's price. These relationships can be further simplified by looking at only two "countries," the U.S. and the rest of the world (ROW).

Empirical Evidence and Estimated Impacts

ERG (2007c) (Document ID 1710) reviewed Gallaway, McDaniel, and Rivera (2000) (Document ID 0694) for estimates of the elasticity of substitution for products from eight of the industries likely to be most affected by the silica rule and for which import and export data are available. These eight industries are listed with their NAICS code in Table VI-6, as well as with their estimated short-run Armington elasticity. These elasticity estimates range from 0.359 (iron foundries, NAICS 331511) to 1.073 (ground or treated mineral and earth manufacturing, NAICS 327992).

Relying on a variant of the imperfect substitutes model developed by Armington as a function of the elasticity of substitution, ERG combined econometric estimates of the elasticity of substitution between foreign and domestic products, Annual Survey of Manufactures data, and assumptions concerning the values for key parameters, such as the ROW consumption, to estimate the effect of a range of hypothetical price increases on total domestic production of a product. In particular, ERG estimated the domestic production that would be replaced by imported products and the decrease in exported products that would result from a one percent increase in prices—under the assumption that firms would attempt to pass on all of a one percent increase in costs arising from the final rule. The sum of the increase in imports and decrease in exports represents the total loss to industry attributable to the rule. These projected losses are presented as a percentage of baseline domestic production to provide some context for evaluating the relative size of these impacts.

The effect of a one percent increase in the price of a domestic product is derived from the baseline level of U.S. domestic production and the baseline level of imports. Table VI-6 shows the baseline ratio of import value to total U.S. consumption for the 8 affected industries. The ratios range from 0.04 for iron foundries to 0.547 for ceramic wall and floor tile manufacturing—that is, baseline imports range from 4 percent to more than 50 percent of domestic production in these 8 industries. Table VI-6 also shows ERG's estimates of the percentage reduction in U.S. production for the 8 affected industries due to increased domestic imports.[18] The estimated percentage reductions in U.S. production due to increased domestic imports (arising from a 1 percent increase in the price of domestic products) range from 0.013 percent for iron foundries to 0.237 percent for cut stone and stone product manufacturing.

The method to project impacts on U.S. exports closely parallels the method used to project the increase in U.S. imports. Under the simplified construction of bilateral trade between the U.S. and the ROW, U.S. exports are identical to ROW imports. Thus, ERG could estimate the change in ROW imports in a manner identical to that used to estimate the change in U.S. imports. However, there is one important difference between projecting the change in U.S. imports and projecting the change in U.S. exports. Projecting the change in U.S. exports (i.e., ROW imports) requires estimating the U.S. export share of ROW consumption. ERG was unable to find any data on ROW consumption for industries affected by the silica rule and instead made the very conservative assumption that ROW consumption of these products was ten times larger than U.S. domestic consumption of these products.[19]

Table VI-6 shows the estimated baseline ratio of ROW imports to ROW consumption for the 8 affected industries. The ratios range from 0.001 for other concrete manufacturing to 0.035 percent for nonclay refractory manufacturing. Table VI-6 also shows ERG's estimates of the percentage decrease in U.S. exports relative to total U.S. production for the 8 affected industries.[20] The estimated percentage reductions in U.S. production due to reduced U.S. exports (arising from a one percent increase in the price of domestic products) range from 0.014 percent for ceramic wall and floor tile manufacturing to 0.201 percent for nonclay refractory manufacturing.

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[18] For more details about the derivation of these estimates, see ERG (2007c) (Document ID 1710).

[19] ERG (2007c) performed a sensitivity analysis on the assumption concerning the size of ROW domestic consumption relative to U.S. domestic consumption. Varying the ROW domestic consumption from 2 to 20 times the size of U.S. domestic consumption had only a small effect on the projected changes in U.S. exports. This is because the U.S. export share of ROW consumption is relatively minor even when, for example, ROW consumption is assumed to be only twice as large as U.S. consumption rather than 10 times larger (Document ID 1710).

[20] For more details about the derivation of these estimates, see ERG (2007c) (Document ID 1710).

Table VI-6: Projected Total Trade Impacts for Selected Industries from a One Percent Price Increase in Response to Silica Rule

NAICS	Industry	Armington Elasticity[a]	Estimated Ratio of Imports to Total U.S. Consumption[b]	Estimated Ratio of ROW Imports to ROW Consumption[c]	Percentage Change in U.S. Production Due to Increased Domestic Imports[d]	Change in U.S. Exports Relative to Total U.S. Production[e]	Total Percentage Change in U.S. Production[f]
327111	Vitreous china plumbing fixtures & bathroom accessories manufacturing	0.784	0.252	0.007	-0.126%	-0.046%	-0.173%
327113	Porcelain electrical supply manufacturing	0.949	0.200	0.020	-0.136%	-0.163%	-0.299%
327122	Ceramic wall and floor tile manufacturing	0.529	0.547	0.003	-0.167%	-0.014%	-0.181%
327125	Nonclay refractory manufacturing	0.797	0.166	0.035	-0.085%	-0.201%	-0.286%
327390	Other concrete product manufacturing	1.027	0.094	0.001	-0.075%	-0.010%	-0.085%
327991	Cut stone and stone product manufacturing	0.874	0.469	0.002	-0.237%	-0.015%	-0.253%
327992	Ground or treated mineral and earth manufacturing	1.073	0.083	0.009	-0.071%	-0.086%	-0.157%
331511	Iron Foundries	0.359	0.040	0.005	-0.013%	-0.015%	-0.028%

[a] Source: ERG (2007c), Table 4-1.
[b] Source: ERG (2007c), Table 4-1. Calculated as a 5-year average.
[c] Source: ERG (2007c), Table 4-2. ROW is an acronym for the Rest of the World (other than the United States).
[d] Source: ERG (2007c), Table 4-1.
[e] Source: ERG (2007c), Table 4-2.
[f] Source: ERG (2007c), Table 4-3. Calculated from sum of change in U.S. imports plus the change in U.S. exports to ROW.

Source: OSHA, Directorate of Standards and Guidance, Office of Regulatory Analysis, based on ERG (2007c).

The last column of Table VI-6 shows ERG's estimates of the total percentage change in U.S. production for the 8 affected industries. Total impacts are calculated as the sum of the 2 previous columns, resulting from increased imports and from a loss of exports. The total percentage reduction in U.S. production arising from a 1 percent increase in the price of domestic products ranges from a low of 0.085 percent for other concrete product manufacturing to a high of 0.299 percent for porcelain electrical supply manufacturing.

These estimates suggest that the silica rule will have modest international trade effects. It was previously hypothesized that if price increases resulted in a substantial loss of revenue to foreign competition, then the increased costs of the rule would have to come out of profits. That possibility has been contradicted by the results reported in this section. The maximum loss to foreign competition in any affected industry due to a one percent price increase has been estimated at approximately 0.3 percent of industry revenue. Because, as reported earlier in this chapter, the maximum cost impact of the final rule for any affected industry would be 0.56 percent of revenue, this means that the maximum loss to foreign competition in any affected industry as a result of the rule would be 0.2 percent of industry revenue—which would hardly qualify as a substantial loss to foreign competition. This analysis cannot tell us whether the resulting change in revenues will lead to a small decline in the number of establishments in the industry or slightly less revenue for each establishment. However it can reasonably be concluded that revenue changes of this magnitude will not lead to the elimination of industries or significantly alter their competitive structure.

Based on the Agency's preceding analysis of economic impacts on revenues, profits, and international trade, along with the discussion of industry concerns below, OSHA concluded that the annualized costs of the final rule are below the threshold level that could threaten the economic viability of any industry in general industry or maritime. OSHA further noted that while there would be additional costs (not attributable to the final rule) for some employers in general industry and maritime to come into compliance with the new silica standard, these costs would not affect the Agency's determination of the economic feasibility of the final rule.

Public Comment on International Trade Effects

Foundries

The following comments discuss the loss of business to foreign competition in the foundry industry. The comments have been grouped together by issue and are followed by OSHA's response. The first group of commenters used impact numbers from an alternative cost model to discuss the loss of business to foreign competition.

The United States Chamber of Commerce ("the Chamber") stated that additional costs of the rule's ancillary provisions along with engineering controls will result in reduced competitiveness relative to foreign foundries (Document ID 2288, pp. 27-28). The Chamber also critiqued OSHA's inability to determine feasibility because of a lack of data to analyze economic impacts across facilities by age, design, operations, condition and region (Document ID 2288, pp. 29-30).

In the comments above, the negative economic effect of losing business to foreign competition is based on an alternative cost model report prepared for the American Foundry Society (AFS) by Environomics. This report is addressed in the Engineering Control Costs section in Chapter V of this FEA, where OSHA concluded that the costs in that report were inflated. Because these inflated costs also underpin the Chamber's claim that the rule will reduce competitiveness with foreign foundries, OSHA does not accept that claim. In response to the Chamber's criticism of OSHA's data sources, the Agency notes that Chapter III, the section on Survey Data and OSHA Economic Analyses, discusses why it was infeasible to collect and compile a full-scale national survey of the kinds of baseline conditions and practices that the Chamber of Commerce urged OSHA to consider.

The following comments from foundry firms and associations address foreign competition in metalcasting from China and India along with the inability to pass the cost on to their customers.

AFS submitted comments that the metalcasting industry would lose business to foreign competition as follows:

> Many foundries have closed in recent years with foreign competition assuming much of that business. Five of the eleven identifiable foundries used in the PEA to support OSHA's assertion of feasibility have closed. Because castings are the starting point of many manufacturing processes, loss of foundry jobs also means loss of other manufacturing jobs.
>
> The U.S. metalcasting industry is made up of 1,978 facilities, down from 2,170 five years ago. This reduction can be attributed to the recession, technological advancements, foreign competition and tightening regulations (Document ID 2379, Attachment 3, p. 42; 4035, p. 5).

The Indiana Cast Metals Association concurred with these comments and also suggested that other industries would also be negatively impacted if U.S. foundries shut down (Document ID 2049, p. 1). The Ohio Cast Metals Association submitted two comments stating that the rule will increase costs and undermine the Ohio-based metalcasting industry's ability to compete in the global marketplace:

> [The silica rule] will significantly increase costs, slow down or eliminate hiring, reduce the number of foundry jobs and undermine our industry's ability to compete in the global marketplace. For some foundries, the rulemaking could be the final straw that destroys their business.
>
> * * * Over the past two decades Ohio foundries along with other manufacturers throughout the United States have faced tremendous international competition from China, Brazil, and India and many foundries have closed and thousands of employees have lost their jobs during this period. To suggest that Ohio foundries can just pass on the tremendous costs associated with compliance with the proposed silica rule with "minimal loss of business to foreign competition" indicates that the individuals performing this analysis were driven by other agendas or misinformed (Document ID 2119, Attachment 3, pp. 1- 2).

Grede Holdings L.L.C. submitted a comment expressing its view that it would be difficult for foundries to pass the cost of compliance to the customer because of international competition, and that the number of foundries in the U.S. has dropped by more than half since 1980, going from 4,200 foundries to 2,050 foundries (Document ID 2298, p. 3).

Sawbrook Steel submitted two comments voicing concern that the implementation of the regulation will cause jobs to move overseas, resulting in a shrinking of the domestic casting manufacturing (Document ID 2227, p. 2; 1995, p. 1).

In the comments above, businesses and associations state that the costs of the rule will be too high and they will lose business to foreign competition. The chief advantage of foreign imports to downstream users, as reported to the U.S. International Trade Commission (ITC) during an investigation they conducted into the competitive conditions in the U.S. foundry market, is their low pricing. Respondents to the investigations said the cost of foreign produced products ranged from ten percent to forty percent less than the cost of U.S. products (Document ID 0753, table 5-60, p. 5-53 as referenced in Document ID 1710, pp. 5-4). U.S. producers have responded to competition with a broad array of initiatives, such as implementing lean manufacturing, improving customer service, and increasing automation (Document ID 0753, pp. 10-14 and 10-15). According to the ITC study:

> The use of technology may also be influenced by the type of castings produced and relative wage rates. Low-value, low-quality castings, for example, generally require a lower level of technology and relatively more semi-skilled labor than foundries producing more complex castings. To lower labor costs, foundries in developed countries with higher wage rates may install more automation and technological improvements, whereas foundries in developing countries with relatively lower wage rates may

> substitute labor for relatively high-cost capital investments (Document ID 0753, p. 2-11).

Before addressing issues on international competition for metalcasters, it should be noted that all foundry industries affected by this rule are below the ten percent cost to profit threshold and one percent cost to revenue threshold. This means that even if the argument that costs cannot be passed on were to be correct, the loss in profits would be less than ten percent and unlikely to effect the feasibility of the industry. Further the costs to be passed on would require less than one percent price increases. In general, metalcasters in the U.S. have shortened lead times, improved productivity through computer design and logistics management, provided expanded design and development services to customers, and provided a higher quality product than foundries in China and other nations where labor costs are low (Document ID 0753, p. 3-12). All of these measures, particularly the higher quality of many U.S. metalcasting products and the ability of domestic foundries to fulfill orders quickly, are substantial advantages for U.S. metalcasters that may outweigh the very modest price increases projected above in Tables VI-3 and VI-4 (Document ID 1710, p. 5-4). According to the ITC study, quality was the number one purchasing decision factor for the majority of purchasers, with price and lead times ranking lower, and U.S. metalcasters are able to deliver that quality (Document ID 0753, p. 4-5). The ITC report noted:

> Certain purchasers noted that when inventory management and complex manufacturing skills are required, U.S. foundries excel. U.S. foundries were also cited by responding U.S. purchasers as manufacturing with a low defect (rejection) rate. (Id.)

Purchaser responses to the ITC’s survey stated that some U.S. foundries are also completely inoculated against foreign competition, even if the prices of U.S. foundry products rise:

> As noted in questionnaire responses, certain purchasers are committed to buying solely U.S.-made castings. One U.S. foundry official noted that if downstream customers require castings to be made in the United States, then U.S. foundries are guaranteed that business. This situation often occurs when foundries supply castings for federally funded operations, such as construction projects (Document ID 0753, p. 4-5).

Foundries in China and India, while expanding their capacities, are also faced with rising domestic demand due to their own rapidly expanding domestic industrial economies, which affect their ability to fulfill export demand (Document ID 0753, p. 5-16). ERG’s research noted a growth in U.S. foundry exports, which could help to offset some of the foreign imports entering the U.S. market. According to one report cited by ERG, U.S.

foundry exports were roughly equivalent to 53 percent of the imports (Document ID 1710, p. 5-5).

ERG's research also provided some evidence that the combination of U.S. and foreign demand for metalcasting may outstrip the supply to such a degree that, even if the U.S. foundries operated at full capacity, their maximum output would fail to meet the demand from the U.S. and foreign markets (Document ID 1710, p. 5-5). The U.S. foundry industry is unlikely to face any significant economic impacts if there is ample demand and a limited supply because such a condition makes it easier to pass along any costs of the rule.

Tile Production

The following comments discuss the difficulties of competing with foreign tile producers followed by OSHA's response.

Tile Council of North America (TCNA) noted the import price sensitivity between domestic tile and imported tile as follows:

> The low cost of imported tile places an enormous burden on U.S. tile manufacturers to maintain current pricing to remain competitive.
>
> According to the latest data collected by TCNA, the average price per square foot of U.S. tile shipments is $1.43. The average price per square foot of Chinese imports is $0.86. With Chinese imports 60% less expensive than U.S. tile in what is an extremely price-competitive market, OSHA's claim that "any price increases would result in minimum loss of business to foreign competition" strains credulity.
>
> To illustrate the tremendous import/price sensitivity between domestic tile and imports, we note the increase in imports from Peru as a result of a bilateral free trade agreement between Peru and the United States eliminating duty on tile from Peru. Although only amounting to a price change of 4 – 5 cents per square foot, from 2008, the year before the bilateral agreement to the end of 2011, tile imports from Peru into the United States grew by 59%. This illustrates how even a small change in price due to modest increases in operating costs and raw material costs pose an existential threat to the tile manufacturing industry.
>
> The import sensitivity of domestic tile manufacturing operations is well known by the United States International Trade Commission (USITC) and the office of the United States Trade Representative (USTR). The assertion made by OSHA that cost increases will not result in lost market share to foreign competition is in direct conflict with information known

> by USITC and the USTR and contrary to established public policy (as reflected in existing Free Trade Agreements) and industry testimony.
>
> Contrary to the assertion made by OSHA, the marginal price increases anticipated by required conformance to the rule as proposed would make the domestic tile manufacturing industry highly uncompetitive threatening the very viability of this import-sensitive industry (Document ID 2363, p. 9).

The National Tile Contractors Association also questioned OSHA’s preliminary determination that the tile industry could pass on most or all costs through higher prices, calling the claim “wildly erroneous”:

> Implementation of the proposed rule's requirements would increase both production and installation costs, and would put pressure on consumer prices. At a time when U.S. consumption of ceramic tile is more than 25% below its peak level (2006), this is a serious concern. The U.S. market is already flooded with lower quality, lower priced imports from many countries that likely do not respect the health, safety, and rights of workers. The low cost of imported tile places an enormous burden on U.S. tile manufacturers to maintain current pricing to remain competitive (Document ID 2267, p. 8).

Dal-Tile echoed the TCNA comments regarding the inability to pass costs onto the customer (Document ID 2147, p. 3).

OSHA does not dispute the commenters’ information indicating that Chinese and Peruvian tile are significantly cheaper than U.S. tile, but that point actually undercuts their claim that a small change in the price of U.S. tile would place an “enormous burden” on U.S. tile manufacturers. The commenters note that Chinese tile is already available in the U.S. at just over half the price of U.S. tile. If the market was actually as sensitive as the commenters suggest, and the Chinese tile was competing for the same market share as U.S. tile, under the commenter’s logic the U.S. tile industry would have already gone out of business. But that has not happened, suggesting that U.S. tile manufacturers have been able to identify customers for whom the tile price is not the predominant factor. Likewise, the example of Peruvian tile demonstrates only that the lower-priced imported tile is sensitive to small price changes. The commenter provides no evidence that the Peruvian tile is competing for the same customers as the U.S. tile industry.

In summary, the TCNA’s argument that cost increases will result in lost market share to foreign competition is unconvincing because it is not clear that there is a strong relationship between the price of the foreign tile and the price of the U.S. tile. One likely cause for this disconnect is that, as TCNA notes, the market is "already flooded with lower quality, lower priced" imports (Document ID 2363, p. 8), suggesting that tile from China, Peru, and the other lower-priced foreign importers are of a lower quality that may be targeted at a different customer base than the higher-quality U.S. tile. This perception that tile from China and other low-cost tile producing countries may be of lower quality produces an imperfect substitution scenario and adds to the inelasticity of demand for domestic tiles, enabling producers to pass some of the costs on to the consumer.

On the other end of the tile price range are the Italian tiles. Italy and China are the top countries of origin for tiles imported into the U.S., but tiles from these countries command very different prices. In terms of general tile products, one source indicates that the average prices of tiles imported by the U.S. in 2012 were $20.20 to $20.90 per square meter for Italian tiles and between $8.30 and $8.70 per square meter for Chinese tiles imported by the U.S, a significant price difference that could be explained by a difference in quality.[21] TCNA stated above that the average price of tile from China is $0.86 per square foot or $9.25 (10.76 X 0.86) per square meter. TCNA's average price of American tile is $1.43 per square foot or $15.39 (10.76 X 1.43) per square meter (Document ID 2363, p. 9), which shows the U.S. producers to be supplying a mid-priced product. Although Italy is also a major source of tile imports in the U.S. despite their higher price, the commenters did not suggest that an increase in U.S. tile prices would cause the U.S. to lose market share to the Italian tile; nor did the commenters suggest that lower-priced U.S. tile could be exported to dominate the Italian market. The implication is, again, that different customers are willing to pay different prices for different quality tile.

Using price as an indicator of quality, the tile market can be segmented into three categories: low quality, mid-grade, and high quality. The U.S. tile industry has located a niche between the lowest quality/lowest priced tile and the highest quality/highest priced tile. While it is possible that a few tile firms that produce very low-quality or very high-quality tile may be negatively impacted by an increase in the price of their tile, OSHA concludes that the majority of firms would not experience a significant negative economic impact. This is along with the fact that the increase in price from this rule is expected to be minimal. TCNA commented that the average price per square foot of U.S. tile shipments is $1.43. The cost to revenue ratio for NAICS 327122 Ceramic Wall and Floor Tiles is 0.35 percent, meaning this final rule will increase the average cost of U.S. tile by five hundredths of a cent (or $0.0005 per square foot). It is therefore fair to say this extremely modest increase in the average price of U.S. tile would not have a significant economic impact on the U.S. tile industry as a whole.

Brick Industry

[21] http://www.scirp.org/journal/PaperInformation.aspx?PaperID=43515

During the public hearing Belden Tri-State Building Materials stated that the brick industry has foreign competition, mostly from Canada, and some from Mexico (particularly in Texas, Oklahoma or Arkansas), and Germany (Document ID 3586, Tr. 3457). They indicated that their competition includes not only imported brick but also “other cladding materials like vinyl siding and HardiePlank,” but the competition from imported brick is typically “more expensive brick” because of “innovations in Europe that we just haven't caught up to, different sizes, different colors, different processes” (Id.).

ACME Brick Company representatives indicated in testimony that oversees competition was virtually nonexistent because it is “hard to get that across the ocean economically” and noted that they generally locate their production facilities strategically to be near their markets because “[p]roduction costs really are about a third of the cost of the brick when we have them close. . .[The] farther away [the bricks come from] -- there are some distinctions in the quality or the makeup of a brick” (Document ID 3577, Tr. 736).

This testimony indicates to OSHA that international competitors will not be able to take advantage of any potential price increases made by U.S. producers in the U.S. domestic brick market. The brick making industry will therefore be able to pass on most, if not all, of the costs of complying with the rule.

Hydraulic Fracturing

To determine the economic impacts for most industries, OSHA used the Census Bureau’s Statistics of U.S. Businesses to estimate revenues on a six-digit NAICS basis but these revenue data were not sufficiently precise to isolate the hydraulic fracturing component from the larger industry (NAICS 213112). As a result, instead of using data from the Economic Census, revenues for hydraulic fracturing firms were based on estimated utilization rates and per stage revenues. As discussed in Chapter III, Profile of Affected Industries, the data on this industry have been updated to reflect the comments in the record and the best data available in 2012. The cost to profit percentage for the hydraulic fracturing industry estimated in this FEA is 7.67 percent (below OSHA’s ten percent threshold) for fleets of all sizes. The ratio of costs to revenues for hydraulic fracturing firms in this FEA is estimated to be 0.54 percent for all establishments in the industry, 0.17 percent for small entities and 0.24 percent for very small entities. Although the costs as a percent of revenue increased for all establishments, the impacts still remain well below the one percent threshold.

However, these estimates are based on the state of the industry in the base year of 2012 supplemented with data provided in comments to the proposed rule in 2013 and early

2014. When the PEA was published in 2006, the price of oil fluctuated between $70 and $80 a barrel. During the years following the publication of the PEA the price of oil has had some large fluctuations. Before the recession of 2008 the price of oil peaked at $146 per barrel but dropped to $44 dollars per barrel during the economic downturn in 2008.[22] As the price of oil steadily increased during 2009, there was an influx of money invested in the hydraulic fracturing industry. This FEA uses revenue data from 2012 when the price per barrel fluctuated between $90 and $100. However, in the fourth quarter of 2014, the price of oil dropped to $49 per barrel. The price of oil in 2015 has oscillated between approximately $45 and $60 per barrel.[23] Because of this major change in the industry since the record closed in 2012, OSHA has supplemented its feasibility analysis with more current data.

The Structure of the Hydraulic Fracturing Industry

Hydraulic fracturing nearly doubled U.S. oil production from 5.6 million barrels a day in 2010 to a rate of 9.3 million barrels a day in 2015. Up until the drop in oil prices during the fourth quarter of 2014, the expected annual increase in production was one million barrels. The economics of hydraulic fracturing wells is much different than conventional wells.[24] The marginal cost of producing a barrel of oil from a conventional well for large oil producing countries is around $15 to $30.[25] Therefore, the owners of conventional wells continue to produce even as the price per barrel decreased from $100 to $40, and would remain in business at costs down to $30. The traditional oil drilling business is driven by marginal costs, not costs spent to drill the well. This means that supply is inelastic relative to demand. This has not been true for the hydraulic fracturing industry.

Hydraulic fracturing wells have a very short life compared to conventional wells. For example, a well in the Bakken region straddling Montana and North Dakota may start out producing 1,000 barrels a day then decline to 280 barrels at the beginning of year two. By year three, more than half of the reserves will be depleted. Therefore, to generate revenue, producers need to constantly drill new wells. In this sense, hydraulic fracturing wells are more like gold or silver mines than conventional oil production.[26] The recent drop in oil prices has caused a series of bankruptcies and closures across the oil

[22] http://www.macrotrends.net/1369/crude-oil-price-history-chart

[23] http://www.macrotrends.net/1369/crude-oil-price-history-chart.

[24] http://fortune.com/2015/01/09/oil-prices-shale-fracking/

[25] http://knoema.com/vyronoe/cost-of-oil-production-by-country

[26] http://fortune.com/2015/01/09/oil-prices-shale-fracking/

industries. Although there was a reduction in the number of rigs from about 1,600 to 800,[27] hydraulic fracturing still accounted for 4.6 million barrels a day out of a total of 9.4 million barrels or 49 percent of total oil produced in February 2015. Hydraulic fracturing also accounted for 54 percent of natural gas output.

The Energy Information Administration (EIA) projects the Brent crude oil price will average $40 a barrel in 2016 and $50 a barrel in 2017. However, EIA expects crude oil prices to rise in future years, rising to over $70 per barrel by 2020 and to $100 per barrel by 2028. EIA's crude oil price forecast remains subject to significant uncertainties as the oil market moves toward balance and could continue to experience periods of heightened volatility.[28] Thus, industry implementation of OSHA's engineering control requirements, which are not required until five years after the effective date of the rule, may come during a period of much higher and rising energy prices. In any case, the price increase required by this rule is a very small fraction of the fluctuation in energy prices during the past several years.

However, the possibility that oil prices are not going to increase in the near future has spurred a new wave of innovation in energy exploration. Now that prices have dropped to around $50 a barrel, companies are focusing on efficiency and getting the most petroleum for the least amount of money. With the effective date of this rule on the horizon, it is possible that some of this innovation will lead to technologies that not only increase efficiency but reduce worker exposures to silica at the same time.

Through the application of new technology OSHA believes that, even in a lower price environment, hydraulic fracturing entrepreneurs will be able to implement the controls required by this final rule without imposing significant costs, causing massive economic dislocations to the hydraulic fracturing industry, or imperiling the industry's existence. Big oil-field-services like Haliburton Co. and Schlumberger Ltd. report that they have witnessed customers concentrating on using technology such as lasers and other high-tech equipment and data analytics before they drill to make sure new wells deliver the most crude for the investment cost. The application of this new technology as well as fiber-optic tools that help monitor a well during hydraulic fracturing to make sure that it's working as well as possible and new techniques to stimulate microbes already present that attach themselves to bits of oil, essentially breaking it up and making it easier for the crude to flow through rock[29] have had positive quantitative results. Productivity at some

[27] http://www.economist.com/node/21648622/print

[28] http://www.eia.gov/forecasts/steo/report/prices.cfm

[29] http://www.wsj.com/articles/oil-companies-tap-new-technologies-to-lower-production-costs-

"super-fracking" wells has increased 400-600 barrels a day per rig from just a few years ago. Drilling efficiency in some areas has increased as much as 26 percent in a single year[30] while the time to drill and fracture a well has come down from an average of 32 days in 2008 to now only about half that time: 14-16 days from start to finish and in some cases even less. These increased efficiencies result in significant cost savings.[31] Also, the lower demand by hydraulic fracturing companies for equipment rental, trucking, and labor has caused a decrease in their prices, reducing the overall cost of hydraulic fracturing.[32]

Although the drop in the price of oil has caused an initial reduction in hydraulic fracturing operations, the application of recently developed technology to new wells has increased per well production. One expert was quoted in Fortune magazine as saying "[t]here tailing off in U.S. drilling activity, but I expect continued development drilling in major new areas, particularly the Bakken, even at $50 (a barrel)."[33] In the Bakken region in 2015 the decrease in oil production resulting from the reduction of rigs was substantially offset by increases in new well oil production per rig. There are reasons to believe in the continuance of tight oil growth. An analysis by IHS shows that most of the potential U.S. tight oil capacity additions in 2015 have a break-even price in the range of $50 to $69 per barrel. Continued productivity gains, such as improvements in well completion and downspacing, also support the continuation of U.S. production growth at lower prices.[34] Based on these advances, it is plausible that hydraulic fracturing shale operations may achieve break-even costs of $5-$20 per barrel.[35]

A sign of the ongoing effectiveness of upgrades in efficiency in the hydraulic fracturing business is evident in the projections for U.S. crude production. The EIA's Annual

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[30] http://www.forbes.com/sites/judeclemente/2015/05/07/u-s-oil-production-forecasts-continue-to-increase/

[31]https://www.aei.org/publication/top-10-things-i-learned-on-my-summer-trip-to-the-bakken-oil-fields-part-ii/

[32] http://fortune.com/2015/01/09/oil-prices-shale-fracking/

[33]http://fortune.com/2015/01/09/oil-prices-shale-fracking/

[34] http://press.ihs.com/press-release/energy-power/tight-oil-test-us-production-growth-remains-resilient-amid-lower-crude-oi

[35] http://economics21.org/commentary/shale-2.0-big-data-revolution-america-oil-fields-05-20-2015

Energy Outlook for 2015 has projected that the U.S. is on track to hit reach a record for crude output at 10.6 million barrels a day in 2020.[36]
While the economic conditions faced by the hydraulic fracturing industry have changed significantly since the publication of the proposed rule, this discussion shows that there is significant reason to believe that this rule will not have a significant impact on the hydraulic fracturing industry. Advancements in technology and the application of new efficient drilling methods continue to increase the per-rig production capacity of new-well oil drilling rigs while lowering the costs of operating these rigs. These technological changes increase the energy recovered through hydraulic fracturing, and thus the value of fracturing services, without increasing the costs per well associated with controlling silica exposures. Further, the demand for fracturing services will depend, in part, on energy prices. The costs associated with complying with the silica rule are a minor issue by comparison. Thus, OSHA's conclusion that this rule is economically feasible for the hydraulic fracturing industry has not changed.

Railroads

In the PEA, OSHA did not include any estimates of costs as percentage of revenues or as a percentage of profits for railroads. This was due to the fact that the standard sources of economic statistics that were used for data on revenues and employment for all other affected industries do not include railroads. The Association of American Railroads (AAR) expressed concern about the impact of the rule on small railroads (although not on larger railroads), but did not provide any estimates or analysis, or suggest that OSHA use any specific sources to conduct such an analysis. For this FEA, OSHA did examine costs as percentage of revenues and profits for the railroad industry as a whole using supplemental information from sources typically relied on by the industry.

For this FEA, OSHA estimated that 16,895 workers in the rail transportation industry (NAICS 4821; "railroads") will be covered by the final standard, including 7,239 workers employed as Ballast Dumpers and 9,656 workers employed as Machine Operators (for the purposes of this analysis, OSHA assumed that the machine operators would be conducting at least some work outside of the cab of the equipment). The Agency estimated that compliance costs for railroads will total $16.6 million, or $980 per affected worker.

Based on these estimates, OSHA judged that the final rule is feasible for railroads because combining supplemental data from BLS37 and the Association of American

[36] http://www.forbes.com/sites/judeclemente/2015/05/07/u-s-oil-production-forecasts-continue-to-increase/
[37] Bureau of Labor Statistics, Quarterly Census of Employment and Wages, Series ID

Railroads38 for the estimated 105 rail transportation establishments in NAICS 4821 with a reported revenue of $72.9 billion, the cost-to-revenue impacts are an estimated 0.02 percent and cost-to-profit impacts are an estimated 0.4 percent. In addition, the per-worker cost for railroads ($980) is lower than the average per-worker cost ($1,231) across all affected NAICS industries in general industry and for 2000-2012, the average profit rate for rail transportation, 6.2 percent, was significantly higher than the average profit rate for all affected NAICS industries throughout general industry (3.4 percent).

The AAR noted that small railroads had not been covered in the Initial Regulatory Flexibility Analysis (Document ID 2366, p. 4). The commenter is correct that OSHA did not examine small entities in this sector but has done so for this FEA using supplemental information on railroads.

In 2012, 574 U.S. freight rail establishments, employing 181,264 workers, operated on roughly 169,000 miles of track.39 The Surface Transportation Board in the U.S. Department of Transportation classifies railroads into three groups based on annual revenues:

- Class I for freight railroads defined as railroads with annual operating revenues above $467.1 million ($2013)
- Class II, includes some regional railroads, defined as railroads each with operating revenues between $37.4 million and $467.1 million ($2013)
- Class III for all other freight rail operations (including smaller regional, short-line, switching, and terminal).40

In 2013**,** in addition to the seven Class I freight railroad systems, there were 21 regional railroads (line-haul railroads operating at least 350 miles of road and/or earning revenue between roughly $40 million and the Class I threshold), and over 500 local railroads (line-haul or short-line railroads smaller than regional railroads).41 Among the 567

ENUUS0002054821, NAICS 4821, Rail Transportation. Accessed November 6, 2015.

[38] Railroad Statistics. Association of American Railroads. AAR Policy and Economics Department. July 15, 2014. https://www.aar.org/StatisticsAndPublications/Documents/AAR-Stats.pdf

[39] Class I Railroad Statistics. Association of American Railroads. AAR Policy and Economics Department. July 15, 2014.

[40] Federal Register, Volume 79, No. 111, June 10, 2014, p. 33257, cited in Summary of Class II and Class III Railroad Capital Needs and Funding Sources – A Report to Congress, Federal Railroad Administration, October 2014, p. 2. https://www.fra.dot.gov/Elib/Document/14131

[41] Freight Railroads Background. (FRA, 2015) Stephanie Lawrence, Office of Policy, Office of Rail

railroads that fell below the Class I revenue threshold, 11 qualified as Class II and the remainder (556, including 10 regional railroads) qualified as Class III (FRA, 2015). Class III railroads are typically local short-line railroads serving a small number of towns and industries or hauling cars for one or more larger railroads. Many Class III railroads were once branch lines of larger railroads or abandoned portions of main lines.

In 2012, employment within 546 local railroad companies totaled 12,293 workers and employment within 21 regional railroads totaled 5,507 workers. Line Haul Railroads are classified in NAICS 482111 and entities within this industry with 1,500 or fewer workers are classified as small by SBA size standards. Local/Short Line Railroads are classified in NAICS 482112 and entities within this industry with 500 or fewer workers are classified as small by the SBA size standard. For 2012, OSHA estimated that all 567 Class II and Class III railroads (combined total of 17,800 workers) qualified as small entities according to the SBA definitions.

In a recent study prepared for Congress42, the Federal Railroad Administration reported that in 2013, 546 Local/Short Line Railroads employed 12,293 workers and earned $2.6 billion in revenue. OSHA estimates that of the 16,895 affected employees throughout rail transportation, 1,146 employees of Short-Line railroads are affected by the final rule.43 According to the BLS Quarterly Census of Employment and Wages, on average 32 establishments were identified within NAICS 482112, Short-Line Railroads (an establishment can operate more than one railroad). Therefore, if all 546 Class III railroads are controlled by 32 establishments, OSHA estimates that revenue per establishment is approximately $81.3 million.

OSHA estimated that compliance costs for rail transportation will total $16,562,059. Therefore, if costs per affected worker ($980 per worker) are apportioned to the establishments operating Short-Line Railroads, OSHA estimates that costs for these local railroads will total $1.1 million, or roughly $35,100 per establishment. As noted above, annual revenues among Short-Line rail operations total approximately $2.6 billion, or $81.3 million per establishment. Applying the industry-wide profit rate of 6.23 percent for NAICS 4821, OSHA estimated that profits per establishment in NAICS 482112 are $5.1 million. Therefore, OSHA estimates that impacts measured as costs as a percent of

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Policy and Development, Federal Railroad Administration April 2015. https://www.fra.dot.gov/eLib/Details/L03011. These regional railroads are almost evenly divided between Class II (11 railroads) and Class III (10 railroads).

[42] Summary of Class II and Class III Railroad Capital Needs and Funding Sources, Federal Railroad Administration, Report to Congress, October 2014. https://www.fra.dot.gov/Elib/Document/14131.

[43] (16,895 affected workers / 181,264 total employees in NAICS 4821) * 12,293 total Short-Line employees = 1,146 affected Short-Line employees.

revenues will not exceed 0.04 percent, and that impacts measured as costs as a percent of profits will not exceed 0.69 percent. Thus, OSHA concludes that the silica standard will not impose a significant impact on a substantial number of small entities in rail transportation and therefore will not threaten the competitive structure or viability of small entities in NAICS 482110.

Economic Feasibility Screening Analysis: Small and Very Small Businesses

The preceding discussion focused on the economic viability of the affected industries in their entirety. Even though OSHA found that the final standard did not threaten the survival of these industries, there is still the possibility that the competitive structure of these industries could be significantly altered.

To address this possibility, OSHA followed its normal rulemaking procedure for examining the annualized costs per affected small entity and very small entity for each affected industry in general industry and maritime. Again, OSHA used its typical minimum threshold level of annualized costs equal to one percent of annual revenues—and, secondarily, annualized costs equal to ten percent of annual profits—below which the Agency has concluded that the costs are unlikely to threaten the survival of small entities or very small entities or, consequently, to alter the competitive structure of the affected industries.

Compliance costs for entities with fewer than 20 employees were estimated, in many cases, using a derived compliance cost per employee. Assuming costs to be equally distributed among all employees, OSHA estimated the compliance cost per employee by dividing total costs for each NAICS by the number of employees. OSHA then multiplied the compliance cost per employee with the ratio of the average number of employees per entity with fewer than 20 employees. Similarly, compliance costs per small entity were estimated from the product of compliance costs per employee and the average number of employees in entities within the SBA classification for the given NAICS. However, some compliance costs, such as some engineering control costs, were modified to reflect diseconomies of scale for very small establishments.

Table VI-7 shows that the annualized cost of the final rule for the average small entity in general industry and maritime is estimated to be $2,967 in 2012 dollars. Table VI-8 shows that the annualized cost of the final rule for the average very small entity in general industry and maritime is estimated to be $1,532 in 2012 dollars. The only industry in which the annualized costs of the final rule for small entities exceed one percent of annual revenues is NAICS 213112 (Support Activities for Oil and Gas Operations), which is estimated to be 1.29 percent. There are two industries for very small entities exceeding one percent of annual revenues - NAICS 213112 (Support Activities for Oil and Gas Operations), 2.09 percent and NAICS 327110 (Pottery, Ceramics, and Plumbing Fixture Manufacturing), 1.21 percent.

Small entities in nine industries in general industry and maritime are estimated to have annualized costs in excess of ten percent of annual profits; NAICS 327110: Pottery, Ceramics, and Plumbing Fixture Manufacturing (38.57 percent); NAICS 327120: Clay Building Material and Refractories Manufacturing (33.59 percent); NAICS 327991: Cut Stone and Stone Product Manufacturing (24.70 percent); NAICS 327999 All Other Miscellaneous Nonmetallic Mineral Product Manufacturing (20.90 percent); NAICS 327390: Other Concrete Product Manufacturing (18.59 percent); NAICS 213112: Support Activities for Oil and Gas Operations (18.15 percent); NAICS 327332: Concrete Pipe Manufacturing (14.53 percent); NAICS 327331: Concrete Block and Brick Manufacturing (13.11 percent); and NAICS 327320: Ready-Mix Concrete Manufacturing (11.51 percent).

Very small entities in sixteen industries are estimated to have annualized costs in excess of ten percent of annual profit: NAICS 327110: Pottery, Ceramics, and Plumbing Fixture Manufacturing (90.64 percent); NAICS 327120 Clay Building Material and Refractories Manufacturing (58.51 percent); NAICS 327999: All Other Miscellaneous Nonmetallic Mineral Product Manufacturing (51.05 percent); NAICS 327991: Cut Stone and Stone Product Manufacturing (30.81 percent); NAICS 327390: Other Concrete Product Manufacturing (29.24 percent); NAICS 213112: Support Activities for Oil and Gas Operations (29.46 percent); NAICS 327212: Other Pressed and Blown Glass and Glassware Manufacturing (22.66 percent); NAICS 327332: Concrete Pipe Manufacturing (22.11 percent); NAICS 327211: Flat Glass Manufacturing (20.44 percent); NAICS 327331: Concrete Block and Brick Manufacturing (19.52 percent); NAICS 327993: Mineral Wool Manufacturing (17.42 percent); NAICS 327992: Ground or Treated Mineral and Earth Manufacturing (16.33 percent); NAICS 327320: Ready-mix Concrete Manufacturing (15.91 percent); NAICS 331513: Steel Foundries (except investment) (12.27 percent); NAICS 331524: Aluminum Foundries (except die-casting) (11.29 percent); NAICS 331511: Iron Foundries (10.03 percent).

In general, cost impacts for affected small entities or very small entities will tend to be somewhat higher, on average, than the cost impacts for the average business in those affected industries. That is to be expected. After all, smaller businesses typically suffer from diseconomies of scale in many aspects of their business, leading to lower revenue per dollar of cost and higher unit costs. Small businesses are able to overcome these obstacles by providing specialized products and services, offering local service and better service, or otherwise creating a market niche for themselves. The higher cost impacts for smaller businesses estimated for this rule generally fall within the range observed in other OSHA regulations for which there is no record of major industry failures.

In allocating the share of costs to very small entities, OSHA did not have direct information about how many very small entities were engaged in silica-related activities. Instead, OSHA assumed that the affected employees would be distributed among entities of different size according to each entity size class's share of total employment. In other words, if 15 percent of employees in an industry worked in very small entities (those with fewer than 20 employees), then OSHA assumed that 15 percent of affected employees in the industry would work in very small entities. However, in reality, OSHA anticipates that in industries with foundries, none of the entities with fewer than 20 employees have foundries or, if they do, that the impacts are much smaller than estimated here.

Table VI-7 Screening Analysis for SBA Establishments in General Industry and Maritime Affected by OSHA's Silica Standard

NAICS	Industry	Compliance Costs	Total Affected SBA Entities	Annual Cost per Affected Entity	Annual Revenue per SBA Entity ($1000)	Percent Profit	Annual Profit per Entity	Cost to Revenue	Cost to Profit
213112	Support Activities for Oil and Gas Operations	$24,247,594	150	$161,651	$12,562	7.09%	$890,424	1.29%	18.15%
324121	Asphalt Paving Mixture and Block Manufacturing	$257,611	422	$610	$13,668	5.96%	$814,552	0.00%	0.07%
324122	Asphalt Shingle and Coating Materials	$1,272,241	118	$10,782	$22,415	5.96%	$1,335,765	0.05%	0.81%
325510	Paint and Coating Manufacturing	$572,603	646	$887	$7,831	3.86%	$302,569	0.01%	0.29%
327110	Pottery, Ceramics, and Plumbing Fixture Manufacturing	$5,059,640	620	$8,161	$1,581	1.34%	$21,157	0.52%	38.57%
327120	Clay Building Material and Refractories Manufacturing	$13,647,591	393	$34,727	$7,725	1.34%	$103,384	0.45%	33.59%
327211	Flat Glass Manufacturing	$129,486	39	$3,282	$7,263	2.63%	$190,646	0.05%	1.72%
327212	Other Pressed and Blown Glass and Glassware Manufacturing	$970,207	157	$6,171	$3,134	2.63%	$82,278	0.20%	7.50%
327213	Glass Container Manufacturing	$2,113,092	26	$81,273	$140,781	2.63%	$3,695,528	0.06%	2.20%
327320	Ready-Mix Concrete Manufacturing	$20,250,184	2,062	$9,821	$5,963	1.43%	$85,310	0.16%	11.51%
327331	Concrete Block and Brick Manufacturing	$4,550,565	486	$9,363	$4,991	1.43%	$71,399	0.19%	13.11%
327332	Concrete Pipe Manufacturing	$1,900,067	147	$12,926	$6,217	1.43%	$88,933	0.21%	14.53%
327390	Other Concrete Product Manufacturing	$14,539,705	1,591	$9,139	$3,436	1.43%	$49,155	0.27%	18.59%
327991	Cut Stone and Stone Product Manufacturing	$13,106,845	1,785	$7,343	$1,696	1.75%	$29,730	0.43%	24.70%
327992	Ground or Treated Mineral and Earth Manufacturing	$2,075,935	123	$16,878	$10,030	1.75%	$175,783	0.17%	9.60%
327993	Mineral Wool Manufacturing	$990,251	113	$8,768	$8,687	1.75%	$152,242	0.10%	5.76%
327999	All Other Miscellaneous Nonmetallic Mineral Product Manufacturing	$5,872,264	277	$21,200	$5,787	1.75%	$101,425	0.37%	20.90%
331110	Iron and Steel Mills and Ferroalloy Manufacturing	$146,290	122	$1,194	$56,635	1.35%	$766,888	0.00%	0.16%
331210	Iron and Steel Pipe and Tube Manufacturing from Purchased Steel	$83,666	66	$1,262	$34,245	2.14%	$733,719	0.00%	0.17%
331221	Rolled Steel Shape Manufacturing	$42,989	36	$1,210	$34,746	2.14%	$744,455	0.00%	0.16%
331222	Steel Wire Drawing	$67,130	54	$1,254	$15,478	2.14%	$331,630	0.01%	0.38%
331314	Secondary Smelting and Alloying of Aluminum	$19,590	16	$1,249	$28,369	2.52%	$715,137	0.00%	0.17%
331420	Copper Rolling, Drawing, Extruding, and Alloying	$68,335	53	$1,280	$53,174	2.14%	$1,139,277	0.00%	0.11%
331492	Secondary Smelting, Refining, and Alloying of Nonferrous Metal (except Copper and Aluminum)	$37,734	31	$1,218	$46,028	2.14%	$986,159	0.00%	0.12%
331511	Iron Foundries	$12,442,276	327	$38,050	$13,689	4.36%	$596,447	0.28%	6.38%
331512	Steel Investment Foundries	$2,672,675	100	$26,727	$13,221	4.36%	$576,068	0.20%	4.64%
331513	Steel Foundries (except Investment)	$5,503,027	175	$31,446	$10,361	4.36%	$451,441	0.30%	6.97%
331524	Aluminum Foundries (except Die-Casting)	$3,130,109	371	$8,437	$4,768	4.36%	$207,744	0.18%	4.06%
331529	Other Nonferrous Metal Foundries (except Die-Casting)	$1,693,459	278	$6,092	$5,236	4.36%	$228,132	0.12%	2.67%

Table VI-7 Screening Analysis for SBA Establishments in General Industry and Maritime Affected by OSHA's Silica Standard (Continued)

NAICS	Industry	Compliance Costs	Total Affected SBA Entities	Annual Cost per Affected Entity	Annual Revenue per SBA Entity ($1000)	Percent Profit	Annual Profit per Entity	Cost to Revenue	Cost to Profit
332111	Iron and Steel Forging	$79,975	67	$1,199	$16,362	3.81%	$622,676	0.01%	0.19%
332112	Nonferrous Forging	$13,664	12	$1,186	$16,835	3.81%	$640,665	0.01%	0.19%
332117	Powder Metallurgy Part Manufacturing	$29,903	25	$1,174	$8,871	3.81%	$337,580	0.01%	0.35%
332119	Metal Crown, Closure, and Other Metal Stamping (except Automotive)	$266,352	226	$1,179	$6,052	3.81%	$230,329	0.02%	0.51%
332215	Metal Kitchen Cookware, Utensil, Cutlery, and Flatware (except Precious) Manufacturing	$27,196	23	$1,181	$6,259	4.12%	$257,752	0.02%	0.46%
332216	Saw Blade and Handtool Manufacturing	$120,315	100	$1,203	$3,769	4.12%	$155,218	0.03%	0.77%
332323	Ornamental and Architectural Metal Work Manufacturing	$35,067	32	$1,081	$2,053	2.70%	$55,457	0.05%	1.95%
332439	Other Metal Container Manufacturing	$42,327	35	$1,221	$5,492	2.93%	$160,829	0.02%	0.76%
332510	Hardware Manufacturing	$91,570	78	$1,178	$6,321	4.63%	$292,894	0.02%	0.40%
332613	Spring Manufacturing	$63,105	51	$1,245	$6,356	4.63%	$294,524	0.02%	0.42%
332618	Other Fabricated Wire Product Manufacturing	$126,762	104	$1,213	$5,118	4.63%	$237,167	0.02%	0.51%
332710	Machine Shops	$1,463,233	1,275	$1,147	$1,815	4.63%	$84,115	0.06%	1.36%
332812	Metal Coating, Engraving (except Jewelry and Silverware), and Allied Services to Manufacturers	$2,755,111	1,488	$1,851	$3,276	2.96%	$96,939	0.06%	1.91%
332911	Industrial Valve Manufacturing	$100,135	83	$1,213	$11,863	5.95%	$706,011	0.01%	0.17%
332912	Fluid Power Valve and Hose Fitting Manufacturing	$88,050	73	$1,211	$11,055	5.95%	$657,958	0.01%	0.18%
332913	Plumbing Fixture Fitting and Trim Manufacturing	$29,537	25	$1,198	$15,381	5.95%	$915,393	0.01%	0.13%
332919	Other Metal Valve and Pipe Fitting Manufacturing	$48,163	40	$1,193	$11,510	5.95%	$685,015	0.01%	0.17%
332991	Ball and Roller Bearing Manufacturing	$28,037	23	$1,237	$10,082	5.95%	$600,001	0.01%	0.21%
332996	Fabricated Pipe and Pipe Fitting Manufacturing	$116,327	99	$1,172	$6,952	5.95%	$413,773	0.02%	0.28%
332999	All Other Miscellaneous Fabricated Metal Product Manufacturing	$398,663	346	$1,153	$3,452	5.95%	$205,448	0.03%	0.56%
333318	Other Commercial and Service Industry Machinery Manufacturing	$220,586	190	$1,162	$7,989	3.05%	$243,775	0.01%	0.48%
333413	Industrial and Commercial Fan and Blower and Air Purification Equipment Manufacturing	$75,552	63	$1,202	$6,962	3.00%	$209,005	0.02%	0.58%
333414	Heating Equipment (except Warm Air Furnaces) Manufacturing	$76,185	65	$1,166	$7,664	3.00%	$230,099	0.02%	0.51%
333511	Industrial Mold Manufacturing	$196,365	169	$1,161	$3,300	3.82%	$126,016	0.04%	0.92%
333514	Special Die and Tool, Die Set, Jig, and Fixture Manufacturing	$239,261	208	$1,150	$2,584	3.82%	$98,690	0.04%	1.17%
333515	Cutting Tool and Machine Tool Accessory Manufacturing	$148,284	127	$1,166	$2,711	3.82%	$103,519	0.04%	1.13%

Table VI-7 Screening Analysis for SBA Establishments in General Industry and Maritime Affected by OSHA's Silica Standard (Continued)

NAICS	Industry	Compliance Costs	Total Affected SBA Entities	Annual Cost per Affected Entity	Annual Revenue per SBA Entity ($1000)	Percent Profit	Annual Profit per Entity	Cost to Revenue	Cost to Profit
333517	Machine Tool Manufacturing	$120,338	103	$1,169	$6,857	3.82%	$261,856	0.02%	0.45%
333519	Rolling Mill and Other Metalworking Machinery Manufacturing	$52,800	45	$1,171	$5,856	3.82%	$223,651	0.02%	0.52%
333612	Speed Changer, Industrial High-Speed Drive, and Gear Manufacturing	$48,595	39	$1,235	$11,287	1.99%	$224,368	0.01%	0.55%
333613	Mechanical Power Transmission Equipment Manufacturing	$43,878	37	$1,196	$9,584	1.99%	$190,516	0.01%	0.63%
333911	Pump and Pumping Equipment Manufacturing	$79,486	67	$1,195	$10,819	3.80%	$410,898	0.01%	0.29%
333912	Air and Gas Compressor Manufacturing	$61,295	51	$1,201	$14,580	3.80%	$553,744	0.01%	0.22%
333991	Power-Driven Handtool Manufacturing	$16,285	14	$1,160	$7,003	3.80%	$265,967	0.02%	0.44%
333992	Welding and Soldering Equipment Manufacturing	$48,996	42	$1,159	$6,852	3.80%	$260,251	0.02%	0.45%
333993	Packaging Machinery Manufacturing	$82,146	70	$1,170	$6,103	3.80%	$231,807	0.02%	0.50%
333994	Industrial Process Furnace and Oven Manufacturing	$52,056	44	$1,188	$6,101	3.80%	$231,716	0.02%	0.51%
333995	Fluid Power Cylinder and Actuator Manufacturing	$64,620	53	$1,210	$9,999	3.80%	$379,750	0.01%	0.32%
333996	Fluid Power Pump and Motor Manufacturing	$22,056	19	$1,158	$7,985	3.80%	$303,270	0.01%	0.38%
333997	Scale and Balance Manufacturing	$11,603	10	$1,184	$4,768	3.80%	$181,100	0.02%	0.65%
333999	All Other Miscellaneous General Purpose Machinery Manufacturing	$197,602	171	$1,156	$4,790	3.80%	$181,927	0.02%	0.64%
334519	Other Measuring and Controlling Device Manufacturing	$115,924	100	$1,163	$5,613	4.51%	$252,930	0.02%	0.46%
335210	Small Electrical Appliance Manufacturing	$17,998	17	$1,077	$17,135	4.01%	$687,713	0.01%	0.16%
335221	Household Cooking Appliance Manufacturing	$13,297	14	$968	$19,226	4.01%	$771,634	0.01%	0.13%
335222	Household Refrigerator and Home Freezer Manufacturing	$4,707	5	$1,005	$31,527	4.01%	$1,265,353	0.00%	0.08%
335224	Household Laundry Equipment Manufacturing	$157	0	$958	$4,818	4.01%	$193,379	0.02%	0.50%
335228	Other Major Household Appliance Manufacturing	$3,765	4	$986	$21,020	4.01%	$843,659	0.00%	0.12%
336111	Automobile Manufacturing	$20,482	20	$1,031	$13,043	-0.50%	-$65,710	0.01%	-1.57%
336112	Light Truck and Utility Vehicle Manufacturing	$7,727	8	$1,017	$17,387	-0.50%	-$87,598	0.01%	-1.16%
336120	Heavy Duty Truck Manufacturing	$36,819	32	$1,164	$47,396	-0.50%	-$238,787	0.00%	-0.49%
336211	Motor Vehicle Body Manufacturing	$164,332	136	$1,207	$10,198	1.30%	$132,333	0.01%	0.91%
336212	Truck Trailer Manufacturing	$97,653	80	$1,220	$9,886	1.30%	$128,290	0.01%	0.95%
336213	Motor Home Manufacturing	$10,810	9	$1,139	$9,051	1.30%	$117,450	0.01%	0.97%
336310	Motor Vehicle Gasoline Engine and Engine Parts Manufacturing	$116,317	102	$1,144	$7,952	1.30%	$103,191	0.01%	1.11%

Table VI-7 Screening Analysis for SBA Establishments in General Industry and Maritime Affected by OSHA's Silica Standard (Continued)

NAICS	Industry	Compliance Costs	Total Affected SBA Entities	Annual Cost per Affected Entity	Annual Revenue per SBA Entity ($1000)	Percent Profit	Annual Profit per Entity	Cost to Revenue	Cost to Profit
336320	Motor Vehicle Electrical and Electronic Equipment Manufacturing	$157,980	134	$1,179	$14,601	1.30%	$189,469	0.01%	0.62%
336330	Motor Vehicle Steering and Suspension Components (except Spring) Manufacturing	$58,720	51	$1,151	$21,278	1.30%	$276,115	0.01%	0.42%
336340	Motor Vehicle Brake System Manufacturing	$60,248	49	$1,241	$23,834	1.30%	$309,289	0.01%	0.40%
336350	Motor Vehicle Transmission and Power Train Parts Manufacturing	$129,753	110	$1,178	$21,926	1.30%	$284,525	0.01%	0.41%
336370	Motor Vehicle Metal Stamping	$310,283	247	$1,254	$23,754	1.30%	$308,249	0.01%	0.41%
336390	Other Motor Vehicle Parts Manufacturing	$366,093	305	$1,199	$18,685	1.30%	$242,469	0.01%	0.49%
336611	Ship Building and Repairing	$2,404,761	309	$7,778	$9,902	6.06%	$600,482	0.08%	1.30%
336612	Boat Building	$1,969,321	301	$6,551	$6,023	6.06%	$365,244	0.11%	1.79%
336992	Military Armored Vehicle, Tank, and Tank Component Manufacturing	$23,894	20	$1,186	$24,833	4.03%	$1,001,935	0.00%	0.12%
337110	Wood Kitchen Cabinet and Countertop Manufacturing	$155,433	173	$900	$1,002	2.77%	$27,765	0.09%	3.24%
337215	Showcase, Partition, Shelving, and Locker Manufacturing	$156,085	133	$1,177	$4,398	2.77%	$121,873	0.03%	0.97%
339114	Dental Equipment and Supplies Manufacturing	$4,331,589	697	$6,215	$4,359	7.32%	$319,165	0.14%	1.95%
339116	Dental Laboratories	$5,719,685	6,518	$878	$514	7.32%	$37,622	0.17%	2.33%
339910	Jewelry and Silverware Manufacturing	$2,065,825	2,091	$988	$1,971	3.92%	$77,339	0.05%	1.28%
339950	Sign Manufacturing	$354,823	326	$1,088	$1,644	3.92%	$64,505	0.07%	1.69%
423840	Industrial Supplies Merchant Wholesalers	$1,287,104	876	$1,469	$4,693	2.98%	$140,037	0.03%	1.05%
444110	Home Centers	$6,043	5	$1,219	$3,327	6.05%	$201,237	0.04%	0.61%
482110	Rail transportation	NA	NA	NA	NA	6.23%	NA	NA	NA
561730	Landscaping Services	$18,249,100	25,500	$716	$440	2.96%	$13,032	0.16%	5.49%
621210	Offices of Dentists	$2,432,481	7,784	$312	$781	7.78%	$60,727	0.04%	0.51%
	Totals	$186,093,853	62,730						

Source: OSHA, Directorate of Standards and Guidance, Office of Regulatory Analysis, based on ERG, 2015

[a] Costs and impact to rail transportation were estimated separately. See the previous discussion in this chapter for more information.

Table VI-8 Screening Analysis for Very Small Entities (fewer than 20 employees) in General Industry and Maritime Affected by OSHA's Silica Standard

NAICS	Industry	Compliance Costs	Affected Entities with <20 Employees	Annual Cost per Affected Entity	Annual Revenue per Entity with <20 Employees ($1000)	Percent Profit	Annual Profit per Entity	Cost to Revenue	Cost to Profit
213112	Support Activities for Oil and Gas Operations	$11,907,226	100	$119,072	$5,703	7.09%	$404,248	2.09%	29.46%
324121	Asphalt Paving Mixture and Block Manufacturing	$57,921	248	$234	$5,359	5.96%	$319,386	0.00%	0.07%
324122	Asphalt Shingle and Coating Materials Manufacturing	$267,935	73	$3,670	$4,278	5.96%	$254,917	0.09%	1.44%
325510	Paint and Coating Manufacturing	$96,372	297	$325	$1,765	3.86%	$68,185	0.02%	0.48%
327110	Pottery, Ceramics, and Plumbing Fixture Manufacturing	$2,389,156	526	$4,542	$374	1.34%	$5,011	1.21%	90.64%
327120	Clay Building Material and Refractories Manufacturing	$1,765,486	217	$8,136	$1,039	1.34%	$13,906	0.78%	58.51%
327211	Flat Glass Manufacturing	$11,319	3	$3,969	$740	2.63%	$19,420	0.54%	20.44%
327212	Other Pressed and Blown Glass and Glassware Manufacturing	$276,747	70	$3,951	$664	2.63%	$17,432	0.59%	22.66%
327213	Glass Container Manufacturing	$23,711	6	$3,927	$2,248	2.63%	$58,998	0.17%	6.66%
327320	Ready-Mix Concrete Manufacturing	$5,616,970	1,309	$4,291	$1,885	1.43%	$26,966	0.23%	15.91%
327331	Concrete Block and Brick Manufacturing	$1,383,138	320	$4,322	$1,548	1.43%	$22,139	0.28%	19.52%
327332	Concrete Pipe Manufacturing	$336,697	73	$4,612	$1,458	1.43%	$20,858	0.32%	22.11%
327390	Other Concrete Product Manufacturing	$4,568,859	1,168	$3,912	$935	1.43%	$13,376	0.42%	29.24%
327991	Cut Stone and Stone Product Manufacturing	$5,664,898	1,477	$3,835	$710	1.75%	$12,449	0.54%	30.81%
327992	Ground or Treated Mineral and Earth Manufacturing	$426,975	64	$6,671	$2,331	1.75%	$40,853	0.29%	16.33%
327993	Mineral Wool Manufacturing	$140,721	35	$3,966	$1,299	1.75%	$22,771	0.31%	17.42%
327999	All Other Miscellaneous Nonmetallic Mineral Product Manufacturing	$2,430,981	199	$12,216	$1,365	1.75%	$23,930	0.89%	51.05%
331110	Iron and Steel Mills and Ferroalloy Manufacturing	$0	0	NA	$2,565	1.35%	$34,731	NA	NA
331210	Iron and Steel Pipe and Tube Manufacturing from Purchased Steel	$0	0	NA	$1,477	2.14%	$31,641	NA	NA
331221	Rolled Steel Shape Manufacturing	$0	0	NA	$3,901	2.14%	$83,577	NA	NA
331222	Steel Wire Drawing	$0	0	NA	$1,555	2.14%	$33,313	NA	NA
331314	Secondary Smelting and Alloying of Aluminum	$0	0	NA	$3,655	2.52%	$92,146	NA	NA
331420	Copper Rolling, Drawing, Extruding, and Alloying	$0	0	NA	$3,316	2.14%	$71,056	NA	NA
331492	Secondary Smelting, Refining, and Alloying of Nonferrous Metal (except Copper and Aluminum)	$0	0	NA	$4,590	2.14%	$98,343	NA	NA
331511	Iron Foundries	$967,507	153	$6,324	$1,447	4.36%	$63,060	0.44%	10.03%
331512	Steel Investment Foundries	$124,895	30	$4,163	$1,669	4.36%	$72,739	0.25%	5.72%
331513	Steel Foundries (except Investment)	$559,542	89	$6,287	$1,176	4.36%	$51,223	0.53%	12.27%
331524	Aluminum Foundries (except Die-Casting)	$842,096	223	$3,776	$767	4.36%	$33,434	0.49%	11.29%

331529	Other Nonferrous Metal Foundries (except Die-Casting)	$816,991	179	$4,564	$1,191	4.36%	$51,903	0.38%	8.79%
332111	Iron and Steel Forging	$0	0	NA	$1,404	3.81%	$53,419	NA	NA

Table VI-8 Screening Analysis for Very Small Entities (fewer than 20 employees) in General Industry and Maritime Affected by OSHA's Silica Standard (Continued)

NAICS	Industry	Compliance Costs	Affected Entities with <20 Employees	Annual Cost per Affected Entity	Annual Revenue per Entity with <20 Employees ($1000)	Percent Profit	Annual Profit per Entity	Cost to Revenue	Cost to Profit
332112	Nonferrous Forging	$0	0	NA	$1,309	3.81%	$49,831	NA	NA
332117	Powder Metallurgy Part Manufacturing	$0	0	NA	$2,016	3.81%	$76,724	NA	NA
332119	Metal Crown, Closure, and Other Metal Stamping (except Automotive)	$0	0	NA	$1,346	3.81%	$51,241	NA	NA
332215	Metal Kitchen Cookware, Utensil, Cutlery, and Flatware (except Precious) Manufacturing	$0	0	NA	$774	4.12%	$31,865	NA	NA
332216	Saw Blade and Handtool Manufacturing	$0	0	NA	$718	4.12%	$29,580	NA	NA
332323	Ornamental and Architectural Metal Work Manufacturing	$13,862	12	$1,158	$690	2.70%	$18,626	0.17%	6.22%
332439	Other Metal Container Manufacturing	$0	0	NA	$1,110	2.93%	$32,507	NA	NA
332510	Hardware Manufacturing	$0	0	NA	$1,084	4.63%	$50,228	NA	NA
332613	Spring Manufacturing	$0	0	NA	$1,152	4.63%	$53,378	NA	NA
332618	Other Fabricated Wire Product Manufacturing	$0	0	NA	$1,178	4.63%	$54,602	NA	NA
332710	Machine Shops	$0	0	NA	$662	4.63%	$30,674	NA	NA
332812	Metal Coating, Engraving (except Jewelry and Silverware), and Allied Services to Manufacturers	$949,586	825	$1,151	$707	2.96%	$20,909	0.16%	5.51%
332911	Industrial Valve Manufacturing	$0	0	NA	$1,985	5.95%	$118,164	NA	NA
332912	Fluid Power Valve and Hose Fitting Manufacturing	$0	0	NA	$1,446	5.95%	$86,038	NA	NA
332913	Plumbing Fixture Fitting and Trim Manufacturing	$0	0	NA	$1,785	5.95%	$106,261	NA	NA
332919	Other Metal Valve and Pipe Fitting Manufacturing	$0	0	NA	$2,294	5.95%	$136,557	NA	NA
332991	Ball and Roller Bearing Manufacturing	$0	0	NA	$1,022	5.95%	$60,812	NA	NA
332996	Fabricated Pipe and Pipe Fitting Manufacturing	$0	0	NA	$1,227	5.95%	$73,052	NA	NA
332999	All Other Miscellaneous Fabricated Metal Product Manufacturing	$0	0	NA	$817	5.95%	$48,638	NA	NA
333318	Other Commercial and Service Industry Machinery Manufacturing	$0	0	NA	$1,377	3.05%	$42,030	NA	NA
333413	Industrial and Commercial Fan and Blower and Air Purification Equipment Manufacturing	$0	0	NA	$1,447	3.00%	$43,427	NA	NA
333414	Heating Equipment (except Warm Air Furnaces) Manufacturing	$0	0	NA	$1,452	3.00%	$43,591	NA	NA
333511	Industrial Mold Manufacturing	$0	0	NA	$938	3.82%	$35,810	NA	NA
333514	Special Die and Tool, Die Set, Jig, and Fixture Manufacturing	$0	0	NA	$772	3.82%	$29,477	NA	NA
333515	Cutting Tool and Machine Tool Accessory Manufacturing	$0	0	NA	$747	3.82%	$28,513	NA	NA

333517	Machine Tool Manufacturing	$0	0	NA	$1,353	3.82%	$51,656	NA	NA
333519	Rolling Mill and Other Metalworking Machinery Manufacturing	$0	0	NA	$1,306	3.82%	$49,863	NA	NA

Table VI-8 Screening Analysis for Very Small Entities (fewer than 20 employees) in General Industry and Maritime Affected by OSHA's Silica Standard (Continued)

NAICS	Industry	Compliance Costs	Affected Entities with <20 Employees	Annual Cost per Affected Entity	Annual Revenue per Entity with <20 Employees ($1000)	Percent Profit	Annual Profit per Entity	Cost to Revenue	Cost to Profit
333612	Speed Changer, Industrial High-Speed Drive, and Gear Manufacturing	$0	0	NA	$1,462	1.99%	$29,062	NA	NA
333613	Mechanical Power Transmission Equipment Manufacturing	$0	0	NA	$1,889	1.99%	$37,559	NA	NA
333911	Pump and Pumping Equipment Manufacturing	$0	0	NA	$2,499	3.80%	$94,924	NA	NA
333912	Air and Gas Compressor Manufacturing	$0	0	NA	$1,833	3.80%	$69,607	NA	NA
333991	Power-Driven Handtool Manufacturing	$0	0	NA	$1,483	3.80%	$56,334	NA	NA
333992	Welding and Soldering Equipment Manufacturing	$0	0	NA	$1,280	3.80%	$48,624	NA	NA
333993	Packaging Machinery Manufacturing	$0	0	NA	$1,119	3.80%	$42,493	NA	NA
333994	Industrial Process Furnace and Oven Manufacturing	$0	0	NA	$1,668	3.80%	$63,337	NA	NA
333995	Fluid Power Cylinder and Actuator Manufacturing	$0	0	NA	$1,296	3.80%	$49,222	NA	NA
333996	Fluid Power Pump and Motor Manufacturing	$0	0	NA	$1,774	3.80%	$67,384	NA	NA
333997	Scale and Balance Manufacturing	$0	0	NA	$1,191	3.80%	$45,231	NA	NA
333999	All Other Miscellaneous General Purpose Machinery Manufacturing	$0	0	NA	$1,331	3.80%	$50,541	NA	NA
334519	Other Measuring and Controlling Device Manufacturing	$0	0	NA	$1,236	4.51%	$55,694	NA	NA
335210	Small Electrical Appliance Manufacturing	$1,302	1	$1,165	$1,797	4.01%	$72,115	0.06%	1.62%
335221	Household Cooking Appliance Manufacturing	$0	0	NA	$1,093	4.01%	$43,865	NA	NA
335222	Household Refrigerator and Home Freezer Manufacturing	$0	0	NA	$1,608	4.01%	$64,554	NA	NA
335224	Household Laundry Equipment Manufacturing	$0	0	NA	$1,408	4.01%	$56,507	NA	NA
335228	Other Major Household Appliance Manufacturing	$0	0	NA	$2,080	4.01%	$83,465	NA	NA
336111	Automobile Manufacturing	$0	0	NA	$4,096	-0.50%	-$20,634	NA	NA
336112	Light Truck and Utility Vehicle Manufacturing	$0	0	NA	$4,241	-0.50%	-$21,365	NA	NA
336120	Heavy Duty Truck Manufacturing	$0	0	NA	$4,121	-0.50%	-$20,760	NA	NA
336211	Motor Vehicle Body Manufacturing	$0	0	NA	$1,432	1.30%	$18,584	NA	NA
336212	Truck Trailer Manufacturing	$0	0	NA	$1,193	1.30%	$15,478	NA	NA
336213	Motor Home Manufacturing	$0	0	NA	$1,414	1.30%	$18,352	NA	NA
336310	Motor Vehicle Gasoline Engine and Engine Parts Manufacturing	$0	0	NA	$901	1.30%	$11,693	NA	NA
336320	Motor Vehicle Electrical and Electronic Equipment Manufacturing	$0	0	NA	$1,131	1.30%	$14,677	NA	NA
336330	Motor Vehicle Steering and Suspension Components (except Spring) Manufacturing	$0	0	NA	$2,015	1.30%	$26,152	NA	NA

336340	Motor Vehicle Brake System Manufacturing	$0	0	NA	$1,092	1.30%	$14,166	NA	NA

Table VI-8 Screening Analysis for Very Small Entities (fewer than 20 employees) in General Industry and Maritime Affected by OSHA's Silica Standard (Continued)

NAICS	Industry	Compliance Costs	Affected Entities with <20 Employees	Annual Cost per Affected Entity	Annual Revenue per Entity with <20 Employees ($1000)	Percent Profit	Annual Profit per Entity	Cost to Revenue	Cost to Profit
336350	Motor Vehicle Transmission and Power Train Parts Manufacturing	$0	0	NA	$1,675	1.30%	$21,733	NA	NA
336370	Motor Vehicle Metal Stamping	$0	0	NA	$2,049	1.30%	$26,584	NA	NA
336390	Other Motor Vehicle Parts Manufacturing	$0	0	NA	$1,677	1.30%	$21,763	NA	NA
336611	Ship Building and Repairing	$110,154	62	$1,778	$1,382	6.06%	$83,779	0.13%	2.12%
336612	Boat Building	$156,109	88	$1,773	$1,215	6.06%	$73,653	0.15%	2.41%
336992	Military Armored Vehicle, Tank, and Tank Component Manufacturing	$0	0	NA	$2,376	4.03%	$95,875	NA	NA
337110	Wood Kitchen Cabinet and Countertop Manufacturing	$64,773	78	$828	$425	2.77%	$11,782	0.19%	7.03%
337215	Showcase, Partition, Shelving, and Locker Manufacturing	$0	0	NA	$787	2.77%	$21,794	NA	NA
339114	Dental Equipment and Supplies Manufacturing	$1,716,366	588	$2,919	$674	7.32%	$49,335	0.43%	5.92%
339116	Dental Laboratories	$4,641,195	6,205	$748	$293	7.32%	$21,460	0.26%	3.49%
339910	Jewelry and Silverware Manufacturing	$993,578	1,862	$534	$626	3.92%	$24,561	0.09%	2.17%
339950	Sign Manufacturing	$140,698	116	$1,211	$497	3.92%	$19,492	0.24%	6.21%
423840	Industrial Supplies Merchant Wholesalers	$528,996	426	$1,241	$2,505	2.98%	$74,736	0.05%	1.66%
444110	Home Centers	$1,681	2	$935	$1,352	6.05%	$81,797	0.07%	1.14%
482110	Rail transportation	NA	NA	NA	NA	6.23%	NA	NA	NA
561730	Landscaping Services	$15,602,766	20,258	$770	$320	2.96%	$9,472	0.24%	8.13%
621210	Offices of Dentists	$2,094,401	6,803	$308	$692	7.78%	$53,802	0.04%	0.57%
	Totals	$67,691,610	44,186						

Source: OSHA, Directorate of Standards and Guidance, Office of Regulatory Analysis, based on ERG, 2015

[a] Costs and impact to rail transportation were estimated separately. See the previous discussion in this chapter for more information.

* In the PEA, OSHA identified a number of industries as having captive foundries and estimated that some very small entities in those industries would have captive foundries. For this FEA, the Agency determined that this assumption was incorrect and that entities with fewer than 20 employees would not have enough workers to perform foundry operations as well as their primary business operations. For the sake of comparability between the PEA and FEA, OSHA has left those industries in this table but shown that very small entities will have no costs associated with this final rule.

SBREFA Comments on Impacts on the General Industry and Maritime

In this section, OSHA reviews comments addressing economic impacts in general industry and maritime that were submitted during the SBREFA process prior to the PEA. OSHA addressed these comments in the PEA that was made available for public comment, but OSHA did not receive comments specifically addressing its responses to the SBREFA recommendations. OSHA is reprinting its responses here for the convenience of the reader.

SERs from foundries stated that there had been a long-run decline in the number of foundries in the United States, with the industry under continued pressure from foreign competitors and the need to meet new domestic regulations. The total expense of the draft standard and inability to meet lower PELs would pressure more U.S. foundries out of business, continuing an historical trend in this industry, SERs said. The variability in the foundry products and small open-area production plants would make meeting lower PELs difficult and costly. Many smaller foundries would be put out of business, the SERs said, and many jobs lost in the industry. “Twenty percent of profits is a great deal to spend on engineering controls with questionable results.… The economics of the foundry industry today are not pretty,” one SER said. And another: “The cost of meeting the standard will be very difficult …. A PEL of 50 would put us out of business.” OSHA found in this FEA that costs as percentage of profits for even very small foundries would not rise to a level of 20 percent.

SERs from the brick industry stated that meeting the provisions of the draft proposed standard, particularly with a lower PEL, would be very tough for their competitive, low margin industry. Similarly, a SER from the pre-cast concrete industry said, “The problem is not putting the company out of business, but that the price of products will increase.” OSHA found that because bricks face limited foreign competition, a very small change in the price of bricks would not affect the viability of the industry.

Other SERs (industrial sand, molding powders, refractory concrete) noted that the impact of the standard on them, particularly if the PEL is lowered, would entail substantial costs, but indirect effects could be significant as well since their major customers (foundries) could be negatively impacted, too. “Refractory companies are going out of business with the foundries,” one SER said. OSHA has concluded that foundries will not, in general go out of business.

Regulatory Flexibility Screening Analysis

To determine if the Assistant Secretary of Labor for OSHA can certify that the final silica standard for general industry and maritime will not have a significant economic impact on a substantial number of small entities, the Agency has developed screening tests to consider minimum threshold effects of the final standard on small entities. The minimum threshold effects for this purpose are annualized costs equal to one percent of annual revenues and annualized costs equal to five percent of annual profits applied to each affected industry. (OSHA uses five percent as a threshold for significant impacts on small entities rather than the ten percent used for potentially serious impacts on industries in order to assure that small entity impacts will always receive special attention.) OSHA has applied these screening tests both to small entities and to very small entities. For purposes of certification, the threshold level cannot be exceeded for affected small entities or very small entities in any affected industry.

Tables VI-7 shows that the only industry for small entities in which the annualized costs of the final rule exceed one percent of annual revenues is NAICS 213112 (Support Activities for Oil and Gas Operations), 1.29 percent. Table VI-8 shows two industries for very small entities exceeding one percent of annual revenues - NAICS 213112 (Support Activities for Oil and Gas Operations), 2.09 percent and NAICS 327110 (Pottery, Ceramics, and Plumbing Fixture Manufacturing), 1.21 percent. These tables also show that the annualized costs of the final standard exceed 5 percent of annual profits for small entities in 15 industries and for very small entities in 25 industries. OSHA is therefore unable to certify that the final standard will not have a significant economic impact on a substantial number of small entities in general industry and maritime and must prepare a Final Regulatory Flexibility Analysis (FRFA). The FRFA is presented in Chapter IX of this FEA

IMPACTS IN CONSTRUCTION

In this section, OSHA will determine whether (1) the final rule is economically feasible for all affected industries in construction, and (2) the Agency can certify that the final rule will not have a significant economic impact on a substantial number of small entities in construction.

Economic Feasibility Screening Analysis: All Establishments

To determine whether the rule's estimated costs of compliance would threaten the economic viability of affected construction industries, OSHA used the same data sources and methodological approach that were used earlier in this chapter for general industry and maritime. OSHA first compared, for each affected industry, annualized compliance costs to annual revenues and profits per (average) affected establishment. The results for all affected establishments in all affected construction industries are presented in Table VI-9, using annualized costs per establishment for the PEL of 50 $\mu g/m^3$. Shown in the table for each affected industry are total annualized costs, annualized costs per affected establishment, annual revenues per establishment, profit rate, annual profits per establishment, annualized compliance costs as a percentage of annual revenues, and annualized compliance costs as a percentage of annual profits.

The annualized costs per affected establishment for each affected construction industry were calculated by distributing the industry-level (incremental) annualized compliance costs among all affected establishments in the industry, where annualized compliance costs reflect a three percent discount rate.[44] The annualized cost of the rule for the average establishment in construction, encompassing all construction industries, is estimated at $1,097 in 2012 dollars. It is clear from Table VI-9 that the estimates of the annualized costs per affected establishment in the ten construction industries vary widely. These estimates range from $4,811 for NAICS 237300 (Highway, Street, and Bridge Construction) and $4,463 for NAICS 237100 (Utility System Construction) to $364 for NAICS 236100 (Residential Building Construction) and $360 for NAICS 221100 (Electric Utilities).

As previously discussed, OSHA has established a minimum threshold level of annualized costs equal to one percent of annual revenues—and, secondarily, annualized costs equal to ten percent of annual profits—below which the Agency has concluded that costs are unlikely to threaten the economic viability of an affected industry. Table VI-9 shows that the annualized costs of the rule do not exceed one percent of annual revenues or ten percent of annual profits for any affected construction industry. NAICS 238100 (Foundation, Structure, and Building Exterior Contractors) has both the highest cost impact as a percentage of revenues, of 0.12 percent, and the highest cost impact as a percentage of profits, of 3.66 percent. For all affected establishments in construction, the estimated annualized cost of the final rule is, on average, equal to 0.05 percent of annual revenue and 1.52 percent of annual profit. These are well below the minimum threshold levels of 1 percent and 10 percent, respectively.

Therefore, even though the annualized costs of the rule incurred by the construction industries as a whole are roughly twice the combined annualized costs incurred by general industry and maritime, OSHA concludes, based on its screening analysis, that the annualized costs as a percentage of annual revenues and as a percentage of annual profits are below the threshold levels that could threaten the economic viability of any of the construction industries. OSHA therefore finds that the final rule is economically feasible for each of the industries engaged in construction activities. OSHA further notes that while there may be additional costs (not attributable to the final rule) for some employers in construction industries to come into compliance with the preceding silica standard, these costs do not affect the Agency's determination of the economic feasibility of the final rule. Below, OSHA provides additional information to further support the Agency's conclusion.

[44] Tables VI-A-3 and VI-A-4 in Appendix VI-A show per-establishment annualized costs and ratios of annualized cost to annual revenue and annualized costs to annual profit using discount rates of seven percent and zero percent, respectively, to annualize costs. As can be seen, the effects of the lower discount rates on these ratios are quite modest in absolute terms.

Table VI-9: Screening Analysis for Establishments in Construction Affected by OSHA's Final Silica Standard

NAICS	Industry	Total Annualized Costs	Affected Establishments	Annual Cost Per Affected Establishment	Annual Revenues per Establishment ($1000)	Percent Profit	Annual Profit Per Establishment	Cost to Revenue	Cost to Profits
221100	Electric Utilities	$3,203,249	4,662	$360	$41,073	0.67%	$275,190	0.00%	0.13%
236100	Residential Building Construction	$54,944,997	151,034	$364	$1,260	2.23%	$28,104	0.03%	1.29%
236200	Nonresidential Building Construction	$52,733,126	41,018	$1,286	$6,843	2.23%	$152,604	0.02%	0.84%
237100	Utility System Construction	$83,397,297	18,686	$4,463	$6,328	3.10%	$196,183	0.07%	2.27%
237200	Land Subdivision	$1,960,835	2,150	$912	$6,479	-1.30%	-$84,222	0.01%	-1.08%
237300	Highway, Street, and Bridge Construction	$48,314,733	10,043	$4,811	$10,023	2.89%	$289,655	0.05%	1.66%
237900	Other Heavy and Civil Engineering Construction	$13,342,117	4,222	$3,160	$5,732	2.89%	$165,660	0.06%	1.91%
238100	Foundation, Structure, and Building Exterior Contractors	$139,227,106	85,801	$1,623	$1,300	3.41%	$44,343	0.12%	3.66%
238200	Building Equipment Contractors	$60,058,912	142,536	$421	$1,788	3.66%	$65,452	0.02%	0.64%
238300	Building Finishing Contractors	$55,340,177	77,330	$716	$858	3.41%	$29,268	0.08%	2.45%
238900	Other Specialty Trade Contractors	$101,830,889	63,214	$1,611	$1,617	3.41%	$55,146	0.10%	2.92%
999200	State Governments	$8,620,645	0	NA	NA	NA	NA	NA	NA
999300	Local Governments	$35,997,165	0	NA	NA	NA	NA	NA	NA
	Totals	$658,971,248	600,695						

Source: OSHA, Directorate of Standards and Guidance, Office of Regulatory Analysis, based on ERG, 2015

Normal Year-to-Year Variations in Profit Rates

As previously noted, the United States has a dynamic and constantly changing economy in which large year-to-year changes in industry profit rates are commonplace.[45] A recession, a downturn in a particular industry, foreign competition, or the increased competitiveness of producers of close domestic substitutes are all easily capable of causing a decline in industry profit rates of well in excess of ten percent in one year or for several years in succession.

To demonstrate the normal year-to-year variation in profit rates for all the establishments in construction affected by the rule, OSHA developed Table VI-10 and Table VI-11, which show, respectively, year-to-year profit rates and year-to-year percentage changes in profit rates, by industry, for the years 2000–20012.[46] For the combined affected industries in construction over the 13-year period, Table VI-11 shows an average change in profit rates of 63.09 percent a year. If the three worst years are excluded, there is still substantial variation in profits, far larger than the change in profits that would be necessary if the costs of this rule cannot be passed on.

These data indicate that even if the annualized costs of the rule for the most significantly affected construction industries were completely absorbed in reduced annual profits, the magnitude of reduced annual profit rates is well within normal year-to-year variations in profit rates in those industries and does not threaten their economic viability. Of course, a permanent loss of profits would present a greater problem than a temporary loss, but it is unlikely that all costs of the rule would be absorbed in lost profits. Given that the overall price elasticity of demand for the outputs of the construction industry is fairly low[47] and that almost all of the costs estimated in Chapter V are variable costs, the data and economic theory suggest that most firms will see small declines in output; none but the most extremely marginal firms would face any real risk of closure. Many parts of the construction industry have already absorbed much more drastic changes in profit without evidence of industry collapse or major change.

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[45] OSHA expects that large year-to-year variations in revenues and prices in construction industries are also commonplace. However, OSHA does not have price data for construction industries comparable to the producer price indices available for manufacturing industries.

[46] The IRS profit data for construction industries were available only at the 3-digit NAICS level in 2000 and 2001. Therefore, the reported profit data were the same for each construction industry in those years.

[47] See, for example, Durlauf and Blume (2008), p. 547, which concludes that recent estimates of the after-tax price elasticity of housing demand cluster around -0.5. The article by Hanushek and Quigley (1980) reaches similar findings. For office and hotel construction, see Wheaton, Torto, and Evans (1997) and Wheaton and Rosoff (1998), whose empirical results suggest a price elasticity of demand for office and hotel construction of -0.4.

Table VI-10: Time Series of Annual Profit Rates for Construction Industries Affected by OSHA's Final Silica Standard

NAICS	Industry	2012	2011	2010	2009	2008	2007	2006	2005	2004	2003	2002	2001	2000	Average
2361	Residential Building	1.73%	0.77%	-0.23%	-1.41%	-0.80%	1.06%	4.40%	5.89%	4.37%	3.59%	3.22%	3.37%	3.07%	**2.23%**
2362	Nonresidential Building Construction	1.73%	0.77%	-0.23%	-1.41%	-0.80%	1.06%	4.40%	5.89%	4.37%	3.59%	3.22%	3.37%	3.07%	**2.23%**
2371	Utility System Construction	3.53%	3.18%	3.89%	4.35%	4.26%	6.63%	4.86%	3.77%	1.92%	0.17%	0.39%	1.23%	2.07%	**3.10%**
2372	Land Subdivision	-8.28%	-11.65%	-15.72%	-24.39%	-15.89%	-1.03%	6.50%	14.24%	11.23%	7.28%	7.59%	7.33%	5.87%	**-1.30%**
2373	Highway, Street, and Bridge Construction	2.67%	1.85%	2.15%	1.59%	1.94%	5.41%	5.18%	6.21%	3.94%	1.53%	1.76%	1.23%	2.07%	**2.89%**
2379	Other Heavy and Civil Engineering Construction	2.67%	1.85%	2.15%	1.59%	1.94%	5.41%	5.18%	6.21%	3.94%	1.53%	1.76%	1.23%	2.07%	**2.89%**
2381	Foundation, Structure, and Building Exterior Contractors	4.10%	2.83%	2.92%	3.63%	4.14%	4.76%	4.57%	3.83%	2.83%	1.94%	2.26%	3.09%	3.36%	**3.41%**
2382	Building Equipment Contractors	4.40%	3.11%	3.03%	4.94%	5.26%	4.92%	4.55%	3.47%	3.07%	1.46%	2.38%	3.29%	3.65%	**3.66%**
2383	Building Finishing Contractors	4.10%	2.83%	2.92%	3.63%	4.14%	4.76%	4.57%	3.83%	2.83%	1.94%	2.26%	3.09%	3.36%	**3.41%**
2389	Other Specialty Trade Contractors	4.16%	2.71%	2.82%	3.21%	3.82%	4.93%	4.79%	4.11%	2.81%	2.05%	2.42%	3.16%	3.32%	**3.41%**

Source: Internal Revenue Service, *Corporation Source Book*, 2012.

Table VI-11: Annual Percentage Change in Profit Rates for Construction Industries Affected by OSHA's Final Silica Standard

NAICS	Industry	2011-2012	2010-2011	2009-2010	2008-2009	2007-2008	2006-2007	2005-2006	2004-2005	2003-2004	2002-2003	2001-2002	2000-2001	Average Change (Absolute Values)
2361	Residential Building Construction	125.47%	-428.29%	-83.39%	76.67%	-175.14%	-75.92%	-25.32%	34.83%	21.58%	11.41%	-4.31%	9.72%	**89.34%**
2362	Nonresidential Building Construction	125.47%	-428.29%	-83.39%	76.67%	-175.14%	-75.92%	-25.32%	34.83%	21.58%	11.41%	-4.31%	9.72%	**89.34%**
2371	Utility System Construction	10.78%	-18.12%	-10.55%	2.09%	-35.74%	36.46%	28.81%	95.99%	1050.60%	-57.31%	-68.17%	-40.50%	**121.26%**
2372	Land Subdivision	-28.90%	-25.93%	-35.55%	53.51%	1446.92%	-115.81%	-54.36%	26.77%	54.29%	-4.03%	3.53%	24.89%	**156.21%**
2373	Highway, Street, and Bridge Construction	44.30%	-13.72%	35.00%	-18.10%	-64.10%	4.32%	-16.53%	57.63%	157.75%	-12.98%	42.75%	-40.50%	**42.31%**
2379	Other Heavy and Civil Engineering Construction	44.30%	-13.72%	35.00%	-18.10%	-64.10%	4.32%	-16.53%	57.63%	157.75%	-12.98%	42.75%	-40.50%	**42.31%**
2381	Foundation, Structure, and Building Exterior Contractors	44.95%	-3.35%	-19.47%	-12.25%	-13.13%	4.16%	19.38%	35.37%	45.76%	-14.11%	-26.76%	-8.11%	**20.57%**
2382	Building Equipment Contractors	41.34%	2.53%	-38.62%	-5.98%	6.99%	8.07%	30.95%	13.08%	110.15%	-38.45%	-27.86%	-9.70%	**27.81%**
2383	Building Finishing Contractors	44.95%	-3.35%	-19.47%	-12.25%	-13.13%	4.16%	19.38%	35.37%	45.76%	-14.11%	-26.76%	-8.11%	**20.57%**
2389	Other Specialty Trade Contractors	53.42%	-3.80%	-12.20%	-15.99%	-22.58%	2.94%	16.46%	46.17%	37.15%	-15.35%	-23.31%	-4.73%	**21.17%**

Source: Internal Revenue Service, *Corporation Source Book*, 2012.

Market Structure and Market Impacts in the Construction Industry

At a conceptual level, the market-determined output of the construction industry depends on the intersection of demand and supply curves. Incremental compliance costs of the rule (which are almost entirely variable costs) shift the construction supply curve upward. The net effect is an increase in the price for construction activities and a reduction in the level of activity (with the magnitude of this effect depending on the price elasticity of demand). Lower levels of activity mean less construction work, a reduction in the number of construction establishments, and a concomitant reduction in construction employment. The greater the price elasticity of demand and the greater the increase in marginal costs, the larger will be the reduction in equilibrium output. In terms of prices, the greater the price elasticity of demand, the smaller the increase in prices will be for a given increment to marginal costs, and the larger the reduction in output.

Increasing the cost of construction project activities that generate silica exposures has two effects on the demand for these activities. First, increasing the cost of silica-related jobs relative to the costs of other construction inputs might result in substitution away from this type of work. Architects, building designers, and contractors might be more likely to choose building methods and materials that eliminate or reduce the need to perform silica-related jobs. For example, pre-cast concrete structures that require a relatively high level of concrete finishing work would become more expensive relative to other building technologies. Contractors and others could reduce the cost impact of the standard by switching to other building methods unaffected by the silica rule when the alternative would result in lower cost than would compliance with the rule. The magnitude of these impacts will depend on the feasibility, characteristics, and relative expense of alternative technologies.

Second, some of the increase in the cost of silica-generating activities will increase the marginal cost of construction output and cause the construction supply curve to shift upward, resulting in a higher price for each quantity produced. The magnitude of the impact of the cost increases due to the silica rule on the supply relationship will depend on the size of the cost increases and the importance of silica-generating activities in the overall cost of construction projects. If the silica-generating activities are a small portion of the overall cost of construction then the supply curve shift will be smaller when compared to a shift in the supply curve from silica-generating activity that is a large portion of the overall cost of construction. If, for example, there is a one percent increase in the costs of a silica generating activity and the silica generating activity constitutes only one percent of the costs of a building, then the total increase in the cost of the building will be an almost unobservable 0.01 percent. Magnitude of shifts in derived demand for a service used in making another product are determined by the price change for the final product, not the price change for the service itself.

In practice, if one considers the costs of the final rule relative to the size of construction activity in the United States, it is clear that the price and profit impacts of the final rule on construction industries must be quite limited. The annualized cost of the final rule would be equal to approximately 0.1 percent of the value of annual construction activity in the U.S. Moreover, construction activity in the U.S. is not subject to any disadvantage from foreign competition-- any foreign firms performing construction activities in the United States would be subject to OSHA regulations.

Impacts by Type of Construction Demand

The demand for construction services originates in three independent sub-sectors: residential building construction, nonresidential building construction, and nonbuilding construction.

Residential Building Construction

Residential building demand is derived from the household demand for housing services. These services are provided by the stock of single and multi-unit residential housing units. Residential housing construction represents changes to the housing stock and includes construction of new units and modifications, renovations, and repairs to existing units. A number of studies have examined the price sensitivity of the demand for housing services. Depending on the data source and estimation methodologies, these studies have estimated the demand for housing services at price elasticity values ranging from -0.40 to -1.0, with the smaller (in absolute value) less elastic values estimated for short-run periods (Glennon, 1989, Document No. 0707; Mayo, 1981, Document No. 0794). In the long run, it is reasonable to expect the demand for the stock of housing to reflect similar levels of price sensitivity.

Many of the silica-generating construction activities affected by the rule are not widely used in single-family construction or renovation (See Profile of Affected Industries, Chapter III). This assessment is consistent with the cost estimates that show relatively low impacts for residential building contractors (See Table VI-9 – the costs as a percent of revenues for Residential Building Construction are estimated to be 0.03 percent and the costs as a percent of profits are estimated to be 1.29 percent). Multi-family residential construction might have more substantial impacts, but, based on Census data, this type of construction represents a relatively small share of net investment in residential buildings.

In 2012 approximately 9,000 multifamily buildings were completed versus 483,000 single family buildings completed.[48]

Nonresidential Building Construction

Nonresidential building construction is defined by the NAICS codes as consisting of industrial, commercial, and other nonresidential structures. As such, construction demand is derived from the demand for the output of the industries that use these types of buildings. For example, the demand for commercial office space is derived from the demand for the output produced by the users of the office space. The price elasticity of demand for this construction category will depend, among other things, on the price elasticity of demand for the final products produced, the importance of the costs of construction in the total cost of the final product, and the elasticity of substitution of other inputs that could substitute for nonresidential building construction. ERG found no studies that attempted to quantify these relationships. But given the costs of the silica rule relative to the size of construction spending in the United States, the resultant price or revenue effects are likely to be quite small as well.

Nonbuilding Construction

Nonbuilding construction includes roads, bridges, and other infrastructure projects. Utility construction (power lines, sewers, water mains, etc.) and a variety of other construction types are also included. A large share of this construction (63.8 percent) is publicly financed (ERG, 2007a, Document ID 1709). For this reason, a large percentage of the decisions regarding the appropriate level of such investments are not made in a private market setting. The relationship between the costs and price of such investments and the level of demand might depend more on political considerations than the factors that determine the demand for privately produced goods and services.

While a number of studies have examined the factors that determine the demand for publicly financed construction projects, these studies have focused on the ability to finance such projects (e.g., tax receipts) and socio-demographic factors (e.g., population growth) to the exclusion of cost or price factors. In the absence of budgetary constraints, the price elasticity of demand for public investment is therefore probably quite low. On the other hand, budget-imposed limits might constrain public construction spending. If the dollar value of public investments were fixed, a price elasticity of demand of one would be implied and any percentage increase in construction costs would be offset with

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[48] http://www.census.gov/construction/chars/pdf/c25ann2012.pdf

an equal percentage reduction in investment (measured in physical units), keeping public construction expenditures constant.

Public utility construction comprises the remainder of nonbuilding construction. This type of construction is subject to the same derived-demand considerations discussed for nonresidential building construction, and for the same reasons, OSHA expects the price and profit impacts to be quite small.

SBREFA Comments on Impacts on the Construction Industry

In this section OSHA reviews comments addressing economic impacts in construction that were submitted during the SBREFA process prior to the PEA. OSHA addressed these comments in the PEA that was made available for public comment, but did not receive comments specifically addressing its responses to the SBREFA recommendations. OSHA is reprinting its responses here for the convenience of the reader.

One commenter believed that OSHA had ignored the range of profitability among businesses, and thus did not adequately recognize that the average percentage reduction in profits could mean bankruptcy for those firms struggling to stay afloat (Document ID 0968, p. 7). The Agency's approach to economic feasibility is designed to address the overall health of industries in compliance with legal precedent, which permits OSHA to find a regulation economically feasible even though it may close some marginal firms.[49] In most years, ten percent or more of construction firms exit the industry (See U.S. Census Bureau Business Dynamics Statistics, available at http://www.census.gov/ces/dataproducts/bds/data_firm.html). The slight acceleration of the closure of such firms is not the kind of economic impact that would make a regulation economically infeasible.[50]

The commenter also asserted that OSHA ignored the cost of credit and that this also varies across businesses (Document ID 0968, p. 7). OSHA believes that the cost of credit is not an important issue in this case because OSHA's analysis demonstrates that, in most cases, upfront costs can usually be met from cash flow. Earlier in this chapter, OSHA noted that its choice of a threshold level of ten percent of annual profits for economic feasibility determinations is low enough that even if, in a hypothetical worst case, all compliance costs were upfront costs, then upfront costs would still equal 88.5 percent of

[49] See, e.g., Am. Iron and Steel Inst. v. OSHA, 939 F.2d 975, 980 (D.C. Cir. 1991); United Steelworkers of Am., AFL-CIO-CLC v. Marshall, 647 F.2d 1189, 1265 (D.C. Cir. 1980).

[50] *Indus Union Dep't v. Hodgson*, 499 F.2d 467 (D.C. Cir. 1974).

profits and thus would be affordable from profits alone without needing to resort to credit markets. As shown in Table VI-12, all industries' costs are a very small percentage of profits, assuring that even upfront costs can be met from profits without resorting to credit markets. Further, a firm that is having trouble meeting upfront costs can rent the appropriate tools without incurring any upfront capital investment costs.

A SER asserted that the impact of the rule would be "catastrophic" for the concrete cutting industry. One SER maintained that the rule would be both economically and technologically infeasible for the specialty trade concrete cutting industry (Document ID 0937, p. 69). The Small Business Advocacy Review (SBAR) Panel recommended that OSHA thoroughly review the economic impacts, and develop a more detailed economic feasibility analysis for certain industries (OSHA, 2003, Document ID 0937, p. 69). OSHA believes that the analyses in this chapter and in Chapter IX of this FEA address the SER's comments and the SBAR Panel recommendations.

Concrete cutting is undertaken for such purposes as grooving for projects such as highways, bridges, and sidewalks along with repairing these structures when they become operationally unsound. These contracts are bid on by firms who will all fall under the final silica rule, so there is no economic disadvantage between firms caused by the silica rule. Because the silica rule only applies in areas subject to OSHA jurisdiction, there is no foreign competition that would not also be subject to the silica standard. The cutting industry also works on runways and parking lots along with homebuilders for smaller projects. The demand for these products are relatively inelastic and not subject to foreign competition, enabling these companies to pass most of the costs of this final rule onto their consumers. Based on these analyses, OSHA disagrees that the rule would be "catastrophic" or economically infeasible for the concrete cutting industry.

Economic Feasibility Screening Analysis: Small and Very Small Businesses

The preceding discussion focused on the economic viability of the affected construction industries in their entirety. However, even though OSHA found that the silica standard did not threaten the survival of these construction industries, there is still the possibility that the industries' competitive structures could be significantly altered.

To address this possibility, OSHA examined the annualized costs per affected small entity and very small entity for each affected construction industry. Again, OSHA used a minimum threshold level of annualized costs equal to one percent of annual revenues—and, secondarily, annualized costs equal to ten percent of annual profits—below which the Agency has concluded that the costs are unlikely to threaten the survival of small entities or very small entities or, consequently, to alter the competitive structure of the affected construction industries.

Compliance costs were distributed across entities using the method described in the general industry screening analysis, above, that is largely in terms of costs per employee, with some exceptions. Table VI-12 and Table VI-13 show that in no construction industries do the annualized costs of the rule exceed one percent of annual revenues or ten percent of annual profits either for small entities or for very small entities. Therefore, OSHA concludes, based on its screening analysis, that the annualized costs as a percentage of annual revenues and as a percentage of annual profits are below the threshold level that could threaten the competitive structure of any of the construction industries.

Table VI-12: Screening Analysis for Small Entities in Construction Affected by OSHA's Final Silica Standard

NAICS	Industry	Total Annualized Costs	Affected Small Entities	Annual Cost Per Affected Establishment	Annual Revenues per Establishment ($1000)	Profit Rate	Annual Profit Per Entity	Costs as a Percentage of Revenue	Costs as a Percentage of Profits
221100	Electric Utilities	$285,915	624	$458	$27,367	0.67%	$183,358	0.00%	0.25%
236100	Residential Building Construction	$49,798,948	149,765	$333	$935	2.23%	$20,849	0.04%	1.59%
236200	Nonresidential Building Construction	$34,357,970	39,073	$879	$4,030	2.23%	$89,871	0.02%	0.98%
237100	Utility System Construction	$30,262,348	16,757	$1,806	$2,391	3.10%	$74,126	0.08%	2.44%
237200	Land Subdivision	$966,584	2,106	$459	$2,136	-1.30%	-$27,771	0.02%	-1.65%
237300	Highway, Street, and Bridge Construction	$21,399,925	8,737	$2,449	$4,417	2.89%	$127,660	0.06%	1.92%
237900	Other Heavy and Civil Engineering Construction	$5,415,610	3,960	$1,368	$2,104	2.89%	$60,802	0.06%	2.25%
238100	Foundation, Structure, and Building Exterior Contractors	$110,212,308	84,369	$1,306	$1,026	3.41%	$34,974	0.13%	3.74%
238200	Building Equipment Contractors	$41,087,873	139,065	$295	$1,126	3.66%	$41,222	0.03%	0.72%
238300	Building Finishing Contractors	$44,499,467	76,597	$581	$695	3.41%	$23,685	0.08%	2.45%
238900	Other Specialty Trade Contractors	$76,873,828	61,966	$1,241	$1,216	3.41%	$41,474	0.10%	2.99%
999200	State Governments	NA	NA	NA	NA	NA	NA	NA	NA
999300	Local Governments	NA	NA	NA	NA	NA	NA	NA	NA
	Totals	$415,160,777	583,018						

Source: OSHA, Directorate of Standards and Guidance, Office of Regulatory Analysis, based on ERG, 2015

Table VI-13: Screening Analysis for Very Small Entities (fewer than 20 employees) in Construction Affected by OSHA's Silica Standard

NAICS	Industry	Total Annualized Costs	Affected Entities with <20 Employees	Annual Cost Per Affected Entity	Revenue per Entity with <20 Employees ($1000)	Profit Rate	Annual Profit Per Entity	Costs as a Percentage of Revenue	Costs as a Percentage of Profits
221100	Electric Utilities	$22,113	49	$451	$5,314,217	0.67%	$43,054	0.01%	1.05%
236100	Residential Building Construction	$41,292,996	146,304	$282	$100,203,852	2.23%	$15,216	0.04%	1.85%
236200	Nonresidential Building Construction	$18,792,402	34,409	$546	$69,489,248	2.23%	$45,015	0.03%	1.21%
237100	Utility System Construction	$13,802,596	14,297	$965	$16,198,831	3.10%	$35,104	0.09%	2.75%
237200	Land Subdivision	$632,988	1,631	$388	$6,154,243	-1.30%	-$14,246	0.04%	-2.72%
237300	Highway, Street, and Bridge Construction	$7,480,629	6,891	$1,086	$12,773,940	2.89%	$53,526	0.06%	2.03%
237900	Other Heavy and Civil Engineering Construction	$2,813,457	3,541	$795	$3,812,866	2.89%	$31,119	0.07%	2.55%
238100	Foundation, Structure, and Building Exterior Contractors	$64,727,230	78,217	$828	$48,524,264	3.41%	$21,148	0.13%	3.91%
238200	Building Equipment Contractors	$27,233,382	121,895	$223	$94,507,036	3.66%	$22,897	0.04%	0.98%
238300	Building Finishing Contractors	$31,391,077	70,079	$448	$43,353,995	3.41%	$15,369	0.10%	2.91%
238900	Other Specialty Trade Contractors	$47,721,089	57,826	$825	$42,192,221	3.41%	$24,871	0.11%	3.32%
999200	State Governments	NA	49	NA	NA	NA	NA	NA	NA
999300	Local Governments	NA	NA	NA	NA	NA	NA	NA	NA
	Totals	**$255,909,961**	**535,188**						

Source: OSHA, Directorate of Standards and Guidance, Office of Regulatory Analysis, based on ERG, 2015

Differential Impacts on Small Entities and Very Small Entities

Below, OSHA provides some additional information about differential compliance costs for small entities and very small entities that might influence the magnitude of differential impacts for these smaller businesses.

The distribution of impacts by size of business is affected by the characteristics of the compliance measures. For silica controls in construction, the dust control measures consist primarily of equipment modifications and additions made to individual tools, rather than large, discrete investments, such as might be applied in a manufacturing setting. As a result, compliance advantages for large firms through economies of scale are limited. It is possible that some large construction firms might derive purchasing power by buying dust control measures in bulk. However, given the simplicity of many control measures, such as the use of wet methods on machines already manufactured to accommodate controls, such differential purchasing power appears to be of limited consequence.

The greater capital resources of large firms will give them some advantage in making the relatively large investments needed for some control measures. For example, cab enclosures on heavy construction equipment or foam-based dust control systems on rock crushers might be particularly expensive for some small entities with an unusual number of heavy equipment pieces. Nevertheless, where differential investment capabilities exist, small construction firms may also have the capability to achieve compliance with lower-cost measures, such as by modifying work practices. In the case of rock crushing, for example, simple water spray systems can be arranged without large-scale investments in the best commercially available systems.

In the program area, large firms might have a slight advantage in the delivery of training or in arranging for health screenings. This phenomenon has been accounted for in the analysis that OSHA provides.

Regulatory Flexibility Screening Analysis

To determine if the Assistant Secretary of Labor for OSHA can certify that the final silica standard for construction will not have a significant economic impact on a substantial number of small entities, OSHA applies the same screening analysis to construction as it does for general industry, as discussed earlier in that section and for the same reasons: annualized costs equal to one percent of annual revenues and annualized costs equal to five percent of annual profits applied to each affected industry. OSHA has applied these screening tests both to small entities and to very small entities. For purposes of certification, the threshold levels cannot be exceeded for affected small entities or very small entities in any affected industry.

Table VI-12 and Table VI-13 show that in no construction industries do the annualized costs of the rule exceed one percent of annual revenues or five percent of annual profits either for small entities or for very small entities. However, as previously noted in this chapter, OSHA is unable to certify that the final standard will not have a significant economic impact on a substantial number of small entities in general industry and maritime and must prepare a Final Regulatory Flexibility Analysis (FRFA). The FRFA is presented in Chapter IX of this FEA.

EMPLOYMENT IMPACTS ON THE U.S. ECONOMY

The discussion below on employment impacts of the silica rule on the U.S. economy is divided into three parts: (1) a brief summary of the employment impacts of the proposed silica rule (based on an analysis performed for OSHA by its subcontractor, Inforum, in 2011) that the Agency included in the PEA in support of the silica proposal; (2) a review of estimates provided by commenters on the employment effects of the silica proposal; and (3) a summary of a recent analysis of the employment effects of the final silica rule that Inforum performed for OSHA, followed by a critique of the commenters' analysis of employment effects relative to Inforum's analysis.

Inforum Analysis of Employment Effects Prepared for Silica Proposal

In October 2011, OSHA directed Inforum[51] to run its macroeconomic model to estimate the employment impacts of the costs[52] of the proposed silica rule. Inforum ran the model for the ten-year period 2014-2023 and reported its annual and cumulative employment and other macroeconomic results. While employment effects varied from year to year and from industry to industry, a key Inforum result was that the proposed silica rule cumulatively would generate an additional 8,625 job-years over the period 2014 - 2023, or an additional 862.5 job-years annually, on average, over the period.[53] A fuller discussion of Inforum's macroeconomic model and the results of its analysis can be found in Chapter VI of the PEA in support of OSHA's silica proposal and in the Inforum report itself (Inforum, 2011).

Estimates by Commenters on Employment Effects of the Silica Proposal

Three commenters on the silica proposal—the National Federation of Independent Business (NFIB) with the NFIB Research Foundation; the American Chemistry Council (ACC) with Stuart Sessions of Environomics, Inc.; and the Construction Industry Safety Coalition (CISC)

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[51] Inforum, which stands for the INterindustry FORecasting at the University of Maryland, is a non-for-profit Maryland corporation. Inforum has over 45 years of experience designing and using macroeconomic models of the United States (and other countries). Details of Inforum's macroeconomic model are presented later in this section.

[52] The estimated cost at the time was approximately $650 million in 2009 dollars using a 3 percent discount rate.

[53] A "job-year" is the term of art used to reflect the fact that an additional person is employed for a year, not that a new job has necessarily been permanently created.

with Environomics, Inc.—provided or reported estimates of the employment effects of the proposed silica rule. These commenter estimates are summarized below.

1. The NFIB Research Foundation performed a study (Document ID 2210, Attachment 2) to estimate the employment and other macroeconomic effects of OSHA's proposed rule, using the Agency's own estimates of the annualized compliance costs of the proposed rule for affected employers of approximately $637 million in 2009 dollars. The study modeled (a) anticipated employer costs due to the proposed rule, (b) changes to private sector demand, and (c) changes to state and local government spending associated with the proposed rule, and then forecast their effects using NFIB's Business Size Impact Module (BSIM) to run a simulation. The BSIM is a dynamic, multi-region model based on the Regional Economic Models, Inc. (REMI) structural economic forecasting and policy analysis model, which integrates input-output, computable general equilibrium, econometric, and economic geography methodologies. Costs were estimated by 5 size classes of firms. It was noted that the annualized compliance costs of the proposed rule

> …also represent new demand for private sector goods and services for firms who assist businesses affected by the new PEL in complying with the proposed rule. In the BSIM, this new demand for goods and services provided by the private sector acts as a countervailing force to any negative impact on employers the new annualized compliance costs may have (Document ID 2210, Attachment 2, p. 8).

The summary findings of the NFIB Research Foundation study included an overall loss of 27,000 jobs and lost output of over $72 billion in the long run, with at least half the loss expected to occur in the small business sector.

2. The American Chemistry Council (ACC) (Document ID 4209-A1) reported on Mr. Sessions's post-hearing brief (Document ID 4231), which provided estimates of the economic and employment impacts of the general industry costs to comply with the proposed silica rule and, in addition, criticized Inforum's estimates of the employment effects of the proposed silica rule (Inforum, 2011).

Mr. Sessions estimated economic impacts based on the URS Corporation estimates of $6.131 billion as the cost of the proposed silica rule on 19 general industry sectors (Document ID 4209-1, pp. 102-103). (Note that the analysis does not include the construction sector and is more than 50 times higher than OSHA's general industry cost estimate in the proposal). The economic impacts were estimated in two analytical steps: (1) estimate the impact of the proposed regulation's compliance costs on the value of output of the affected industries; and (2) estimate how the expected changes in output will reverberate throughout the economy, using IMPLAN—a well-known input-output model of the U.S. economy.

The first step was achieved by estimating the amount of cost pass-through of the compliance costs, using a supply elasticity of 1.0, and then estimating the demand response to this price increase assuming a demand elasticity of -1.5. This results in a decline in industry revenue equal to about 20 percent of annualized compliance costs, which—given URS's estimates of compliance costs—is equal to $1.23 billion per year. Again using the IMPLAN model, the corresponding estimated employment effect is 18,000 lost jobs annually (5,400 direct effect;

5,000 indirect effect; and 7,500 induced effect) and a loss in economic output/GDP of more than $1.6 billion per year.

Additionally, Mr. Sessions reviewed Inforum's analysis of the employment impacts of the proposed rule. He asserted that OSHA had supplied Inforum with year-by-year compliance costs that were only 53 percent of the annualized costs that OSHA had estimated in the PEA so that Inforum's projections of employment effects would be seriously underestimated:

> OSHA estimates the cost of the Proposed Standard to be $658 million per year in 2009 dollars on an annualized basis, excluding the hydraulic fracturing industry. Assuming a 7%/year discount rate, this annual cost, *continuing forever* as OSHA estimates it will, is equivalent to a present value cost of $9.4 billion dollars in the initial year of compliance. For comparison with this figure, I calculate (also assuming a 7% discount rate) that the present value in the first year for the ten-year schedule of compliance costs shown in Inforum's Table 1 is only $5.0 billion [italics added] (Document ID 4231).

In reviewing the above procedures, OSHA concludes that Mr. Sessions has misinterpreted his own calculations. The annualized value of an infinite series of costs (i.e., continuing forever) discounted at 7 percent is equal to 0.07 (the annualization factor) x the present value (PV). Hence, the annualized cost of Mr. Session's present value of $9.4 billion should equal $658 million. Now, OSHA provided a stream of costs for 10 years, not forever. The annualization factor for annualized costs incurred over ten years using a 7 percent discount rate is equal to 0.1424. Therefore, the PV of OSHA's costs given to Inforum should be $658 million/0.1424, or about $4.6 billion. Mr. Sessions only confused issues by using first-year costs (which is irrelevant to his exercise) rather than annualized costs. So, there is nothing in Mr. Sessions's calculations that would suggest that OSHA had provided Inforum with seriously incomplete costs. However, just to make sure, OSHA and ERG also reviewed the year-by-year proposal cost data given to Inforum (for Inforum, 2011) and found nothing amiss.

3. The Construction Industry Safety Coalition, submitted a late comment on the silica proposal (CISC, 2015), which contains estimates prepared by Environomics, Inc. (Environomics, 2015) of the employment impacts of the proposed silica rule on the construction sector. This late comment, including the contained Environomics study, has been excluded from OSHA decision-making consideration, but is presented here for informational purposes only.

The employment effects estimated by Environomics (2015) reflect annual costs to construction industries of $4.9 billion, which includes almost $3.9 billion of direct compliance costs to construction employers and another $1.05 billion of costs passed through from general industry (as a result of the silica rule for general industry) to the construction industry. Environomics used the IMPLAN model to translate the estimated $4.9 billion annual cost of the silica rule into more than 52,700 lost jobs related to the construction industry. These job losses would consist of about 20,800 in construction; 12,180 additional jobs lost in industries that supply materials, products, and services to the construction industry; and nearly 20,000 further jobs lost when those who lose their jobs in construction and supplier industries no longer have earnings to spend (i.e. "induced" jobs). Furthermore, Environomics argued that "(t)hese job figures are expressed on a full-time equivalent basis. Given the number of part-time and seasonal jobs in construction, the number of actual workers and actual jobs affected will be much more than 52,700" (Environomics, 2015, p. 2).

Inforum Analysis of Employment Effects of the Final Silica Rule

In December 2015, OSHA directed Inforum to run its macroeconomic model to estimate the industry and aggregate employment impacts on the U.S. economy of the cost of OSHA's final silica rule.[54] The Agency believes that the specific model of the U.S. economy that Inforum uses—called the LIFT (Long-term Interindustry Forecasting Tool) model—is particularly suitable for this work because it combines the industry detail of a pure input-output model (which shows, in matrix form, how the output of each industry serves as inputs in other industries) with macroeconomic modeling of demand, investment, and other macroeconomic parameters.[55] The Inforum model can thus both trace changes in particular industries through their effect on other industries and also examine the effects of these changes on aggregate demand, imports, exports, and investment, and in turn determine net changes to Gross Domestic Product (GDP), employment, prices, etc.

Using industry-by-industry compliance cost estimates provided by OSHA,[56] Inforum employed the LIFT model of the U.S. economy to compute the industry-level and macroeconomic impacts expected to follow implementation of the silica standard. The general methodology was to embed the compliance costs into the industry price functions of the LIFT model, solve the equations of the model with the additional costs included in the calculations, and then compare the simulation to a baseline scenario which did not include the additional costs. Enforcement of the rule was

[54] The estimated cost of the final rule that OSHA provided Inforum was about $962 in annualized terms in December 2015. The final cost presented in this FEA is about $1,030 million in annualized terms, or about 7 percent ($68 million) higher than the costs used by Inforum to estimate the employment effects of the final rule. OSHA believes that if the most recent cost estimates had been used, they would have had a minor effect on Inforum's estimate of the employment impact of the final rule.

[55] The LIFT model combines a dynamic input-output (I-O) core for 110 productive sectors with a full macroeconomic model with more than 1,200 macroeconomic variables that are consistent with the National Income and Product Accounts (NIPA) and other published data. LIFT employs a "bottom-up" regression approach to macroeconomic modeling (so that aggregate investment, employment, and exports, for example, are the sum of investment and employment by industry and exports by commodity). Unlike some simpler forecasting models, price effects are embedded in the model and the results are time-dependent (that is, they are not static or steady-state, but present year-by-year estimates of impacts consistent with economic conditions at the time).

[56] OSHA contractor ERG provided silica-rule compliance cost data for 13 segments of the construction sector plus construction activity by state and local governments, and for 102 industrial sectors. The costs were specified in 2012 dollars and covered a 10 year horizon, beginning with the implementation of the rule. The data covered eight cost types and were classified as intermediate, capital, and direct labor costs. In order to integrate the compliance costs within the LIFT model framework, Inforum established a mapping between the OSHA NAICS-based industries and the LIFT production sectors. See Inforum (2016) for a discussion of these and other transformations of OSHA's cost estimates to conform to the specifications of the LIFT model.

assumed to start in 2017 in construction and in 2018 in general industry and maritime (with enforcement of engineering control requirements for hydraulic fracturing activities beginning in 2021). The timing of the compliance costs reflected the phased-in enforcement of the rule, and the LIFT model results were calculated over a ten-year horizon, that is, through 2026.

The most significant Inforum result is that the final silica rule cumulatively generates an additional 9,500 job-years over the period 2017-2026, or an additional 950 job-years annually, on average, over the period (Inforum, 2016). It should be noted, however, that these results vary significantly from year to year. For example, in 2017, the first year in which the silica final rule would be in effect and when most capital costs for control equipment would be incurred, an additional 21,100 job-years would be generated as a result of the silica rule. Then, through 2026, the change in job-years relative to the baseline ranges from a high of 19,600 (in 2019) to a low of -17,300 (in 2020).[57] Inforum emphasized that all of these estimated job-year impacts of the silica rule, both positive and negative, should be viewed as negligible—relative to total U.S. employment of between 157 and 168 million workers during the time period under consideration and not statistically different from an estimate of 0 job-years (that is, that the silica rule would have no job impact).

The employment impacts of the silica rule would also vary significantly from industry to industry and from sector to sector. For example, for the period 2017 - 2026, the construction industry would, on average, gain 4,260 job-years annually while the rest of the U.S. economy would, on average, lose 3,310 job-years annually. Again, relative to total employment in the construction sector of about 10 million workers and employment in the rest of the U.S. economy of about 150 million workers over the 10-year period, these employment impacts should be considered negligible. For a fuller discussion of OSHA's estimate of the employment and other macroeconomic impacts of the silica rule, see Inforum (2016).

One obvious question is why the employment impacts of the silica rule would be positive in construction and negative elsewhere. There seem to be two major reasons. One is that, as reflected in the Inforum model, there is little foreign competition in U.S. construction and the price elasticity of demand in construction is extremely low relative to demand for products in most other industries. Hence, output and employment would be expected to decline minimally in response to any price increase if employers in construction pass on the costs of the silica rule. Second, and probably more important in OSHA's view, compliance with many of the provisions in the silica rule is relatively labor-intensive, often requiring the application of additional labor in the regulated firms themselves. Examples would include time spent for training, medical surveillance, and activities to meet the PEL (such as setting up and using control equipment and performing housekeeping tasks). The increased labor required to produce a unit of output in regulated firms would tend to increase employment in those industries (holding output constant). This is particularly true in construction, where compliance with the PEL would be much more

[57] The fluctuations in employment from year to year as a result of the proposed rule reflect how the Inforum model works The model has large short-term multipliers (from the initial increase in compliance expenditures) but long-term stabilizers to return to an equilibrium output and employment level. Hence, the short-term multipliers may cause output and employment to overshoot in one year and adjust in the other direction in the next year or two as the model (and the real-world economy) equilibrates

labor-intensive—both because engineering controls in construction are typically mobile and require more worker activity and because housekeeping and other worker actions are expected to play a larger role in achieving compliance with the PEL. By comparison, engineering control equipment in general industry/maritime is usually in a fixed location (eliminating the need for workers to move the equipment) and worker actions would play a smaller role in achieving compliance with the PEL.

Finally, OSHA turns to a critique of the commenters' analysis of employment effects of the proposed silica rule relative to Inforum's analysis of employment effects of the final silica rule. This critique reflects comments provided in the Inforum report (Inforum, 2016).

The NFIB Research Foundation Analysis: Although the NFIB Research Foundation study (Document ID 2210, Attachment 2) reported that careful attention was given to the analysis of costs and their attribution by firm size, it doesn't offer much information on how the BSIM model works or how the results were obtained. "From what is generally known about the REMI model upon which it is based, the general mechanism is probably the sequence of (1) increased costs leading to (2) increased output price leading to (3) reduced demand and therefore jobs" (Inforum, 2016, p. 8). The study does acknowledge that the costs also represent new private sector demand for firms that assist affected employers in complying with the new PEL, but the purported positive impacts of this private sector demand are not visible in the study. Presumably the reported impacts are net effects that combine the negative effects from the increased prices and reduced demand of the affected sectors with the stimulus from spending on the supplying sectors; however, that is not clear, and the stimulus is not quantified. In Inforum's analysis (Inforum, 2016), these effects are explicitly considered, both for intermediate goods and services as well as investment.

Another important difference from Inforum's analysis is that the NFIB study did not attempt to quantify the additional jobs created in the affected industries. In Inforum's LIFT model, these were captured as changes in labor productivity. For several industries, especially construction, although the industry does experience increased costs, it must also hire more workers to comply with the silica rule. The additional jobs required in the affected industries are not discussed or apparently modeled in the NFIB study. In summary, it seems that the counteracting influences due to intermediate and investment related purchases from other industries, and the job-creating expenditures in the affected industries were not, in fact, captured in the study.

The CISC and ACC Studies: These two studies are being critiqued together because they both rely on costs many times higher than OSHA's estimates and because they both made projections using the IMPLAN model.

What accounts for the difference between LIFT simulations and the CISC and ACC estimates? There are several factors at play:

Probably most importantly, CISC's estimate starts with annual compliance costs for the construction industry that are nearly 7 times larger than OSHA's estimates for the construction industry (only) ($4.1 billion vs. an average of over $600 million, both in 2012 dollars). Meanwhile, the ACC study estimates costs for general industry that are more than 16 times larger than OSHA's estimates for the final rule ($6.1 billion in 2009 dollars versus $359 million in 2012 dollars. Moreover, the CISC and ACC studies assumes that the same annualized cost estimates are imposed each year, whereas the OSHA cost estimates vary over the 10 year time period, with peak costs occurring in the first year.

Neither the CISC nor the ACC application of the IMPLAN model accounted for the increase in demand for capital equipment and intermediate goods and services needed to comply with the proposed silica rule. Thus, the employment and income boosting impacts of these expenditures are not captured in their analysis. In contrast, Inforum's methodology uses an explicit price function where annual compliance costs by industry change commodity prices in proportion to their share of total annual gross costs. In turn, price changes affect production and employment through a dynamic general equilibrium framework. Demand and supply price elasticities in the LIFT model are composites of several sets of empirically estimated functions for final demand, exports, imports, and price mark-ups. Furthermore, the parameters of these functions vary by type of product according to the econometric estimation.

At OSHA's request, Inforum made a separate run using the LIFT model in the absence of the final silica rule for the construction industry but with the final silica rule for general industry and maritime. The purpose of this run was to calculate the indirect effects (only) of the final silica rule for general industry and maritime on prices and employment in the construction industry (Inforum, 2016). This LIFT simulation estimated that the final silica rule for general industry and maritime indirectly increased prices in the construction industry by an average of .005 percent. The direction, if not the magnitude of this effect, is consistent with the CISC/Environomics results (Environomics, 2015). This led to a modest decline in construction output and construction jobs. As shown in Table 9, the decline in jobs varied from +290 to -940 a year over the period 2017 to 2026, with a cumulative job impact of -4.8 thousand jobs over the 10-year period. Again, it should be emphasized that this separate run was made in the absence of the final silica rule for the construction industry.[58]

The IMPLAN model is static and cannot compute employment and output impacts over time, and it cannot show how the economy evolves to cope with changes in costs. In order to extrapolate over ten years, the authors simply multiply the first year effects by 10. The results are implausible for a dynamic economy as the full static one-year impact is unlikely to be the average impact over the course of several years. At least theoretically, the economy contains powerful forces pushing it towards full employment equilibrium. Therefore, most changes to output and employment due to cost or demand shocks tend to be neutralized through time. That is, most impacts, negative or positive, will approach zero over the long term. Indeed, Inforum's LIFT model produces dynamic results that vary from year to year, which is consistent with fluctuations in the state of the economy and with short and long term expenditure effects. It

[58] As shown in Table 6, the cumulative effect of the final rule for general industry, maritime, and construction is to increase construction employment by 42,600 job years over the 10-year time period (from Table 6), or about 4,260 jobs a year, on average. Hence, the cumulative effect of the final rule for construction alone is to increase construction employment by about 47,400 (42,600+4,800) jobs, or about 4,740 jobs a year, to the extent that the two components are additive.

shows how the employment is reallocated among industries and how the economy eventually will return to the baseline, or potential, level of employment.

While the IMPLAN study places the regulatory analysis within the context of the overall economy, it does not take full advantage of the framework. For instance, given data for gross output in the base year it is possible to compute the industry price effect so that the revenue shocks can be judged relative to a price elasticity of demand. Instead, the study employs an unrealistically large construct of a 5 to 1 compliance cost to revenue loss. Finally, the IMPLAN model's inability to model the long-term properties of the economy severely undermines the study's conclusion of long term cost to the economy.

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Appendix VI-A

Screening Analysis for Establishments in General Industry, Maritime, and Construction Affected by the Final Silica Standard (Applying Alternative Discount Rates of 7% and 0%)

Table VI-A-1: Screening Analysis for Establishments in General Industry and Maritime Affected by OSHA's Silica Standard (7% discount rate)

NAICS	Industry	Total Annualized Costs	No. of Affected Establishments	Annual Cost per Affected Establishment	Revenues per Establishment	Profit Rate [a]	Profits per Establishment	Costs as a Percentage of Revenues	Costs as a Percentage of Profits
213112	Support Activities for Oil and Gas Operations	$100,244,816	444	$225,777	$39,182,010	7.09%	$2,777,295	0.56%	7.94%
324121	Asphalt Paving Mixture and Block Manufacturing	$566,638	1,362	$416	$9,645,893	5.96%	$574,834	0.00%	0.07%
324122	Asphalt Shingle and Coating Materials Manufacturing	$3,918,614	223	$17,572	$47,114,735	5.96%	$2,807,740	0.04%	0.61%
325510	Paint and Coating Manufacturing	$1,073,862	772	$1,391	$20,351,974	3.86%	$786,325	0.01%	0.17%
327110	Pottery, Ceramics, and Plumbing Fixture Manufacturing	$9,226,002	655	$14,085	$3,254,786	1.34%	$43,558	0.41%	30.80%
327120	Clay Building Material and Refractories Manufacturing	$22,380,068	586	$38,191	$8,719,710	1.34%	$116,694	0.42%	31.08%
327211	Flat Glass Manufacturing	$762,468	56	$13,730	$37,273,447	2.63%	$978,432	0.04%	1.34%
327212	Other Pressed and Blown Glass and Glassware Manufacturing	$2,318,605	171	$13,580	$7,550,430	2.63%	$198,200	0.17%	6.53%
327213	Glass Container Manufacturing	$2,323,649	62	$37,456	$51,794,722	2.63%	$1,359,618	0.07%	2.62%
327320	Ready-Mix Concrete Manufacturing	$30,602,177	5,377	$5,691	$3,786,538	1.43%	$54,169	0.15%	10.30%
327331	Concrete Block and Brick Manufacturing	$7,242,954	817	$8,865	$4,762,805	1.43%	$68,135	0.18%	12.61%
327332	Concrete Pipe Manufacturing	$3,930,957	352	$11,167	$5,720,378	1.43%	$81,834	0.19%	13.23%
327390	Other Concrete Product Manufacturing	$21,541,018	1,973	$10,918	$4,379,366	1.43%	$62,650	0.24%	16.89%
327991	Cut Stone and Stone Product Manufacturing	$15,227,229	1,859	$8,191	$1,889,912	1.75%	$33,122	0.42%	23.76%
327992	Ground or Treated Mineral and Earth Manufacturing	$4,474,496	249	$17,970	$13,359,835	1.75%	$234,143	0.13%	7.36%
327993	Mineral Wool Manufacturing	$2,745,877	174	$15,817	$17,670,877	1.75%	$309,697	0.09%	4.86%
327999	All Other Miscellaneous Nonmetallic Mineral Product Manufacturing	$12,150,544	452	$26,882	$8,950,704	1.75%	$156,869	0.29%	16.36%
331110	Iron and Steel Mills and Ferroalloy Manufacturing	$706,128	280	$2,520	$201,470,548	1.35%	$2,728,087	0.00%	0.08%
331210	Iron and Steel Pipe and Tube Manufacturing from Purchased Steel	$177,829	110	$1,610	$54,854,802	2.14%	$1,175,284	0.00%	0.13%
331221	Rolled Steel Shape Manufacturing	$55,620	41	$1,345	$35,875,377	2.14%	$768,643	0.00%	0.16%
331222	Steel Wire Drawing	$100,472	78	$1,291	$19,232,510	2.14%	$412,064	0.01%	0.29%
331314	Secondary Smelting and Alloying of Aluminum	$38,442	30	$1,262	$49,325,439	2.52%	$1,243,421	0.00%	0.09%
331420	Copper Rolling, Drawing, Extruding, and Alloying	$147,505	107	$1,383	$93,804,771	2.14%	$2,009,801	0.00%	0.06%
331492	Secondary Smelting, Refining, and Alloying of Nonferrous Metal (except Copper and Aluminum)	$77,133	58	$1,328	$55,758,349	2.14%	$1,194,643	0.00%	0.10%
331511	Iron Foundries	$24,444,332	407	$60,060	$26,575,737	4.36%	$1,157,952	0.22%	4.96%
331512	Steel Investment Foundries	$5,735,697	128	$44,810	$29,128,852	4.36%	$1,269,196	0.15%	3.35%
331513	Steel Foundries (except Investment)	$11,633,497	208	$55,930	$21,811,029	4.36%	$950,345	0.25%	5.62%

Table VI-A-1: Screening Analysis for Establishments in General Industry and Maritime Affected by OSHA's Silica Standard (7% discount rate) (Continued)

NAICS	Industry	Total Annualized Costs	No. of Affected Establishments	Annual Cost per Affected Establishment	Revenues per Establishment	Profit Rate [a]	Profits per Establishment	Costs as a Percentage of Revenues	Costs as a Percentage of Profits
331524	Aluminum Foundries (except Die-Casting)	$4,339,248	406	$10,688	$6,972,010	4.36%	$303,783	0.15%	3.34%
331529	Other Nonferrous Metal Foundries (except Die-Casting)	$2,705,355	300	$9,018	$8,042,850	4.36%	$350,441	0.11%	2.44%
332111	Iron and Steel Forging	$168,554	125	$1,351	$29,983,048	3.81%	$1,141,045	0.00%	0.11%
332112	Nonferrous Forging	$43,685	29	$1,529	$38,519,113	3.81%	$1,465,896	0.00%	0.10%
332117	Powder Metallurgy Part Manufacturing	$57,711	46	$1,254	$15,216,835	3.81%	$579,097	0.01%	0.20%
332119	Metal Crown, Closure, and Other Metal Stamping (except Automotive)	$371,208	288	$1,288	$7,883,132	3.81%	$300,003	0.01%	0.39%
332215	Metal Kitchen Cookware, Utensil, Cutlery, and Flatware (except Precious) Manufacturing	$52,388	37	$1,433	$19,914,229	4.12%	$820,139	0.01%	0.16%
332216	Saw Blade and Handtool Manufacturing	$195,957	147	$1,333	$6,670,332	4.12%	$274,708	0.02%	0.45%
332323	Ornamental and Architectural Metal Work Manufacturing	$46,401	40	$1,158	$2,622,788	2.70%	$70,844	0.04%	1.55%
332439	Other Metal Container Manufacturing	$82,934	62	$1,338	$10,763,763	2.93%	$315,184	0.01%	0.39%
332510	Hardware Manufacturing	$187,018	134	$1,398	$12,347,008	4.63%	$572,156	0.01%	0.22%
332613	Spring Manufacturing	$104,609	82	$1,277	$9,171,923	4.63%	$425,023	0.01%	0.28%
332618	Other Fabricated Wire Product Manufacturing	$173,220	137	$1,267	$5,920,491	4.63%	$274,353	0.02%	0.42%
332710	Machine Shops	$1,722,691	1,384	$1,245	$2,015,260	4.63%	$93,386	0.06%	1.22%
332812	Metal Coating, Engraving (except Jewelry and Silverware), and Allied Services to Manufacturers	$3,563,926	1,620	$2,200	$5,226,085	2.96%	$154,661	0.04%	1.37%
332911	Industrial Valve Manufacturing	$249,885	177	$1,409	$23,996,948	5.95%	$1,428,175	0.01%	0.09%
332912	Fluid Power Valve and Hose Fitting Manufacturing	$239,779	139	$1,722	$27,900,650	5.95%	$1,660,504	0.01%	0.10%
332913	Plumbing Fixture Fitting and Trim Manufacturing	$53,910	36	$1,506	$32,065,223	5.95%	$1,908,358	0.00%	0.07%
332919	Other Metal Valve and Pipe Fitting Manufacturing	$100,768	75	$1,352	$19,968,428	5.95%	$1,188,418	0.01%	0.10%
332991	Ball and Roller Bearing Manufacturing	$158,660	99	$1,605	$38,699,614	5.95%	$2,303,203	0.00%	0.06%
332996	Fabricated Pipe and Pipe Fitting Manufacturing	$209,818	160	$1,312	$11,162,659	5.95%	$664,344	0.01%	0.18%
332999	All Other Miscellaneous Fabricated Metal Product Manufacturing	$501,163	396	$1,266	$4,158,301	5.95%	$247,481	0.03%	0.47%
333318	Other Commercial and Service Industry Machinery Manufacturing	$380,391	258	$1,472	$12,612,049	3.05%	$384,822	0.01%	0.35%
333413	Industrial and Commercial Fan and Blower and Air Purification Equipment Manufacturing	$170,080	131	$1,303	$12,256,450	3.00%	$367,965	0.01%	0.32%
333414	Heating Equipment (except Warm Air Furnaces) Manufacturing	$126,594	102	$1,246	$11,240,782	3.00%	$337,472	0.01%	0.34%
333511	Industrial Mold Manufacturing	$247,390	194	$1,273	$3,653,488	3.82%	$139,525	0.03%	0.84%

Table VI-A-1: Screening Analysis for Establishments in General Industry and Maritime Affected by OSHA's Silica Standard (7% discount rate) (Continued)

NAICS	Industry	Total Annualized Costs	No. of Affected Establishments	Annual Cost per Affected Establishment	Revenues per Establishment	Profit Rate [a]	Profits per Establishment	Costs as a Percentage of Revenues	Costs as a Percentage of Profits
333514	Special Die and Tool, Die Set, Jig, and Fixture Manufacturing	$300,713	236	$1,275	$3,106,457	3.82%	$118,634	0.04%	0.99%
333515	Cutting Tool and Machine Tool Accessory Manufacturing	$199,757	161	$1,244	$3,474,136	3.82%	$132,676	0.03%	0.86%
333517	Machine Tool Manufacturing	$170,796	129	$1,326	$10,852,563	3.82%	$414,454	0.01%	0.29%
333519	Rolling Mill and Other Metalworking Machinery Manufacturing	$82,643	62	$1,330	$8,534,499	3.82%	$325,928	0.01%	0.37%
333612	Speed Changer, Industrial High-Speed Drive, and Gear	$112,169	76	$1,467	$20,704,431	1.99%	$411,587	0.01%	0.33%
333613	Mechanical Power Transmission Equipment Manufacturing	$109,467	82	$1,328	$19,068,718	1.99%	$379,071	0.01%	0.32%
333911	Pump and Pumping Equipment Manufacturing	$237,550	165	$1,441	$28,278,876	3.80%	$1,074,041	0.00%	0.12%
333912	Air and Gas Compressor Manufacturing	$148,118	99	$1,491	$34,027,631	3.80%	$1,292,380	0.00%	0.11%
333991	Power-Driven Handtool Manufacturing	$61,549	37	$1,652	$28,169,053	3.80%	$1,069,870	0.01%	0.14%
333992	Welding and Soldering Equipment Manufacturing	$107,787	58	$1,861	$17,097,238	3.80%	$649,359	0.01%	0.26%
333993	Packaging Machinery Manufacturing	$140,706	108	$1,306	$9,811,831	3.80%	$372,657	0.01%	0.32%
333994	Industrial Process Furnace and Oven Manufacturing	$77,786	62	$1,250	$7,795,276	3.80%	$296,067	0.01%	0.39%
333995	Fluid Power Cylinder and Actuator Manufacturing	$167,148	106	$1,579	$20,249,583	3.80%	$769,086	0.01%	0.19%
333996	Fluid Power Pump and Motor Manufacturing	$74,477	51	$1,461	$27,468,365	3.80%	$1,043,257	0.00%	0.13%
333997	Scale and Balance Manufacturing	$26,672	21	$1,272	$11,015,909	3.80%	$418,388	0.01%	0.28%
333999	All Other Miscellaneous General Purpose Machinery Manufacturing	$358,995	261	$1,375	$9,113,043	3.80%	$346,116	0.01%	0.36%
334519	Other Measuring and Controlling Device Manufacturing	$241,844	164	$1,476	$12,672,736	4.51%	$571,009	0.01%	0.24%
335210	Small Electrical Appliance Manufacturing	$25,876	20	$1,273	$26,870,480	4.01%	$1,078,458	0.00%	0.11%
335221	Household Cooking Appliance Manufacturing	$30,360	15	$2,066	$45,714,755	4.01%	$1,834,780	0.00%	0.11%
335222	Household Refrigerator and Home Freezer Manufacturing	$27,591	11	$2,497	$117,768,533	4.01%	$4,726,688	0.00%	0.05%
335224	Household Laundry Equipment Manufacturing	$13,095	3	$4,148	$101,336,939	4.01%	$4,067,200	0.00%	0.10%
335228	Other Major Household Appliance Manufacturing	$28,372	12	$2,404	$125,404,833	4.01%	$5,033,174	0.00%	0.05%
336111	Automobile Manufacturing	$396,898	39	$10,171	$600,655,006	-0.50%	-$3,026,184	0.00%	-0.31%
336112	Light Truck and Utility Vehicle Manufacturing	$355,594	27	$13,060	$1,521,926,795	-0.50%	-$7,667,681	0.00%	-0.16%
336120	Heavy Duty Truck Manufacturing	$201,124	40	$4,973	$354,848,988	-0.50%	-$1,787,779	0.00%	-0.25%
336211	Motor Vehicle Body Manufacturing	$283,933	190	$1,495	$15,228,919	1.30%	$197,621	0.01%	0.69%
336212	Truck Trailer Manufacturing	$196,480	121	$1,621	$19,658,470	1.30%	$255,102	0.01%	0.58%
336213	Motor Home Manufacturing	$49,872	16	$3,087	$39,043,629	1.30%	$506,657	0.01%	0.56%
336310	Motor Vehicle Gasoline Engine and Engine Parts Manufacturing	$364,536	196	$1,861	$37,520,147	1.30%	$486,887	0.00%	0.35%

Table VI-A-1: Screening Analysis for Establishments in General Industry and Maritime Affected by OSHA's Silica Standard (7% discount rate) (Continued)

NAICS	Industry	Total Annualized Costs	No. of Affected Establishments	Annual Cost per Affected Establishment	Revenues per Establishment	Profit Rate [a]	Profits per Establishment	Costs as a Percentage of Revenues	Costs as a Percentage of Profits
336320	Motor Vehicle Electrical and Electronic Equipment Manufacturing	$344,603	200	$1,720	$30,162,034	1.30%	$391,403	0.01%	0.40%
336330	Motor Vehicle Steering and Suspension Components (except Spring) Manufacturing	$197,157	108	$1,830	$48,079,633	1.30%	$623,914	0.00%	0.27%
336340	Motor Vehicle Brake System Manufacturing	$153,326	100	$1,538	$51,448,277	1.30%	$667,628	0.00%	0.21%
336350	Motor Vehicle Transmission and Power Train Parts Manufacturing	$397,651	196	$2,029	$68,200,565	1.30%	$885,017	0.00%	0.21%
336370	Motor Vehicle Metal Stamping	$563,827	355	$1,590	$40,671,247	1.30%	$527,778	0.00%	0.28%
336390	Other Motor Vehicle Parts Manufacturing	$848,777	510	$1,666	$38,533,574	1.30%	$500,038	0.00%	0.31%
336611	Ship Building and Repairing	$9,643,639	353	$27,345	$36,357,091	6.06%	$2,204,764	0.07%	1.23%
336612	Boat Building	$2,583,723	313	$8,249	$8,054,436	6.06%	$488,437	0.10%	1.68%
336992	Military Armored Vehicle, Tank, and Tank Component Manufacturing	$76,220	31	$2,433	$81,906,183	4.03%	$3,304,704	0.00%	0.07%
337110	Wood Kitchen Cabinet and Countertop Manufacturing	$215,226	206	$1,046	$1,554,973	2.77%	$43,087	0.06%	2.31%
337215	Showcase, Partition, Shelving, and Locker Manufacturing	$235,091	177	$1,325	$5,949,451	2.77%	$164,853	0.02%	0.74%
339114	Dental Equipment and Supplies Manufacturing	$6,227,075	727	$8,565	$7,144,773	7.32%	$523,086	0.11%	1.56%
339116	Dental Laboratories	$7,199,860	6,818	$1,056	$675,698	7.32%	$49,470	0.15%	2.03%
339910	Jewelry and Silverware Manufacturing	$2,795,368	2,119	$1,319	$3,549,274	3.92%	$139,242	0.04%	0.91%
339950	Sign Manufacturing	$428,930	363	$1,180	$1,925,106	3.92%	$75,524	0.06%	1.49%
423840	Industrial Supplies Merchant Wholesalers	$2,375,893	1,683	$1,412	$8,430,352	2.98%	$251,560	0.02%	0.54%
444110	Home Centers	$116,539	107	$1,090	$2,122,394	6.05%	$128,360	0.05%	0.80%
482110	Rail transportation	$16,596,146	NA	NA	NA	6.23%	NA	NA	NA
561730	Landscaping Services	$25,101,018	25,982	$966	$566,354	2.96%	$16,767	0.17%	5.62%
621210	Offices of Dentists	$2,733,888	8,525	$321	$786,888	7.78%	$61,216	0.04%	0.50%
	Totals	**$383,525,832**	**75,074**						

Source: OSHA, Directorate of Standards and Guidance, Office of Regulatory Analysis, based on ERG, 2015

Table VI-A-2: Screening Analysis for Establishments in Construction Affected by OSHA's Proposed Silica Standard (7% discount rate)

NAICS	Industry	Total Annualized Costs	Affected Establishments	Annualized Costs per Affected Establishments	Revenues per Establishment	Profit Rate [a]	Profits per Entity	Costs as a Percentage of Revenues	Costs as a Percentage of Profits
221100	Electric Utilities	$3,324,686	4,662	$713	$41,073,120	0.67%	NA	0.00%	NA
236100	Residential Building Construction	$57,073,084	151,034	$378	$1,260,265	2.23%	$28,104	0.03%	1.34%
236200	Nonresidential Building Construction	$53,890,151	41,018	$1,314	$6,843,237	2.23%	$152,604	0.02%	0.86%
237100	Utility System Construction	$84,338,755	18,686	$4,513	$6,328,499	3.10%	$196,183	0.07%	2.30%
237200	Land Subdivision	$2,008,050	2,150	$934	$6,478,583	-1.30%	-$84,222	0.01%	NA
237300	Highway, Street, and Bridge Construction	$48,978,092	10,043	$4,877	$10,022,676	2.89%	$289,655	0.05%	1.68%
237900	Other Heavy and Civil Engineering Construction	$13,525,085	4,222	$3,203	$5,732,181	2.89%	$165,660	0.06%	1.93%
238100	Foundation, Structure, and Building Exterior Contractors	$141,876,932	85,801	$1,654	$1,300,391	3.41%	$44,343	0.13%	3.73%
238200	Building Equipment Contractors	$62,392,817	142,536	$438	$1,788,299	3.66%	$65,452	0.02%	0.67%
238300	Building Finishing Contractors	$56,658,011	77,330	$733	$858,312	3.41%	$29,268	0.09%	2.50%
238900	Other Specialty Trade Contractors	$103,292,586	63,214	$1,634	$1,617,189	3.41%	$55,146	0.10%	2.96%
999200	State Governments	$8,734,017	NA	NA	NA	NA	NA	NA	NA
999300	Local Governments	$36,510,322	NA	NA	NA	NA	NA	NA	NA
	Totals	$672,602,589	600,695						

Source: OSHA, Directorate of Standards and Guidance, Office of Regulatory Analysis, based on ERG, 2015

Table VI-A-3: Screening Analysis for Establishments in General Industry and Maritime Affected by OSHA's Proposed Silica Standard (0% discount rate)

NAICS	Industry	Total Annualized Costs	No. of Affected Establishments	Annual Cost per Affected Establishment	Revenues per Establishment	Profit Rate [a]	Profits per Establishment	Costs as a Percentage of Revenues	Costs as a Percentage of Profits
213112	Support Activities for Oil and Gas Operations	$96,343,128	444	$216,989	$39,182,010	7.09%	$2,777,295	0.55%	7.81%
324121	Asphalt Paving Mixture and Block Manufacturing	$476,328	1,362	$350	$9,645,893	5.96%	$574,834	0.00%	0.06%
324122	Asphalt Shingle and Coating Materials Manufacturing	$3,739,001	223	$16,767	$47,114,735	5.96%	$2,807,740	0.04%	0.60%
325510	Paint and Coating Manufacturing	$964,040	772	$1,249	$20,351,974	3.86%	$786,325	0.01%	0.16%
327110	Pottery, Ceramics, and Plumbing Fixture Manufacturing	$8,489,025	655	$12,960	$3,254,786	1.34%	$43,558	0.40%	29.75%
327120	Clay Building Material and Refractories Manufacturing	$20,479,615	586	$34,948	$8,719,710	1.34%	$116,694	0.40%	29.95%
327211	Flat Glass Manufacturing	$700,083	56	$12,607	$37,273,447	2.63%	$978,432	0.03%	1.29%
327212	Other Pressed and Blown Glass and Glassware Manufacturing	$2,133,278	171	$12,494	$7,550,430	2.63%	$198,200	0.17%	6.30%
327213	Glass Container Manufacturing	$2,136,722	62	$34,443	$51,794,722	2.63%	$1,359,618	0.07%	2.53%
327320	Ready-Mix Concrete Manufacturing	$29,597,121	5,377	$5,504	$3,786,538	1.43%	$54,169	0.15%	10.16%
327331	Concrete Block and Brick Manufacturing	$6,868,579	817	$8,407	$4,762,805	1.43%	$68,135	0.18%	12.34%
327332	Concrete Pipe Manufacturing	$3,727,325	352	$10,589	$5,720,378	1.43%	$81,834	0.19%	12.94%
327390	Other Concrete Product Manufacturing	$20,424,409	1,973	$10,352	$4,379,366	1.43%	$62,650	0.24%	16.52%
327991	Cut Stone and Stone Product Manufacturing	$14,216,988	1,859	$7,648	$1,889,912	1.75%	$33,122	0.40%	23.09%
327992	Ground or Treated Mineral and Earth Manufacturing	$4,161,359	249	$16,712	$13,359,835	1.75%	$234,143	0.13%	7.14%
327993	Mineral Wool Manufacturing	$2,525,985	174	$14,550	$17,670,877	1.75%	$309,697	0.08%	4.70%
327999	All Other Miscellaneous Nonmetallic Mineral Product Manufacturing	$11,219,292	452	$24,821	$8,950,704	1.75%	$156,869	0.28%	15.82%
331110	Iron and Steel Mills and Ferroalloy Manufacturing	$605,511	280	$2,161	$201,470,548	1.35%	$2,728,087	0.00%	0.08%
331210	Iron and Steel Pipe and Tube Manufacturing from Purchased Steel	$152,911	110	$1,385	$54,854,802	2.14%	$1,175,284	0.00%	0.12%
331221	Rolled Steel Shape Manufacturing	$47,938	41	$1,160	$35,875,377	2.14%	$768,643	0.00%	0.15%
331222	Steel Wire Drawing	$86,547	78	$1,112	$19,232,510	2.14%	$412,064	0.01%	0.27%
331314	Secondary Smelting and Alloying of Aluminum	$33,170	30	$1,089	$49,325,439	2.52%	$1,243,421	0.00%	0.09%
331420	Copper Rolling, Drawing, Extruding, and Alloying	$126,960	107	$1,191	$93,804,771	2.14%	$2,009,801	0.00%	0.06%
331492	Secondary Smelting, Refining, and Alloying of Nonferrous Metal (except Copper and Aluminum)	$66,449	58	$1,144	$55,758,349	2.14%	$1,194,643	0.00%	0.10%
331511	Iron Foundries	$22,623,753	407	$55,587	$26,575,737	4.36%	$1,157,952	0.21%	4.80%
331512	Steel Investment Foundries	$5,255,262	128	$41,057	$29,128,852	4.36%	$1,269,196	0.14%	3.23%
331513	Steel Foundries (except Investment)	$10,766,235	208	$51,761	$21,811,029	4.36%	$950,345	0.24%	5.45%

Table VI-A-3: Screening Analysis for Establishments in General Industry and Maritime Affected by OSHA's Proposed Silica Standard (0% discount rate) (Continued)

NAICS	Industry	Total Annualized Costs	No. of Affected Establishments	Annual Cost per Affected Establishment	Revenues per Establishment	Profit Rate [a]	Profits per Establishment	Costs as a Percentage of Revenues	Costs as a Percentage of Profits
331524	Aluminum Foundries (except Die-Casting)	$3,971,194	406	$9,781	$6,972,010	4.36%	$303,783	0.14%	3.22%
331529	Other Nonferrous Metal Foundries (except Die-Casting)	$2,476,637	300	$8,255	$8,042,850	4.36%	$350,441	0.10%	2.36%
332111	Iron and Steel Forging	$145,091	125	$1,163	$29,983,048	3.81%	$1,141,045	0.00%	0.10%
332112	Nonferrous Forging	$37,647	29	$1,318	$38,519,113	3.81%	$1,465,896	0.00%	0.09%
332117	Powder Metallurgy Part Manufacturing	$49,755	46	$1,081	$15,216,835	3.81%	$579,097	0.01%	0.19%
332119	Metal Crown, Closure, and Other Metal Stamping (except Automotive)	$319,536	288	$1,109	$7,883,132	3.81%	$300,003	0.01%	0.37%
332215	Metal Kitchen Cookware, Utensil, Cutlery, and Flatware (except Precious) Manufacturing	$45,148	37	$1,235	$19,914,229	4.12%	$820,139	0.01%	0.15%
332216	Saw Blade and Handtool Manufacturing	$168,695	147	$1,148	$6,670,332	4.12%	$274,708	0.02%	0.42%
332323	Ornamental and Architectural Metal Work Manufacturing	$42,376	40	$1,058	$2,622,788	2.70%	$70,844	0.04%	1.49%
332439	Other Metal Container Manufacturing	$71,449	62	$1,153	$10,763,763	2.93%	$315,184	0.01%	0.37%
332510	Hardware Manufacturing	$160,982	134	$1,204	$12,347,008	4.63%	$572,156	0.01%	0.21%
332613	Spring Manufacturing	$90,116	82	$1,100	$9,171,923	4.63%	$425,023	0.01%	0.26%
332618	Other Fabricated Wire Product Manufacturing	$149,165	137	$1,091	$5,920,491	4.63%	$274,353	0.02%	0.40%
332710	Machine Shops	$1,483,162	1,384	$1,072	$2,015,260	4.63%	$93,386	0.05%	1.15%
332812	Metal Coating, Engraving (except Jewelry and Silverware), and Allied Services to Manufacturers	$3,361,164	1,620	$2,075	$5,226,085	2.96%	$154,661	0.04%	1.34%
332911	Industrial Valve Manufacturing	$215,030	177	$1,213	$23,996,948	5.95%	$1,428,175	0.01%	0.08%
332912	Fluid Power Valve and Hose Fitting Manufacturing	$206,078	139	$1,480	$27,900,650	5.95%	$1,660,504	0.01%	0.09%
332913	Plumbing Fixture Fitting and Trim Manufacturing	$46,452	36	$1,298	$32,065,223	5.95%	$1,908,358	0.00%	0.07%
332919	Other Metal Valve and Pipe Fitting Manufacturing	$86,795	75	$1,164	$19,968,428	5.95%	$1,188,418	0.01%	0.10%
332991	Ball and Roller Bearing Manufacturing	$136,503	99	$1,381	$38,699,614	5.95%	$2,303,203	0.00%	0.06%
332996	Fabricated Pipe and Pipe Fitting Manufacturing	$180,629	160	$1,129	$11,162,659	5.95%	$664,344	0.01%	0.17%
332999	All Other Miscellaneous Fabricated Metal Product Manufacturing	$432,383	396	$1,092	$4,158,301	5.95%	$247,481	0.03%	0.44%
333318	Other Commercial and Service Industry Machinery Manufacturing	$327,187	258	$1,266	$12,612,049	3.05%	$384,822	0.01%	0.33%
333413	Industrial and Commercial Fan and Blower and Air Purification Equipment Manufacturing	$146,455	131	$1,122	$12,256,450	3.00%	$367,965	0.01%	0.30%
333414	Heating Equipment (except Warm Air Furnaces) Manufacturing	$109,045	102	$1,074	$11,240,782	3.00%	$337,472	0.01%	0.32%

333511	Industrial Mold Manufacturing	$212,997	194	$1,096	$3,653,488	3.82%	$139,525	0.03%	0.79%

Table VI-A-3: Screening Analysis for Establishments in General Industry and Maritime Affected by OSHA's Proposed Silica Standard (0% discount rate) (Continued)

NAICS	Industry	Total Annualized Costs	No. of Affected Establishments	Annual Cost per Affected Establishment	Revenues per Establishment	Profit Rate [a]	Profits per Establishment	Costs as a Percentage of Revenues	Costs as a Percentage of Profits
333514	Special Die and Tool, Die Set, Jig, and Fixture Manufacturing	$258,893	236	$1,098	$3,106,457	3.82%	$118,634	0.04%	0.93%
333515	Cutting Tool and Machine Tool Accessory Manufacturing	$172,018	161	$1,071	$3,474,136	3.82%	$132,676	0.03%	0.81%
333517	Machine Tool Manufacturing	$147,046	129	$1,141	$10,852,563	3.82%	$414,454	0.01%	0.28%
333519	Rolling Mill and Other Metalworking Machinery Manufacturing	$71,203	62	$1,145	$8,534,499	3.82%	$325,928	0.01%	0.35%
333612	Speed Changer, Industrial High-Speed Drive, and Gear	$96,527	76	$1,262	$20,704,431	1.99%	$411,587	0.01%	0.31%
333613	Mechanical Power Transmission Equipment Manufacturing	$94,276	82	$1,144	$19,068,718	1.99%	$379,071	0.01%	0.30%
333911	Pump and Pumping Equipment Manufacturing	$204,417	165	$1,240	$28,278,876	3.80%	$1,074,041	0.00%	0.12%
333912	Air and Gas Compressor Manufacturing	$127,434	99	$1,283	$34,027,631	3.80%	$1,292,380	0.00%	0.10%
333991	Power-Driven Handtool Manufacturing	$52,959	37	$1,422	$28,169,053	3.80%	$1,069,870	0.01%	0.13%
333992	Welding and Soldering Equipment Manufacturing	$92,605	58	$1,599	$17,097,238	3.80%	$649,359	0.01%	0.25%
333993	Packaging Machinery Manufacturing	$121,165	108	$1,125	$9,811,831	3.80%	$372,657	0.01%	0.30%
333994	Industrial Process Furnace and Oven Manufacturing	$67,034	62	$1,078	$7,795,276	3.80%	$296,067	0.01%	0.36%
333995	Fluid Power Cylinder and Actuator Manufacturing	$143,714	106	$1,358	$20,249,583	3.80%	$769,086	0.01%	0.18%
333996	Fluid Power Pump and Motor Manufacturing	$64,139	51	$1,259	$27,468,365	3.80%	$1,043,257	0.00%	0.12%
333997	Scale and Balance Manufacturing	$23,039	21	$1,099	$11,015,909	3.80%	$418,388	0.01%	0.26%
333999	All Other Miscellaneous General Purpose Machinery Manufacturing	$308,863	261	$1,183	$9,113,043	3.80%	$346,116	0.01%	0.34%
334519	Other Measuring and Controlling Device Manufacturing	$208,014	164	$1,270	$12,672,736	4.51%	$571,009	0.01%	0.22%
335210	Small Electrical Appliance Manufacturing	$23,596	20	$1,161	$26,870,480	4.01%	$1,078,458	0.00%	0.11%
335221	Household Cooking Appliance Manufacturing	$27,642	15	$1,881	$45,714,755	4.01%	$1,834,780	0.00%	0.10%
335222	Household Refrigerator and Home Freezer Manufacturing	$25,095	11	$2,271	$117,768,533	4.01%	$4,726,688	0.00%	0.05%
335224	Household Laundry Equipment Manufacturing	$11,929	3	$3,778	$101,336,939	4.01%	$4,067,200	0.00%	0.09%
335228	Other Major Household Appliance Manufacturing	$25,771	12	$2,184	$125,404,833	4.01%	$5,033,174	0.00%	0.04%
336111	Automobile Manufacturing	$339,056	39	$8,689	$600,655,006	-0.50%	-$3,026,184	0.00%	-0.29%
336112	Light Truck and Utility Vehicle Manufacturing	$303,608	27	$11,151	$1,521,926,795	-0.50%	-$7,667,681	0.00%	-0.15%
336120	Heavy Duty Truck Manufacturing	$172,135	40	$4,256	$354,848,988	-0.50%	-$1,787,779	0.00%	-0.24%
336211	Motor Vehicle Body Manufacturing	$244,250	190	$1,286	$15,228,919	1.30%	$197,621	0.01%	0.65%
336212	Truck Trailer Manufacturing	$168,934	121	$1,394	$19,658,470	1.30%	$255,102	0.01%	0.55%
336213	Motor Home Manufacturing	$42,810	16	$2,650	$39,043,629	1.30%	$506,657	0.01%	0.52%

336310	Motor Vehicle Gasoline Engine and Engine Parts Manufacturing	$313,180	196	$1,599	$37,520,147	1.30%	$486,887	0.00%	0.33%

Table VI-A-3: Screening Analysis for Establishments in General Industry and Maritime Affected by OSHA's Proposed Silica Standard (0% discount rate) (Continued)

NAICS	Industry	Total Annualized Costs	No. of Affected Establishments	Annual Cost per Affected Establishment	Revenues per Establishment	Profit Rate [a]	Profits per Establishment	Costs as a Percentage of Revenues	Costs as a Percentage of Profits
336320	Motor Vehicle Electrical and Electronic Equipment Manufacturing	$296,107	200	$1,478	$30,162,034	1.30%	$391,403	0.00%	0.38%
336330	Motor Vehicle Steering and Suspension Components (except Spring) Manufacturing	$169,393	108	$1,573	$48,079,633	1.30%	$623,914	0.00%	0.25%
336340	Motor Vehicle Brake System Manufacturing	$131,921	100	$1,324	$51,448,277	1.30%	$667,628	0.00%	0.20%
336350	Motor Vehicle Transmission and Power Train Parts Manufacturing	$341,386	196	$1,742	$68,200,565	1.30%	$885,017	0.00%	0.20%
336370	Motor Vehicle Metal Stamping	$484,813	355	$1,367	$40,671,247	1.30%	$527,778	0.00%	0.26%
336390	Other Motor Vehicle Parts Manufacturing	$729,685	510	$1,432	$38,533,574	1.30%	$500,038	0.00%	0.29%
336611	Ship Building and Repairing	$9,546,978	353	$27,071	$36,357,091	6.06%	$2,204,764	0.07%	1.23%
336612	Boat Building	$2,555,107	313	$8,158	$8,054,436	6.06%	$488,437	0.10%	1.67%
336992	Military Armored Vehicle, Tank, and Tank Component Manufacturing	$65,486	31	$2,090	$81,906,183	4.03%	$3,304,704	0.00%	0.06%
337110	Wood Kitchen Cabinet and Countertop Manufacturing	$197,097	206	$958	$1,554,973	2.77%	$43,087	0.06%	2.22%
337215	Showcase, Partition, Shelving, and Locker Manufacturing	$202,382	177	$1,140	$5,949,451	2.77%	$164,853	0.02%	0.69%
339114	Dental Equipment and Supplies Manufacturing	$5,728,131	727	$7,879	$7,144,773	7.32%	$523,086	0.11%	1.51%
339116	Dental Laboratories	$6,622,460	6,818	$971	$675,698	7.32%	$49,470	0.14%	1.96%
339910	Jewelry and Silverware Manufacturing	$2,619,795	2,119	$1,236	$3,549,274	3.92%	$139,242	0.03%	0.89%
339950	Sign Manufacturing	$394,667	363	$1,086	$1,925,106	3.92%	$75,524	0.06%	1.44%
423840	Industrial Supplies Merchant Wholesalers	$2,236,322	1,683	$1,329	$8,430,352	2.98%	$251,560	0.02%	0.53%
444110	Home Centers	$106,182	107	$993	$2,122,394	6.05%	$128,360	0.05%	0.77%
482110	Rail transportation	$16,538,702	NA	NA	NA	6.23%	NA	NA	NA
561730	Landscaping Services	$24,063,157	25,982	$926	$566,354	2.96%	$16,767	0.16%	5.52%
621210	Offices of Dentists	$2,495,078	8,525	$293	$786,888	7.78%	$61,216	0.04%	0.48%
	Totals	$362,114,885	75,074						

Source: OSHA, Directorate of Standards and Guidance, Office of Regulatory Analysis, based on ERG, 2015

Table VI-A-4: Screening Analysis for Establishments in Construction Affected by OSHA's Proposed Silica Standard (0% discount rate)

NAICS	Industry	Total Annualized Costs	Affected Establishments	Annualized Costs per Affected Establishments	Revenues per Establishment	Profit Rate [a]	Profits per Entity	Costs as a Percentage of Revenues	Costs as a Percentage of Profits
221100	Electric Utilities	$3,119,632	4,662	$669	$41,073,120	0.67%	$275,190	0.00%	0.24%
236100	Residential Building Construction	$53,479,897	151,034	$354	$1,260,265	2.23%	$28,104	0.03%	1.26%
236200	Nonresidential Building Construction	$51,930,990	41,018	$1,266	$6,843,237	2.23%	$152,604	0.02%	0.83%
237100	Utility System Construction	$82,747,185	18,686	$4,428	$6,328,499	3.10%	$196,183	0.07%	2.26%
237200	Land Subdivision	$1,928,509	2,150	$897	$6,478,583	-1.30%	-$84,222	0.01%	NA
237300	Highway, Street, and Bridge Construction	$47,852,805	10,043	$4,765	$10,022,676	2.89%	$289,655	0.05%	1.64%
237900	Other Heavy and Civil Engineering Construction	$13,216,441	4,222	$3,130	$5,732,181	2.89%	$165,660	0.05%	1.89%
238100	Foundation, Structure, and Building Exterior Contractors	$137,375,126	85,801	$1,601	$1,300,391	3.41%	$44,343	0.12%	3.61%
238200	Building Equipment Contractors	$58,433,935	142,536	$410	$1,788,299	3.66%	$65,452	0.02%	0.63%
238300	Building Finishing Contractors	$54,432,194	77,330	$704	$858,312	3.41%	$29,268	0.08%	2.40%
238900	Other Specialty Trade Contractors	$100,816,280	63,214	$1,595	$1,617,189	3.41%	$55,146	0.10%	2.89%
999200	State Governments	$8,543,573	NA	NA	NA	NA	NA	NA	NA
999300	Local Governments	$35,644,833	NA	NA	NA	NA	NA	NA	NA
	Totals	$649,521,403	600,695						

Source: OSHA, Directorate of Standards and Guidance, Office of Regulatory Analysis, based on ERG, 2015

CHAPTER VII: BENEFITS AND NET BENEFITS

INTRODUCTION

In this chapter, OSHA discusses the benefits and net benefits of the final silica rule. To set out an approach to estimate the benefits, the Agency will, in the following sections, estimate the number of silica-related diseases prevented as a result of the rule, estimate the timing of the potentially avoided diseases, monetize their economic value, and discount them. Taking into account the estimated costs of the final rule, presented in Chapter V of this FEA, OSHA will then estimate the net benefits and incremental benefits of the rule. Finally, the Agency will assess the sensitivity of the estimates to changes in various cost and benefit parameters.

This chapter presents OSHA's quantitative estimates of what rule-induced benefits would be under certain assumptions. OSHA acknowledges that these estimates are heavily influenced by the underlying assumptions, and also that the long time frame of this analysis (60 years) is a source of uncertainty. The assumptions underlying these estimates of deaths and morbidity avoided will be discussed in detail as they appear in the remainder of this chapter, but the major ones are as follows:

- The exposure profile and other industrial profile data presented in Chapter III of this FEA reflect both current conditions and future conditions (extending over the next sixty years);
- To separate the effects of this new rule from the effects of compliance with existing standards, it is assumed that any workers currently exposed above the preceding PEL are exposed to levels of silica that exactly meet the preceding PEL;
- The rule will result in workers being exposed at the new PEL but will never reduce exposures below the new PEL;
- Workers have identical exposure tenures (45 years, except where otherwise noted);
- The effects of baseline respirator use on risk are ignored; and
- The assumptions inherent in developing the exposure-response functions discussed in Section VI, presented in Table VI-1 of the preamble are reasonable throughout the exposure ranges relevant to this benefits analysis. (The reasonableness of these assumptions is discussed in Section VI.)

The first two assumptions are also the basis for the cost analysis in Chapter V of this FEA. The basis for the last assumption is discussed in greater detail in Section VI of the preamble and will be briefly reviewed in this section. It bears emphasis, however, that the sources of data for OSHA's benefits analysis are the same as those used in the Quantitative Risk Assessment (Section VI of the preamble) and the technological feasibility analysis in Chapter IV of this FEA.

While OSHA did not quantify the benefits of the ancillary provisions, consistent with the statute (29 U.S.C. 655(b)(7), section 6(b)(7)), the Agency finds that these provisions are beneficial and necessary in order for the standard to be fully and correctly implemented and for the full benefits of the rule to be realized. On the whole, OSHA intends the requirements for training on control measures, housekeeping, and other ancillary provisions of the rule to apply where those measures are used to limit exposures. Without effective training on use of engineering controls, for example, it is unreasonable to expect that such controls will be used properly and consistently. The ancillary provisions found in the rule are generally standard and common throughout OSHA regulations.

The provision requiring exposure assessment in general industry is integral to determining the engineering controls and work practices needed to control employee exposure to the new PEL, to evaluate the effectiveness of the required engineering and work practice controls, and to determine whether additional controls must be instituted. In addition, monitoring is necessary to determine which respirator, if any, must be used by the employee, and it is also necessary for compliance purposes.

The requirement for regulated areas in general industry and maritime serves several important purposes including alerting employees to the presence of respirable crystalline silica at levels above the PEL, restricting the number of people potentially exposed to respirable crystalline silica at levels above the PEL, and ensuring that those who must be exposed are properly protected. Similarly, the competent person requirement in the construction standard will protect bystanders by restricting access to work areas only when necessary, benefiting those bystanders through reduced exposures.

Written exposure control plans provide a systematic approach for ensuring proper function of engineering controls and effective work practices that can prevent overexposures from occurring. OSHA expects a written exposure control plan will be instrumental in ensuring that employers comprehensively and consistently protect their employees.

The medical surveillance provisions have the potential to protect workers through the early detection of silica-related illnesses and will enable employees to take actions in response to information about their health status gleaned from medical surveillance. Additionally, by requiring medical surveillance to general industry and maritime workers exposed at or above the action level, OSHA provides an incentive for employers to further reduce exposures, where possible, to avoid incurring the costs of medical surveillance.

ESTIMATES OF THE NUMBER OF AVOIDED CASES OF SILICA-RELATED DISEASE

For reasons described in detail in the preamble, OSHA has adopted a PEL of 50 μg/m^3 in its silica standards covering general industry, maritime, and construction, along with an alternative method of compliance (Table 1) in construction. Analogous to the estimates in the PEA, OSHA has calculated estimates of the benefits associated with the PEL of 50 μg/m^3 for respirable crystalline silica, and corresponding Table 1 in construction, by applying the dose-response relationships developed in OSHA's quantitative risk assessment (QRA) to exposures at or below the preceding PELs.

Exposure profiles

OSHA determined exposure levels at or below the preceding PELs by first developing an exposure profile of current exposures for industries with workers exposed to respirable crystalline silica, using OSHA inspection and site-visit data, and then applying this exposure profile to the total current worker population. The industry-by-industry exposure profile is presented in Chapter III of this FEA.

Because OSHA relied solely on measurement of airborne exposures, respirator use may result in lower baseline exposures inside the respirator than would be indicated by the airborne exposures measurements. The extent to which this affects OSHA's benefits calculations depends on the extent to which there was baseline respirator use in the risk assessment studies OSHA relied on and how these studies accounted for respirator use, if they did so at all. OSHA reviewed the risk assessment studies it is relying on as well as earlier studies that described the source of exposure data for each cohort and how exposures were estimated for cohort members to determine whether respirator use was accounted for. OSHA found that the overwhelming majority of studies did not mention either respirator use or how they accounted for respirator use, even though many took place in time periods and at exposures levels where some respirator use could have been expected. Some studies accounted for use of "dust controls" but did not state whether these "dust controls" included respirator use. Two studies (Rando et al. (2001, Document ID 0415), whose exposure estimates for North American industrial sand workers were used by Hughes et al. (2001, Document ID 1060), and Dosemeci et al. (1993), whose exposure estimates for Chinese mine and pottery workers were modified and used by Chen et al. (2001, Document ID 0332; 2005, Document ID 0985), mention adjusting exposure estimates to account for respirator use, but did not discuss in detail how these adjustments were calculated. Most studies OSHA relied on, directly or indirectly, cover long periods of time, over which respirator use varied. Most cover some time after OSHA set a general industry PEL of approximately 100 μg/m^3 and required the use of a respirator if that exposure level was exceeded. In summary, OSHA does not know the extent of respirator use in the risk assessment studies relied on for the benefits analysis, nor how they might differ from current respirator use. As a result, OSHA is unable to accurately adjust its estimates to account for baseline respirator use.

OSHA also is not able to quantify the effectiveness of respirator use. (OSHA regulations provide for assigned protection factors, but these are based on ideal conditions rather than real world conditions.) It is thus difficult to know how to correct for possible respirator use. As will be discussed below, OSHA estimates benefits relative to a baseline characterized by compliance with the preceding PEL. The preceding PEL in construction and maritime is approximately 250 μg/m^3. If respirators have a protection factor of five, then they would be equivalent to the new PEL of 50 μg/m^3 if fully effective at 250 μg/m^3. In general industry there is a preceding PEL of approximately 100 μg/m^3. If respirators have a protection factor of two, then they would be equivalent to the new PEL of 50 μg/m^3, if fully effective Beyond this, OSHA does not have the data to quantify the effects of respirator use because it is well known that in actual practice in work settings, respirators are not always as protective as the assigned protection factors would indicate. For the purpose of estimating the health benefits of the final rule, exposures above the relevant preceding PELs were set at the relevant preceding PEL; for purposes of comparing the effects of the preceding and the new standards, the analysis thus assumes full compliance with both, without taking baseline respirator use into account.

By applying the dose-response relationships from the literature to estimates of exposures at or below the preceding PELs across industries, it is possible to estimate the number of cases of the following diseases expected to occur in the worker population given exposures at or below the preceding PELs (the "baseline"):

- fatal cases of lung cancer,
- fatal cases of non-malignant respiratory disease (NMRD) (including silicosis),
- fatal cases of end-stage renal disease, and
- cases of silicosis morbidity.

Non-fatal cases of lung cancer, NMRD and end-stage renal disease were not estimated. In that respect, the estimates of benefits are understated. However, OSHA's benefits calculations do not, for example, factor in any impact on the rule's implementation of the following aspect of the Agency's enforcement approach: as a general matter, where compliance with a standard's requirement clearly creates a new hazard, employers can raise a defense that compliance with the requirement is not feasible, and OSHA would work with the employer to implement an alternative means of protection that does not create a serious hazard.[1]

In a comment suggesting that some reductions in exposures (and thus some benefits) were not included in OSHA's analysis, Dr. Ruth Ruttenberg noted that "OSHA/ERG did not consider stomach cancer, autoimmune disease, and other cancer and non-cancer health effects of silica exposure" (Document ID 2256, Attachment 4, p. 11). These potential benefits were not quantified, for the PEA or FEA because the Agency does not, at this time, have sufficient exposure-response data to perform a quantitative risk assessment for these illnesses. The Health Effects and Significance of Risk sections of the preamble contain a more detailed discussion of these potential silica-related health effects that were not quantified.

OSHA's Method for Using Risk Models and Exposure Profile to Estimate Cases Avoided as a Result of the Rule

The core of OSHA's methodology for benefits analysis is to calculate the number of estimated premature deaths and illness cases avoided as a result of the new rule. To do this, OSHA will first estimate the expected number of mortality and morbidity cases expected to occur under the assumption that the preceding PEL is being met (i.e. those workplaces where the preceding PEL is currently exceeded are set equal to the preceding PEL), and then subtract the expected number of mortality and morbidity cases estimated to occur with the new rule in place. To estimate benefits, the Agency first estimates the numbers of disease cases (silicosis morbidities) and deaths (mortalities) that result given the current numbers of workers exposed to silica, assuming full compliance with the preceding PEL (baseline exposure levels). OSHA then estimates the numbers of disease cases and deaths that would result after the new standard goes into effect (i.e., assuming full compliance in that no worker will be exposed in excess of the new PEL). For this purpose, OSHA assumes all exposures above the new PEL are reduced to the new PEL of 50 $\mu g/m^3$. The difference between these estimates represents the numbers of disease cases and deaths that the Agency estimates would be avoided as a result of issuing the

1 In FEA Chapter 4, OSHA responds to commenters who have stated that safety hazards would increase in the presence of the rule (due to, for instance, use of wet methods on roofs) by suggesting technologically feasible alternatives, including using wet methods or exhaust ventilation on the ground or on platforms or scaffolds. Other commenters also described how fall protection on roofs was already being used where wet methods are employed.

new standard. That is, this approach focuses on calculating estimates derived from eliminating those exposures between the preceding PEL and the new PEL. As explained later, these estimated mortality and morbidity cases avoided are then monetized to comprise the benefits (in dollar terms) of the rule.

By focusing on exposures between the preceding PEL (even for workers exposed above the preceding PEL) and the new PEL exclusively, and ignoring the possibility that workers' exposures are reduced below the new PEL, OSHA's calculations will have a tendency toward underestimation. Some exposures may be reduced to below the new PEL of 50 $\mu g/m^3$ as a result of engineering controls that do more than needed. Also, some exposures below the new PEL of 50 $\mu g/m^3$ may be reduced further due to "bystander effects," by which those already exposed below the new PEL but working near other exposed workers would have their exposures reduced further.

In order to estimate the number of deaths prevented, OSHA uses a lifetime risk model, which is a mathematical framework that explicitly follows workers from the beginning of their work lives until retirement. Workers are assumed to start work at age 20 and work continuously until age 65, resulting in a 45-year work life, and then assumed to live another 15 years post-retirement, or until age 80. This estimate is useful because the OSH Act requires OSHA to examine exposures for an entire working life. Shorter job tenures will be discussed further below.

Using this model, OSHA calculates the workers' cumulative workplace exposures to silica, and estimates the probability of their dying each year from silica-related diseases. The model also establishes the background probability of the workers' dying from non-silica-related causes. The increase in the workers' probability of dying due to cumulative silica exposure in the workplace is added to this background probability. As will be explained in more detail later, the difference in these probabilities is used to form the basis for estimating the number of illnesses and deaths due to silica exposures as they currently exist and the estimated number of illnesses and deaths that would be avoided when the standard is fully in effect, assuming full compliance.

The background, age-specific survival probabilities are based on the current (2011) U.S. (male) population, the latest year for which age-specific all-cause mortality statistics are available.[2] The exposure-response functions for different diseases, which relate

[2] Overall, approximately 3 percent of all construction workers are women. (BLS, 2014--Labor Force Statistics from the Current Population Survey, available at http://www.bls.gov/cps/cpsaat11.pdf). There is no comparable breakdown for manufacturing occupations as a whole but, for selected occupations for which data are available, women are always fewer than 15 percent of the relevant manufacturing workforce. OSHA used background mortality rates for the U.S. male population because the cohorts in the

cumulative silica exposure and increased probabilities of respective disease endpoints, are drawn from specific studies discussed in the preamble, Section VI – Final Quantitative Risk Assessment and Significance of Risk.[3] Estimates of the number of cases of silicosis prevented by the new standard were also based on cumulative risk models taken from several morbidity studies, but were not used in life table analyses as was done for mortality (see Section VI of the preamble, Final Quantitative Risk Assessment and Significance of Risk). The exposure levels used in the model cover the U.S. exposure profile as presented in Table III-9 in Chapter III Industry Profile of this FEA. OSHA's exposure profiles for general industry and maritime and for construction contain the estimated numbers of employees exposed within specific bands of exposure levels, assuming full compliance with the preceding PEL: below 25 $\mu g/m^3$, 25 to 50 $\mu g/m^3$, and above 50 $\mu g/m^3$ (in bands of 50 $\mu g/m^3$ to 100 $\mu g/m^3$, 100 $\mu g/m^3$ to 250 $\mu g/m^3$, and above 250 $\mu g/m^3$, whenever any of these bands are above the preceding PEL, OSHA lowered the estimate for the band to the preceding PEL).

The results in Table III-9 represent average daily exposures in the risk model for general industry and maritime. In construction, occupational exposure is commonly intermittent (i.e., not occurring every workday), necessitating an adjustment to accurately estimate

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key studies used in the Agency's quantitative risk assessment were composed overwhelmingly of male workers. OSHA used the exposure-response models from these studies in a life table analysis to estimate excess risk of disease mortality from exposure to respirable crystalline silica after accounting for competing causes of death due to background causes. Because, in most key studies, the exposure-response models were built using data from male workers only, it is unknown how these models would change for female workers, or for mixed-gender populations, as it is not clear that females would react to the silica exposure in the same exact way as males. There is no such model data available for these cohorts. Furthermore, OSHA believes that use of all-cause mortality data for the U.S. population as a whole is not appropriate since the working populations studied in the cohort studies, as well as the present population of workers covered by the rule, are overwhelmingly male and do not reflect the nearly equal proportion of males and females represented by the all-cause mortality data for the U.S. population as a whole. If one were to assume that the exposure-response model for female workers was the same as that for male workers, then the resulting relative risk (RR, the ratio of the risk of disease mortality occurring in the exposed to the risk of disease mortality occurring in the unexposed) for a particular cumulative exposure would be the same. Because the risk of disease mortality in the exposed population is calculated by multiplying the RR by the background risk in the unexposed population, the risk of mortality in the exposed population would be different between females and males and would depend upon the background gender-specific disease risks. Because the background cause-specific (e.g., lung cancer or NMRD) mortality for females is generally lower than that for males, the Agency would expect that the predicted risk of mortality to exposed females may be slightly lower than that for exposed males. On the other hand, this effect may be offset by female workers' greater likelihood of surviving to the advanced age groups in which silica-related diseases most typically appear in severe forms and become a cause of death. Given the absence of exposure-response models for female workers, which are required to estimate a proper RR of disease for females, it is impossible to make any sound conclusion on how the risk estimates would change for female workers.

[3] Specifically the low estimate for lung cancer uses estimates from ToxaChemica (2004), the high estimate for lung cancer uses Attfield and Costello (2004), the renal disease estimate uses Steenland, Attfield, and Mannetje (2002), the morbidity estimate for silicosis uses Buchanan, Miller, and Soutar (2003), and the mortality estimate for silicosis uses Mannetje, et al. (2002). See Section VI – Final Quantitative Risk Assessment and Significance of Risk in the preamble for more discussion.

these workers' cumulative exposure and risk. Workers in the construction sector perform a multitude of tasks, only some of which involve silica exposure. OSHA's estimated exposure levels represent the 8-hour time-weighted average of exposure on days when workers perform tasks involving silica exposures. However, to account for the fact that, in most affected construction occupations, workers do not do such tasks every day, the cumulative exposure estimate for these workers needed to be adjusted. To account for this intermittent exposure, the risk model uses an adjustment factor which estimates the percentage of days in which a worker will typically perform tasks that generate silica exposures. These adjustment factors are generally based on the proportion of time workers perform silica-generating activities along with associated work crew sizes.[4] So, for example, if, on average, 20 percent of a group of workers' time is estimated to be spent performing tasks involving silica exposure, the model multiplies the base exposure level—the exposure that the group of workers is estimated to have based on the exposure profile—by this 20 percent. In the Agency's model, this adjustment factor is calculated as the total number of full time equivalent days that affected employees spend on silica-related tasks divided by total affected employment as shown in Chapter III of this FEA. For all construction occupations other than hole drillers using hand-held drills, OSHA calculated an FTE adjustment factor of 28 percent that was derived from the exposure profile. Hole drillers using hand-held drills have a large number of employees and an extremely low adjustment factor as compared to all other occupations. Because the risk models are nonlinear, averaging such disparate groups together provides unrepresentative results and therefore, this occupation has its risk calculated separately. For hole drillers using hand-held drills, OSHA calculated an adjustment factor of 3.5 percent.

In order to calculate the number of expected and avoided cases for each health outcome, OSHA assumes that all workers whose exposures fall within a band are exposed the same and assigns the average of all individual exposure observations within the relevant band (i.e., the mean exposure) as the single point estimate within each band.[5] This point estimate of exposure is then used with the associated risk estimate for each health outcome, which is multiplied by the estimated number of workers exposed within the exposure band to calculate the number of workers who experience that health outcome in the absence of the new rule. For workers currently exposed above the new PEL, OSHA assumes that their post-rule exposures will be lowered to the new PEL of 50 μg/m^3. This reflects the fact that the Agency is estimating no benefits for reducing exposure above the

[4] Detailed methodology and estimates for each occupation are discussed in the construction engineering control cost section in Chapter V of this FEA, in the subsection entitled "Aggregate 'Key' and 'Secondary' Labor Costs for Representative Projects."

[5] Individual exposure data are presented within various sections of Chapter IV, Technological Feasibility, of this FEA. All individual observations are in OSHA (2016) included in the public docket containing the rulemaking record.

preceding PELs to the preceding PELs. The analysis starts from a baseline of the preceding PELs. A similar calculation is then performed at these new exposure levels for these currently overexposed workers: The numbers of workers exposed within each exposure band of the post-rule exposure profile is then multiplied by the associated risk estimates for each health outcome to yield estimates of the numbers of disease cases and fatalities that will occur after the standard is implemented. Finally, subtracting this post-implementation number of deaths and disease cases from those estimated under baseline (pre-rule) conditions yields an estimate of the number of deaths and illness cases averted due to the standard.

As an example, Exhibit VII-1 presents the summary calculations for a risk model that produces one estimate of the number of lung cancer deaths avoided by the revised standard for workers in general industry and maritime if they were all exposed to silica for 45 years (this uses the ToxaChemica, 2004 risk model of lung cancer deaths avoided).

Exhibit VII-1 Lung Cancer Benefits Model

For an Illustrative Scenario in Which Workers Are Uniformly Exposed to Silica for 45 Years Exposure Profile - General Industry (PEL 50 μg/m3)

	Total	**<25** μg/m³	**25-50** μg/m³	**50-100** μg/m³	**100-250** μg/m³	**>250** μg/m³
Number of Workers at risk	291,019	142,071	51,377	40,831	28,297	28,443
Modeled Exposure Level- Baseline*		14	36	70	100	100
Model Exposure Level- PEL 50 μg/m3		14	36	50	50	50
Baseline						
Excess Death Rate Per 1,000 Workers**		14.7	17.9	20.1	21.1	21.1
Excess Number of Deaths**	5,021	2,084	921	819	597	600
PEL 50						
Excess Death Rate Per 1,000 Workers**		14.7	17.9	19.0	19.0	19.0
Excess Number of Deaths**	4,858	2,084	921	776	538	540
Difference Baseline - PEL 50						
Differential Death Rate per 1,000 Workers		0.0	0.0	1.1	2.1	2.1
Lung Cancer Deaths Averted	**163**	0.0	0.0	43	60	60
Annual Lung Cancer Deaths Averted	**4**					

*From the current exposure profile except that exposures above 100 μg/m³ are set to 100 μg/m³
**Relative to lung cancer mortality among the U.S. male population as a whole
Source: OSHA, Directorate of Standards and Guidance, Office of Regulatory Analysis and Office of Technological Feasibility

In Exhibit VII-1, the total General Industry population at risk for excess lung cancer is 291,019. There are 142,071 workers in the range of silica exposure of below 25 μg/m^3, 51,377 workers exposed between 25 and 50 μg/m^3, etc. The "Model Exposure Level-Baseline" row provides the mean exposure level within each range, which is the point estimate of exposure for which the associated lifetime risk estimate is used to estimate the number of lung cancer deaths that occur among workers exposed within each exposure range. For example, from the exposure profile, the mean exposure for workers in General Industry who are exposed below 25 μg/m^3 is 14 μg/m^3, and the risk of lung cancer for all workers in this exposure band is calculated from this average exposure of 14 μg/m^3. Though the exposure profile includes 28,297 workers exposed in the range of 100-250 μg/m^3 and 28,443 workers exposed above 250 μg/m^3, to estimate the number of baseline lung cancer deaths, those workers' exposure levels are set at the preceding PEL of 100 μg/m^3. In this example, estimated benefits due to the new PEL do not include any benefits to workers for their exposures being reduced to the preceding PEL; only those benefits associated with the exposure levels being reduced from the preceding PEL or lower to the new PEL are included in the estimates. The row labeled "Model Exposure Level-50 PEL" shows the expected exposures among workers that result after the standard is promulgated. Exposures of workers exposed below 50 μg/m^3 are expected to remain unchanged while the exposures of all workers who are currently exposed above 50 μg/m^3 are expected to be reduced to the new PEL of 50 μg/m^3.[6]

Exhibit VII-1 also presents the estimated excess risk of lung cancer per 1,000 workers for each exposure band and the number of lung cancer deaths that would occur among workers exposed within each exposure band for 45 years. For example, among workers exposed within the lowest exposure band, the lifetime risk model estimates an increased risk of lung cancer above the background mortality risk of 14.7 deaths per 1,000 workers at a constant exposure to 14 μg/m^3 silica for 45 years. Multiplying this risk estimate by the number of workers at risk in that exposure band, (142,071) yields an estimated 2,084 lung cancer deaths. Doing the same across the various baseline exposure level bands results in an estimated baseline total of 5,021 lung cancer deaths due to exposure to silica for the population of workers at risk. The table shows similar estimated lung cancer risks and estimated numbers of deaths in the post-standard scenario. For all workers whose baseline 45-year exposures are at or above 50 μg/m^3, the estimated risk of lung cancer associated with exposure at the new PEL of 50 μg/m^3 is 19.0 per 1,000 workers. Multiplying this risk by the number of workers exposed to silica at levels between 50 and 100 μg/m^3 (41,596), for example, yields an estimated 776 deaths occurring in this group for the post-standard scenario. Doing the same for each exposure band for the post-standard scenario and summing across all exposure bands, the number of estimated

[6] For the purposes of estimating costs and benefits, OSHA assumes full compliance with all applicable OSHA standards.

excess lung cancer deaths post-standard is 4,858. The next two rows show the difference between the baseline and the post-standard scenarios, both for lung cancer death risks ("differential lung cancer death rate") and numbers of deaths ("lung cancer deaths averted"). The final total number of lung cancer deaths averted is 163. Dividing by the analytic time horizon of 45 years results in about 4 annual deaths averted.

The preceding example assumes a constant exposure level each year for 45 years. Elsewhere in this chapter, OSHA examines what would happen if the day-to-day exposure remains the same but job tenure is shorter. In order to have a valid comparison, OSHA compares each scenario to what is estimated to happen over 45 years. All job tasks, and hence cumulative exposure, do not change with decreased job tenure; they are just spread over more workers. Thus, if OSHA were to examine a job tenure of 25 years, almost twice as many workers would be exposed for almost half as long as for the 45-year assumption. With a strictly proportional (linear) risk function the benefits of having half the exposure for twice the number of workers would exactly offset each other and final benefits would be the same. Hence the net effect of such changes is directly related to non-linearities in the various lifetime risk models.

Results for Cases Avoided

OSHA received a number of comments concerning the Agency's preliminary risk assessment and discussion of the health effects of silica in the preamble to the proposed rule. Those comments are discussed in detail in Sections V (Health Effects) and VI (Final Quantitative Risk Assessment and Significance of Risk) of the preamble to the final rule.

OSHA examined the various lung cancer risk models presented in its QRA to estimate the benefits of lowering the PEL. As can be inferred from Table VI-1 of the Final QRA, the ToxaChemica, Inc. (2004) log-linear model estimated the lowest estimate of lung cancer cases avoided from lowering the PEL to 50 or 100 $\mu g/m^3$, whereas the Attfield and Costello (2004) model estimated the highest number of lung cancer cases avoided. The remainder of the studies indicated an intermediate reduction in risk. OSHA used the ToxaChemica 2004 (log-linear model) and Attfield and Costello studies to characterize a range of estimated lung cancer reduction, acknowledging that neither of these estimates captures the full range of uncertainty associated with the models and data used.

Table VII-1 shows the range of modeled estimates for the number of avoided fatal lung cancers for PELs of 50 μg/m^3 and 100 μg/m^3 for the scenario in which workers are uniformly exposed to silica for 45 years. At the final PEL of 50 μg/m^3, the modeling approach yields estimates of 2,921 to 8,246 lung cancers prevented over the lifetime of the worker population, with a midpoint estimate of 5,584 fatal lung cancers prevented. This is the equivalent of between 65 and 183 cases avoided annually, with a midpoint estimate of 124 cases avoided annually, given a 45-year working life of exposure.

Following Park (2002), as discussed in the Agency's QRA, OSHA's estimation model suggests that the final PEL of 50 μg/m^3 would, in the scenario in which workers are uniformly exposed to silica for 45 years, prevent 14,606 fatalities over the lifetime of the worker population from non-malignant respiratory diseases arising from silica exposure.[7] This is equivalent to 325 fatal cases prevented annually. Some of these fatalities would be classified as silicosis, but most would be classified as other pneumoconiosis and chronic obstructive pulmonary disease (COPD), which includes chronic bronchitis and emphysema. That is one reason why we would expect this estimate to exceed the count based solely on death certificates (for instance, in 2013, CDC's count based on state-provided vital records is 111 deaths annually from silicosis in the United States).

Certain commenters argued that the recent CDC count of silicosis mortality from death certificates is evidence that OSHA's benefits were overestimated.

Some commenters, such as the American Chemistry Council and Faten Sabry, Ph.D., representing the Chamber of Commerce, argued—based on the numbers of silicosis-related deaths recorded in recent years reported in mortality surveillance data—that OSHA overestimated the estimated benefits of the standard (Document ID 2263, p. 57; 3729, p. 1; 2288, Appendix 6; 4209, pp. 3-4). Dr. Sabry stated that the 52 deaths reported by the CDC in 2010 where silicosis was identified as an underlying cause of death were considerably fewer than the number of silicosis-related deaths that OSHA claimed would be avoided once the proposed standard becomes fully implemented. Dr. Sabry concluded, "[s]o, by OSHA's calculation, reducing the PEL to 50 μg/m^3 will prevent more silicosis-related deaths than actually occur in the United States today – which suggests that OSHA's risk assessment is faulty" (Document ID 2288, Appendix 6). The National Utility Contractors Association (NUCA) made the same argument when it asserted: "OSHA predicts that this proposed rule will prevent approximately 600 silica related deaths per year, but the CDC is recording less than 100 deaths per year" (Document ID 3729, p. 1). The National Federation of Independent Business also argued that OSHA estimated 375 prevented cases of silicosis that would have led to deaths, but the CDC

[7] Park et al. (2002) also found that silica exposure was responsible for a significant number of deaths that had been attributed to diseases other than silicosis.

reported only about 150 deaths per year where silicosis was the underlying cause or a contributing factor, causing OSHA to overestimate lives saved due to the standard by about 150 percent (Document 2210, Attachment 1, p. 3).

OSHA disagrees that the silicosis mortality surveillance data alone provides evidence that OSHA has overstated the quantitative benefits of the rule. OSHA derived its benefits estimates from exposure data presented in the Industry Profile chapter of this FEA and from its quantitative risk assessment, which is based on epidemiological data that quantify relationships between exposure and disease risk. OSHA relied on these estimates to estimate the number of silicosis-related deaths and illnesses that would occur absent a revised standard and the number of deaths that would be avoided by promulgation of such a standard. From this analysis, OSHA estimated that 325 deaths from silicosis and other non-malignant lung disease and 918 silicosis morbidity cases are estimated to be avoided annually once the full effects of the standards are realized. The 52 deaths cited by Dr. Sabry appears to refer to only the number of deaths with silicosis coded as the “underlying” cause of death on death certificates, and does not include deaths coded with silicosis as a “contributing” cause. Combined with the deaths where silicosis is coded as a “contributing” cause, in this case 49, CDC/NIOSH reported a total of 101 deaths where silicosis was either an underlying cause of death or a contributing cause of death.

OSHA’s model does not only count fatalities related to silicosis. OSHA’s estimate of the impact of exposure to respirable crystalline silica includes deaths from other diseases (lung cancer, non-malignant respiratory disease such as chronic bronchitis and emphysema, and end-stage renal disease) that, according to scientific evidence, can be caused by exposure to respirable crystalline silica (Document ID 1711; 2175, p. 2). OSHA also estimated, based on the Park study discussed previously, that 325 cases of fatal non-malignant respiratory diseases associated with exposure to silica, including, but not limited to silicosis, that would be prevented annually due to the final standard. Thus, OSHA’s estimates of the numbers of deaths prevented that are due to non-malignant respiratory disease are not comparable to surveillance statistics that only capture silicosis as a cause of death. Furthermore, Dr. Sabry’s comments are primarily focused on the hydraulic fracturing industry, which only recently became a major source of silica exposure, where most of the effects of current exposures will likely not be seen for a number of years, underlining why this analysis of past trends is not instructive for epidemiological estimates.

In response to NUCA’s comparison of OSHA’s estimate of 679 deaths avoided to the estimate of fewer than 100 deaths from the surveillance data, the Agency again points out that the model accounts for causes of death other than those resulting from silicosis and therefore reported to CDC/NIOSH in the surveillance data. Therefore, NUCA's comparison is faulty because focusing exclusively on silicosis mortality fails to capture silicosis morbidity, as well as mortality and morbidity resulting from other diseases related to silica exposure, including lung cancer, other non-malignant respiratory disease such as chronic bronchitis and emphysema, and renal disease (see Section VI, Final Quantitative Risk Assessment and Significance of Risk, Table VI-1).

Table VII-1
Estimated Number of Avoided Fatal & Nonfatal Illnesses Resulting from a Reduction in Crystalline Silica Exposure of At-Risk Workers over 45 Years Due to Final PEL of 50 µg/m³ and Alternative PEL of 100 µg/m³**

	Total Number of Avoided Cases						**Annual Number of Avoided Cases**					
	50 µg/m³			**100 µg/m³**			**50 µg/m³**			**100 µg/m³**		
	Total	**Construction**	**GI & Maritime**	**Total**	**Construction**	**GI & Maritime**	**Total**	**Construction**	**GI & Maritime**	**Total**	**Construction**	**GI & Maritime**
Lung Cancers												
Attfield and Costello 2004 (higher estimate)	8,246	6,360	1,886	4,454	4,264	190	183	141	42	99	95	4
Midpoint	5,584	4,554	1,029	2,792	2,695	97	124	101	23	62	60	2
ToxaChemica 2004 (lower estimate)	2,921	2,749	172	1,129	1,125	4	65	61	4	25	25	0
Silicosis & Other Non-Malignant Respiratory Diseases	14,606	12,052	2,554	7,669	7,591	78	325	268	57	170	169	2
End Stage Renal Disease	8,689	7,902	787	3,746	3,720	26	193	176	17	83	83	1
Total Number of Fatal Illnesses Prevented												
Attfield and Costello 2004 (higher estimate)	31,541	26,314	5,228	15,869	15,575	293	701	585	116	353	346	7
Midpoint	28,879	24,508	4,370	14,206	14,006	200	642	545	97	316	311	4
ToxaChemica 2004 (lower estimate)	26,216	22,703	3,513	12,544	12,437	107	583	505	78	279	276	2
Total Number of Silicosis Morbidity Cases Prevented*	41,293	23,863	17,429	21,481	20,245	1,236	918	530	387	477	450	27

*Assessed at 2/1 or higher X-ray, following ILO criteria

**OSHA estimates are based on point estimates. The sensitivity analysis and the probabilistic uncertainty analysis incorporate standard errors

Source: OSHA, Directorate of Standards and Guidance, Office of Regulatory Analysis

George Kennedy of the National Utilities Contractor's Association makes a similar "apples and oranges" error in his comment:

> OSHA predicts that this rule will prevent approximately 600 silica-related deaths per year. But how is this possible if the CDC is reporting less than 100? (Document ID 3583, p. 2240)

Mr. Kennedy's comment is based on comparing CDC counts of documented silicosis fatality cases, but this count is not a report on *all* silica-related deaths. The Agency's articulated need for the standard, however, is based on the finding that silica exposure results in an array of adverse, mutually independent health endpoints. In contrast, the CDC estimate deals with a small part of the overall health risk from silica exposure.

As also discussed in the Agency's QRA, OSHA finds that workers with higher cumulative exposures to silica are at elevated risk of lung cancer, end-stage renal disease, and non-malignant respiratory diseases. Based on the midpoint of the high-end estimate (Attfield and Costello, 2004) and the low-end estimate (ToxaChemica, 2004 log-linear model), OSHA's estimation model estimates that the new PEL of 50 $\mu g/m^3$ would, in the scenario in which workers are uniformly exposed to silica for 45 years prevent 5,584 cases of lung cancer, or about 124 cases annually upon reaching "steady state" (see later discussion of this concept) in 60 years. Based on Steenland, Attfield, and Mannetje (2002), OSHA's estimation model estimates that the final PEL would prevent 8,689 cases of end-stage renal disease, or about 193 cases annually in steady state. And based on Park (2002), OSHA's estimation model estimates that the new PEL would prevent 14,606 cases of non-malignant respiratory diseases (including silicosis) over the lifetime of 45 cohorts' worth of worker population, or about 325 cases annually in steady state, of which 2,970 (66 annually) are attributable to diagnosed cases of silicosis, based on Mannetje (2002).

Combining the three major fatal health endpoints—lung cancer, non-malignant respiratory diseases, and end-stage renal disease—OSHA's modeling approach yields estimates that the new PEL would prevent between 26,216 and 31,541 premature fatalities over the lifetime of the current worker population, with a midpoint estimate of 28,879 fatalities prevented. This is the equivalent of between 583 and 701 premature fatalities avoided annually, with a midpoint estimate of 642 premature fatalities avoided annually, given a 45-year working life of exposure.

In addition, the final silica rule is estimated to prevent a large number of cases of silicosis morbidity. Table VII-2 is designed to compare available estimates of actual silicosis cases to the estimates generated by OSHA exposure profile and models. The first set of rows compares present estimates of 2/1 and the second set of rows estimates of 1/0 cases of silicosis generated by various risk models using OSHA's exposure profile. Going across, the first columns are for a tenure length of 45 years, the second set for a tenure length of 13 years. Then below in the second panel, the final set of rows is based on Rosenman, et al. (2003) estimates of actual silicosis cases, generated with an alternative modeling approach. To be consistent with OSHA's jurisdiction, OSHA revised Rosenman's estimate to remove workers not in OSHA's jurisdiction, such as miners. The lower panel, based on Rosenman, et al. shows, assuming 45 years of exposure, that between 2,700 and 5,475 new cases of silicosis, at an ILO x-ray rating of 1/0 or higher, are estimated to occur annually at current exposure levels as a result of silica exposure at establishments within OSHA's jurisdiction (i.e. excluding miners).[8] The various models OSHA used yield estimates of between 836 and 8,011 cases, assuming 45 years of exposure and between 393 and 10,107 cases assuming 13 years of exposure at an ILO x-ray rating of 1/0 or higher. OSHA's risk models for morbidity using OSHA's exposure profile are thus somewhat consistent with epidemiologically based estimates of silicosis cases though some are a bit over the epidemiological estimates. When a job tenure of 13 years is assumed, the table shows that for most models, as compared to the 45 year job tenure analysis, the results are a lower numbers of cases, while other models yield estimates of cases within the range estimated by Rosenman for U.S. workers other than miners (who are outside OSHA's jurisdiction.) There are, however, exceptions. The estimated number of cases for some models falls below Rosenman's estimates. On the other hand, two models show an increased number of cases which are above the range of Rosenman's estimates. This is a result of very high rates of cases expected to occur in persons exposed at levels above the preceding PELs. Since OSHA does not estimate benefits to workers exposed at levels above the preceding PELs, any estimated increase in cases among such workers will not affect OSHA's benefits analysis.

[8] Rosenman indicated that the underlying cases of silicosis morbidity have changed little over time, testifying that data from the National Intake Survey indicated that the nationwide number of hospitalizations where silicosis was one of the discharge diagnoses has remained constant, with 2,028 hospitalizations reported in 1993 and 2,082 in 2011 (Document ID 3425, p. 2).

Table VII-2

Estimate of Annual Number of Silicosis Cases Currently and Annual Number of Silicosis Cases Prevented According to Various Risk Models For the Illustrative Scenario in Which Workers Are Uniformly Exposed to Silica for 45 Years, or Alternatively, 13

		45 Years		13 Years	
		OSHA Estimated Number of Cases Based on Relevant Study		OSHA Estimated Number of Cases Based on Relevant Study	
ILO rating	Study	At Current Exposures*	Under Theoretical Compliance with Preceding PELs	At Current Exposures*	Under Theoretical Compliance with Preceding PELs
2/1+	Miller (1998)	5,498	2,008	5,206	3,556
	Buchanan (2003)**	5,588	1,642	3,164	1,592
1/0+	Chen (2005) pottery worker	836	214	393	39
	Chen (2005) tungsten miner	1,977	283	489	39
	Chen (2005) tin miner	5,337	2,600	4,942	2,296
	Buchanan (2003)	8,011	5,433	10,107	5,380
	Chen (2001)	6,531	3,967	7,172	1,875
	Hnizdo and Sluis-Cremer (1993)	6,148	3,508	3,981	103

		Estimate of Current Cases	
		Low	High
1/0+	Rosenman	3,600	7,300
	Rosenman, estimated portion in OSHA jurisdiction***	2,700	5,475

*as indicated in exposure profile in FEA Chapter III, Table III-9
**estimate of *all* silicosis morbidity cases, including ones that may ultimately be fatal
****excluding 25%, based on portion of death certificates listing mining as occupation
Source: OSHA, Directorate of Standards and Guidance, Office of Regulatory Analysis

A number of commenters took issue with the general idea that silicosis is an occupational health problem for workers whose exposures to silica did not exceed the preceding PELs. These commenters typically pointed to the significant decline in the number of silicosis deaths reported by the CDC in the last few decades.

OSHA does not find these comments persuasive. As explained in depth in the Health Effects and Risk Assessment sections of the preamble, while the Agency welcomes any apparent decline in silicosis cases, the Agency has substantial evidence that significant risk remains at preceding PELs. The commenters do not account for the undercounting of silicosis deaths from death certificates, as demonstrated by Rosenman and others; nor do they address other health endpoints beyond fatal silicosis. Although the decline in reported cases may indicate the Agency's success up to this point in reducing the incidence of silicosis, it cannot be taken as an absolute measure of how many silica-related disease cases currently exist in the population. Most silicosis cases are not fatal—given that the total cases of silicosis have apparently remained largely constant, fewer silicosis fatalities may mean that more individuals are living with silicosis for longer periods while ultimately dying of other causes.[9]

While OSHA has estimated morbidity from silicosis, it has not attempted to estimate the number of morbidity cases from these other health endpoints. Including these other endpoints would increase estimates of the number of overall cases avoided.

As summarized in Table VII-2, OSHA expects that, in the scenario in which workers are uniformly exposed to silica for 45 years, the silica rule will eliminate the majority of 1/0, 1/1, and 1/2 silicosis cases. However, the Agency has not included the elimination of these less severe silicosis cases in its estimates of the monetized benefits and net benefits of the final rule. Instead, as shown above in Table VII-1, OSHA focused its morbidity-only benefits and related net benefits analysis exclusively on the number of silicosis cases reaching the more severe levels of 2/1 and above (moderate-to-severe silicosis, using the ILO method for assessing severity). As discussed in the Agency's QRA, OSHA estimates that the new PEL of 50 $\mu g/m^3$ for the current worker population would, in the scenario in which workers are uniformly exposed to silica for 45 years, prevent 41,293 cases of moderate-to-severe silicosis (2/1 or more) over a working life, or about 918 cases prevented annually.[10]

[9] As indicated previously, Rosenman found that the underlying cases of silicosis morbidity have changed little over time, remaining constant, even while reported fatalities have declined (Document ID 3425, p. 2).

[10] The unfiltered count of morbidity cases is reported only in Table VII-2. The Agency believes the actual number of morbidity-only cases prevented by the standard in the scenario in which workers are uniformly exposed for 45 years is somewhere between 918 and 984 cases annually, using Mannetje (2002)

As previously discussed, OSHA based its estimates of reductions in the number of silica-related diseases using estimates that reflect a working life of constant exposure for workers who are employed in a respirable crystalline silica-exposed occupation for their entire working lives, from ages 20 to 65.[11] In other words, these estimates reflect an assumption that workers do not enter or exit jobs with silica exposure mid-career or switch to other exposure groups during their working lives. While the Agency is legally obligated to examine the effect of exposures from a 45-year working lifetime of exposure,[12] in an alternative analysis purely for informational purposes, the Agency examined the effect of assuming that workers are exposed to silica for three other tenure lengths: 25, 13, and 6.6 working years. See Table VII-3a through Table VII-3c for number of cases and Table VII-5a through Table VII-5d for monetary benefits for all four tenure levels.

Table VII-3a presents cases for a worker exposed for 25 years. While each individual worker is estimated to have less cumulative exposure under the 25-years-of-exposure assumption, in fact 56 percent (25/45) as much, the effective exposed population over time is proportionately increased (due to the turnover of workforce for a constant number of jobs, and hence total exposure), over the same time period. A comparison of Table VII-3a to Table VII-1, reflecting exposures over 25 working years versus 45 working years, shows variations in the number of estimated prevented cases by health outcome. Estimated prevented cases of fatal end-stage renal disease are higher in the 25-year model, whereas cases of fatal non-malignant respiratory disease and silicosis morbidity are lower. In the case of lung cancer, the effect varies by model, with a decrease in the

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to estimate the number of prevented silicosis fatalities (66) and excluding these fatalities from the estimated "morbidity-only" cases. While the Agency received no comment on its methodology for counting morbidity cases, in preparing the FEA OSHA discovered that the simultaneous accounting for morbidity in Buchanan's study of coal miners (2003) and pre-mortality morbidity in Park (2002) could result in a potential double-counting of morbidity valuation (discussed later in this chapter), as some of the Buchanan's cases diagnosed with 2/0+ silicosis at retirement could ultimately proceed to death. A precise estimate of the morbidity-only cases is not possible, as Buchanan also excluded a number of cases where the workers had already died, possibly from silicosis, so that Buchanan was, in turn, likely underestimating the total lifetime morbidity risk from silicosis. By relying on Mannetje, OSHA avoids any potential double counting of benefits.

[11] In construction, the analysis assumes that while workers gain additional exposure annually, they are not necessarily exposed to silica constantly, depending upon the demands of the job.

[12] Section 6(b)(5) of the OSH Act states: "The Secretary, in promulgating standards dealing with toxic materials or harmful physical agents under this subsection, shall set the standard which most adequately assures, to the extent feasible, on the basis of the best available evidence, that no employee will suffer material impairment of health or functional capacity even if such employee has regular exposure to the hazard dealt with by such standard for the period of his working life." Given that OSHA must analyze significant risk over a working life, the Agency estimated benefits for the affected population over the same period.

Attfield and Costello, 2004 higher estimate and an increase in the ToxaChemica, Inc, 2004 lower estimate. Looking at overall totals, the midpoint estimate of the number of avoided fatalities under the new PEL of 50 μg/m^3 is 642 for 45 years, increasing to 772 for 25 years. For total morbidity, there instead is a decrease: from 918 cases avoided for 45 years down to 443 cases avoided for 25 years, Table VII-3b presents results for 13 years of exposure. For a 13 year job tenure, the midpoint for the number of fatalities avoided is 982 while the total number morbidity cases avoided is 246. Finally, Table VII-3c presents the results for 6.6 years of exposure. In this scenario, the midpoint for the number of fatalities avoided is 1,382 and the total number of morbidity cases avoided is 194. Looking across the tenure results shows that midpoint mortality significantly increases with lower tenure, while total morbidity has a large decrease with lower tenure.

A commenter, Joseph Liss, objected to the Agency's approach of simultaneously increasing the estimated exposed population—not because it was technically incorrect, but because it makes it harder to see the difference in risk to a particular exposed population (Document ID 1950, pp. 16-19).

Table VII-3a
Estimated Number of Avoided Fatal & Nonfatal Illnesses Resulting from a Reduction in Crystalline Silica Exposure of At-Risk Workers over 25 Years Due to Final PEL of 50 μg/m³ and Alternative PEL of 100 μg/m³**

	Total Number of Avoided Cases						Annual Number of Avoided Cases					
	50 μg/m³			100 μg/m³			50 μg/m³			100 μg/m³		
	Total	**Construction**	**GI & Maritime**	**Total**	**Construction**	**GI & Maritime**	**Total**	**Construction**	**GI & Maritime**	**Total**	**Construction**	**GI & Maritime**
Lung Cancers												
Attfield and Costello 2004 (higher estimate)	7,349	5,787	1,562	3,897	3,776	121	163	129	35	87	84	3
Midpoint	6,301	5,344	957	2,981	2,916	65	140	119	21	66	65	1
ToxaChemica 2004 (lower estimate)	5,253	4,900	352	2,064	2,056	8	117	109	8	46	46	0
Silicosis & Other Non-Malignant Respiratory Diseases	14,964	12,233	2,731	7,888	7,736	152	333	272	61	175	172	3
End Stage Renal Disease	13,458	12,235	1,223	3,760	3,720	40	299	272	27	84	83	1
Total Number of Fatal Illnesses Prevented												
Attfield and Costello 2004 (higher estimate)	35,771	30,255	5,516	15,545	15,232	313	795	672	123	345	338	7
Midpoint	34,723	29,812	4,912	14,629	14,372	257	772	662	109	325	319	6
ToxaChemica 2004 (lower estimate)	33,675	29,368	4,307	13,713	13,512	200	748	653	96	305	300	4
Total Number of Silicosis Morbidity Cases Prevented*	19,931	12,701	7,230	11,190	9,625	1,565	443	282	161	249	214	35

*Assessed at 2/1 or higher X-ray, following ILO criteria
** Results are estimates based on assumptions outlined in the benefits analysis.
Source: OSHA, Directorate of Standards and Guidance, Office of Regulatory Analysis.

Table VII-3b

Estimated Number of Avoided Fatal & Nonfatal Illnesses Resulting from a Reduction in Crystalline Silica Exposure of At-Risk Workers over 13 Years Due to Proposed PEL of 50 μg/m^3 and Alternative PEL of 100 μg/m^3**

	Total Number of Avoided Cases						**Annual Number of Avoided Cases**					
	50 μg/m^3			**100 μg/m^3**			**50 μg/m^3**			**100 μg/m^3**		
	Total	**Construction**	**GI & Maritime**	**Total**	**Construction**	**GI & Maritime**	**Total**	**Construction**	**GI & Maritime**	**Total**	**Construction**	**GI & Maritime**
Lung Cancers												
Attfield and Costello 2004 (higher estimate)	10,353	9,016	1,337	3,998	3,906	91	230	200	30	89	87	2
Midpoint	8,265	7,260	1,005	3,786	3,732	54	184	161	22	84	83	1
ToxaChemica 2004 (lower estimate)	6,177	5,503	674	3,575	3,558	17	137	122	15	79	79	0
Silicosis & Other Non-Malignant Respiratory Diseases	14,091	11,411	2,680	7,523	7,370	152	313	254	60	167	164	3
End Stage Renal Disease	21,853	19,859	1,995	9,441	9,376	65	486	441	44	210	208	1
Total Number of Fatal Illnesses Prevented												
Attfield and Costello 2004 (higher estimate)	46,297	40,285	6,011	20,961	20,653	309	1,029	895	134	466	459	7
Midpoint	44,209	38,529	5,680	20,750	20,478	272	982	856	126	461	455	6
ToxaChemica 2004 (lower estimate)	42,121	36,772	5,348	20,539	20,304	235	936	817	119	456	451	5
Total Number of Silicosis Morbidity Cases Prevented*	11,069	8,379	2,690	6,333	5,878	455	246	186	60	141	131	10

*Assessed at 2/1 or higher X-ray, following ILO criteria
** Results are estimates based on assumptions outlined in the benefits analysis.
Source: OSHA, Directorate of Standards and Guidance, Office of Regulatory Analysis.

Table VII-3c

Estimated Number of Avoided Fatal & Nonfatal Illnesses Resulting from a Reduction in Crystalline Silica Exposure of At-Risk Workers over 6.6 Years Due to Proposed PEL of 50 μg/m³ and Alternative PEL of 100 μg/m³**

	Total Number of Avoided Cases						Annual Number of Avoided Cases					
	50 μg/m³			100 μg/m³			50 μg/m³			100 μg/m³		
	Total	Construction	GI & Maritime	Total	Construction	GI & Maritime	Total	Construction	GI & Maritime	Total	Construction	GI & Maritime
Lung Cancers												
Attfield and Costello 2004 (higher estimate)	17,707	16,394	1,314	7,306	7,227	79	393	364	29	162	161	2
Midpoint	12,107	10,819	1,288	5,377	5,320	57	269	240	29	119	118	1
ToxaChemica 2004 (lower estimate)	6,507	5,244	1,263	3,449	3,413	35	145	117	28	77	76	1
Silicosis & Other Non-Malignant Respiratory Diseases	14,031	11,319	2,712	7,422	7,266	156	312	252	60	165	161	3
End Stage Renal Disease	36,031	32,727	3,304	15,587	15,479	108	801	727	73	346	344	2
Total Number of Fatal Illnesses Prevented												
Attfield and Costello 2004 (higher estimate)	67,769	60,439	7,330	30,316	29,972	344	1,506	1,343	163	674	666	8
Midpoint	62,169	54,865	7,304	28,387	28,065	322	1,382	1,219	162	631	624	7
ToxaChemica 2004 (lower estimate)	56,569	49,290	7,279	26,458	26,158	300	1,257	1,095	162	588	581	7
Total Number of Silicosis Morbidity Cases Prevented*	8,733	6,782	1,951	9,480	6,782	2,699	194	151	43	424	151	60

*Assessed at 2/1 or higher X-ray, following ILO criteria

Results are estimates based on assumptions outlined in the benefits analysis.

Source: OSHA, Directorate of Standards and Guidance, Office of Regulatory Analysis.

OSHA reported in the PEA that in the construction industry, which has an unusually high rate of job turnover compared to other industries, BLS data show that the mean job tenure with one's current employer is 6.6 years (BLS, 2010a), and the median age of construction workers in the U.S. is 41.6 years (BLS, 2010b). OSHA further noted that BLS does not have data on occupational tenure within an industry, but that the Agency would expect that job tenure in the construction occupations as a whole would be substantially greater than the job tenure with a worker's current employer. None of the commenters disagreed. Furthermore, many workers may return to the construction industry after unemployment or work in another industry. Job tenure with the current employer, however, is longer in the other industries affected by the silica rule (BLS, 2010a).

Dr. Ronald Bird, submitting a comment on behalf of the U.S. Chamber of Commerce—as well as an unaffiliated commenter, Joseph Liss—suggested that OSHA's estimates of disease cases prevented from 45 years of silica exposure is unrepresentative of the typical tenure of workers affected by the standard, particularly in construction (Document ID 2368, p. 18; Document ID 1950, pp. 15-19). Dr. Bird suggested that workers will routinely change occupations in the course of their lifetime. From a probabilistic standpoint, he calculated that workers would, on average, likely work in an occupation for less than six years. The comments directly from the Chamber of Commerce go further, to say that "[n]o such 45-year career silica exposures exist in today's working world…" (Document ID 2288, p. 11).

The article (Rytina, 1983**)** that Dr. Bird cited for his data on occupational turnover also provides data that refute the assumptions of Dr. Bird's model. While Dr. Bird assumes that occupational turnover is constant without regard to age or length of occupational experience, the Rytina article states:

> Not surprisingly, occupational mobility rates declined sharply with age…The rate for workers age 35-44 was less than one fourth as high as that for workers 18 and 19 years of age. . . .[O]ccupational change among older workers occurs less frequently because of attachments to a particular occupation or the risks of losing income, job security, and pension rights, which might accompany an occupational shift (Rytina, 1983, p. 5).

Furthermore, the Rytina article shows that among workers 45 to 54 years of age, 16.5 percent of workers have been in the same occupation for 25 years or more, and among workers 55 and older, 32.9 percent have been in the same occupation for 25 years or more. By comparison, Dr. Bird's model suggests that, regardless of age, no more than 13 percent of workers will remain in a given occupation for more than 20 years.

Two commenters also provided evidence of the average tenures of their workers that is contrary to Dr. Bird's estimates. The National Industrial Sand Association (NISA) noted, "many NISA member company employees work at their workplaces for all or much of their worklives. In 2004, a study calculated the mean tenure for NISA member company employees fitting the definition of the study's cohort to be 19.7 years" (Document ID 2195, p. 19). Southern Company, an electric utility, noted that it "has approximately 8000 employees in job titles performing activities with potential exposures to silica-containing materials. The average tenure for these employees is 17 years; 37 % of these employees have over 20 years work experience" (Document ID 2185, p. 3).

Other commenters provided evidence to refute the Chamber of Commerce claim that that 45-year career silica exposures no longer exist in today's working world (Document ID 2288, p. 11). During the public hearing, participants on a panel comprised of members of the International Union of Bricklayers and Allied Craftworkers (BAC) were asked if they had colleagues who had worked longer than forty years in their trade. All six of the participants affirmed that they did (Document ID 3585, Tr. 3053). Further, several labor groups submitted evidence of lengthy worker tenure. The BAC noted that:

> A review of our International Pension Fund records documented 116 individuals who have worked for 40 years or more. We consider this figure to understate the work lives of Fund participants because many of these individuals had previous work experience in the construction industry before being represented by BAC. In additional, we believe this figure understates the number of participants with work lives of 45 years, because the Fund was established in 1972 and it was not until roughly a decade later that even half of BAC affiliates had commenced participation in the Fund (Document ID 4053, Attachment 1, p. 2).

Similarly, The United Association of Plumbers, Fitters, Welders, and HVAC Service Techs, submitted that "a review of membership records documented 35,649 active members who have worked 45 years or more while they have been a member of the union." They also echo the BAC statement that the number may be understated given previous work experience (Document ID 4073, Attachment 3, p. 1). And the International Union of Operating Engineers' Central Pension Fund found the average operating engineer has over 20 years of service in the trade with a range up to 49.93 years (Document ID 4025, Attachment 1, pp. 6-7).

For this FEA, OSHA is adding clarifying information and supplemental data on the issue of occupational tenure. Occupational tenure refers to the cumulative (although not necessarily consecutive) length of time a worker has been employed in a given occupation. Employer tenure (also referred to as job tenure), while similar sounding, refers to the continuous length of time a worker has been employed by his or her current employer. In the context of worker exposure to respirable crystalline silica, it is clear that the more relevant factor is occupational tenure in an at-risk occupation rather than at-risk employer tenure.[13]

It is reasonable to expect that workers will remain in one occupation for many years. Many occupations where workers are exposed to silica, such as certain construction trades, require specific education or skills. This makes it costly and difficult for some workers to change to a wholly new occupation and increases the likelihood that these workers will continuously or nearly continuously work in the same field or industry even if they have multiple employers throughout their working lives.

Unfortunately, most collected and reported data on worker tenure have been for employer tenure rather than occupational tenure, and the regular reporting of occupational tenure data has become increasingly scarce. Therefore, most available data on occupational tenure is at least 25 years old. On the other hand, there is little evidence that the older data are no longer relevant. Two factors support this position. First, employer tenure has not been decreasing over time. In fact, in the construction industry, which is by far the largest sector affected by the rule, job tenure has nearly doubled since 1983—from 2 years to 3.9 years, as shown in Table 1 below. The second factor is that one of the most significant demographic employment changes in recent decades has been the steady increase in the percentages of the workforce that are over 55 and over 65 years of age. Obviously, if workers tend to work for more years before retiring, other things equal, that will tend to increase occupational tenure.

Exhibit VII-2: Tenure and employment in the construction industry

	Jan-83	Jan-87	Jan-91	Feb-96	Feb-98	Feb-00	Jan-02	Jan-04	Jan-06	Jan-08	Jan-10	Jan-12	Jan-14
Median years of tenure with current employer, construction industry	2	2	2.6	2.9	2.7	2.7	3	3	3	3.5	4.2	4.3	3.9

Source: BLS CPS and CES

Cross-sectional data on occupational tenure is suggestive but limiting, in the sense that the relevant occupational tenure statistic is for cumulative tenure at the end of a working life. BLS occupational employment data from 1991 for the 35 occupations with the longest occupational tenure, for example, show that the construction occupations of brickmasons and stonemasons; electricians; and plumbers, pipefitters, and steamfitters have an average occupational tenure of about 12.6 years at an average median age of 38.3 years.[14] Since at this age these workers would have reached less than 50 percent of their

[13] Even better would be cumulative exposure to respirable crystalline silica over a working life, which could involve more than one occupation.

[14] No. 656. Occupational and Employer Tenure, by Occupation: 1991. Covers occupations with 50,000 or more workers. Based on Current Population Survey. Source: BLS, News, USDL 92-366 and

typical working life, it is reasonable to expect that their end of career occupational tenure would exceed 25 years.

Broadly speaking, occupational tenure will increase as workers age. The portion of the labor force most highly affected by the silica rule is older than the labor force in general, meaning that occupational tenure in the affected occupations is likely higher than for the labor force in general. A recent Forbes article cited a study by a consulting firm specializing in economic modeling (EMSI) that showed that

> [i]n 2012, 53 percent of skilled-trade workers in the U.S. were 45 years and older and 18.6 percent were between the ages of 55 and 64. (We are using the Virginia Manufacturers Association's definition of skilled trades [which, by and large, would be activities covered by the silica rule], which encompasses 21 particular occupations.) Contrast those numbers with the overall labor force, where 44 percent of workers were at least 45 years old, and 15.5 percent of jobs were held by the 55-to-64 demographic.[15]

A 1981 (BLS) publication on job tenure and occupational changes found that occupational tenure is strongly linked with age.[16] This study found that about 41 percent of workers age 35–46, about 55 percent of workers age 45-54, and about 67 percent of workers over the age of 55 had been in their current occupation for 10 or more years. In addition, about 17 percent and 33 percent of workers age 45-54 and age 55 and older, respectively were reported to have been in the same occupation for 25 years or more. Similar results were reported in an article from the Summer 1990 Occupational Outlook Quarterly (now referred to as the Career Outlook). This article showed that while median tenure across occupations was 6.6 years (from cross-sectional data), almost half of the workers approaching retirement (those who were ages 55-59) had been in their current occupation at least 20 years and almost 20 percent of workers aged 65-69 reported 40 years or more of tenure.[17] If workers are consistently retiring in construction trades, there is a reasonable likelihood that they did not first take up these trades in in their forties or fifties. This is supported by the number who report long tenures in their occupations.

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unpublished data.
https://books.google.com/books?id=vIxBAQAAIAAJ&pg=PA419&lpg=PA419&dq=occupational+tenure&source=bl&ots=kXqDb5FXUK&sig=phMGNJZMhEE2nu7g00BeVwvZXvI&hl=en&sa=X&ved=0CCUQ6AEwATgUahUKEwiL29q_zZrJAhVB6yYKHThKAoY#v=onepage&q=occupational%20tenure&f=false

[15] http://www.forbes.com/sites/emsi/2013/03/07/americas-skilled-trades-dilemma-shortages-loom-as-most-in-demand-group-of-workers-ages/

[16] https://books.google.com/books?id=s-RZAAAAYAAJ&pg=PA8&lpg=PA8&dq=occupational+tenure&source=bl&ots=abb6p8YY5e&sig=FHcR07Qa2Z6Oq2ERU8BEaJjlgkA&hl=en&sa=X&ved=0CFcQ6AEwCWoVChMIoPeEs8iayQIVivAmCh3jSgUZ#v=onepage&q=occupational%20tenure&f=false

[17] Carey, Max. "Occupational Tenure, Employer Tenure, and Occupational Mobility." *Occupational Outlook Quarterly;* 34, 2: pp. 54-60. Summer 1990.

Thus, from the evidence on the record and the supplemental data provided, occupational tenure at the end of a working life could easily average 20 to 25 years for occupations covered by the final rule, and a non-trivial percentage of workers covered by the rule will have working lives of 40 to 45 year or longer.

In conclusion, despite high average job turnover, many workers remain in the same occupation for decades. In addition, it should be noted that because silica is such a widespread occupational contaminant, it would not be at all unusual for someone to change occupations and encounter further cumulative silica exposure or to return to a silica-generating occupation.

Dr. Bird also objected to OSHA's approach of using a single representative exposure to measure lifetime exposure. He states: "If exposures are variable over the course of a year, the lifetime exposure pattern is contrary to OSHA's assumption and the benefits from the proposed reduction in the PEL would be considerably less" (Document ID 2368, p. 19). Dr. Bird apparently faults the Agency for not considering the possibility that future exposures may be lower than those observed on a given day. However, it is equally plausible that a worker's future exposures may be higher than on the day they were observed by OSHA. The single-day exposure data is the best available data in the record for those workers, and the Agency does not find any persuasive evidence in this record to suggest an obvious bias to characterizing exposure from a single day rather over the course of consecutive days.

Paragraph (i)(2)(v) of the general industry and maritime standard and paragraph (h)(2)(v) of the construction standard also contain specific provisions for diagnosing latent tuberculosis (TB) in the silica-exposed population and thereby reducing the risk of TB being spread to the population at large. OSHA currently lacks good methods for quantifying these benefits. Nor has the Agency attempted to assess benefits directly stemming from enhanced medical surveillance in terms of reducing the severity of symptoms from the illnesses that do result from present or future exposure to silica. Dr. Ruth Ruttenberg, an economist representing the AFL-CIO, noted this as a source of the underestimation of the benefits in her comments (Document ID 2256, Attachment 4, pp. 9-12). However, no commenters suggested how to quantify these effects.

OSHA's risk estimates are based on application of exposure-response models derived from several individual epidemiological studies as well as the pooled cohort studies of Steenland et al. (2001) and Mannetje et al. (2002). However, OSHA recognizes that, in addition to difference in point estimates, there is also uncertainty around any point estimates of risk derived from any single study. In its risk assessment (summarized in Section VI of the preamble), OSHA has made efforts to characterize some of the more significant sources of uncertainty to the extent that available data permit. This specifically includes characterizing statistical uncertainty by reporting the confidence intervals around each of the risk estimates (presented in the Preliminary Quantitative Risk Assessment, Document ID 1711); by quantitatively evaluating the impact of uncertainties in underlying exposure data used in the cohort studies; and by exploring the use of alternative exposure-response model forms. OSHA finds that these efforts reflect much, but not necessarily all, of the uncertainties associated with the approaches taken by investigators in their respective risk analyses. However, for reasons explained in Section VI of the preamble, OSHA concludes that characterizing the risks and benefits as a range of estimates derived from the full set of available studies, rather than relying on any single study as the basis for its estimates, better reflects the uncertainties in the estimates and more fairly captures the range of risks likely to exist across a wide range of industries and exposure situations.

Section VI of the preamble provides a more complete discussion of the source of uncertainty in the risk assessment functions used in this benefits analysis. The sources of uncertainty include the degree to which OSHA's risk estimates reflect the risk of disease among workers with widely varying exposure patterns. Some workers are exposed to fairly high concentrations of crystalline silica only intermittently, while others experience more regular and constant exposure. Risk models employed in the quantitative assessment are based on a cumulative exposure metric, which is the product of average daily silica concentration and duration of worker exposure for a specific task. Consequently, these models assume the same risk for a given cumulative exposure regardless of the pattern of exposure, reflecting a worker's long-term average exposure without regard to intermittencies or other variances in exposure. That is, the use of the cumulative exposure metric in these models assumes that there are no significant dose-rate effects in the relationship between silica exposure and risk. OSHA's reliance on a cumulative exposure metric to assess the risks of respirable crystalline silica is discussed in Section V of the preamble. Uncertainty with respect to the form of the statistical models used to characterize the relationship between exposure level and risk of adverse health outcomes is discussed in Section VI.

In its quantitative risk assessment, OSHA used the exposure-response models from the best available evidence (i.e., the key studies discussed at length in Section V, Health Effects and Section VI, Final Quantitative Risk Assessment and Significance of Risk) to estimate risks for 45 years of exposure to the previous PELs, revised PEL, and the action level. When examining the risk estimates specifically for silicosis mortality and morbidity in Table VI, one interesting observation is the apparent difference in the exposure-response relationship for these two endpoints. For example, for 45 years of exposure to the action level (25 μg/m^3), there would be an estimated 4 deaths from silicosis and 21 cases of silicosis (with chest X-ray ILO category of 2/1 or greater) per 1,000 workers; at the previous PEL (100 μg/m^3), there would be an estimated 11 deaths from silicosis and 301 cases of silicosis per 1,000 workers. In other words, nearly 20 percent of silicosis cases are estimated to be fatal at the relatively low exposure of 25 µg/m^3 but only about 4 percent are estimated to be fatal at the relatively high exposure of 100 µg/m^3.18 Moreover, as noted previously, morbidity and mortality estimates change in opposite directions in response to varying the assumption about workers' total length of exposure. Although this issue was not explicitly raised in the rulemaking record, OSHA notes and addresses it here.

OSHA attributes this apparent difference in the exposure-response relationships for silicosis mortality and morbidity to several factors. First, the silicosis mortality study (ToxaChemica, Inc., 2004) defined deaths using death certificate data, in which silicosis or unspecified pneumoconiosis was recorded as the underlying cause of death. In contrast, the silicosis morbidity study (Buchanan et al., 2003) defined silicosis cases using data from chest x-rays showing radiographic opacities. These radiographic signs of silicosis represent an early endpoint that is very different from silicosis death as the underlying cause of death. Such disparate endpoints are alone one reason why OSHA does not believe that the exposure-response curves should necessarily be proportional In addition, as discussed in Section V.E, Comments and Responses Concerning Surveillance Data on Silicosis Morbidity and Mortality, silicosis is well-known to be underreported on death certificates in that deaths due to silicosis could have been reported as tuberculosis or chronic obstructive pulmonary disease (Document ID 1089, pp. 724-725; 1030; 3425, p. 2; 3577, Tr. 855, 867; 4204, p. 17; 2175, p. 3; 3577, Tr. 772). Also, silica-exposed workers are at risk for other silica-related diseases, including lung cancer and renal disease, as well as other non-exposure-related causes of death such that many workers who contract silicosis will not ultimately die from silicosis. Therefore the reported silicosis deaths at any level are the lowest possible number of such deaths. Workers with higher cumulative exposures are also likely to be older, and therefore may have a higher rate of other conditions that could have been listed on death certificates. Furthermore, as discussed in Section VI, OSHA's risk assessment required some degree of extrapolation at high doses (e.g., 45 years of exposure to 250 and 500 µg/m^3 respirable crystalline silica) that result in cumulative exposures not experienced by many of the cohort members studied. Thus, OSHA attributes the apparent non-proportionality in the exposure-response curves for silicosis mortality and morbidity to these factors. It is possible nonetheless, that future research may shed additional light on this topic.

[18] Even if one subtracts off the Table VI-1 estimates of other silica-attributable diseases (e.g., lung cancer) from the 100 µg/m^3 denominator, on the assumption that those diseases cause mortality before silicosis has a chance to do so, the ratio of fatal silicosis cases to the remaining silicosis diagnoses is still no more than 6.6 percent at 100 µg/m^3, as opposed to the ratio of nearly 20 percent at 25 µg/m^3.

ESTIMATING A STREAM OF BENEFITS OVER TIME

Risk assessments in the occupational environment are generally designed to estimate the risk of an occupationally related illness over the course of an individual worker's lifetime. As demonstrated previously in this chapter, the current occupational exposure profile for a particular substance for the current cohort of workers can be matched up against the expected profile after the final standard takes effect, creating a "steady state" estimate of benefits. However, in order to annualize the benefits for the period of time after the silica rule takes effect, it is necessary to create a timeline of benefits for an entire active workforce over that period.

There are various approaches for modeling the workforce. As explained below, OSHA uses a model that considers the effect of lowering exposures for the entire working population. At one extreme, however, one could assume that all of the relevant silica exposures will occur after the standard goes into effect and none of the benefits occurs until after the worker retires, or at least 45 years in the future. In the case of lung cancer, that period would effectively be 60 years, since the 45 years of exposure must be added to a 15-year latency period during which it is assumed that lung cancer does not develop.[19] At the other extreme, one could assume that the benefits occur immediately, or at least immediately after a designated lag. Neither extreme reflects the reality that silica-related diseases that this standard aims to reduce significantly occur at various times during and after the working lives of these populations of workers, with the majority of cases occurring sometime after the typical worker is middle aged. Indeed, based on the various risk models (as detailed in model life tables in Appendix A to the QRA), which reflect real-world experience with development of disease over an extended period of time; it appears that the actual pattern occurs at some point between these two extremes.

The model OSHA uses, therefore, is one that considers the effect of lowering exposures for the entire working population. This population-based approach does not simply follow the pattern of the risk assessments, which are based in part on life tables, and observe that typically the risk of the illness grows gradually over the course of a working life and into retirement. While this would be a good working model for an individual exposed over a working life, it is not very descriptive of the exposed population as a whole. In the latter case, in order to estimate the benefits of the standard over time, OSHA considers that workers currently being exposed to silica are going to vary considerably in age. Since the health risks from crystalline silica exposure depend on a worker's cumulative exposure over a working lifetime, the overall benefits of the final

[19] This assumption is consistent with the 15-year lag incorporated in the lung cancer risk models used in OSHA's QRA.

standard will phase in over several decades, as the cumulative exposure gradually falls for all age groups, until those now entering the workforce reach retirement and the annual stream of silica-related illnesses reaches a new, significantly lowered “steady state.” However, the beneficial effects of the rule begin in the near term and increase over time until that "steady state" is reached; and, for a given level of cumulative exposure, the near-term impact of the final rule will be greater for workers who are now middle-aged or older, compared to younger workers with similar current levels of cumulative exposure. This conclusion follows from the structure of the relative risk models used in this analysis and the fact that the background mortality rates for diseases such as lung cancer, chronic obstructive pulmonary disease and renal disease increase with age.

In order to characterize the magnitude of benefits before the steady state is reached, OSHA created a linear phase-in model to reflect the potential timing of benefits. Specifically, OSHA estimated that, for all non-cancer cases, while the number of cases of silica-related disease would gradually decline as a result of the final rule, they would not reach the steady-state level until 45 years had passed. The reduction in cases in any given year in the future was estimated to be equal to the steady-state reduction (the number of cases in the baseline minus the number of cases in the new steady state) times the ratio of the number of years since the standard was implemented and a working life of 45 years; in other words, the number of non-malignant silica-related cases of disease avoided is assumed to increase in direct proportion to the number of years the standard is in effect until year 45, at which point the numbers hold steady. This formulation also assumes that the number of workers is constant over the entire time frame. Expressed mathematically:

$$N_t = (C - S) \times (t / 45),$$

where N_t is the number of non-malignant silica-related diseases avoided in year t; C is the current annual number of non-malignant silica-related diseases; S is the steady-state annual number of non-malignant silica-related diseases; and t represents the number of years after the final standard takes effect, with $t \leq 45$.

In the case of lung cancer, the function representing the decline in the number of silica-related cases as a result of the final rule is similar, but a 15-year lag before any reduction in cancer cases is achieved is added into the equation. Expressed mathematically, for lung cancer:

$$L_t = (C_m - S_m) \times ((t-15) / 45),$$

where $15 \leq t \leq 60$ and L_t is the number of lung cancer cases avoided in year t as a result of the final rule; C_m is the current annual number of silica-related lung cancers; and S_m is the steady-state annual number of silica-related lung cancers.

This model was extended to 60 years for all the health effects previously discussed in order to incorporate the 15 year lag, in the case of lung cancer, and a 45-year working life. (The left-hand columns in the tables in Appendix VII-A provide estimates using this model of the stream of prevented fatalities and illnesses due to the final silica rule.)

OSHA also has estimated the benefits using other job tenures. For this purpose, OSHA examined scenarios for the same number of years—60 years—but with the work force restarting exposure whenever the first job tenure cycle was complete.

In order to estimate the comparison of costs to benefits, OSHA assumes that economic conditions remain constant and that annualized costs will continue for the entire 60-year time horizon used for the benefits analysis (as discussed in Chapter V of this FEA). OSHA invited comments on this assumption in the PEA, for both the benefit and cost analysis. OSHA was particularly interested in what assumptions and time horizon should be used instead and why. The Agency did not receive any comments on this point.

MONETIZING BENEFITS

OSHA also estimates the monetary value of health and longevity improvements of the type associated with the final silica rule. These estimates are for informational purposes only because OSHA cannot use benefit-cost analysis as a basis for determining the PEL for a health standard. The Agency's methodology for monetizing benefits is based on both the relevant academic literature and on the approaches OSHA and other regulatory agencies have taken in the past for similar regulatory actions.

In explaining OSHA's methodology for monetizing health and longevity improvements, OSHA will rely on a 45 year occupational tenure. At the end of the section, OSHA will discuss monetization under alternative occupational tenures of 26, 13 and 6.6 years.

Placing a Monetary Value on Individual Silica-Related Fatalities Avoided

To estimate the monetary value of reductions in the number of silica-related fatalities, OSHA relied, as OMB recommends in its Circular A-4, on estimates developed from the willingness of affected individuals to pay to avoid a marginal increase in the risk of fatality. While a willingness-to-pay (WTP) approach clearly has theoretical merit, an *individual's* willingness to pay to reduce the risk of fatality may underestimate the total willingness to pay, which would include the willingness of others—particularly the immediate family—to pay to reduce that individual's risk of fatality.[20]

For estimates using the willingness-to-pay concept, OSHA relies on existing studies of the imputed value of fatalities avoided based on the theory of compensating wage differentials in the labor market. These studies rely on certain critical assumptions for their estimates, particularly that workers understand the risks to which they are exposed and that workers have legitimate choices between high- and low-risk jobs. Actual labor markets only imperfectly reflect these assumptions.[21] A number of academic studies, as summarized in Viscusi and Aldy (2003), have shown a correlation between higher job risk and higher wages, suggesting that employees demand monetary compensation in return for a greater risk of injury or fatality. The estimated trade-off between lower wages and marginal reductions in fatal occupational risk—that is, workers' willingness to pay for marginal reductions in such risk—yields an imputed value of an avoided fatality: the willingness-to-pay amount for a reduction in risk divided by the reduction in risk.[22]

OSHA has used this approach in many recent proposed and final rules (see, for example, 69 FR 59305 (Oct. 4, 2004) and 71 FR 10099 (Feb. 28, 2006), the preambles for the proposed and final hexavalent chromium rule.) Limitations to this approach (see, for example, Hintermann, Alberini and Markandya, (2010)), have been examined in a recent WTP analysis, by Kniesner et al. (2012), using panel data to examine the trade-off between fatal job risks and wages. This article addressed many of the earlier econometric criticisms by controlling for measurement error, endogeneity, and heterogeneity. Accordingly, OSHA views this analysis as buttressing the estimates in Viscusi and Aldy (2003), which the Agency is continuing to rely on for this FEA.[23]

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[20] See, for example, Thaler and Rosen (1976), pp. 265-266; Sunstein (2004), p. 433; or Viscusi, Magat, and Forrest (1988), the last of whom write that benefits from improvement in public health ''consist of two components, the private valuation consumers attach to their own health, plus the altruistic valuation other members of society place on their health.'' That paper uses contingent valuation methods to suggest that the effect of altruism could significantly alter willingness-to-pay estimates for some kinds of health improvement. There are, however, many questions concerning how to measure the altruistic component and the conditions under which it might matter.

[21] On the former assumption, see the discussion in Chapter II of this FEA on imperfect information. On the latter, see, for example, the discussion of wage compensation for risk for union versus nonunion workers in Dorman and Hagstrom (1998).

[22] For example, if workers are willing to pay $50 each for a 1/100,000 reduction in the probability of dying on the job, then the imputed value of an avoided fatality would be $50 divided by 1/100,000, or $5,000,000. Another way to consider this result would be to assume that 100,000 workers made this trade-off. On average, one life would be saved at a cost of $5,000,000.

OSHA received several comments on the use of willingness-to-pay measures and estimates based on compensating wage differentials. For example, Peter Dorman, Professor of Economics, Evergreen State College, Eric Frumin of Change to Win, and Dr. Ruth Ruttenberg, representing the AFL-CIO, in addition to critiquing the academic studies used to develop the willingness-to-pay measure, cited the absence of effective labor markets for capturing a wage differential for hazardous work (Document ID 2260, Attachment 1; 2372, Attachment 1, pp. 4-15; 2256, Attachment 4, p. 9). OSHA acknowledges that there has been an absence of a wage premium for risk in certain labor markets, and cites this absence in Chapter II of this FEA as an example of market failure. Nonetheless, while the Agency agrees that the absence of a wage premium for risk demonstrates the need for regulatory intervention in the labor market, it does not, in itself, invalidate the use of the willingness-to-pay approach for the informational purposes for which OSHA calculates benefits, so long as there are some reasonably well-functioning parts of the labor market that can be used to estimate the willingness to pay for some subset of workers. OSHA finds that there are such sections of the labor market.

Several studies indicate that there are enough functional parts of the labor market to allow for some quantification of the risk, typically expressed as the value of a statistical life (VSL), a possible measure of willingness to pay. For example, Viscusi and Aldy (2003) conducted a meta-analysis of studies in the economics literature that use a willingness-to-pay methodology to estimate the imputed value of life-saving programs and found that each fatality avoided was valued at approximately $7 million in 2000 dollars. For the PEA, the Agency used the GDP Deflator (U.S. BEA, 2010) to convert this estimate to $8.7 million in 2009 dollars for each fatality avoided.[24] For this FEA, the base year has been further updated to 2012 using the GDP Deflator (U.S. BEA, 2013), yielding an estimate of $9.0 million per fatality avoided.

There are a number of factors that could influence the value of a statistical life (VSL) calculation in different labor markets, but for the purpose of its analysis OSHA has identified methods for normalizing the risk between markets. For example, in Kniesner, Viscusi, and Ziliak (2010), the authors addressed the issue of the heterogeneity of the VSL approach among various labor markets by developing analytical tools (quantile regressions) for differentiating by income. For the purpose of quantifying the effects of income growth over time on the value of a statistical life, OSHA relies on their data,

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[24] An alternative approach to valuing an avoided fatality is to monetize, for each year that a life is extended, an estimate from the economics literature of the value of that statistical life-year (VSLY). See, for instance, Aldy and Viscusi (2007) for discussion of VSLY theory and FDA (2003), pp. 41488-9, for an application of VSLY in rulemaking. OSHA has not investigated this approach which was not recommended by any commenter in the record. It acknowledges, however, that such an approach would have the effect of lowering estimated benefits because silica-related health outcomes largely affect older workers and retirees as they approach actuarially expected life expectancies.

which generally show that VSL increases with increased worker income (as banded by quartile). Despite potential weaknesses in the VSL approach, Executive Order 12866 recommends monetization of regulatory benefits (including increases in longevity), and the Agency concludes this constitutes the best available method for this purpose.

Placing a Monetary Value on Individual Non-Fatal Silica-Related Diseases Avoided

In addition to the benefits that are based on the imputed value of fatalities avoided, workers also place a value on occupational injuries or illnesses avoided, which reflect their willingness to pay to avoid monetary costs (for medical expenses and lost wages) and quality-of-life losses as a result of occupational illness. Silicosis, lung cancer, and renal disease can be totally disabling and adversely affect individuals for years or even decades in non-fatal cases, or before ultimately proving fatal. Because monetary measures of the willingness to pay for avoiding these illnesses are rare and difficult to find OSHA has included a range based on a variety of estimation methods.

Consistent with Buchanan et al. (2003), OSHA estimated the total number of moderate-to-severe silicosis cases prevented by the rule, as measured by 2/1 or more severe x-rays (based on the ILO rating system). However, while radiological evidence of moderate-to-severe silicosis is evidence of significant risk of material impairment of health, placing a precise monetary value on this condition is difficult, in part because the severity of symptoms may vary significantly among individuals. For that reason, in the PEA, as well as in this FEA, the Agency has employed a broad range of valuation, which should encompass the range of severity these individuals may encounter. Using the willingness-to-pay approach, discussed in the context of the imputed value of fatalities avoided, OSHA has estimated a range in valuations (updated and reported in 2012 dollars) that runs from approximately $64,000 per case—which reflects estimates developed by Viscusi and Aldy (2003), based on a series of studies primarily describing simple accidents—to upwards of $5.2 million per case—which reflects estimates developed by Magat, Viscusi, and Huber (1996) for non-fatal cancer. The latter number is based on an approach that applies a willingness-to-pay value to avoid serious illness that is calibrated relative to the value of an avoided fatality. OSHA (2006) previously used this approach in the FEA supporting its hexavalent chromium final rule, and EPA (2003) used this approach in its Stage 2 Disinfection and Disinfection Byproducts Rule concerning regulation of primary drinking water. EPA used the study by Magat, Viscusi & Huber (1996) on the willingness to pay to avoid nonfatal lymphoma and chronic bronchitis as a basis for valuing a case of nonfatal cancer at 58.3 percent of the value of a fatal cancer.

OSHA's estimate of $5.2 million in 2012 dollars for an avoided case of non-fatal cancer is based on this 58.3 percent figure.[25]

There are several benchmarks for valuation of health impairment due to silica exposure, using a variety of techniques, which provide a number of mid-range estimates between OSHA's high and low estimates of $5.2 million and $64,000. For example, EPA (2008) recently estimated a cost of approximately $460,000, in 2008 dollars, per case of chronic bronchitis, which OSHA (2009) used as the basis for comparison with less severe lung impairments from diacetyl exposure. Another approach is to employ a cost-of-injury model. Combining estimates of productivity losses (i.e., lost wages, fringe benefits, and household production), medical costs (including hospitalizations), and loss of quality-of-life components, Miller (2005), using an enhanced cost-of-injury model, estimated the average silicosis disease cost the equivalent of $335,000 in 2012 dollars).[26]

Miller (2005) also estimated the morbidity costs of several different pneumoconioses other than silicosis and found the other cases to be even more costly to society than silicosis. While the full costs of renal disease are less well known, the medical costs alone of dealing with end-stage renal disease run over $64,000 annually per patient (Winkelmayer, 2002). This suggests that a more comprehensive analysis of the direct costs of renal disease, as well as for the various lung impairments, would produce an estimate well above the $64,000 estimate of injuries in Viscusi and Aldy (2003). Moreover, several studies (e.g., Alberini and Krupnick, 2000) have found that the cost of injury approach tends to significantly underestimate the true economic cost of an injury or illness, relative to the willingness to pay approach, which includes quality of life impacts and psychic costs as well as medical costs and lost income. In this way, looking only at specific elements of this valuation, such as a workers compensation payouts (to the extent they can be linked to a specific employer in a timely manner), would dramatically underestimate the cost of the illness to society.

Thus, the various studies presented in this section suggest that the imputed value of avoided morbidity associated with silica exposure, both for cases preceding death and for non-fatal cases, ranges between $64,000 and $5.2 million, depending in part on the model used to compute the value and in part on the severity and duration of the case. OSHA considers this wide range of estimates is descriptive of the value of preventing morbidity associated with moderate-to-severe silicosis, as well as the morbidity preceding mortality due to other causes enumerated here—lung cancer, lung diseases other than cancer, and

[25] In the PEA, the value for an avoided case of non-fatal cancer was reported as $5.1 million in 2009 dollars.

[26] Miller (2005) estimated the cost of a silicosis case, using an enhanced direct cost approach—including a quality-adjusted-life-years component—to be $265,808 in 2002 dollars.

renal disease. OSHA is therefore applying these values to monetize cases of avoided silica-related morbidity.[27] OSHA has included these estimates of silicosis morbidity throughout the analysis. For mortality, OSHA has included the midpoints of $64,000 and $5.2 million ($2.63 million) for all mortality cases. The high and low estimates in the remainder of this document for mortality not only reflect different point estimates, but different levels for the morbidity effect.

Public Comment on Valuing Non-Fatal Cases of Silicosis

OSHA requested public input on the issue of valuing the cost to society of non-fatal cases of moderate-to-severe silicosis, as well as the morbidity associated with other related diseases of the lung, and with renal disease. A number of commenters did not directly provide quantitative estimates of the cost of silicosis or other silica-related health effects, but provided qualitative descriptions of the heavy burden to health, work, and family life incurred by having silicosis.

For example, Alan White, of the United Steelworkers Local Union 593, who developed silicosis after working in a foundry for 16 years as a general helper, described the practical implications of developing silicosis:

> First of all, for me, there was the growing problem of being out of breath sooner than I used to. That's a difficult situation for a competitor, especially since I didn't know why. Then, I received a big surprise during the conversation with the first doctor when I found out that I have silicosis and that I will lose my job. He and the other doctors all agreed that the diagnosis is silicosis. Watching your wife and other loved ones cry as they figure out what silicosis is was a big hit and then, shortly afterward, there was the radical pay cut from a transfer out of the foundry to a department where I knew nothing because I chose my health over money…There are also difficulties outside of work and issues for me to look forward to in the future. Walking while talking on a cell phone is very exhaustive, as well as walking up the stairs from my basement to my second floor apartment. I have increasing difficulty on my current job. Certain irritants like air fresheners, potpourri and cleaners make home life

[27] For the purpose of simplifying the estimation of the monetized benefits of avoided illness and death, OSHA simply added the monetized benefits of morbidity preceding mortality to the monetized benefits of mortality at the time of death, and both would be discounted at that point. In theory, however, the monetized benefits of morbidity should be recognized (and discounted) at the onset of morbidity, as this is what a worker's willingness to pay is presumed to measure—that is, the risk of *immediate* death or an *immediate* period of illness that a worker is willing to pay to avoid—a practice that would increase the present value of discounted morbidity benefits. A parallel tendency toward underestimation occurs with regard to morbidity not preceding mortality, since it implicitly assumes that the benefits occur at retirement, as per the Buchanan model, but many, if not most, of the 2/0 or higher silicosis cases will have begun years before (with those classifications, in turn, preceded by a 1/0 classification). As a practical matter, however, the Agency lacks sufficient data at this time to refine the analysis in this way.

> increasingly difficult and I was told that it's downhill from here for both work and home life (Document ID 3477, p. 2).

Mr. White also described how the foundry went to considerable expense to hire people to do the job he previously had done, including the costs to the foundry for mistakes made by the trainees replacing him. Such personnel costs to the employer would not be captured by either the willingness-to-pay approach or cost-of-injury approach.

In addition to questioning the underlying willingness to pay approach, at least one commenter indicated various ways in which the approach employed by OSHA would tend to underestimate the economic benefits of the rulemaking. Dr. Ruttenberg argued that the WTP approach does not include costs to third parties of silica-related illnesses and injuries, starting with a number of government programs:

> In its *Preliminary Economic Analysis*, OSHA says that it wants public input on the issue of valuing the cost to society of non-fatal cases of moderate-to severe silicosis, as well as the morbidity associated with other related diseases of the lung, and with renal disease. (PEA, p. VII-15) This is a key request because adding such societal costs can double the benefits of preventing these diseases. In an article by a lawyer and two economists looking at the social cost of dangerous products, Shapiro, Ruttenberg, and Leigh argue that a large economic burden is borne by private insurance, government programs, the business community and the victims and their families. Those affected by occupational exposures, such as silica, may become eligible for a range of cash or in-kind assistance. Such programs may include unemployment compensation, food stamps, Medicaid, Medicare, State Children's Health Insurance Program (SCHIP), Temporary Assistance for Needy Families (TANF), Social Security Disability, and Old Age, Survivors and Disability Insurance. There are also costs for use of military hospitals and clinics (Document ID 2256, Attachment 4, pp. 9-10)(citations omitted).

Part of the cost of the injury or fatality may be borne in substantial part by the victim's family:

> There is another group of costs that can easily double, or even triple, the direct and indirect totals. These are social and economic impacts that are also caused by an incident. They often involve third-party payments, or stress on the victim or his/her family members. The financial pressures on a family can include the need for a caregiver, need for additional income from children or spouse to fill the gap between previous earnings and workers compensation, or psychotherapy for family members to cope with harsh new realities. When children lose their chance at college and higher future earnings, the impact can be hundreds of thousands of dollars (Document ID 2256, Attachment 4).

Dr. Ruttenberg pointed to an existing Department of Transportation study, which suggested that only a fraction of the economic cost of motor vehicle accidents was actually borne by the victim, with the remainder of the costs split between governmental bodies, insurers, and other parties (Document ID 2256, Attachment 4, p. 11).[28]

The Center for Progressive Reform argued that there is value to reducing economic inequities created by occupational illnesses related to silica exposure:

> The proposal's implications for fair treatment of workers also deserve more attention. The proposed standards would benefit a population comprising mostly construction workers (more than 85% of the total affected population). This is an industry that is a bastion for middle class workers and those striving to attain middle class status. It is also an industry that employs a significant number of foreign-born and non-union workers, groups who typically have limited power to negotiate improved working conditions. Ensuring that these workers' health is better protected against the hazards of silica exposure is an important step toward reducing socioeconomic inequality, given the linkages between individual health and social mobility. Other federal agencies, including the National Highway Traffic Safety Administration (NHTSA) and Department of Justice (DOJ), have gone so far as to argue that equity and other non-monetizable benefits are sufficient to justify rules for which the monetized costs far outweigh the monetized benefits. (As with the OSH Act, the authorizing statutes under which NHTSA and DOJ were acting do not require cost-benefit analysis, much less require the agencies to produce rules with monetized benefits that outweigh monetized costs) (Document ID 2351, p. 7)(citations omitted).

The Agency recognizes that, as with third party effects, there are aspects of economic equity issues related to occupational injury, illness, and mortality that merit attention for policy making. As noted previously, however, the OSH Act requires that OSHA policy for toxic substances be ultimately determined by issues of risk and feasibility, as opposed to cost-benefit criteria.

Adjusting Monetized Benefits to Reflect Rising Future Value

In the PEA, OSHA suggested, provided estimates, and requested comment on adjusting future values of illness and mortality prevention to account for changes in real income over time. Ronald White of the Center for Effective Government favored integrating this

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[28] The Agency acknowledges this is a likely and potentially substantial source of underestimation of morbidity costs and is currently investigating ways to capture this currently unquantified dimension of benefits for potential use in future rulemakings.

element into the monetized benefits analysis (Document ID 2341, p. 3).[29] No commenters argued against it. For the reasons provided in the PEA and described below, the Agency is adopting this approach.

OSHA's estimates of the monetization approach are based on the imputed value of each avoided fatality and each avoided silica-related disease. As previously discussed, these, in turn, are derived from a worker's willingness-to-pay to avoid a fatality (with an imputed value per fatality avoided of $9.0 million in 2012 dollars) and to avoid a silica-related disease (with an imputed value per disease avoided of between $64,000 and $5.2 million in 2012 dollars). Two related factors suggest that these values will tend to increase over time and help to better identify the amount that a worker would be willing to pay to avoid a fatality.

First, economic theory and empirical evidence from the relevant studies indicate that the value of reducing life-threatening and health-threatening risks—and correspondingly the willingness of individuals to pay to reduce these risks—will increase as real per capita income increases.[30] With increased income, an individual's health and life becomes more valuable relative to other goods because, unlike other goods, they are without close substitutes. Expressed differently, as income increases, consumption will increase but the marginal utility of consumption will decrease. In contrast, added years of life (in good health) are, in the model of Hall and Jones (2007), not subject to the same type of diminishing returns and, indeed, may be viewed as the ultimate good.

Second, real per capita income has broadly been increasing throughout U.S. history, including during recent periods.[31] For example, for the period 1950 through 2000, real per capita income grew at an average rate of 2.31 percent a year (Hall and Jones, 2007),[32]

[29] The estimates of monetized benefits to reflect changes in real income over time developed in the PEA contained an error in the formulas (an inconsistent discount rate was used) that resulted in underestimated benefits. That error has been corrected in the estimates presented in this FEA.

[30] Simple modeling can show this directly. For example, Rosen (1988) demonstrates that the value of life can be expressed as the marginal rate of substitution between wealth and the probability of survival. An increase in wealth or income will therefore increase an individual's willingness to pay.

[31] In addition, as Costa (1998) and Costa and Kahn (2004) point out, elderly health, longevity, and well-being in the United States have historically been improving, which also has the effect of increasing the imputed value of life. Of course, improvements in elderly health, longevity, and well-being are not independent of increases in per capita income over the same period.

[32] The results are similar if the historical period includes a major economic downturn (such as the United States has recently experienced). From 1929 through 2003, a period in U.S. history that includes the Great Depression, real per capita income still grew at an average rate of 2.22 percent a year (Gomme and Rupert, 2004).

although real per capita income for the recent 25 year period 1983 through 2008 grew at an average rate of only 1.3 percent a year (U.S. Census Bureau, 2010). More important is the fact that real U.S. per capita income is estimated to grow significantly in future years. The Annual Energy Outlook (AEO) estimates, prepared by the Energy Information Administration (EIA) in the Department of Energy (DOE), estimate an average annual growth rate of per capita income in the United States of 2.7 percent for the period 2011-2035.[33] The U.S. Environmental Protection Agency prepared its economic analysis of the Clean Air Act using the AEO estimates. However, based on the fact that the estimated increase in real per capita income in the United States has flattened in recent years and could remain so, OSHA has selected an estimate of 1.4 percent as the average annual future increase in the growth rate of per capita income in the United States. This estimate is more in keeping with recent trends while allowing for some modest increase in growth rates in future years.

On the basis of the estimated increase in real per capita income in the United States over time and the expected resulting increase in the value of avoided fatalities and diseases, OSHA has adjusted its estimates of the benefits of the final rule to reflect the anticipated increase in their value over time. This type of adjustment has been supported by EPA's Science Advisory Board (EPA, 2000b)[34] and applied by EPA.[35] OSHA accomplished this adjustment by modifying benefits in year i from $[B_i]$ to $[B_i * (1 + k)^i]$, where "k" is the estimated annual increase in the magnitude of the benefits of the final rule.[36]

What remains is to estimate a value for "k" with which to increase benefits annually in response to annual increases in real per capita income, where "k" is equal to $(1 + g) * (\eta)$, "g" is the expected annual percentage increase in real per capita income, and "η" is the income elasticity of the value of a statistical life. Probably the most direct evidence of the value of "k" comes from the work of Costa and Kahn (2003, 2004). They estimate repeated labor market compensating wage differentials from cross-sectional hedonic regressions using census and fatality data from the Bureau of Labor Statistics for 1940, 1950, 1960, 1970, and 1980. In addition, with the imputed income elasticity of the value of life on per capita GNP of 1.7 derived from the 1940-1980 data, they then predict the

[33] The EIA used DOE's National Energy Modeling System (NEMS) to produce the Annual Energy Outlook (AEO) estimates (EIA, 2011). Future per capita GDP was calculated by dividing the estimated real gross domestic product each year by the estimated U.S. population for that year.

[34] Supplementary evidence in support for this type of adjustment comes from EPA (2010) and U.S. Department of Transportation (2014) guidelines.

[35] See, for example, EPA (2003, 2008).

[36] This precise methodology was suggested in Ashford and Caldart (1996).

value of an avoided fatality in 1900, 1920, and 2000. Given the change in the value of an avoided fatality over time, it is possible to estimate a value of "k" of 3.4 percent a year from 1900-2000; of 4.3 percent a year from 1940-1980; and of 2.5 percent a year from 1980-2000.[37]

Other, more indirect evidence comes from estimates in the economics literature on the income elasticity of the value of a statistical life. Viscusi and Aldy (2003) performed a meta-analysis on 49 wage-risk studies and concluded that the confidence interval upper bound on the income elasticity did not exceed 1.0 and that the point estimates across a variety of model specifications ranged between 0.5 and 0.6.[38] Applied to a long-term increase in per capita income of about 2.7 percent a year, this would suggest a value of "k" of about 1.5 percent a year.

More recently, Kniesner, Viscusi, and Ziliak (2010), using panel data quintile regressions, developed an estimate of the overall income elasticity of the value of a statistical life of 1.44. Applied to a long-term increase in per capita income of about 1.4 percent a year, this would suggest a value of "k" of about 2 percent a year.

Based on the preceding discussion of these three approaches and the recent decline in real per capita income in the United States, OSHA has selected a value for "k" of 2 percent a year over the next 60 years.

Thus, based on the best current thinking and data on willingness to pay and its relationship to income elasticity as income increases, OSHA concludes that a 2 percent increase in benefits per year, as measured by a corresponding anticipated increase in VSL, is a reasonable, mid-range estimate. However, OSHA recognizes the uncertainties surrounding these estimates and has subjected them to sensitivity analysis, as discussed below.

Accordingly, OSHA concludes that the rising value, over time, of health benefits is a real phenomenon that should be taken into account. Table VII-4, in the following section, and the monetized results that follow it, show estimates with this adjustment integrated into the valuation. OSHA provides a sensitivity analysis of the effects of this approach later in this chapter.

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[37] These estimates for "k" were not reported in Costa and Kahn (2003, 2004) but were derived by OSHA from the data presented. The changes in the value of "k" for the different time periods mainly reflect different growth rates of per capita income during those periods.

[38] These results conflict with the more recent work by Hall and Jones (2007), which concludes that the income elasticity of the value of life should be larger than 1.

Summary of Estimates of Monetized Benefits

Table VII-4 presents, for the scenario in which workers are uniformly exposed to silica for 45 years, the estimated annualized (over 60 years, using a 0 percent discount rate) benefits from each of these components of the valuation, and the range of estimates, based on the use of different studies (notably in the case of lung cancer), and the range of uncertainty regarding valuation of morbidity. Mid-point estimates of the undiscounted benefits for each of the first 60 years are provided in the middle columns of Table VII-A-1 in Appendix VII-A at the end of this chapter. The estimates by year reach a peak of $32.4 billion in the 60th year. As will be discussed further, the application of the QRA functions shows that the 45-year results represent the lowest possible estimates because the increasing population exposed more than makes up for the reductions in risk.

As shown, the range of monetized benefits that OSHA quantified, undiscounted, for the new PEL of 50 μg/m^3 runs from $7.3 billion annually, in the case of the lowest estimate of lung cancer risk and the lowest valuation for morbidity, up to $19.3 billion annually, for the highest of both. Notably, the value of total benefits (ranging from $7.9 billion to $18.5 billion, given estimates at the midpoint of the lung cancer models) is more sensitive to the valuation of morbidity than to the lung cancer model used (which ranges from $12.5 to $13.8 billion, given estimates at the midpoint of the morbidity valuation).[39]

This result comports with the very wide range of valuation for morbidity. At the low end of the valuation range, the total value of the benefits is dominated by mortality ($7.7 billion out of $7.9 billion at the case frequency midpoint), whereas at the high end the majority of the benefits are attributable to morbidity ($11.2 billion out of $18.7 billion at the case frequency midpoint). Also, the analysis illustrates that most of the morbidity benefits are related to silicosis cases that are not ultimately fatal. At the valuation and case frequency midpoint of $13.3 billion, $7.7 billion in benefits are attributable to mortality, $2.0 billion are attributable to morbidity preceding mortality, and $3.5 billion are attributable to morbidity not preceding mortality.

[39] As previously indicated, these valuations include all the various estimated health endpoints. In the case of mortality this includes lung cancer, non-malignant respiratory disease and end-stage renal disease. OSHA highlighted lung cancers in this discussion due to the model uncertainty. In calculating the monetized benefits of the final PEL of 50 μg/m^3, the Agency is typically referring to the midpoint of the high and low ends of potential valuation—in this case, the undiscounted midpoint of $7.7 billion and $19.5 billion.

TABLE VII-4
Estimated Annualized Undiscounted Monetized Benefits of the Silica Rule for Morbidity and Mortality For the Scenario in Which Workers Are Uniformly Exposed to Silica for 45 Years *

PEL	50 μg/m³			100 μg/m³		
	Valuation			Valuation		
	Low	Midpoint	High	Low	Midpoint	High
Cases						
Fatalities - Total						
ToxaChemica 2004 (lower estimate)	$7,207,460,195	$7,207,460,195	$7,207,460,195	$3,473,656,028	$3,473,656,028	$3,473,656,028
Midpoint	$7,718,678,442	$7,718,678,442	$7,718,678,442	$3,792,868,857	$3,792,868,857	$3,792,868,857
Attfield and Costello 2004 (higher estimate)	$8,229,896,689	$8,229,896,689	$8,229,896,689	$4,112,081,687	$4,112,081,687	$4,112,081,687
Morbidity Preceding Mortality						
ToxaChemica 2004 (lower estimate)	$45,177,585	$1,857,928,191	$3,346,609,761	$21,604,397	$888,480,816	$1,755,357,235
Midpoint	$48,812,915	$2,007,431,128	$3,966,049,340	$23,874,355	$981,832,835	$1,939,791,315
Attfield and Costello 2004 (higher estimate)	$52,448,245	$2,156,934,064	$4,261,419,883	$26,144,313	$1,075,184,853	$2,124,225,394
Morbidity Not Preceding Mortality						
Total	$83,781,052	$3,445,495,765	$6,807,210,478	$43,583,880	$1,792,387,046	$3,541,190,213
TOTAL						
ToxaChemica 2004 (lower estimate)	$7,336,418,832	$12,510,884,151	$17,361,280,434	$3,538,844,305	$6,154,523,891	$8,770,203,477
Midpoint	$7,851,272,409	$13,317,472,941	$18,491,938,260	$3,860,327,092	$6,658,170,799	$9,273,850,385
Attfield and Costello 2004 (higher estimate)	$8,366,125,986	$13,832,326,518	$19,298,527,050	$4,181,809,879	$6,979,653,586	$9,777,497,293

Source: OSHA, Directorate of Standards and Guidance, Office of Regulatory Analysis.
* Results are estimates based on the assumption outlined throughout this chapter.

DISCOUNTING OF MONETIZED BENEFITS

As previously noted, the stream of benefits arising from the silica rule will not be constant from year to year, both because of the 45 year delay after the rule takes effect until all active workers obtain reduced silica exposure over their entire working lives and because of, in the case of lung cancer, a 15 year latency period between reduced exposure and a reduction in the probability of disease. An appropriate discount rate is needed to reflect the timing of benefits over the 60 year period after the rule takes effect and to allow conversion to an equivalent steady stream of annualized benefits.[40]

Alternative Discount Rates for Annualizing Benefits

Following OMB (2003) guidelines, OSHA has estimated the annualized benefits of the final rule using separate discount rates of three percent and seven percent. Consistent with the Agency's own practices in recent proposed and final rules,[41] OSHA has also estimated, for benchmarking purposes, undiscounted benefits—that is, benefits using a zero percent discount rate.

The "appropriate" or "preferred" discount rate to use to monetize health benefits is a controversial topic, which has been the source of scholarly economic debate for several decades.[42] However, in simplest terms, the basic choices involve a social opportunity cost of capital approach or social rate of time preference approach. OSHA analyzes the benefits of this rule under both approaches.

The social opportunity cost of capital approach reflects the fact that private funds spent to comply with government regulations have an opportunity cost in terms of foregone private investments that could otherwise have been made. The relevant discount rate in this case is the pre-tax rate of return on the foregone investments (Lind, 1982b, pp. 24-32).

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[40] This essential point was missed in a comment by Dr. Ruttenberg, which claimed that OSHA's estimates of the benefits of an avoided fatality were forty percent below the VSL estimate of $8.7 million (in 2009 dollars) that the Agency was using (Document ID 2256, Attachment 4, p. 9). The difference is due to the fact that the avoided fatalities occurred over a 60 year period and had to be discounted.

[41] See, for example, 69 FR 59305 (Oct. 4, 2004) and 71 FR 10099 (Feb. 28, 2006), the preambles for the proposed and final hexavalent chromium rule.

[42] For a more detailed discussion of the major issues, see, for example, Lind (1982a, 1982b, and 1990); EPA (2000a), Chapter 6; and OMB (2003), pp. 31-37.

The rate of time preference approach is intended to measure the tradeoff between current consumption and future consumption, or in the context of the final rule, between current benefits and future benefits. The *individual* rate of time preference is influenced by uncertainty about the availability of the benefits at a future date and whether the individual will be alive to enjoy the delayed benefits. By comparison, the *social* rate of time preference takes a broader view over a longer time horizon—ignoring individual mortality and the riskiness of individual investments (which can be accounted for separately).[43]

A usual method for estimating the social rate of time preference is to calculate the pre-tax real rate of return on long-term, risk-free assets, such as U.S. Treasury securities (OMB, 2003, p. 33). A variety of studies have estimated these rates of return over time and reported them to be in the range of approximately 1 - 4 percent.[44]

OMB Circular A-4 (2003) recommends using discount rates of 3 percent (representing the social rate of time preference) and 7 percent (a rate estimated using the social cost of capital approach) to estimate benefits and net benefits. Ronald White of the Center for Effective Government endorsed the use of a 3 percent discount rate—since it "appropriately reflects a social rate of time preference approach consistent with recommendations for benefits evaluation by the U.S. Environmental Protection Agency" (Document ID 2341, pp. 3-4). Charles Gordon argued for a 0 percent discount rate:

> The economic literature indicates that the social discount rate should be 2 percent or 3 percent. But I believe the social discount rate should be zero, because if you were asked the question, do you want yourself saved from crystalline silica exposure…or do you want your son to be saved from crystalline silica death 20 years from now, you could not answer that question. You could not give a preference (Document ID 3588, Tr. 3789-90).

[43] It is not always possible to explicitly model all forms of uncertainty that are relevant to a regulatory cost-benefit analysis (e.g., medical innovations that allow for more successful treatment of illnesses or changes in industrial practices or locations that in turn change the exposure profile of workers subject to a regulation). Because these uncertainties tend to increase as the time horizon being analyzed lengthens, application of a discount rate provides a reduced-form approach to less heavily weighting the least-certain estimated benefits and costs.

[44] For example, the Congressional Budget Office (CBO, 1988) has estimated the cost of government borrowing to be 2 percent. Farber and Hemmersbaugh (1993) cite rates of return on long-term government securities ranging from approximately 0.5 percent to 3.0 percent. OMB (2003) calculates that the pre-tax yield on 10-year Treasury notes has averaged 3.1 percent in real terms over the 30 years prior to publication of its Circular A-4 in 2003. Newell and Pizer (2003) report real rates of return of nearly 4 percent on 30-year Treasury securities. Nordhaus (2008), page 170, cites a real rate of return of 2.7 percent in 2007 on 20-year Treasury securities.

In accordance with OMB Circular A-4, the Agency is presenting results using both a 3 percent discount rate and a 7 percent discount rate.

Summary of Estimates of Annualized Benefits under Alternative Discount Rates

Table VII-5a through Table VII-5d presents OSHA's estimates of the sum of the annualized benefits of the final rule, under various occupational tenure assumptions, using alternative discount rates of 0, 3, and 7 percent, with a breakout between construction and general industry/maritime, with each table presenting these results for a different tenure level. All of these benefits calculations reflect willingness-to-pay values that, as previously discussed, increase in real value at 2 percent a year.

Given that the stream of benefits extends out 60 years, the value of future benefits is highly sensitive to the choice of discount rate. As previously established in Table VII-4, the undiscounted benefits (i.e., using the 0 percent discount rate) for the scenario in which workers are uniformly exposed to silica for 45 years range from $7.3 billion to $19.3 billion annually. In Table VII-5a, for 45 years tenure, using a 3 percent discount rate, the annualized benefits range from $4.8 billion to $12.6 billion. Using a 7 percent discount rate, the annualized benefits range from $2.7 billion to $6.9 billion. As can be seen, going from undiscounted benefits (with a midpoint of $13.3 billion) to benefits calculated at a 7 percent discount rate (with a midpoint of $4.8 billion) has the effect of cutting the annualized benefits of the final rule by 64 percent. Tables VII-A-1 and VII-A-2 in Appendix VII-A demonstrate how annualized benefits are derived (over the 60 years after the silica rule becomes effective), using the midpoint value of annualized benefits for alternate discount rates of 3 and 7 percent (with the annualized undiscounted benefits—using a 0 percent discount rate—derived in the middle columns of each table in Appendix VII-A).

Comparing across tenure levels for representative benefits, Table VII-5a for 45 years tenure has total benefits at the midpoint estimate of $8.7 billion at a 3 percent discount rate and $4.8 billion at 7 percent discount rate. Table VII-5b for 25 years tenure has total benefits at the midpoint estimate of $10.0 billion at a 3 percent discount rate and $5.5 billion at 7 percent discount rate. Table VII-5c for 13 years tenure has total benefits at the midpoint estimate of $12.3 billion at a 3 percent discount rate and $6.8 billion at 7 percent discount rate. Finally, Table VII-5d for 6.6 years tenure has total benefits at the midpoint estimate of $16.1 billion at a 3 percent discount rate and $9.0 billion at 7 percent discount rate.

As previously mentioned, OSHA has not attempted to estimate the monetary value of less-severe silicosis cases, measured at 1/0 to 1/2 on the ILO scale. The Agency believes the economic loss to individuals with less severe cases of silicosis could be substantial, insofar as those individuals may have a lifetime of medical surveillance and lung damage may potentially require a change in career, or diminished work productivity, with resulting lower wages. Dr. Ruttenberg noted this as a source of underestimation of the benefits (Document ID 2256, Attachment 4, pp. 9-10). The Center for Progressive Reform suggested that the economic effect was potentially significant, as many of these workers may continue working, but at diminished productivity (Document ID 2351). However, the Agency did not attempt to estimate the monetary value of this benefit because many of these effects can be difficult to isolate and measure in economic terms, particularly when there is no obvious existing effect on physiological function or performance.

Table VII-5a
Total Annual Monetized Benefits Resulting from a Reduction in Exposure to Crystalline Silica
Due to PEL of 50 μg/m^3 and Alternative PEL of 100 μg/m^3
For the Scenario in Which Workers Are Uniformly Exposed to Silica for 45 Years
($Billions)*

PEL		**50**			**100**		
Discount Rate	**Range**	**Total**	**Construction**	**GI & Maritime**	**Total**	**Construction**	**GI & Maritime**
Undiscounted (0%)	ToxaChemica 2004 (lower estimate)	$7.3	$6.3	$1.0	$3.5	$3.5	$0.0
	Midpoint	$13.3	$10.4	$2.9	$6.7	$6.5	$0.2
	Attfield and Costello 2004 (higher estimate)	$19.3	$14.5	$4.8	$9.8	$9.5	$0.3
Discounted at 3%	ToxaChemica 2004 (lower estimate)	$4.8	$4.1	$0.7	$2.3	$2.3	$0.0
	Midpoint	$8.7	$6.8	$1.9	$4.3	$4.2	$0.1
	Attfield and Costello 2004 (higher estimate)	$12.6	$9.4	$3.1	$6.4	$6.2	$0.2
Discounted at 7%	ToxaChemica 2004 (lower estimate)	$2.7	$2.3	$0.4	$1.3	$1.3	$0.0
	Midpoint	$4.8	$3.7	$1.1	$2.4	$2.3	$0.1
	Attfield and Costello 2004 (higher estimate)	$6.9	$5.2	$1.7	$3.5	$3.4	$0.1

Source: OSHA, Directorate of Standards and Guidance, Office of Regulatory Analysis
Results are estimates based on the assumption outlined throughout this chapter.

Table VIII-5b
Total Annual Monetized Benefits Resulting from a Reduction in Exposure to Crystalline Silica
Due to PEL of 50 μg/m^3 and Alternative PEL of 100 μg/m^3
For the Scenario in Which Workers are Uniformly Exposed to Silica for 25 Years
($Billions)*

PEL		**50**			**100**		
Discount Rate	**Range**	**Total**	**Construction**	**GI & Maritime**	**Total**	**Construction**	**GI & Maritime**
Undiscounted (0%)	ToxaChemica 2004 (lower estimate)	$9.0	$7.8	$1.2	$4.3	$4.2	$0.1
	Midpoint	$15.2	$12.0	$3.2	$6.5	$6.3	$0.2
	Attfield and Costello 2004 (higher estimate)	$21.4	$16.3	$5.2	$8.7	$8.3	$0.4
Discounted at 3%	ToxaChemica 2004 (lower estimate)	$5.9	$5.1	$0.8	$2.8	$2.7	$0.0
	Midpoint	$10.0	$7.9	$2.1	$4.2	$4.1	$0.1
	Attfield and Costello 2004 (higher estimate)	$14.0	$10.6	$3.4	$5.6	$5.4	$0.2
Discounted at 7%	ToxaChemica 2004 (lower estimate)	$3.3	$2.8	$0.4	$1.6	$1.5	$0.0
	Midpoint	$5.5	$4.4	$1.2	$2.3	$2.3	$0.1
	Attfield and Costello 2004 (higher estimate)	$7.8	$5.9	$1.9	$3.1	$3.0	$0.1

Source: OSHA, Directorate of Standards and Guidance, Office of Regulatory Analysis
Results are estimates based on the assumption outlined throughout this chapter.

Table VIII-5c
Total Annual Monetized Benefits Resulting from a Reduction in Exposure to Crystalline Silica
Due to PEL of 50 μg/m^3 and Alternative PEL of 100 μg/m^3
For the Scenario in Which Workers are Uniformly Exposed to Silica for 13 Years
($Billions)*

PEL		**50**			**100**		
Discount Rate	**Range**	**Total**	**Construction**	**GI & Maritime**	**Total**	**Construction**	**GI & Maritime**
Undiscounted (0%)	ToxaChemica 2004 (lower estimate)	$12.3	$10.8	$1.5	$5.6	$5.6	$0.1
	Midpoint	$18.8	$15.2	$3.5	$7.7	$7.6	$0.1
	Attfield and Costello 2004 (higher estimate)	$25.2	$19.6	$5.6	$9.8	$9.6	$0.2
Discounted at 3%	ToxaChemica 2004 (lower estimate)	$8.0	$7.0	$1.0	$3.7	$3.6	$0.0
	Midpoint	$12.3	$9.9	$2.3	$5.0	$4.9	$0.1
	Attfield and Costello 2004 (higher estimate)	$16.5	$12.9	$3.7	$6.4	$6.3	$0.1
Discounted at 7%	ToxaChemica 2004 (lower estimate)	$4.4	$3.8	$0.6	$2.0	$2.0	$0.0
	Midpoint	$6.8	$5.5	$1.3	$2.8	$2.7	$0.0
	Attfield and Costello 2004 (higher estimate)	$9.2	$7.2	$2.1	$3.5	$3.5	$0.1

Source: OSHA, Directorate of Standards and Guidance, Office of Regulatory Analysis
Results are estimates based on the assumption outlined throughout this chapter.

Table VIII-5d
Total Annual Monetized Benefits Resulting from a Reduction in Exposure to Crystalline Silica
Due to PEL of 50 μg/m^3 and Alternative PEL of 100 μg/m^3
For the Scenario in Which Workers are Uniformly Exposed to Silica for 6.6 Years
($Billions)*

PEL		50			100		
Discount Rate	**Range**	**Total**	**Construction**	**GI & Maritime**	**Total**	**Construction**	**GI & Maritime**
Undiscounted (0%)	ToxaChemica 2004 (lower estimate)	$17.9	$15.9	$2.0	$8.0	$7.9	$0.1
	Midpoint	$24.7	$20.6	$4.1	$10.1	$10.0	$0.1
	Attfield and Costello 2004 (higher estimate)	$31.6	$25.3	$6.3	$12.2	$12.0	$0.2
Discounted at 3%	ToxaChemica 2004 (lower estimate)	$11.5	$10.2	$1.3	$5.2	$5.1	$0.1
	Midpoint	$16.1	$13.4	$2.7	$6.6	$6.5	$0.1
	Attfield and Costello 2004 (higher estimate)	$20.8	$16.6	$4.1	$8.0	$7.9	$0.1
Discounted at 7%	ToxaChemica 2004 (lower estimate)	$6.3	$5.5	$0.7	$2.8	$2.8	$0.0
	Midpoint	$9.0	$7.4	$1.5	$3.6	$3.6	$0.0
	Attfield and Costello 2004 (higher estimate)	$11.7	$9.3	$2.3	$4.5	$4.4	$0.1

Source: OSHA, Directorate of Standards and Guidance, Office of Regulatory Analysis

ESTIMATES OF NET BENEFITS OF THE FINAL RULE

OSHA has estimated, as shown in Table VII-6, the monetized and annualized net benefits of the final rule (with a PEL of 50 µg/m^3 in general industry and construction and Table 1 governing almost all controls in Construction), based on the benefits model and costs previously presented in this chapter and in Chapter V of this FEA. Net benefits are the difference between benefits and costs.

As previously noted, the OSH Act requires the Agency to set standards based on eliminating significant risk to the extent feasible. An alternative criterion of maximizing net (monetized) benefits may result in very different regulatory outcomes. Thus, this analysis of estimated net benefits has not been used by OSHA as the basis for its decision concerning the choice of a PEL or of ancillary requirements for the final silica rule. Instead, it is provided to pursuant to Executive Orders 12866 and 13563. OSHA has used the 45 year occupational tenure in its main analysis. OSHA has also examined other possible tenures and provided the results. The occupational tenure results are such the benefits are higher the shorter the occupational tenure. Examination of shorter tenure would actually increase the net benefits because more workers are exposed to silica, albeit for a shorter time each.

Table VII-6 also shows results of estimates of annualized net benefits for an alternative PEL of 100 µg/m^3. Under this regulatory alternative, the PEL would be changed from 50 µg/m^3 to 100 µg/m^3 for all industries covered by the final rule, and the action level would be changed from 25 µg/m^3 to 50 µg/m^3 (thereby keeping the action level at one-half of the PEL). The ancillary provisions of the standard, such as the medical surveillance provisions, would remain the same in this alternative as in this final rule, but would be impacted by factors such as changes in respirator use and effects on other provisions such as medical surveillance. For example, in the construction sector where medical surveillance requirements are triggered by respirator use, a reduction in respirator use would result in a decrease in the costs associated with medical surveillance. Under this alternative, OSHA determined in the PEA that Table 1 requirements for respirator use would be eliminated and that only abrasive blasters and some underground construction workers, which are not included in Table 1, would be required to wear respirators. However, the number of mortalities and morbidities would rise if workers were exposed to higher levels of silica. OSHA did not receive comment on its analysis of this alternative.

Table VII-6 shows net benefits using alternative discount rates of 0, 3, and 7 percent for benefits and costs, including the previously discussed adjustment to monetized benefits to reflect increases in real per capita income over time. An expanded version of Table VII-6, with a breakout of net benefits between construction and general industry/maritime, is provided in Table VII-B-1 in Appendix B, at the end of this chapter.

As previously noted in this chapter, the choice of discount rate for annualizing benefits has a significant effect on annualized benefits. The same is true for net benefits. For example, the net benefits using a 7 percent discount rate for benefits are considerably smaller than the net benefits using a 0 percent discount rate, declining by more than half to two-thirds under all scenarios. (Conversely, as noted in Chapter V of this FEA, the choice of discount rate for annualizing costs has only a very minor effect on annualized costs.)

The estimates of net benefits in Table VII-6 show that:

- While the net benefits of the final rule vary considerably—depending on the choice of discount rate used to annualize benefits and on whether the calculated benefits are in the high, midpoint, or low range—benefits exceed costs for the 50 μg/m^3 PEL in all scenarios that OSHA considered (i.e., the highest estimate for costs is lower than the lowest estimate for benefits).

- The Agency's best estimate of the net annualized benefits of the final rule—using a uniform discount rate for both benefits and costs of 3 percent—and cognizant of the uncertainties inherent in the analysis, is between $3.8 billion and $11.6 billion, with a midpoint value of $7.7 billion.

- The alternative of a 100 μg/m^3 PEL has lower net benefits under all assumptions, relative to the 50 μg/m^3 PEL. However, for this alternative PEL, benefits were also found to exceed costs in all scenarios that OSHA considered.

One commenter, the Mercatus Institute, argued that the benefits for the proposed rule were overestimated due to OSHA's assumption of full compliance, and that this simultaneously underestimated costs, since the cost of complying with existing rules is assumed away. This commenter stated that the Agency should not assume that firms will necessarily comply with the Agency's rules and the benefits estimates should therefore be lower (Document ID 1819, p. 9). OSHA makes three points in response. First, the argument is logically inconsistent—if the Agency did not assume full compliance with the previous PELs and assumes compliance with the new PEL, as Mercatus advocates, it is true that the estimated costs would increase, but so would the estimated benefits. Second, the logic for the Mercatus Institute's argument seems to be undercut by the Mercatus Institute's own observation that the Agency has had success in reducing silicosis, which suggests that in the long run, at least, firms actually do comply with OSHA rules (Document ID 1819, pp. 4-5). Finally, as discussed in the engineering controls section of Chapter V of this FEA, the Agency has determined that the best way for it to calculate costs and benefits is to estimate the incremental costs and benefits of the standard by assuming full compliance. OSHA also emphasizes that the compliance assumption applies to both costs and benefits so that the comparison of one to the other is not necessarily unduly weighted in either direction (an exception would be a hypothetical scenario in which extremely high non-compliance by a few employers changed benefits estimates substantially but cost estimates only slightly).[45]

[45] If this rulemaking has the potential to increase compliance with existing regulations, it would be appropriate for the analysis conducted under Executive Order 12866 and 13563 to include both cost and benefits estimates that reflect the new compliance. This is not, however, a legal requirement of the OSH

ESTIMATES OF INCREMENTAL BENEFITS OF THE FINAL RULE

Incremental costs and benefits are those that are associated with increasing the stringency of the standard. A comparison of incremental benefits and costs provides an indication of the relative economic efficiency of the final PEL and the alternative PEL on which OSHA solicited comment in the NPRM. Again, OSHA has conducted these calculations for informational purposes only and has not used these results as the basis for selecting the PEL for the final rule, for which the legally determinative inquiry is whether the final PEL is the lowest level feasible at which significant risk of material health impairment remains.

Tables VII-7A and VII-7B show result of estimates of the costs and benefits of reducing exposure levels from the preceding PELs of approximately 250 µg/m^3 (for construction and maritime) and 100 µg/m^3 (for general industry) to the final rule PEL of 50 µg/m^3 and to the alternative PEL of 100 µg/m^3, using the alternative discount rates of 3 and 7 percent. These tables also introduce a second alternative PEL. Under this second alternative standard, addressed in Tables VII-7A and VII-7B, the PEL would be lowered from 50 µg/m^3 to 25 µg/m^3 for all industries covered by the final rule, while the action level would remain at 25 µg/m^3 (because of difficulties in accurately measuring exposure levels below 25 µg/m^3). For the construction sector under this second alternative, Table 1 requirements would also be modified to include respiratory protection for all workers covered under Table 1 (because all exposures for Table 1 activities are assumed to be above 25 µg/ m^3), and all these covered workers would be subject to the medical surveillance provision.[46]

Table VII-7A breaks out costs by provision and benefits by type of disease and by morbidity/mortality, while Table VII-7B breaks out costs and benefits by major industry sector or construction task sector. As Table VII-7A shows, at a discount rate of 3 percent, a PEL of 50 µg/m^3, relative to a PEL of 100 µg/m^3, imposes incremental costs of $381 million per year; incremental benefits of $4.3 billion per year, and additional net benefits of $3.9 billion per year. The final PEL of 50 µg/m^3 also has higher net benefits than 100 µg/m^3 either at a 3 percent or 7 percent discount rate.

Table VII-7B continues this incremental analysis but with breakdowns between construction and general industry/maritime. As shown, both sectors show strong positive net benefits, which are greater for the final PEL of 50 µg/m^3 than the alternative of 100 µg/m^3.

Act. OSHA knows of no way to make such estimates and lacks any persuasive evidence in this rulemaking record that this rulemaking would affect compliance with the preceding PEL.

[46]As with general industry and maritime employees, the limited number of construction workers not covered by Table 1 and estimated to exceed 25 µg/m^3 currently, such as abrasive blasters, are assumed to need respiratory protection under this alternative.

The estimates in Tables VII-7A and VII-7B indicate that, across all discount rates, there are net benefits to be achieved by lowering exposures from the preceding PEL (250 $\mu g/m^3$ or 100 $\mu g/m^3$) to 100 $\mu g/m^3$ and then, in turn, lowering them further to 50 $\mu g/m^3$ and then to 25 $\mu g/m^3$), and the lower the PEL, the greater the net benefits.[47] Net benefits decline across all incremental changes in PELs as the discount rate for annualizing benefits increases. The incremental net benefit of reducing the PEL from 100 $\mu g/m^3$ to 50 $\mu g/m^3$ is greater than the incremental net benefit of reducing the PEL from 50 $\mu g/m^3$ to 25 $\mu g/m^3$ under both the 3 percent discount rate and the 7 percent discount rate.

However, the majority of the benefits and costs that OSHA estimates for the final rule (PEL of 50 $\mu g/m^3$) are from the initial effort to lower exposures from the preceding PEL of 250 $\mu g/m^3$ in both construction and maritime to 100 $\mu g/m^3$, as shown in the 100 $\mu g/m^3$ column and the Incremental Costs/Benefits column between the 100 $\mu g/m^3$ column and the 50 $\mu g/m^3$ column in Table VII-7A. The majority of the costs and benefits attributable to lowering exposures to 100 $\mu g/m^3$ are in the construction industry. OSHA did not estimate any costs or benefits for general industry employers lowering exposures to an alternative of 100 $\mu g/m^3$ because the preceding PEL was already 100 $\mu g/m^3$, but a relatively small amount of costs and benefits would be attributed to maritime employers lowering exposures to the alternative of 100 $\mu g/m^3$ from the preceding PEL of 250 $\mu g/m^3$. Because a single standard would cover both general industry and maritime employers, those costs and benefits are grouped together in Table VII-7A and VII-7B.

In addition to examining alternative PELs, OSHA also examined alternatives to other provisions of the standard. These alternatives are discussed in the following Chapter VIII of this FEA: Regulatory Alternatives.

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[47] The lowest PEL considered as an alternative was 25 $\mu g/m^3$. In addition, the costs exceed the benefits using the 7 percent discount rate for the 100 $\mu g/m^3$ alternative, since quantified benefits for this FEA are based entirely on the various quantitative risk assessments, and the PEL for general industry is already set at 100 $\mu g/m^3$. (There would, however, be net benefits for construction.) . As noted previously, the Agency is claiming no quantified benefits for the various ancillary provisions, such as medical surveillance.

Table VII-6

Annual Monetized Net Benefits Resulting from a Reduction in Exposure to Crystalline Silica Due to the Final PEL of 50 μg/m^3 and Alternative PEL of 100 μg/m^3

($Billions)**

PEL		50	100*
Discount Rate	**Range**		
Undiscounted (0%)	ToxaChemica 2004 (lower estimate)	$6.3	$2.9
	Midpoint	$12.3	$6.0
	Attfield and Costello 2004 (higher estimate)	$18.3	$9.2
3%	ToxaChemica 2004 (lower estimate)	$3.8	$1.7
	Midpoint	$7.7	$3.7
	Attfield and Costello 2004 (higher estimate)	$11.6	$5.7
7%	ToxaChemica 2004 (lower estimate)	$1.7	$0.7
	Midpoint	$3.8	$1.8
	Attfield and Costello 2004 (higher estimate)	$5.9	$2.8

Source: OSHA, Directorate of Standards and Guidance, Office of Regulatory Analysis

*No benefits related to achieving the preceding general industry PEL of 100 μg/m^3 are included in these estimates.

Table VII-7a: Annualized, Costs, Benefits, and Incremental Benefits of OSHA's Final Silica Standard, Compared with 100 μg/m^3 and 25 μg/m^3 Regulatory Alternatives*

Millions ($2012)

	Regulatory Alternative #2						Final Rule						Regulatory Alternative #1		
	25 μg/m^3			Incremental Costs Between 50 and 25 μg/m^3			50 μg/m^3			Incremental Costs Between 100 and 50 μg/m^3			100 μg/m^3		
Discount Rate		**3%**	**7%**		**3%**	**7%**		**3%**	**7%**		**3%**	**7%**		**3%**	**7%**
Annualized Costs															
Engineering Controls		$661	$674		$0	$0		$661	$674		$241	$261		$421	$413
Respirators		$82	$82		$49	$49		$33	$33		$32	$32		$1	$1
Exposure Assessment		$141	$142		$45	$53		$96	$98		$32	$32		$64	$65
Medical Surveillance		$485	$492		$388	$392		$96	$100		$73	$75		$24	$24
Familiarization and Training		$96	$100		$0	$0		$96	$102		$0	$2		$96	$100
Regulated Area		$12	$12		$9	$9		$3	$3		$3	$3		$0	$0
Written Control Plan		$44	$47		$0	$0		$44	$47		$0	$1		$44	$47
Total Annualized Costs (point estimate)		**$1,521**	**$1,552**		**$491**	**$496**		**$1,030**	**$1,056**		**$381**	**$406**		**$649**	**$650**
Annual Benefits: Number of Cases Prevented	**Cases**			**Incremental Benefits Between 50 and 25 μg/m^3-- Cases**			**Cases**			**Incremental Benefits Between 100 and 50 μg/m^3-- Cases**			**Cases**		
Fatal Lung Cancers (midpoint estimate) **	178			54			123			62			62		
Fatal Silicosis & other Non-Malignant Respiratory Diseases**	438			113			325			154			170		
Fatal Renal Disease**	321			128			193			110			83		
Silica-Related Mortality**	937	9,340	5,119	295	**$2,942**	**$1,612**	642	$6,398	$3,507	326	$3,248	$1,783	316	$3,151	$1,724
Silicosis Morbidity**	1,040	2,593	1,478	122	**$304**	**$173**	918	$2,289	$1,305	440	$1,098	$626	477	$1,191	$679
Monetized Annual Benefits (midpoint estimate) **		**$11,933**	**$6,597**		**$3,246**	**$1,786**		**$8,687**	**$4,812**		**$4,346**	**$2,409**		**$4,341**	**$2,403**
Net Benefits**		**$10,412**	**$5,046**		**$2,755**	**$1,290**		**$7,657**	**$3,756**		**$3,965**	**$2,003**		**$3,692**	**$1,753**

Table VIII-7b: Annualized Costs, Benefits and Incremental Benefits of OSHA's Final Silica Standard compared with 100 μg/m³ and 25 μg/m³ Regulatory Alternatives, by Major Industry Sector*

Millions ($2012)

	Regulatory Alternative #2						Final Rule						Regulatory Alternative #1		
	25 μg/m³			Incremental Costs Between 50 and 25 μg/m³			50 μg/m³			Incremental Costs Between 100 and 50 μg/m³			100 μg/m³**		
Discount Rate		**3%**	**7%**		**3%**	**7%**		**3%**	**7%**		**3%**	**7%**		**3%**	**7%**
Annualized Costs															
Construction		$1,046	$1,059		$387	$387		$659	$673		$104	$120		$555	$553
General Industry/Maritime		$475	$492		$104	$109		$371	$384		$276	$286		$95	$97
Total Annualized Costs		**$1,521**	**$1,552**		**$491**	**$496**		**$1,030**	**$1,056**		**$381**	**$408**		**$649**	**$650**
Annual Benefits: Number of Cases Prevented	**Cases**			**Cases**			**Cases**			**Cases**			**Cases**		
Silica-Related Mortality															
Construction	754	$7,304	$4,119	209	$2,085	$1,143	545	$5,430	$2,976	233	$2,324	$1,276	311	$3,106	$1,700
General Industry/Maritime	183	$1,826	$1,001	86	$857	$470	97	$968	$531	93	$924	$506	4	$44	$24
Total	937	$9,340	$5,119	295	$2,942	$1,612	642	$6,398	$3,507	326	$3,248	$1,783	316	$3,151	$1,724
Silicosis Morbidity															
Construction	573	$1,430	$815	43	$107	$61	530	$1,323	$754	80	$201	$114	450	$1,122	$640
General Industry/Maritime	466	$1,163	$663	79	$197	$112	387	$966	$551	360	$898	$512	27	$69	$39
Total	1,040	$2,593	$1,478	122	$304	$173	918	$2,289	$1,305	440	$1,098	$626	477	$1,191	$679
Monetized Annual Benefits (midpoint estimate)				**Incremental Benefits Between 50 and 25 μg/m³**						**Incremental Benefits Between 100 and 50 μg/m³**					
Construction***		$8,945	$4,934		$2,192	$1204		$6,753	$3,730		$2,524	$1,391		$4,228	$2,340
General Industry/Maritime***		$2,988	$1,664		$1,054	$582		$1,939	$1,081		$1,821	$1,018		$113	$63
Total* **		**$11,933**	**$6,598**		**$3,246**	**$1,786**		**$8,687**	**$4,812**		**$4,346**	**$2,409**		**$4,341**	**$2,403**
Net Benefits															
Construction***		$7,898	$3,875		$1,805	$817		$6,094	$3,056		$2,420	$1,271		$3,674	$1,787
General Industry/Maritime***		$2,512	$1,171		$950	$473		$1,564	$698		$1,545	$732		$18	($34)
Total* **		**$10,412**	**$5,046**		**$2,755**	**$1,290**		**$7,657**	**$3,756**		**$3,965**	**$2,003**		**$3,692**	**$1,753**

Source: OSHA, Directorate of Standards and Guidance, Office of Regulatory Analysis

* Benefits are assessed over a 60-year time horizon, during which it is assumed that economic conditions remain constant, except that the value of VSLs increase with income and then annualized. Costs are annualized over ten years, with the exception of equipment expenditures, which are annualized over the life of the equipment. Annualized costs are assumed to continue at the same level for sixty years, which is consistent with assuming that economic conditions remain constant for the sixty year time horizon.

SENSITIVITY ANALYSIS

In this section, OSHA presents the results of two different types of sensitivity analysis. In the first type of sensitivity analysis, OSHA made a series of isolated changes to individual cost and benefit input parameters in order to determine their effects on the Agency's estimates of annualized costs, annualized benefits, and annualized net benefits. In the second type of sensitivity analysis—a so-called "break-even" analysis—OSHA also investigated isolated changes to individual cost and benefit input parameters, but with the objective of determining how much they would have to change for annualized costs to equal annualized benefits.

Again, the Agency has conducted these calculations for informational purposes only and has not used these results as the basis for selecting the PEL or any other provisions for the final rule.

Analysis of Isolated Changes to Inputs

The methodology and calculations underlying the estimation of the costs and benefits associated with this rulemaking are generally linear and additive in nature. Thus, the sensitivity of the results and conclusions of the analysis will generally be proportional to isolated variations in a particular input parameter. For example, if the estimated time that employees need to travel to and from medical screenings is doubled, the corresponding labor costs double as well.

OSHA evaluated a series of such changes in input parameters to test whether and to what extent the general conclusions of the economic analysis held up. OSHA separately considered changes to input parameters that affected only costs and then changes to input parameters that affected only benefits. Each of the sensitivity tests on cost parameters had only a very minor effect on total costs or net benefits. Much larger effects were observed when the benefits parameters were modified. On the whole, OSHA found that the conclusions of the analysis are reasonably robust. The results of the individual sensitivity tests are summarized in Tables VII-8A and B and are described in more detail below.

For this FEA, OSHA has tailored the sensitivity analysis to examine issues raised by commenters, particularly with respect to costs. (For more detail, see Chapter V of this FEA.) For each alternative, the estimated cost increase is equivalent to the estimated decrease in net benefits (except for minor rounding discrepancies). For instance, in the first example of sensitivity testing, when OSHA doubled the estimated portion of the affected self-employed population from 25 to 50 percent, and estimates of other input parameters remained unchanged, Table VII-8A shows that the estimated total costs of the final rule increased by $17.9 million annually, or by about 1.7 percent, while estimated net benefits also declined by $17.9 million, from $7,657 million to $7,639 million annually.

OSHA recognizes that there is not one uniform approach to estimating the marginal cost of labor. For the economic analysis in support of the final rule, OSHA has estimated the marginal costs of labor as wages plus a fringe benefit rate of 46.2% (which includes some fixed costs such as health insurance). However, this approach does not account for overhead costs. For illustrative purposes in the context of this sensitivity analysis, OSHA has modified the cost estimates by including an overhead rate when estimating the marginal cost of labor. It is important to note that there is not one broadly accepted overhead rate in academic literature and estimating the most appropriate overhead rate for this FEA would require significant modeling. Further, the Department has not further analyzed an appropriate quantitative adjustment. Therefore, DOL adopted for the purposes of this specific exercise an overhead rate of 17%. This rate has been used by the EPA in its final rules (see for example, EPA Electronic Reporting under the Toxic Substances Control Act Final Rule, June 17, 2013), and is based upon a Chemical Manufacturers Association study.

Using an overhead rate of 17% would increase costs by $22.5 million per year, or 2.2 percent above the best estimate of costs. (See Table VII-8A) One explanation as to why including overheads would not have a significant impact on final costs estimates in this FEA is that marginal labor costs do not account for a significant share of overall costs.

Table VII-8A

Sensitivity Tests-Costs

Impact Variable	OSHA's Best Estimate	Sensitivity Test	Impact on Annualized Costs	Percentage Impact on Costs	Adjusted Annualized Costs	Adjusted Annualized Net Benefit*
OSHA's Best Estimate of (a) Annualized Total Cost and (b) Annualized Net Benefits					*(a)* *$1,029,781,777*	*(b)* *$7,657,131,438*
Affected self-employed population	25.0%	Double	$17,885,843	1.7%	$1,047,667,621	$7,639,245,595
Familiarization	4 to 40 hours depending on establishment size	Double	$15,936,313	1.5%	$1,045,718,091	$7,641,195,125
Housekeeping	10 mins per worker per day	Double	$12,487,297	1.2%	$1,042,269,074	$7,644,644,141
Thorough cleaning	Initial cleaning only	Annual cleaning	$17,191,599	1.7%	$1,046,973,377	$7,639,939,839
	Initial cleaning only	Cleaning every 5 years	$1,963,372	0.2%	$1,031,745,150	$7,655,168,066
Respirator use in General Industry	10% of workers otherwise exposed above the PEL**	Double	$20,004,553	1.9%	$1,049,786,330	$7,637,126,886
Productivity in construction	Range from 3 to 5%	50% increase	$99,612,982	9.7%	$1,129,394,760	$7,557,518,456
		50% decrease	-$99,613,982	-9.7%	$930,168,795	$7,756,744,420
Fringe plus Overhead costs	Includes only fringe value of 46.2 percent of wages	Includes an overhead value of 17 percent for a total of 63.2 loading factor on wages	$22,529,044	2.2%	$1,052,310,821	*$7,657,131,438*

Table VII-8B

Sensitivity Tests-Benefits**

Impact Variable	OSHA's Best Estimate	Sensitivity Test	Impact on Annualized Benefits	Percentage Impact on Benefits		Adjusted Annualized Benefits		Adjusted Annualized Net Benefit
OSHA's Best Estimate of (c) Annualized Total Benefits and (b) Annualized Net Benefits					***(c)***	*$8,686,913,216*	***(b)***	*$7,657,131,438*
Monetized Benefits (High Morbidity Valuation/High Mortality Case Estimate)	Midpoint	Attfield and Costello 2004 (higher estimate)	$3,872,364,448	45%		$12,559,277,664		$11,529,495,886
Monetized Benefits (Low Morbidity Valuation/Low Mortality Case Estimate)	Midpoint	ToxaChemica 2004 (lower estimate)	-$3,872,364,448	-45%		$4,814,548,767		$3,784,766,990
Discount rate for benefits (7%)	3%	7%	-$3,875,099,068	-45%		$4,811,814,147		$3,782,032,370
Discount rate for benefits (3%), with Adjustment to Monetized Benefits to Reflect Increases in Real Per Capita Income Over Time	2% annual increase in benefit valuation	0%	-$4,374,670,466	-50%		$4,312,242,750		$3,282,460,972

Source: OSHA, Directorate of Standards and Guidance, Office of Regulatory Analysis

* Benefits are assessed over a 60-year time horizon, during which it is assumed that economic conditions remain constant except that the value of VSLs increase with income. Costs are annualized over ten years, with the exception of equipment expenditures, which are annualized over the life of the equipment. Annualized costs are assumed to continue at the same level for sixty years, which is consistent with assuming economic conditions remain constant for the sixty year time horizon.

** Except as otherwise noted in this FEA, OSHA accounted for respirator use for all workers whose exposures would still exceed the PEL after all feasible controls are in place. In addition, OSHA added to that number an additional 10% of the remaining population to account for special circumstances in which additional workers would require respirators. For this sensitivity analysis, the additional 10% was doubled to 20%.

In the second example, OSHA doubled the estimated familiarization time needed to understand the requirements of the new standard relative to OSHA's best estimate, which ranged from 4 to 40 hours depending on establishment size (see Chapter V for more detail). As shown in Table VII-8A, if OSHA's estimates of other input parameters remained unchanged, the total estimated costs of the final rule increased by $15.9 million annually, or by about 1.5 percent, while net benefits declined by the same amount annually, from approximately $7,657 million to $7,641 million annually.

In the third example, OSHA doubled the estimated daily amount of housekeeping per worker necessary to comply with the standard, from 10 minutes to 20 minutes. As shown in Table VII-8A, if OSHA's estimates of other input parameters remained unchanged, the total estimated costs of the final rule increased by $12.5 million annually, or by about 1.2 percent, while net benefits declined by the same amount annually, from approximately $7,657 million to $7,645 million annually.

In the fourth example, OSHA examined the effect of increasing its estimate of the frequency with which thorough cleaning of the workplace would be performed in general industry. The Agency examined the effect of increasing the frequency from only one initial thorough cleaning to the initial cleaning *plus* an annual thorough cleaning, or alternately, a thorough cleaning every 5 years. As shown in Table VII-8A, if thorough cleaning were an annual cost, the total estimated costs of the final rule increased by $17.2 million annually, or by about 1.7 percent, while net benefits declined by the same amount annually, from $7,657 million to $7,640 million annually. In the second variation of this test, for a thorough cleaning every 5 years, as shown in Table VII-8, the increase in annual costs is only 0.2 percent.

In the fifth example, OSHA increased its estimate of respirator use. In Chapter V of this FEA, OSHA explained that it calculated the costs of respirators for general industry and maritime workers who will still be exposed above the PEL after all feasible controls are in place. In addition, to be conservative, OSHA added costs to provide respirators to 10 percent of the remaining population. For this sensitivity test, OSHA doubled its estimate of the amount of additional respirator use in general industry from 10 percent to 20 percent. As shown in Table VII-8A, the total estimated costs of the final rule increased by $20.0 million annually, or by about 1.9 percent, while net benefits decreased by the same amount annually, from approximately $7,657 million to $7,637 million annually.

In the sixth example, reflecting in part the range of comments the Agency received on the issue (discussed in detail in Chapter V), OSHA explored the effect of increasing, and alternately decreasing, by 50 percent the size of the productivity impact arising from the use of engineering controls in construction. As shown in Table VII-8A, if OSHA's estimates of other input parameters remained unchanged, under the first variation, the total estimated costs of the final rule increased by $99.6 million annually, or by about 9.7 percent, while net benefits declined by the same amount annually, from $7,657 million to $7,558 million annually. Under the second variation, the decrease in costs and increase in net benefits would be of the same magnitude, with final estimated net benefits rising to $7,757 million.

As shown in Table VII-8B, OSHA also performed sensitivity tests on several input parameters used to estimate the benefits of the final rule. In the first two tests, in an extension of results previously presented in Table VII-5, the Agency examined the effect on annualized net benefits of employing the high-end estimate of the benefits, as well as the low-end estimate. As discussed previously, the Agency examined the sensitivity of the benefits to both the valuation of individual silica-related disease cases prevented, as well as the number of lung cancer deaths prevented. Table VII-8B presents the effect on annualized net benefits of using the extreme values of these ranges, the high count of cases prevented *and* the high valuation per case prevented, and the low count *and* the low valuation per case prevented. As indicated, using the high estimate of cases prevented and their valuation, the benefits rise by 45 percent to $12.6 billion, yielding net benefits of $11.5 billion. For the low estimate of both cases prevented and their valuation, the benefits decline by 45 percent, to $4.8 billion, yielding net benefits of $3.8 billion.

In the third sensitivity test of benefits, OSHA examined the effect of raising the discount rate for benefits to 7 percent. The fourth sensitivity test of benefits examined the effect of removing the adjustment to monetized benefits to reflect increases in real per capita income over time. The results of the first of these sensitivity tests for net benefits was previously shown in Table VII-6 and is repeated in Table VII-8B. Raising the interest rate to 7 percent lowers the estimated benefits by 45 percent, to $4.8 billion, yielding annualized net benefits of $3.8 billion. Removing the two-percent annual increase to monetized benefits to reflect increases in real per capita income over time decreases the benefits by 50 percent, to $4.3 billion, yielding net benefits of $3.3 billion.

“Break-Even” Analysis

OSHA also performed sensitivity tests on several other parameters used to estimate the net costs and benefits of the final rule. However, for these, the Agency performed a “break-even” analysis, examining how much the various cost and benefits inputs would have to vary in order for the costs to equal, or break even with, the benefits estimates. The results are shown in Table VII-9.

In the first break-even test on cost estimates, OSHA examined how much costs would have to increase in order for costs to equal estimated benefits. As shown in Table VII-9, this point would be reached if costs increased by $7.7 billion

In a second test, looking specifically at the estimated engineering control costs, the Agency found that these costs would also need to increase by $7.7 billion for costs to equal estimated benefits.

In a third sensitivity test, on benefits, OSHA examined how much its estimated monetary valuation of an avoided illness or an avoided fatality would need to be reduced in order for the costs to equal the benefits. Since the total valuation of prevented mortality and morbidity are each estimated to exceed at least $2.6 billion, while the estimated costs are $1.0 billion, an independent break-even point for each is impossible. In other words, for example, if no value is attached to an avoided illness associated with the rule, but the estimated value of an avoided fatality is held constant, the rule still has substantial net benefits. Only through a reduction in the estimated net value of both components is a break-even point possible.

OSHA, therefore, examined how large an across-the-board reduction in the monetized value of all avoided illnesses and fatalities would be necessary for the benefits to equal the costs. As shown in Table VII-9, for costs to equal estimated benefits, the estimated value per life saved would have to decline to $1.1 million per life saved, and an equivalent percentage reduction to about $0.3 million per illness prevented.

In a break-even sensitivity test, OSHA estimated how many silica-related fatalities and illnesses would be required for benefits to equal costs. As shown in Table VII-9, a reduction of 88 percent, relative to the morbidity and mortality estimates is required to reach the break-even point—566 fewer fatalities prevented annually, and 809 fewer silica-related illnesses prevented annually.

Table VII-9

Break-Even Sensitivity Analysis

	OSHA's Best Estimate of Annualized Cost or Benefit Factor	Factor Value at which Benefits Equal Costs	Required Factor Dollar/Number Change	Percentage Factor Change
Total Costs	$1,029,781,777	$8,686,913,216	$7,657,131,438	743.6%
Engineering Control Costs	$661,456,736	$8,318,588,174	$7,657,131,438	1157.6%
Benefits Valuation per Case Avoided				
Monetized Benefit per Death Avoided*	$9,000,000	$1,066,896	-$7,933,104	-88.1%
Monetized Benefit per Illness Avoided*	$2,632,000	$312,008	-$2,319,992	-88.1%
Cases Avoided				
Deaths Avoided*	642	76	-566	-88.1%
Illnesses Avoided*	918	109	-809	-88.1%

*Note: These numbers represent a reduction in the composite valuation of an avoided fatality or illness or in the composite number of cases avoided.

Source: OSHA, Directorate of Standards and Guidance, Office of Regulatory Analysis.

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APPENDIX VII-A

ESTIMATES OF HEALTH AND LONGEVITY IMPROVEMENTS BY YEAR

TABLE VII-A-1

Benefits by Year After Promulgation of the Silica Standard (60-Year Time Horizon): Cases, Undiscounted Values and Values at a 3% Discount Rate

Based On Midpoint Estimates*

Year After Promulgation	Cases Prevented by Year After Promulgation					Undiscounted Value of Cases Prevented by Year After Promulgation ($M)						Present Value by Year After Promulgations - 3% Discount Rate ($M)					
	Lung Cancer	Lung Diseases Other Than Cancer	End-Stage Renal Disease	Total	Morbidity Cases Prevented	Lung Cancer	Lung Diseases Other Than Cancer	End-Stage Renal Disease	Total	Value of Morbidity Cases Prevented	Grand Total	Fatal Lung Cancer	Fatal Lung Diseases Other Than Cancer	Fatal End-Stage Renal Disease	Fatality Total	Morbidity	Grand Total
1	0	7	4	12	20	$0.0	$80.0	$49.9	$129.9	$54	$183.6	$0.0	$80.0	$49.9	$129.9	$54	$183.6
2	0	14	9	23	41	$0.0	$163.3	$101.9	$265.1	$110	$374.7	$0.0	$158.4	$98.8	$257.3	$106	$363.5
3	0	22	13	35	61	$0.0	$249.9	$155.9	$405.8	$168	$573.5	$0.0	$235.3	$146.8	$382.1	$158	$539.9
4	0	29	17	46	82	$0.0	$340.0	$212.1	$552.2	$228	$780.2	$0.0	$310.6	$193.8	$504.4	$208	$712.8
5	0	36	21	58	102	$0.0	$433.7	$270.6	$704.3	$291	$995.2	$0.0	$384.4	$239.8	$624.3	$258	$882.1
6	0	43	26	69	122	$0.0	$531.1	$331.3	$862.4	$356	$1,218.6	$0.0	$456.7	$284.9	$741.7	$306	$1,048.1
7	0	50	30	81	143	$0.0	$632.2	$394.4	$1,026.6	$424	$1,450.7	$0.0	$527.6	$329.1	$856.7	$354	$1,210.7
8	0	58	34	92	163	$0.0	$737.3	$460.0	$1,197.2	$495	$1,691.8	$0.0	$597.0	$372.4	$969.4	$400	$1,369.9
9	0	65	39	104	184	$0.0	$846.4	$528.0	$1,374.4	$568	$1,942.2	$0.0	$665.0	$414.8	$1,079.8	$446	$1,525.9
10	0	72	43	115	204	$0.0	$959.6	$598.7	$1,558.3	$644	$2,202.0	$0.0	$731.5	$456.4	$1,187.9	$491	$1,678.6
11	0	79	47	127	224	$0.0	$1,077.1	$672.0	$1,749.1	$723	$2,471.6	$0.0	$796.7	$497.0	$1,293.8	$534	$1,828.2
12	0	87	51	138	245	$0.0	$1,199.0	$748.0	$1,947.0	$804	$2,751.3	$0.0	$860.5	$536.9	$1,397.4	$577	$1,974.7
13	0	94	56	150	265	$0.0	$1,325.4	$826.9	$2,152.3	$889	$3,041.5	$0.0	$923.0	$575.8	$1,498.9	$619	$2,118.1
14	0	101	60	161	285	$0.0	$1,456.5	$908.7	$2,365.2	$977	$3,342.3	$0.0	$984.2	$614.0	$1,598.2	$660	$2,258.4
15	0	108	64	173	306	$0.0	$1,592.4	$993.4	$2,585.8	$1,068	$3,654.1	$0.0	$1,044.0	$651.3	$1,695.4	$700	$2,395.8
16	3	115	69	187	326	$48.0	$1,733.2	$1,081.3	$2,862.5	$1,163	$4,025.2	$30.5	$1,102.6	$687.9	$1,821.0	$740	$2,560.7
17	6	123	73	201	347	$98.0	$1,879.1	$1,172.3	$3,149.4	$1,261	$4,410.0	$60.5	$1,159.9	$723.6	$1,944.0	$778	$2,722.2
18	8	130	77	215	367	$149.9	$2,030.3	$1,266.6	$3,446.8	$1,362	$4,808.8	$89.8	$1,216.0	$758.6	$2,064.4	$816	$2,880.2
19	11	137	82	230	387	$204.0	$2,186.8	$1,364.3	$3,755.1	$1,467	$5,222.0	$118.5	$1,270.8	$792.8	$2,182.2	$853	$3,034.8
20	14	144	86	244	408	$260.2	$2,348.9	$1,465.4	$4,074.4	$1,576	$5,650.1	$146.7	$1,324.5	$826.3	$2,297.5	$889	$3,186.0
21	17	151	90	258	428	$318.6	$2,516.6	$1,570.1	$4,405.3	$1,688	$6,093.5	$174.3	$1,376.9	$859.0	$2,410.3	$924	$3,334.0
22	19	159	94	272	449	$379.3	$2,690.3	$1,678.4	$4,748.0	$1,805	$6,552.7	$201.4	$1,428.2	$891.0	$2,520.6	$958	$3,478.7
23	22	166	99	287	469	$442.3	$2,870.0	$1,790.5	$5,102.8	$1,925	$7,028.0	$227.8	$1,478.4	$922.3	$2,628.5	$992	$3,620.2
24	25	173	103	301	489	$507.7	$3,055.9	$1,906.5	$5,470.1	$2,050	$7,520.1	$253.8	$1,527.4	$952.9	$2,734.0	$1,025	$3,758.6
25	28	180	107	315	510	$575.7	$3,248.2	$2,026.4	$5,850.3	$2,179	$8,029.3	$279.2	$1,575.3	$982.8	$2,837.2	$1,057	$3,893.9
26	30	188	112	329	530	$646.2	$3,447.0	$2,150.5	$6,243.7	$2,312	$8,556.1	$304.1	$1,622.0	$1,011.9	$2,938.1	$1,088	$4,026.2
27	33	195	116	344	551	$719.3	$3,652.7	$2,278.8	$6,650.8	$2,450	$9,101.1	$328.4	$1,667.8	$1,040.5	$3,036.6	$1,119	$4,155.4
28	36	202	120	358	571	$795.1	$3,865.3	$2,411.4	$7,071.8	$2,593	$9,664.8	$352.3	$1,712.4	$1,068.3	$3,133.0	$1,149	$4,281.7
29	39	209	124	372	591	$873.8	$4,085.0	$2,548.5	$7,507.3	$2,740	$10,247.6	$375.6	$1,756.0	$1,095.5	$3,227.1	$1,178	$4,405.1
30	41	216	129	386	612	$955.3	$4,312.1	$2,690.2	$7,957.6	$2,893	$10,850.3	$398.5	$1,798.6	$1,122.1	$3,319.1	$1,207	$4,525.6
31	44	224	133	401	632	$1,039.8	$4,546.8	$2,836.6	$8,423.2	$3,050	$11,473.3	$420.8	$1,840.1	$1,148.0	$3,408.9	$1,234	$4,643.3
32	47	231	137	415	653	$1,127.3	$4,789.2	$2,987.9	$8,904.4	$3,213	$12,117.2	$442.7	$1,880.7	$1,173.3	$3,496.6	$1,262	$4,758.3
33	50	238	142	429	673	$1,218.0	$5,039.7	$3,144.1	$9,401.8	$3,381	$12,782.6	$464.1	$1,920.2	$1,198.0	$3,582.3	$1,288	$4,870.4
34	52	245	146	444	693	$1,311.9	$5,298.4	$3,305.5	$9,915.8	$3,554	$13,470.1	$485.0	$1,958.8	$1,222.1	$3,665.9	$1,314	$4,980.0
35	55	252	150	458	714	$1,409.1	$5,565.5	$3,472.2	$10,446.8	$3,734	$14,180.3	$505.5	$1,996.5	$1,245.5	$3,747.5	$1,339	$5,086.8
36	58	260	154	472	734	$1,509.8	$5,841.4	$3,644.3	$10,995.4	$3,919	$14,914.0	$525.5	$2,033.2	$1,268.5	$3,827.2	$1,364	$5,191.1
37	61	267	159	486	754	$1,613.9	$6,126.1	$3,821.9	$11,562.0	$4,110	$15,671.6	$545.1	$2,069.0	$1,290.8	$3,904.8	$1,388	$5,292.8
38	63	274	163	501	775	$1,721.7	$6,420.1	$4,005.3	$12,147.2	$4,307	$16,454.0	$564.2	$2,103.9	$1,312.5	$3,980.6	$1,411	$5,391.9
39	66	281	167	515	795	$1,833.3	$6,723.5	$4,194.6	$12,751.4	$4,510	$17,261.8	$582.9	$2,137.8	$1,333.7	$4,054.5	$1,434	$5,488.6

TABLE VII-A-1 (continued)

Benefits by Year After Promulgation of the Silica Standard (60-Year Time Horizon): Cases, Undiscounted Values and Values at a 3% Discount Rate

Based On Midpoint Estimates

Year After Promulgation	Cases Prevented by Year After Promulgation					Undiscounted Value of Cases Prevented by Year After Promulgation ($M)						Present Value by Year After Promulgations - 3% Discount Rate ($M)					
	Lung Cancer	Lung Diseases Other Than Cancer	End-Stage Renal Disease	Total	Morbidity Cases Prevented	Lung Cancer	Lung Diseases Other Than Cancer	End-Stage Renal Disease	Total	Value of Morbidity Cases Prevented	Grand Total	Fatal Lung Cancer	Fatal Lung Diseases Other Than Cancer	Fatal End-Stage Renal Disease	Fatality Total	Morbidity	Grand Total
40	69	289	172	529	816	$1,948.6	$7,036.7	$4,390.0	$13,375.3	$4,720	$18,095.7	$601.2	$2,171.0	$1,354.4	$4,126.5	$1,456	$5,582.9
41	72	296	176	543	836	$2,067.9	$7,359.8	$4,591.6	$14,019.3	$4,937	$18,956.4	$619.0	$2,203.2	$1,374.5	$4,196.8	$1,478	$5,674.7
42	74	303	180	558	856	$2,191.3	$7,693.2	$4,799.5	$14,684.0	$5,161	$19,844.8	$636.5	$2,234.6	$1,394.1	$4,265.2	$1,499	$5,764.2
43	77	310	185	572	877	$2,318.8	$8,037.1	$5,014.1	$15,370.0	$5,392	$20,761.5	$653.5	$2,265.1	$1,413.2	$4,331.8	$1,520	$5,851.4
44	80	317	189	586	897	$2,450.7	$8,391.8	$5,235.4	$16,077.9	$5,629	$21,707.4	$670.2	$2,294.9	$1,431.7	$4,396.7	$1,539	$5,936.2
45	83	325	193	600	918	$2,586.9	$8,757.7	$5,463.7	$16,808.3	$5,875	$22,683.2	$686.4	$2,323.8	$1,449.7	$4,459.9	$1,559	$6,018.8
46	85	325	193	603	918	$2,727.7	$8,936.4	$5,575.2	$17,239.3	$5,995	$23,234.1	$702.3	$2,300.8	$1,435.4	$4,438.4	$1,543	$5,981.9
47	88	325	193	606	918	$2,873.1	$9,118.8	$5,689.0	$17,680.9	$6,117	$23,798.1	$717.7	$2,278.0	$1,421.2	$4,416.9	$1,528	$5,945.1
48	91	325	193	609	918	$3,023.4	$9,304.9	$5,805.1	$18,133.3	$6,242	$24,375.3	$732.9	$2,255.4	$1,407.1	$4,395.4	$1,513	$5,908.4
49	94	325	193	611	918	$3,178.6	$9,494.8	$5,923.5	$18,596.9	$6,369	$24,966.3	$747.6	$2,233.1	$1,393.2	$4,373.9	$1,498	$5,871.9
50	97	325	193	614	918	$3,338.8	$9,688.6	$6,044.4	$19,071.8	$6,499	$25,571.2	$762.0	$2,211.0	$1,379.4	$4,352.3	$1,483	$5,835.5
51	99	325	193	617	918	$3,504.3	$9,886.3	$6,167.8	$19,558.4	$6,632	$26,190.4	$776.0	$2,189.1	$1,365.7	$4,330.8	$1,469	$5,799.3
52	102	325	193	620	918	$3,675.2	$10,088.0	$6,293.6	$20,056.9	$6,767	$26,824.2	$789.6	$2,167.4	$1,352.2	$4,309.3	$1,454	$5,763.2
53	105	325	193	622	918	$3,851.5	$10,293.9	$6,422.1	$20,567.5	$6,905	$27,473.0	$802.9	$2,146.0	$1,338.8	$4,287.7	$1,440	$5,727.3
54	108	325	193	625	918	$4,033.6	$10,504.0	$6,553.1	$21,090.7	$7,046	$28,137.1	$815.9	$2,124.7	$1,325.6	$4,266.2	$1,425	$5,691.5
55	110	325	193	628	918	$4,221.4	$10,718.4	$6,686.9	$21,626.7	$7,190	$28,816.9	$828.5	$2,103.7	$1,312.4	$4,244.7	$1,411	$5,655.9
56	113	325	193	631	918	$4,415.3	$10,937.1	$6,823.3	$22,175.7	$7,337	$29,512.7	$840.8	$2,082.9	$1,299.4	$4,223.1	$1,397	$5,620.4
57	116	325	193	633	918	$4,615.2	$11,160.3	$6,962.6	$22,738.2	$7,487	$30,224.9	$852.8	$2,062.2	$1,286.6	$4,201.6	$1,383	$5,585.1
58	119	325	193	636	918	$4,821.6	$11,388.1	$7,104.7	$23,314.3	$7,639	$30,953.8	$864.5	$2,041.8	$1,273.8	$4,180.1	$1,370	$5,549.9
59	121	325	193	639	918	$5,034.4	$11,620.5	$7,249.7	$23,904.6	$7,795	$31,699.9	$875.8	$2,021.6	$1,261.2	$4,158.7	$1,356	$5,514.8
60	124	325	193	642	918	$5,253.9	$11,857.6	$7,397.6	$24,509.2	$7,954	$32,463.6	$886.9	$2,001.6	$1,248.7	$4,137.2	$1,343	$5,479.9
Totals - 60 years				25,525	34,870			$192,258	$592,319	$206,730	$799,048				$177,073.0	$63,343	$240,415

Source: OSHA, Directorate of Standards and Guidance, Office of Regulatory Analysis

* Results are Results are estimates based on the assumption outlined throughout this chapter.

TABLE VII-A-2

Benefits by Year After Promulgation of the Silica Standard (60-Year Time Horizon): Cases, Undiscounted Values and Values at a 7% Discount Rate

Based On Midpoint Estimates*

Year After Promulgation	Cases Prevented by Year After Promulgation					Undiscounted Value of Cases Prevented by Year After Promulgation ($M)						Present Value by Year After Promulgations - 7% Discount Rate ($M)					
	Lung Cancer	Lung Diseases Other Than Cancer	End-Stage Renal Disease	Total	Morbidity Cases Prevented	Lung Cancer	Lung Diseases Other Than Cancer	End-Stage Renal Disease	Total	Value of Morbidity Cases Prevented	Grand Total	Fatal Lung Cancer	Fatal Lung Diseases Other Than Cancer	Fatal End-Stage Renal Disease	Fatality Total	Morbidity	Grand Total
1	0	7	4	12	20	$0.0	$80.0	$49.9	$129.9	$53.7	$183.6	$0.0	$80.0	$49.9	$129.9	$54	$183.6
2	0	14	9	23	41	$0.0	$163.3	$101.9	$265.1	$109.5	$374.7	$0.0	$152.4	$95.1	$247.5	$102	$349.7
3	0	22	13	35	61	$0.0	$249.9	$155.9	$405.8	$167.7	$573.5	$0.0	$217.7	$135.8	$353.5	$146	$499.6
4	0	29	17	46	82	$0.0	$340.0	$212.1	$552.2	$228.1	$780.2	$0.0	$276.4	$172.5	$448.9	$185	$634.4
5	0	36	21	58	102	$0.0	$433.7	$270.6	$704.3	$290.9	$995.2	$0.0	$329.1	$205.3	$534.4	$221	$755.2
6	0	43	26	69	122	$0.0	$531.1	$331.3	$862.4	$356.3	$1,218.6	$0.0	$376.1	$234.7	$610.8	$252	$863.1
7	0	50	30	81	143	$0.0	$632.2	$394.4	$1,026.6	$424.1	$1,450.7	$0.0	$417.9	$260.7	$678.6	$280	$959.0
8	0	58	34	92	163	$0.0	$737.3	$460.0	$1,197.2	$494.6	$1,691.8	$0.0	$454.9	$283.8	$738.7	$305	$1,043.8
9	0	65	39	104	184	$0.0	$846.4	$528.0	$1,374.4	$567.8	$1,942.2	$0.0	$487.4	$304.1	$791.4	$327	$1,118.4
10	0	72	43	115	204	$0.0	$959.6	$598.7	$1,558.3	$643.7	$2,202.0	$0.0	$515.7	$321.7	$837.5	$346	$1,183.4
11	0	79	47	127	224	$0.0	$1,077.1	$672.0	$1,749.1	$722.6	$2,471.6	$0.0	$540.3	$337.1	$877.4	$362	$1,239.8
12	0	87	51	138	245	$0.0	$1,199.0	$748.0	$1,947.0	$804.3	$2,751.3	$0.0	$561.3	$350.2	$911.5	$377	$1,288.1
13	0	94	56	150	265	$0.0	$1,325.4	$826.9	$2,152.3	$889.1	$3,041.5	$0.0	$579.2	$361.3	$940.5	$389	$1,329.0
14	0	101	60	161	285	$0.0	$1,456.5	$908.7	$2,365.2	$977.1	$3,342.3	$0.0	$594.0	$370.6	$964.6	$398	$1,363.1
15	0	108	64	173	306	$0.0	$1,592.4	$993.4	$2,585.8	$1,068.2	$3,654.1	$0.0	$606.1	$378.1	$984.3	$407	$1,390.9
16	3	115	69	187	326	$48.0	$1,733.2	$1,081.3	$2,862.5	$1,162.7	$4,025.2	$17.1	$615.8	$384.1	$1,017.0	$413	$1,430.0
17	6	123	73	201	347	$98.0	$1,879.1	$1,172.3	$3,149.4	$1,260.6	$4,410.0	$32.5	$623.1	$388.7	$1,044.3	$418	$1,462.3
18	8	130	77	215	367	$149.9	$2,030.3	$1,266.6	$3,446.8	$1,362.0	$4,808.8	$46.4	$628.3	$392.0	$1,066.7	$421	$1,488.2
19	11	137	82	230	387	$204.0	$2,186.8	$1,364.3	$3,755.1	$1,467.0	$5,222.0	$58.9	$631.6	$394.1	$1,084.6	$424	$1,508.3
20	14	144	86	244	408	$260.2	$2,348.9	$1,465.4	$4,074.4	$1,575.7	$5,650.1	$70.1	$633.2	$395.1	$1,098.4	$425	$1,523.2
21	17	151	90	258	428	$318.6	$2,516.6	$1,570.1	$4,405.3	$1,688.2	$6,093.5	$80.2	$633.2	$395.1	$1,108.4	$425	$1,533.2
22	19	159	94	272	449	$379.3	$2,690.3	$1,678.4	$4,748.0	$1,804.7	$6,552.7	$89.1	$631.8	$394.2	$1,115.0	$424	$1,538.8
23	22	166	99	287	469	$442.3	$2,870.0	$1,790.5	$5,102.8	$1,925.3	$7,028.0	$96.9	$629.1	$392.4	$1,118.4	$422	$1,540.4
24	25	173	103	301	489	$507.7	$3,055.9	$1,906.5	$5,470.1	$2,050.0	$7,520.1	$103.9	$625.1	$390.0	$1,119.0	$419	$1,538.4
25	28	180	107	315	510	$575.7	$3,248.2	$2,026.4	$5,850.3	$2,179.0	$8,029.3	$109.9	$620.2	$386.9	$1,117.0	$416	$1,533.1
26	30	188	112	329	530	$646.2	$3,447.0	$2,150.5	$6,243.7	$2,312.4	$8,556.1	$115.2	$614.3	$383.2	$1,112.7	$412	$1,524.7
27	33	195	116	344	551	$719.3	$3,652.7	$2,278.8	$6,650.8	$2,450.3	$9,101.1	$119.6	$607.5	$379.0	$1,106.2	$408	$1,513.7
28	36	202	120	358	571	$795.1	$3,865.3	$2,411.4	$7,071.8	$2,592.9	$9,664.8	$123.4	$600.0	$374.3	$1,097.8	$403	$1,500.3
29	39	209	124	372	591	$873.8	$4,085.0	$2,548.5	$7,507.3	$2,740.3	$10,247.6	$126.6	$591.9	$369.2	$1,087.7	$397	$1,484.8
30	41	216	129	386	612	$955.3	$4,312.1	$2,690.2	$7,957.6	$2,892.7	$10,850.3	$129.2	$583.1	$363.8	$1,076.1	$391	$1,467.3
31	44	224	133	401	632	$1,039.8	$4,546.8	$2,836.6	$8,423.2	$3,050.1	$11,473.3	$131.2	$573.9	$358.0	$1,063.1	$385	$1,448.1
32	47	231	137	415	653	$1,127.3	$4,789.2	$2,987.9	$8,904.4	$3,212.8	$12,117.2	$132.8	$564.2	$352.0	$1,048.9	$378	$1,427.4
33	50	238	142	429	673	$1,218.0	$5,039.7	$3,144.1	$9,401.8	$3,380.8	$12,782.6	$133.9	$554.1	$345.7	$1,033.7	$372	$1,405.4
34	52	245	146	444	693	$1,311.9	$5,298.4	$3,305.5	$9,915.8	$3,554.3	$13,470.1	$134.6	$543.7	$339.2	$1,017.5	$365	$1,382.2
35	55	252	150	458	714	$1,409.1	$5,565.5	$3,472.2	$10,446.8	$3,733.5	$14,180.3	$135.0	$533.0	$332.5	$1,000.5	$358	$1,358.1

TABLE VII-A-2

Benefits by Year After Promulgation of the Silica Standard (60-Year Time Horizon): Cases, Undiscounted Values and Values at a 7% Discount Rate (continued)

Based On Midpoint Estimates *

	Cases Prevented by Year After Promulgation					Undiscounted Value of Cases Prevented by Year After Promulgation ($M)						Present Value by Year After Promulgations - 7% Discount Rate ($M)					
Year After Promulgation	**Lung Cancer**	**Lung Diseases Other Than Cancer**	**End-Stage Renal Disease**	**Total**	**Morbidity Cases Prevented**	**Lung Cancer**	**Lung Diseases Other Than Cancer**	**End-Stage Renal Disease**	**Total**	**Value of Morbidity Cases Prevented**	**Grand Total**	**Fatal Lung Cancer**	**Fatal Lung Diseases Other Than Cancer**	**Fatal End-Stage Renal Disease**	**Fatality Total**	**Morbidity**	**Grand Total**
36	58	260	154	472	734	$1,509.8	$5,841.4	$3,644.3	$10,995.4	$3,918.6	$14,914.0	$135.0	$522.2	$325.8	$982.9	$350	$1,333.2
37	61	267	159	486	754	$1,613.9	$6,126.1	$3,821.9	$11,562.0	$4,109.6	$15,671.6	$134.7	$511.1	$318.9	$964.6	$343	$1,307.5
38	63	274	163	501	775	$1,721.7	$6,420.1	$4,005.3	$12,147.2	$4,306.8	$16,454.0	$134.1	$499.9	$311.9	$945.9	$335	$1,281.2
39	66	281	167	515	795	$1,833.3	$6,723.5	$4,194.6	$12,751.4	$4,510.4	$17,261.8	$133.2	$488.6	$304.9	$926.7	$328	$1,254.5
40	69	289	172	529	816	$1,948.6	$7,036.7	$4,390.0	$13,375.3	$4,720.4	$18,095.7	$132.2	$477.3	$297.8	$907.3	$320	$1,227.5
41	72	296	176	543	836	$2,067.9	$7,359.8	$4,591.6	$14,019.3	$4,937.2	$18,956.4	$130.9	$465.9	$290.7	$887.6	$313	$1,200.1
42	74	303	180	558	856	$2,191.3	$7,693.2	$4,799.5	$14,684.0	$5,160.8	$19,844.8	$129.5	$454.6	$283.6	$867.7	$305	$1,172.6
43	77	310	185	572	877	$2,318.8	$8,037.1	$5,014.1	$15,370.0	$5,391.5	$20,761.5	$127.9	$443.2	$276.5	$847.7	$297	$1,145.0
44	80	317	189	586	897	$2,450.7	$8,391.8	$5,235.4	$16,077.9	$5,629.5	$21,707.4	$126.1	$432.0	$269.5	$827.6	$290	$1,117.3
45	83	325	193	600	918	$2,586.9	$8,757.7	$5,463.7	$16,808.3	$5,874.9	$22,683.2	$124.3	$420.7	$262.5	$807.5	$282	$1,089.7
46	85	325	193	603	918	$2,727.7	$8,936.4	$5,575.2	$17,239.3	$5,994.8	$23,234.1	$122.3	$400.7	$250.0	$773.0	$269	$1,041.8
47	88	325	193	606	918	$2,873.1	$9,118.8	$5,689.0	$17,680.9	$6,117.2	$23,798.1	$120.2	$381.6	$238.1	$739.9	$256	$995.9
48	91	325	193	609	918	$3,023.4	$9,304.9	$5,805.1	$18,133.3	$6,242.0	$24,375.3	$118.1	$363.4	$226.7	$708.3	$244	$952.1
49	94	325	193	611	918	$3,178.6	$9,494.8	$5,923.5	$18,596.9	$6,369.4	$24,966.3	$115.9	$346.1	$215.9	$678.0	$232	$910.2
50	97	325	193	614	918	$3,338.8	$9,688.6	$6,044.4	$19,071.8	$6,499.4	$25,571.2	$113.6	$329.7	$205.7	$648.9	$221	$870.1
51	99	325	193	617	918	$3,504.3	$9,886.3	$6,167.8	$19,558.4	$6,632.0	$26,190.4	$111.3	$314.0	$195.9	$621.1	$211	$831.7
52	102	325	193	620	918	$3,675.2	$10,088.0	$6,293.6	$20,056.9	$6,767.4	$26,824.2	$108.9	$299.0	$186.5	$594.5	$201	$795.1
53	105	325	193	622	918	$3,851.5	$10,293.9	$6,422.1	$20,567.5	$6,905.5	$27,473.0	$106.5	$284.8	$177.7	$569.0	$191	$760.0
54	108	325	193	625	918	$4,033.6	$10,504.0	$6,553.1	$21,090.7	$7,046.4	$28,137.1	$104.1	$271.2	$169.2	$544.6	$182	$726.5
55	110	325	193	628	918	$4,221.4	$10,718.4	$6,686.9	$21,626.7	$7,190.2	$28,816.9	$101.7	$258.3	$161.1	$521.2	$173	$694.4
56	113	325	193	631	918	$4,415.3	$10,937.1	$6,823.3	$22,175.7	$7,336.9	$29,512.7	$99.3	$246.0	$153.5	$498.8	$165	$663.8
57	116	325	193	633	918	$4,615.2	$11,160.3	$6,962.6	$22,738.2	$7,486.7	$30,224.9	$96.9	$234.3	$146.2	$477.3	$157	$634.5
58	119	325	193	636	918	$4,821.6	$11,388.1	$7,104.7	$23,314.3	$7,639.5	$30,953.8	$94.5	$223.1	$139.2	$456.8	$150	$606.5
59	121	325	193	639	918	$5,034.4	$11,620.5	$7,249.7	$23,904.6	$7,795.4	$31,699.9	$92.1	$212.5	$132.6	$437.1	$143	$579.7
60	124	325	193	642	918	$5,253.9	$11,857.6	$7,397.6	$24,509.2	$7,954.5	$32,463.6	$89.7	$202.4	$126.3	$418.3	$136	$554.1
Totals - 60 years				22,525	34,870				$592,319	$206,730	$799,048				$49,235	$18,319	$67,554

Source: OSHA, Directorate of Standards and Guidance, Office of Regulatory Analysis

* Results are estimates based on assumptions in the text.

APPENDIX VII-B

ESTIMATES, DISAGGREGATED FOR GENERAL INDUSTRY/MARITIME AND CONSTRUCTION

Table VII-B-1

Annual Monetized Net Benefits Resulting from a Reduction in Exposure to Crystalline Silica to Final PEL of 50 μg/m³ and Alternative PEL of 100 μg/m³

($Billions)**

PEL		**50**			**100**		
Discount Rate	**Range**	**Total**	**Construction**	**GI & Maritime**	**Total**	**Construction**	**GI & Maritime***
Undiscounted (0%)	ToxaChemica 2004 (lower estimate)	$6.3	$5.7	$0.7	$2.9	$3.0	($0.1)
	Midpoint	$12.3	$9.8	$2.6	$6.0	$6.0	$0.1
	Attfield and Costello 2004 (higher estimate)	$18.3	$13.8	$4.5	$9.2	$8.9	$0.2
Discounted at 3%	ToxaChemica 2004 (lower estimate)	$3.8	$3.5	$0.3	$1.7	$1.8	($0.1)
	Midpoint	$7.7	$6.1	$1.5	$3.7	$3.7	$0.0
	Attfield and Costello 2004 (higher estimate)	$11.6	$8.8	$2.8	$5.7	$5.6	$0.1
Discounted at 7%	ToxaChemica 2004 (lower estimate)	$1.7	$1.6	$0.0	$0.7	$0.7	($0.1)
	Midpoint	$3.8	$3.1	$0.7	$1.8	$1.8	($0.0)
	Attfield and Costello 2004 (higher estimate)	$5.9	$4.5	$1.4	$2.8	$2.8	$0.0

Source: OSHA, Directorate of Standards and Guidance, Office of Regulatory Analysis

* Net Benefits for the combined General Industry/Maritime sector may be negative for some assumptions for the alterative PEL of 100 μg/m³ because all quantified benefits are calculated solely on the reduction of the PEL, which is already 100 μg/m³ for General Industry. As noted, the

Agency anticipates substantial benefits from ancillary provisions such as medical surveillance, but these have quantified costs, with no offsetting quantified benefits.

APPENDIX VII-C

PROBABILITY DISTRIBUTION ANALYSIS:

COSTS, BENEFITS, AND NET BENEFITS

PROBABILITY DISTRIBUTION ANALYSIS: COSTS, BENEFITS, AND NET BENEFITS

OSHA's best estimate, as presented in Chapter V of this FEA, is that the annualized cost of the silica rule will exceed $1 billion. Therefore, in accordance with OMB's Circular A-4, OMB's standard guidance document on conducting cost-benefit analysis for government agencies, the Agency has developed, as described below, a formal analysis of uncertainty—a probability distribution analysis—of the costs, benefits, and net benefits of the silica rule.[48]

The Agency is providing this analysis for informational purposes only; OSHA's economic feasibility determinations conducted to comply with the OSH Act must be determined by OSHA's best estimates derived from the information in the record rather than these hypothetical statistical simulations.

OSHA conducted the simulations both for the benefits model and the cost model using a 3 percent discount rate. OSHA also combined the results to produce statistical measures of net benefits as well. The various mechanics of the calculations are explained first, and then the results are presented in a series of tables.

To develop its probability analysis, OSHA used a Monte Carlo simulation approach to probe the effects of changes in the magnitude of various key cost and benefit input variables on important cost and benefit outputs.[49] Monte Carlo analysis consists of randomly drawing from specified distributions for various pre-determined input variables and recording the relevant output variables created as the input values flow through the full calculations of the model. This random drawing process is repeated a large number of times, and the resulting dataset of output numbers can then be analyzed (for example, sample statistics of the mean and the 95% confidence interval) to give a picture of how outputs change in accordance with a specified statistical uncertainty in input values.

OSHA's based the data simulations on the full cost and benefit spreadsheets prepared for this FEA, which, along with the Monte Carlo simulation spreadsheets, are available in the public docket of this rule. The Agency's best estimates of the key input magnitudes and the resulting costs and benefits were previously presented in this FEA. In general, OSHA's selection of input variables to test in these simulations was based on a judgment as to which variables would have the largest effect on the Agency's estimates of costs and benefits and would therefore be most likely to create a significant effect on the

[48] Circular A-4 states: "For major rules involving annual economic effects of $1 billion or more, you should present a formal quantitative analysis of the relevant uncertainties about benefits and costs. In other words, you should try to provide some estimate of the probability distribution of regulatory benefits and costs. In summarizing the probability distributions, you should provide some estimates of the central tendency (e.g., mean and median) along with any other information you think will be useful such as ranges, variances, specified low-end and high-end percentile estimates, and other characteristics of the distribution." (OMB, 2003, p. 40)

[49] This analysis was conducted using the software package @RISK, Version 7, of Palisades Corporation.

results of the Monte Carlo analysis. OSHA limited its analysis to uncertainty in the variable values and did not address uncertainties arising from alternative functional forms in the cost and benefit models. For a more complete discussion of uncertainties in the risk assessment, see the Quantitative Risk Assessment section of the preamble. In all, OSHA chose 15 input variables specific to costs and 7 input variables specific to benefits. No input variable was common to both.

Below is a list of the 15 cost input variables, with their Monte Carlo simulation name and the baseline simulation estimate in parentheses:

1. The percentage of all engineering control costs in general industry and maritime attributable to compliance with the new PEL ("100 PEL compliance factor," 50);

2. The average capital and operating cost of local exhaust ventilation (LEV) per cubic foot per minute (cfm) in general industry or maritime ("CFM cost," $13.34);

3. The average additional number of minutes of routine housekeeping needed per day per affected worker in general industry and maritime ("Cleaning time," 10 minutes);

4. The average number of hours needed for an employer to develop a written exposure control plan ("Control Plan Development," 4 hours)[50];

5. The average number of hours needed for a construction employer to revise the written exposure control plan to tailor direct access control to the specific conditions of a new job worksite ("Control Plan Job Revision," 0.25 hours);

6. For the employee notification or briefing option when implementing the written exposure control plan in construction, the average number of hours needed per job to brief each at-risk crew member ("Control Plan Communicate," 0.1 hours);

7. Other than workers that the Agency's technological feasibility analysis has determined will require respirators, the percentage of the remaining workers currently exposed above 50 $\mu g/m^3$ in general industry or maritime that will require respirators ("Default respirator use factor," 10%);

8. The cost for an industrial hygienist to perform initial exposure monitoring ("Industrial Hygienist daily rate," $2,500)[51];

9. The cost per square foot for an initial thorough cleaning of a facility in general industry or maritime ("Initial cleaning per sq ft," $0.15);

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[50] Four hours is the point estimate for establishments with between 20 and 499 employees. The number of hours for other-sized establishments was calculated in proportion to four hours, based on the ratio of the point estimates. (For example, for establishments with fewer than 20 employees, the ratio applied was 25 percent, since the point estimate in the PEA was 1 hour for establishments of this size.) Similarly, the time needed to review, evaluate, and update the plan annually was calculated relative to (50 percent of, in all cases) the time needed to develop the plan.

[51] The same cost was applied for an industrial hygienist to perform exposure monitoring at construction or hydraulic fracturing sites, which are sites that generally will not have been previously well characterized. For routine periodic monitoring at sites in general industry and maritime that have previously been well characterized, the cost was set at 50 percent of initial exposure monitoring cost (consistent with the estimates developed in the FEA).

10. The average cost for an initial health screening for current employees in general industry or maritime ("Medical visit costs," $421)[52];

11. For exposure monitoring in general industry or maritime, the percentage of workers requiring an additional sample annually due to a change in working conditions ("Monitoring for change," 25%);

12. In construction, a productivity penalty multiplier applied to the various productivity penalty point estimates for various construction tasks ("Productivity impact," 1);

13. In construction, the ratio of the number of full-time-equivalent (FTE) at-risk self-employed workers imposing engineering control costs on host employers relative to the number of FTE at-risk employees ("Self employment," 4.6%);

14. The average number of minutes of training each at-risk worker needs to comply with the silica rule, with no baseline training other than that already required by the Hazard Communication standard ("Training time," 60); and

15. For establishments in general industry or maritime with 20 or more workers, the number of workers per control—only for controls that OSHA has estimated have 4 or more workers per control ("Workers per control," 4)[53].

Below is a list of the seven benefit input variables, with their Monte Carlo simulation name and the baseline simulation estimate in parentheses:

1. The baseline risk coefficient for the "lower" point estimate lung cancer silica exposure risk model ("ToxaChemica LC—lower," 0.06);

2. The baseline risk coefficient for the "higher" point estimate lung cancer silica exposure risk model ("Attfield LC—higher," 0.19);

3. The baseline risk coefficient for the selected lung-disease-other-than-cancer silica exposure risk model ("Park LDOC," 0.547);

4. The baseline risk coefficient for the selected end-stage-renal-disease silica exposure risk model ("Steenland Renal Disease," 0.269);

5. The value of a statistical life (VSL) to be applied to every fatality prevented by the silica rule ("VSL," $9,000,000);

[52] This cost of $421 is the point estimate for an initial health screening for current employees in general industry or maritime working in an establishment with between 20 and 499 employees. Proportional costs are estimated for initial health screenings for new hires, periodic health screenings, health screenings in construction, and for any combination of the above. Again, the various health screening costs are calculated in proportion to the $421 point estimate, based on the ratio of the various other point estimates to $421. Note that the cost of an examination by a specialist was not included in the simulations.

[53] Controls in establishments with 20 or more employees that OSHA has estimated have fewer than 4 workers per control were excluded from this simulation. For establishments in general industry or maritime with fewer than 20 employees and at least 2 workers per control, the number of workers per control was estimated at 50 percent of the number of controls for establishments with 20 or more employees. Controls for all establishments were constrained in the simulation not to be less than 1 worker per control, in accordance with OSHA's FEA cost estimates.

6. The annual increase in the magnitude of the benefits (in 2012 dollars) of the final rule ("Income growth rate," 2%); and

7. The average number of years of workplace exposure to respirable crystalline silica over a working lifetime ("Working years," 25.8)[54].

Table VII-C-1 below presents all input variables along with assumed distributional parameters. All distributions were assumed to be normally distributed, so these are fully specified by their mean and standard deviation. All mean values were set at the best estimates developed and presented earlier in this FEA. For cost variables other than "100 PEL compliance factor," which are all ratios multiplying a specific variable, the mean value was set at one. The record and data only allowed the Agency to estimate point values for cost variables, so the Agency applied a standard deviation of 25% of the mean (which means there is a 95% confidence interval of about 50% to 150% of the mean) as a reasonable range for exploring uncertainty in the analysis.

For benefit variables, in many cases OSHA had estimates of uncertainty from the risk studies used in the FEA that could be used in the simulations. Specifically, most of the risk models present an associated standard error to the estimated coefficient on cumulative exposure, which for each risk model is the variable OSHA is simulating. The one exception is Park LDOC, which does not present a standard error. Instead, the standard error for Park LDOC was selected such that the coefficient would just be statistically significant at the 95% confidence level. These coefficients were then simulated in the risk portion of the benefits model. The VSL standard deviation was based on the original estimation of the VSL in Viscusi and Aldy (2003). Finally, the two percent income growth rate factor has a standard deviation that was again chosen using the 25% above/below mean rule.

These benefit simulations with these given parameters were not constrained to have positive values for certain variables that a priori cannot be negative, such as the risk model coefficients. As a result, there are a few cases where the simulation generated either a negative coefficient on cumulative exposure in a specific risk model (i.e., yielding more fatalities as a result of reduced exposure to respirable crystalline silica) or the VSL was negative. These perverse simulation results were considered an artifact of the simulation method used and were simply dropped from the output dataset. An adjustment for this deletion of negative values was performed by dropping the same number of cases at the high end of each variable. Out of an original 3,000 simulations, 171 had such a negative number in some variable, with about 33% of the 171 simulations having a negative VSL, and the rest arising among the Park and ToxaChemica input variables, with Park having about twice as many perverse cases as ToxaChemica. OSHA initially performed 3,000 simulations to be sure to obtain 2,500 valid simulations, so after these 171 negative cases and the associated number of positive cases were dropped,[55]

[54] OSHA selected 25.8 years as the baseline simulation estimate because it is the mean of the high and low work-life estimates (45 and 6.6 work-years) that the Agency analyzed.

[55] In practice, only 161 positive cases were dropped because 10 of the negative cases also contained a high-end variable which would have (otherwise) caused the case to be dropped.

OSHA then randomly selected among the remainder to obtain the target of 2,500 simulations. These 2,500 benefit simulations were then randomly assigned one of the 2,500 cost simulations. These 2,500 pairs were then fixed to create net benefit statistics.

Table VII-C-1: Simulation Input Variables and Distribution Parameters

Variable	Mean	Standard Deviation
Cost Input Variables		
100 PEL compliance factor	0.5	0.125
CFM cost	1	0.25
Cleaning time	1	0.25
Control Plan Development	1	0.25
Control Plan Job Revision	1	0.25
Control Plan Communicate	1	0.25
Default respirator use factor	1	0.25
Industrial Hygienist daily rate	1	0.25
Initial cleaning per sq ft	1	0.25
Medical visit costs	1	0.25
Monitoring for change	1	0.25
Productivity impact	1	0.25
Self employment	1	0.25
Training time	1	0.25
Workers per control	1	0.25
Benefit Input Variables		
Steenland LC (lower)	0.06	0.015
Attfield LC (higher)	0.19	0.06
Park LDOC	0.547	0.279
Steenland Renal Disease	0.269	0.12
VSL	$9,000,000	$4,365,644
Income growth rate	2%	0.5%
Working years	25.8	6.5

Source: Office of Regulatory Analysis, OSHA

The results of the Monte Carlo simulation are reflected in the output variables, which are presented in three tables separately for costs, benefits, and net benefits. Table VII-C-2 shows total cost simulations, with total annualized costs for general industry and maritime at a 95% confidence interval of $309 million to $431 million. Total annualized construction costs simulations have a range of $561 million to $749 million, with overall total annualized cost simulations for the silica rule ranging from $899 million to $1,144 million.

Table VII-C-3 presents the outputs of the benefits simulations and shows a 95% confidence interval for general industry and maritime with the total number of mortality cases prevented of 56 to 207 and a mean of 119. The total general industry monetized benefits generated through this simulation, using the midpoint values, have a 95% confidence interval of $427 million to $4,906 million. For construction, the range for the total number of mortality cases prevented is 328 to 1,435, with construction monetized benefits ranging from $1,703 million to $20,566 million. The 95% confidence interval for the overall total number of mortality cases prevented is 388 to 1,638, while overall total monetized benefits from these simulations range from $2,155 million to $25,373 million.

Finally, Table VII-C-4, the simulated net benefits table, first repeats total costs and benefits from the previous tables for convenience and then presents the net benefits from the simulations. The 95% confidence interval for simulated net benefits is $1,147 million to $24,387 million.

Table VII-C-2: Simulated Cost Variable Outputs

Name	5%	Mean	95%
Self employment	2.7%	4.6%	6.5%
Workers per control	2.4	4.0	5.6
CFM cost	7.8	13.3	18.8
Cleaning time	5.9	10.0	14.1
Default respirator use factor	5.9%	10.0%	14.1%
Initial cleaning per sq ft	$0.09	$0.15	$0.21
100 PEL compliance factor	29.4%	50.0%	70.6%
Industrial Hygienist daily rate	$1,470	$2,500	$3,526
Medical visit costs	$248	$421	$594
Training time	35.3	60.0	84.6
Control Plan Development	2.4	4.0	5.6
Control Plan Revise	0.15	0.25	0.35
Control Plan Communicate	0.06	0.10	0.14
Monitoring for change	0.15	0.25	0.35
Gen Ind Cost	$309,140,300	$365,097,700	$431,009,000
Construction Cost	$561,312,500	$656,689,900	$749,343,300
Total Cost	$899,161,900	$1,021,788,000	$1,143,813,000

Source: Office of Regulatory Analysis, OSHA

Table VII-C-3: Simulated Benefit Output Variables

Name	5% Percentile	Mean	95% Percentile
Gen Ind Benefits_Higher	$671,791,042	$3,571,619,799	$7,806,158,202
Gen Ind Benefits_Lower	$168,777,293	$914,926,377	$2,094,610,447
Gen Ind Benefits_Mid	$427,426,230	$2,243,273,088	$4,906,340,763
Gen Ind LC Cases_Higher	13	35	61
Gen Ind LC Cases_Lower	3	8	15
Gen Ind LC Cases_Mid	10	22	35
Gen Ind LDOC Cases	15	58	98
Gen Ind Renal Cases	3	40	125
Gen Ind Total Mortality Cases	56	119	207
Gen Ind Total Morbidity Cases	109	411	702
Construction Benefits_Higher	$2,300,050,354	$12,042,586,238	$27,165,256,469
Construction Benefits_Lower	$1,105,324,199	$6,047,138,806	$14,561,486,636
Construction Benefits_Mid	$1,702,582,759	$9,044,862,522	$20,566,360,335
Construction LC Cases_Higher	57	130	210
Construction LC Cases_Lower	52	115	206
Construction LC Cases_Mid	73	123	180
Construction LDOC Cases	64	257	450
Construction Renal Cases	35	367	1,057
Construction Total Mortality Cases	328	747	1,435
Construction Total Morbidity Cases	132	532	932
Total Benefits_Higher	$3,026,575,526	$15,614,206,037	$34,775,822,804
Total Benefits_Lower	$1,287,571,863	$6,962,065,182	$16,738,343,292
Total Benefits_Mid	$2,154,967,268	$11,288,135,610	$25,372,512,854
Total LC Cases_Higher	71	166	270
Total LC Cases_Lower	55	123	222
Total LC Cases_Mid	85	144	212
Total_LDOC Cases	79	315	549
Total_Renal Cases	38	407	1,184
Total Mortality Cases	388	866	1,638
Total Morbidity Cases	241	943	1,636

Source: Office of Regulatory Analysis, OSHA

Table VII-C-4: Simulated Net Benefit Output Variables

Name	5% Percentile	Mean	95% Percentile
Total Benefits	$2,154,967,268	$11,288,135,610	$25,372,512,854
Costs	$899,379,409	$1,021,787,547	$1,143,820,593
Net Benefits	$1,147,481,346	$10,266,348,063	$24,387,240,151

Source: Office of Regulatory Analysis, OSHA

CHAPTER VIII: REGULATORY ALTERNATIVES

This chapter discusses several major regulatory alternatives to the final OSHA silica standard, as required by Executive Orders 13653 and 12866. The focus in this chapter is OSHA's estimate of the costs and benefits of these alternatives—in monetized terms where possible. A more comprehensive, but qualitative, discussion of the various possible alternatives to the final rule—including comments in the record concerning possible alternatives and the Agency's responses to them—is presented in Section XV of the preamble, Summary and Explanation of the Standards.

The presentation of regulatory alternatives in this chapter serves two important functions. The first is to demonstrate that OSHA explored less costly ways (compared to the final rule) to provide workers an adequate level of protection from exposure to respirable crystalline silica. The second is tied to the Agency's statutory requirement, which underlies the final rule, to reduce significant risk to the extent feasible. If OSHA had been unable to support its findings of significant risk and feasibility based on evidence presented during notice and comment, the Agency would then have had to consider regulatory alternatives that do satisfy its statutory obligations.

Each regulatory alternative presented here is described and analyzed relative to the final rule. Where relevant, the Agency notes that some regulatory alternatives are not permissible based on the required legal findings OSHA has made regarding significant risk and feasibility. The regulatory alternatives have been organized into four categories similar to those used in the PEA: (1) alternative PELs to the PEL of 50 $\mu g/m^3$, with corresponding changes to Table 1 in construction; (2) regulatory alternatives that affect ancillary provisions; (3) a regulatory alternative that would modify the methods of compliance; and (4) regulatory alternatives concerning when different provisions of the final rule would take effect.

Some commenters suggested a different alternative in which OSHA simply enforced the previous silica rules (which consist solely of different PELs), rather than adopting any regulatory alternative. However, OSHA has already been actively enforcing the previous silica rule, as well as undertaken significant silica compliance assistance initiatives (as described in Section III of the preamble), and has concluded that, within the context of the Agency's limited resources, it will not be able to achieve a significant increase in worker protection through increased enforcement of the previous rules, which would remain permanently in effect under this alternative. Furthermore, section (6)(b)(5) of the OSH Act requires that when the Agency engages in rulemaking to promulgate standards dealing with toxic materials or harmful physical agents such as respirable crystalline silica, the Agency must select the "standard which most adequately assures, to the extent feasible … that no employee will suffer material impairment of health or functional capacity." Given that OSHA has demonstrated that the final rule significantly reduces worker risk from silica exposure and that the final rule is both technologically and economically feasible, OSHA views the final rule as the rulemaking option that most adequately furthers the purposes of the OSH Act and concludes that merely preserving the status quo, perhaps with enhanced enforcement or compliance outreach, would be significantly less protective of workers and not supported by the weight of evidence in the rulemaking record.

THE FINAL RULE

OSHA selected a new PEL for respirable crystalline silica of 50 $\mu g/m^3$ for all industries covered by the final rule and developed and included Table 1 for many work activities within the construction sector. The final rule is based on the requirements of the Occupational Safety and Health Act (OSH Act) and court interpretations of the Act. For health standards issued under section 6(b)(5) of the OSH Act (29 U.S.C. 655(b)(5)), OSHA is required to promulgate a standard that reduces the risk of material impairment of health to the extent that it is technologically and economically feasible to do so. See Section II of the preamble, Pertinent Legal Authority, for a full discussion of the legal requirements for promulgating new health standards under the OSH Act.

OSHA conducted an extensive review of the literature on the adverse health effects associated with exposure to respirable crystalline silica. The Agency also developed estimates of the risk of silica-related diseases, assuming exposure over a working lifetime at the PEL and action level, as well as at OSHA's previous PELs. OSHA's preliminary analyses on these topics were presented in a background document entitled "Occupational Exposure to Respirable Crystalline Silica – Review of Health Effects Literature and Preliminary Quantitative Risk Assessment" (Document ID 1711) and its final findings are described in the preamble to the final rule in Section V, Health Effects, and Section VI, Final Quantitative Risk Assessment and Significance of Risk. The available evidence indicates that employees exposed to respirable crystalline silica well below the previous PELs are at increased risk of lung cancer mortality and silicosis mortality and morbidity. Occupational exposures to respirable crystalline silica also can result in the development of kidney and autoimmune diseases and in death from other nonmalignant respiratory diseases. As discussed in Section VI, Final Quantitative Risk Assessment and Significance of Risk, in the preamble, OSHA finds that worker exposure to respirable crystalline silica at the previous and new PELs constitutes a significant risk and that the final standard will substantially reduce this risk.

Section 6(b)(5) of the OSH Act (29 U.S.C. 655(b)(5)) requires OSHA to determine that its standards are technologically and economically feasible. OSHA's examination of the technological and economic feasibility of the final rule is presented in this FEA and summarized in Section VII of the preamble. For general industry and maritime, OSHA has concluded that the PEL of 50 μg/m^3 is technologically feasible for all affected industries. In other words, OSHA has found that engineering and work practice controls will be sufficient to reduce and maintain silica exposures to the PEL of 50 μg/m^3 or below in most operations most of the time in the affected industries in general industry, and the rule is also feasible in maritime (feasibility for maritime (shipyards) partly depends on it being subject to other standards regulating abrasive blasting). For those few operations where the PEL cannot be achieved even when employers install all feasible engineering and work practice controls, employers in general industry and maritime can supplement controls with respirators to achieve exposure levels at or below the PEL.

For construction, OSHA has determined that the engineering and work practice controls specified in Table 1 are feasible for all affected activities and in most cases will keep exposures at or below 50 μg/m^3 most of the time. For those few activities where the engineering and work practice controls specified in Table 1 are not sufficiently protective of worker health, Table 1 specifies respirator use to supplement those controls. A limited number of activities, such as tunneling and abrasive blasting, are not dealt with under Table 1, but are governed more directly by the PEL of 50 μg/m^3, as in general industry and maritime. For construction, while a few tasks like abrasive blasting and those specified on Table 1 as requiring respirators cannot achieve the PEL most of the time with engineering and work practice controls alone, OSHA has concluded that the PEL of 50 μg/m^3 is technologically feasible for the construction industry overall because most operations can meet the PEL using the specified controls in Table 1or under the traditional approach.

OSHA developed quantitative estimates of the compliance costs of the final rule for each of the affected industries. The estimated compliance costs were compared with industry revenues and profits to provide a screening analysis of the economic feasibility of complying with the revised standard and an evaluation of the potential economic impacts. Industries with unusually high costs as a percentage of revenues or profits were further analyzed for possible economic feasibility issues. After performing these analyses, OSHA has concluded in Chapter VI of this FEA that compliance with the requirements of the final rule will be economically feasible in every affected industry.

ALTERNATIVE PELS

As discussed in the Benefits section of Chapter VII of this FEA, incremental costs and benefits are those that are associated with increasing the stringency of the standard. A comparison of incremental benefits and costs provides an indication of the relative efficiency of the final PEL and the alternative PEL. Again, OSHA has conducted these calculations for informational purposes only and has not used these results as the basis for selecting the PEL for the final rule. The following discussion of Alternatives #1 and #2 is also included in the Estimates of Net Benefits section of Chapter VII, and Tables VIII-1 and VIII-2 correspond to Tables VII-7A and VII-7B, respectively.

Tables VIII-1 and VIII-2 show the costs and estimates of benefits of reducing exposure levels from the preceding PELs of 250 $\mu g/m^3$ (for construction and maritime) and 100 $\mu g/m^3$ (for general industry) to the final rule PEL of 50 $\mu g/m^3$ and to the first alternative PEL of 100 $\mu g/m^3$ (Alternative #1), all at the alternative discount rates of 3 and 7 percent. These tables also introduce a second alternative PEL. Under this second alternative (Alternative #2), also addressed in Tables VIII-1 and VIII-2, the PEL would be lowered from 50 $\mu g/m^3$ to 25 $\mu g/m^3$ for all industries covered by the final rule, while the action level would remain at 25 $\mu g/m^3$ (because of potential difficulties in accurately measuring exposure levels below 25 $\mu g/m^3$). For the construction sector under this second alternative, Table 1 requirements would also be modified to include respiratory protection for all workers covered under Table 1 (because none are expected to be mostly under 25 $\mu g/m^3$ for any of the tasks), and all these covered workers would be subject to the medical surveillance provision.[1]

Table VIII-1 breaks out costs by provision and estimates benefits by type of disease and by morbidity/mortality, while Table VIII-2 breaks out costs and benefits by major industry sector. As Table VIII-1 shows, at a discount rate of 3 percent, a PEL of 50 $\mu g/m^3$, relative to a PEL of 100 $\mu g/m^3$, imposes additional costs of $381 million per year.

Table VIII-2 continues this incremental analysis but with breakdowns between construction and general industry/maritime.

Tables VIII-1 and VIII-2 would demonstrate that, across all discount rates, there are estimated net benefits to be achieved by lowering exposures from the preceding PEL (250 $\mu g/m^3$ or 100 $\mu g/m^3$) to 100 $\mu g/m^3$ and then, in turn, lowering them further to 50

[1] As with general industry and maritime employees, the limited number of construction workers not covered by Table 1 and estimated to exceed 25 $\mu g/m^3$ currently, such as abrasive blasters, are also assumed to need respiratory protection under this alternative.

μg/m^3 and then to 25 μg/m^3.[2] Consistent with the previous analysis, net benefits decline across all increments as the discount rate for annualizing benefits increases. The incremental net benefit of reducing the PEL from 100 μg/m^3 to 50 μg/m^3 is greater than the incremental net benefit of reducing the PEL from 50 μg/m^3 to 25 μg/m^3 under both the 3 percent discount rate and the 7 percent discount rate.

However, the majority of the benefits and costs attributable to the final rule (PEL of 50 μg/m^3) are from the initial effort to lower exposures from the preceding PEL of 250 μg/m^3 in both construction and maritime to 100 μg/m^3, as shown in the 100 μg/m^3 column and the Incremental Costs/Benefits column in between the 50 μg/m^3 column and the 100 μg/m^3 column in Table VIII-1. The majority of the costs and benefits attributable to lowering exposures to 100 μg/m^3 are in the construction industry. There would not be any costs or benefits for general industry employers lowering exposures to an alternative of 100 μg/m^3 because the preceding PEL was already 100 μg/m^3, and OSHA assumes full compliance with the preceding PEL for purposes of this analysis, but a relatively small amount of costs and benefits would be attributed to maritime employers lowering exposures to the alternative of 100 μg/m^3 from the preceding PEL of 250 μg/m^3. Because a single standard will cover the general industry and maritime employers, those costs and benefits are grouped together in Table VIII-1 and VIII-2.

[2] The costs exceed the benefits using the 7 percent discount rate for the 100 μg/m^3 alternative, since quantified benefits for this FEA are based entirely on the various quantitative risk assessments, and the PEL for general industry is already set at 100 μg/m^3. As noted previously, the Agency is claiming no quantified benefits for the various ancillary provisions, such as medical surveillance.

Table VIII-1: Annualized, Costs, Benefits, and Incremental Benefits of OSHA's Final Silica Standard, Compared with 100 μg/m³ and 25 μg/m³ Regulatory Alternatives* Millions ($2012)															
	Regulatory Alternative #2						Final Rule						Regulatory Alternative #1		
	25 $\mu g/m^3$			Incremental Costs Between 50 and 25 $\mu g/m^3$			50 $\mu g/m^3$			Incremental Costs Between 100 and 50 $\mu g/m^3$			100 $\mu g/m^3$		
Discount Rate		**3%**	**7%**		**3%**	**7%**		**3%**	**7%**		**3%**	**7%**		**3%**	**7%**
Annualized Costs															
Engineering Controls		$661	$674		$0	$0		$661	$674		$241	$261		$421	$413
Respirators		$82	$82		$49	$49		$33	$33		$32	$32		$1	$1
Exposure Assessment		$141	$142		$45	$53		$96	$98		$32	$32		$64	$65
Medical Surveillance		$485	$492		$388	$392		$96	$100		$73	$75		$24	$24
Familiarization and Training		$96	$100		$0	$0		$96	$102		$0	$2		$96	$100
Regulated Area		$12	$12		$9	$9		$3	$3		$3	$3		$0	$0
Written Control Plan		$44	$47		$0	$0		$44	$47		$0	$1		$44	$47
Total Annualized Costs (point estimate)		**$1,521**	**$1,552**		**$491**	**$496**		**$1,030**	**$1,056**		**$381**	**$406**		**$649**	**$650**
Annual Benefits: Number of Cases Prevented	**Cases**			**Incremental Benefits Between 50 and 25 $\mu g/m^3$--Cases**			**Cases**			**Incremental Benefits Between 100 and 50 $\mu g/m^3$--Cases**			**Cases**		
Fatal Lung Cancers (midpoint estimate) **	178			54			123			62			62		
Fatal Silicosis & other Non-Malignant Respiratory Diseases**	438			113			325			154			170		
Fatal Renal Disease**	321			128			193			110			83		
Silica-Related Mortality**	937	9,340	5,119	295	**$2,942**	**$1,612**	642	$6,398	$3,507	326	$3,248	$1,783	316	$3,151	$1,724
Silicosis Morbidity**	1,040	2,593	1,478	122	**$304**	**$173**	918	$2,289	$1,305	440	$1,098	$626	477	$1,191	$679
Monetized Annual Benefits (midpoint estimate) **		**$11,933**	**$6,597**		**$3,246**	**$1,786**		**$8,687**	**$4,812**		**$4,346**	**$2,409**		**$4,341**	**$2,403**
Net Benefits**		**$10,412**	**$5,046**		**$2,755**	**$1,290**		**$7,657**	**$3,756**		**$3,965**	**$2,003**		**$3,692**	**$1,753**

Table VIII-2: Annualized Costs, Benefits and Incremental Benefits of OSHA's Final Silica Standard compared with 100 $\mu g/m^3$ and 25 $\mu g/m^3$ Regulatory Alternatives, by Major Industry Sector*

Millions ($2012)

	Regulatory Alternative #2						Final Rule						Regulatory Alternative #1		
	25 $\mu g/m^3$			Incremental Costs Between 50 and 25 $\mu g/m^3$			50 $\mu g/m^3$			Incremental Costs Between 100 and 50 $\mu g/m^3$			100 $\mu g/m^{3**}$		
Discount Rate		3%	7%		3%	7%		3%	7%		3%	7%		3%	7%
Annualized Costs															
Construction		$1,046	$1,059		$378	$387		$659	$673		$104	$120		$555	$553
General Industry/Maritime		$475	$492		$104	$109		$371	$384		$276	$286		$95	$97
Total Annualized Costs		**$1,521**	**$1,552**		**$491**	**$496**		**$1,030**	**$1,056**		**$381**	**$408**		**$649**	**$650**
Annual Benefits: Number of Cases Prevented	**Cases**			**Cases**			**Cases**			**Cases**			**Cases**		
Silica-Related Mortality															
Construction	754	$7,304	$4,119	209	$2,085	$1,143	545	$5,430	$2,976	233	$2,324	$1,276	311	$3,106	$1,700
General Industry/Maritime	183	$1,826	$1,001	86	$857	$470	97	$968	$531	93	$924	$506	4	$44	$24
Total	937	$9,340	$5,119	295	$2,942	$1,612	642	$6,398	$3,507	326	$3,248	$1,783	316	$3,151	$1,724
Silicosis Morbidity															
Construction	573	$1,430	$815	43	$107	$61	530	$1,323	$754	80	$201	$114	450	$1,122	$640
General Industry/Maritime	466	$1,163	$663	79	$197	$112	387	$966	$551	360	$898	$512	27	$69	$39
Total	1,040	$2,593	$1,478	122	$304	$173	918	$2,289	$1,305	440	$1,098	$626	477	$1,191	$679
Monetized Annual Benefits (midpoint estimate)				**Incremental Benefits Between 50 and 25 $\mu g/m^3$**						**Incremental Benefits Between 100 and 50 $\mu g/m^3$**					
Construction***		$8,945	$4,934		$2,192	$1204		$6,753	$3,730		$2,524	$1,391		$4,228	$2,340
General Industry/Maritime***		$2,988	$1,664		$1,054	$582		$1,939	$1,081		$1,821	$1,018		$113	$63
Total***		**$11,933**	**$6,598**		**$3,246**	**$1,786**		**$8,687**	**$4,812**		**$4,346**	**$2,409**		**$4,341**	**$2,403**
Net Benefits															
Construction***		$7,898	$3,875		$1,805	$817		$6,094	$3,056		$2,420	$1,271		$3,674	$1,787
General Industry/Maritime***		$2,512	$1,171		$950	$473		$1,564	$698		$1,545	$732		$18	($34)

Total* **	**$10,412**	**$5,046**	**$2,551**	**$1,290**	**$7,657**	**$3,756**	**$3,965**	**$2,003**	**$3,692**	**$1,753**

Source: OSHA, Directorate of Standards and Guidance, Office of Regulatory Analysis

* Benefits are assessed over a 60-year time horizon, during which it is assumed that economic conditions remain constant, except that the value of VSLs increase with income and then annualized. Costs are annualized over ten years, with the exception of equipment expenditures, which are annualized over the life of the equipment. Annualized costs are assumed to continue at the same level for sixty years, which is consistent with assuming that economic conditions remain constant for the sixty year time horizon.

**No benefits or costs related to achieving the preceding general industry PEL of 100 μg/m3 are included in these estimates.

As shown in Tables VIII-1 and VIII-2, going from the final rule to Regulatory Alternative #2 (PEL of 25 μg/m^3) is estimated to prevent, annually, an additional 282 silica-related fatalities and an additional 173 cases of silicosis. These estimates support OSHA's finding that there is significant risk remaining at the final PEL of 50 μg/m^3. However, The Agency has determined that a PEL of 25 μg/m^3 is not technologically feasible for most sectors or operations, and for that reason, has not selected it. See the introduction to Chapter IV of this FEA.

REGULATORY ALTERNATIVES THAT AFFECT ANCILLARY PROVISIONS

Section 6(b)(7) of the OSH Act, 29 U.S.C. 655(b)(7), requires standards to prescribe, where appropriate, the monitoring or measuring of employee exposure for the protections of employees. Section 6(b)(7) also requires the standards to prescribe, where appropriate, the type and frequency of medical exams to be provided by employers "in order to most effectively determine whether the health of [exposed] employees is adversely affected by such exposure." The final rule contains several ancillary provisions (provisions other than the PEL), including requirements for exposure assessment, medical surveillance, familiarization and training, regulated areas (in general industry and maritime), and a written exposure control plan.

OSHA's reasons for including each of the ancillary provisions are detailed in Section XV of the preamble, Summary and Explanation of the Standards. In particular, OSHA has determined that requirements for exposure assessment (or alternately, using specified exposure control methods for selected construction operations) provide a basis for ensuring that appropriate measures are in place to limit worker exposures. Medical surveillance is particularly important because workers exposed at levels below the new PEL are still at significant risk of death and illness (OSHA's decision not to lower the PEL further was due to limitations on technological feasibility, rather than a determination that significant risk was eliminated at the new PEL). Medical surveillance will allow for identification of respirable crystalline silica-related adverse health effects at an early stage so that appropriate intervention measures can be taken. Regulated areas and a written exposure control plan are important in part because they help limit exposure to respirable crystalline silica to as few employees as possible. Finally, worker training is necessary to inform employees of the hazards to which they are exposed, along with associated protective measures, so that employees understand how they can minimize potential health hazards. Worker training on silica-related work practices is particularly important in controlling silica exposures because engineering controls frequently require action on the part of workers to function effectively.

As shown in Table VIII-1, these ancillary provisions represent approximately $379 million (or about 37 percent) of the total annualized costs of the final rule of $1,030 billion (using a 3 percent discount rate). The three most expensive of the ancillary provisions are the requirements for medical surveillance, with annualized costs of $96 million; the requirements for training and familiarization, with annualized costs of $946 million; and exposure assessment, with annualized costs of $96 million.

The requirements for exposure assessment in general industry and maritime are triggered by the action level. The exposures of workers in construction for whom all Table 1 requirements have been met do not have to be assessed, but if Table 1 requirements are not met, the requirements for exposure assessment in construction would also be triggered by the action level. As described in the preamble, OSHA has defined the action level for the standard as an airborne concentration of respirable crystalline silica of 25 $\mu g/m^3$ calculated as an eight-hour time-weighted average. In this final rule, as in other OSHA health standards, the action level has been set at one-half of the PEL.

As explained in Chapter IV of this FEA, OSHA finds that proper implementation of engineering and work practice controls, particularly those specified in Table 1, will eliminate much of the variability in silica exposure that characterizes baseline conditions in the general industry, maritime, and construction sectors. OSHA recognizes, however, that some variability is unavoidable and uncontrollable even with such controls. Because of this variability of employee exposures to airborne concentrations of respirable crystalline silica, maintaining exposures below the action level should provide reasonable assurance that employees will not be exposed to respirable crystalline silica at levels above the PEL on days when no exposure measurements are made. Even when all measurements on a given day fall between the PEL and the action level, there is some chance that on another day, when exposures are not measured, actual exposure may exceed the PEL. When exposure measurements are below the PEL but above the action level, the employer cannot be certain that employees have not been exposed to respirable crystalline silica concentrations in excess of the PEL during at least some part of the work week. Therefore, requiring periodic exposure measurements when the action level is exceeded provides the employer with a reasonable degree of confidence in the results of the exposure monitoring.

As specified in the final rule, all workers in general industry and maritime exposed to respirable crystalline silica at or above the action level of 25 $\mu g/m^3$ are subject to the medical surveillance requirements. In the construction sector, medical surveillance is triggered by respirator use for 30 days or more per year (which generally corresponds to a risk of exposure above 50 $\mu g/m^3$ that prompted the Table 1 respirator requirement), For the final rule, the medical surveillance requirements will apply to an estimated 141,594 workers in general industry and 270,581 workers in construction. OSHA estimates that 989 possible ILO 2/0 silicosis cases will be referred to specialists annually as a result of this medical surveillance.

OSHA's conclusion is that the requirements triggered by the action level will result in a very real and necessary, but non-quantifiable, reduction in risk beyond that provided by the PEL alone. OSHA has determined that these ancillary provisions (periodic exposure assessment, medical surveillance in general industry/maritime) will reduce significant risk in at least three ways: (1) providing economic incentives to employers to reduce exposures to below 25 $\mu g/m^3$ to avoid the costs of medical surveillance and exposure monitoring; (2) helping to ensure the PEL is not exceeded;, and (3) providing medical exams to workers exposed at the action level, resulting in additional specialist referrals for X-ray findings consistent with silicosis and allowing employees who find out they have a silica-related disease to take action, such as changing jobs or wearing a respirator for additional protection. In sum, the ancillary provisions triggered by the action level in the final rule provide significant benefits to worker health by providing additional layers and types of protection to employees exposed to respirable crystalline silica. Not least, the OSH Act requires OSHA to adopt ancillary measures that further reduce a significant health risk and are feasible to implement (Pub. Citizen Health Research Grp., 796 F.2d 1479, 1505 (D.C. Cir. 1986). The Supreme Court has described an additional benefit to the type of ancillary provisions OSHA is including here: "It should also be noted that, in setting a permissible exposure level in reliance on less-than-perfect methods, OSHA would have the benefit of a backstop in the form of monitoring and medical testing. Thus, if OSHA properly determined that the permissible exposure limit should be set at 5 ppm, it could still require monitoring and medical testing for employees exposed to lower levels. By doing so, it could keep a constant check on the validity of the assumptions made in developing the permissible exposure limit, giving it a sound evidentiary basis for decreasing the limit if it was initially set too high. Moreover, in this way it could ensure that workers who were unusually susceptible to benzene could be removed from exposure before they had suffered any permanent damage." Indus. Union Dep't, AFL-CIO v. Am. Petroleum Inst., 448 U.S. 607, 657-658 (1980) (Benzene plurality opinion). Medical surveillance is particularly important for this rule because those exposed at the action level are still at significant risk of illness. OSHA did not estimate, and the benefits analysis does not include, monetary benefits resulting from early discovery of illness. OSHA's choice of using an action level for exposure monitoring of one-half of the PEL is based on the Agency's enforcement experience with other standards, including those for inorganic arsenic (29 CFR 1910.1018), ethylene oxide (29 CFR 1910.1047), benzene (29 CFR 1910.1028), and methylene chloride (29 CFR 1910.1052).

In response to comments on the proposed rule and PEA, among other changes discussed in Chapter V, OSHA added familiarization costs and increased estimated training costs in this FEA, and increased the cost of an industrial hygienist when conducting exposure monitoring. These changes, however, were the result of OSHA revisions to its cost estimates, not changes to the text of the regulation. Medical surveillance and exposure assessments were the ancillary provisions that were the focus of regulatory alternatives in the PEA. For these reasons, the Agency has examined four regulatory alternatives (Regulatory Alternatives #3, #4, #5, and #6) involving changes to one or the other of these two ancillary provisions. These four regulatory alternatives are defined below and the incremental cost impact of each is summarized in Table VIII-3. In addition, OSHA has qualitatively considered a regulatory alternative (Regulatory Alternative #7) that would remove all ancillary provisions.

Table VIII-3: Cost of Regulatory Alternatives Affecting Ancillary Provisions

	Cost			Incremental Cost Relative to Final Rule		
3% Discount Rate						
	Construction	**GI & M**	**Total**	**Construction**	**GI & M**	**Total**
Final Rule	$658,971,248	$370,810,530	$1,029,781,777	$0	$0	$0
Alternative 3: PEL=50; AL=50	$658,971,248	$299,027,174	$957,998,422	$0	-$71,783,356	-$71,783,356
Alternative 4: PEL=50; AL=25 with medical surveillance triggered by the PEL	$658,971,248	$347,860,049	$1,006,831,297	$0	-$22,950,480	-$22,950,480
Alternative5: PEL=50; AL=25 with medical exams annually	$725,253,746	$414,461,893	$1,139,715,639	$66,282,499	$43,651,363	$109,933,862
Alternative 6: PEL=50; AL=25 with medical surveillance triggered by the PEL and medical exams annually	$725,253,746	$357,463,770	$1,082,717,516	$66,282,499	-$13,346,760	$52,935,739

	Cost			Incremental Cost Relative to Final Rule		
7% Discount Rate						
	Construction	**GI & M**	**Total**	**Construction**	**GI & M**	**Total**
Final Rule	$672,602,589	$383,525,832	$1,056,128,421	$0	$0	$0
Alternative 3: PEL=50; AL=50	$659,564,804	$289,423,402	$948,988,206	-$13,037,785	-$94,102,430	-$107,140,215
Alternative 4: PEL=50; AL=25 with medical surveillance triggered by the PEL	$659,564,804	$347,005,802	$1,006,570,606	-$13,037,785	-$36,520,030	-$49,557,815
Alternative 5: PEL=50; AL=25 with medical exams annually	$724,872,111	$418,572,113	$1,143,444,225	$52,269,522	$35,046,281	$87,315,804
Alternative 6: PEL=50; AL=25 with medical surveillance triggered by the PEL and medical exams annually	$724,872,111	$349,890,676	$1,074,762,788	$52,269,522	-$33,635,156	$18,634,366

Source: OSHA, Directorate of Standards and Guidance, Office of Regulatory Analysis

Under Regulatory Alternative #3, the action level would be raised from 25 μg/m^3 to 50 μg/m^3 in the standard for general industry and maritime, while keeping the PEL at 50 μg/m^3. As a result, exposure monitoring and medical surveillance requirements would be triggered only if workers were exposed above 50 μg/m^3. No changes would be made to the construction standard because the medical surveillance trigger for that standard is respirator use, not an action level. As shown in Table VIII-3, Regulatory Alternative #3 would reduce the annualized cost of the final rule by about $72 million, using a discount rate of 3 percent, and about $107 million using a discount rate of 7 percent.

Under Regulatory Alternative #4, the action level in general industry and maritime would remain at 25 μg/m^3 but medical surveillance would now be triggered by the PEL, not the action level. As a result, medical surveillance requirements would be triggered only if workers in general industry and maritime were exposed above the PEL of 50 μg/m^3. No changes would be made to the construction standard. This alternative is similar to Alternative #3, but because the action level would remain lower, the amount of exposure monitoring would not decrease in Alternative #4 (applicable to general industry and maritime (and for construction employers following the exposure monitoring method of compliance)), exposure monitoring is required when levels exceed the action level). As shown in Table VIII-3, Regulatory Alternative #4 would reduce the annualized cost of the final rule by about $23 million, using a discount rate of 3 percent and about $50 million using a discount rate of 7 percent).

Under Regulatory Alternative #5, the only change to the final rule would be to the medical surveillance frequency requirements. Instead of requiring qualifying workers to be offered a medical check-up every three years, an annual medical check-up would be required to be offered. Assuming all workers will accept this offer, as shown in Table VIII-3, Regulatory Option #5 would increase the annualized cost of the final rule by about $110 million, using a discount rate of 3 percent (and by about $87 million, using a discount rate of 7 percent).

Under Regulatory Alternative #6, medical surveillance would be triggered by the PEL (in general industry and maritime), not the action level, and all workers (including in construction) subject to medical surveillance would be required to have a medical check-up annually rather than triennially. As shown in Table VIII-3, Regulatory Alternative #6 would cause a net increase of the annualized cost of the final rule by about $53 million, using a discount rate of 3 percent (and by about $19 million, using a discount rate of 7 percent).

OSHA has not calculated any changes in benefits for the medical surveillance alternatives in relation to the benefits of the final rule because OSHA did not quantify any benefits attributable to medical surveillance for the final rule. While the Agency expects there will be substantial benefits related to its ancillary provisions, it does not have the same quantitative basis for estimating benefits, and therefore does not have quantitative estimates for the benefits of the preceding four regulatory alternatives.

The final regulatory alternative affecting ancillary provisions, Regulatory Alternative #7, would eliminate all of the ancillary provisions of the final rule, including exposure assessment, medical surveillance, training, regulated areas, and the written exposure control plan. This alternative would be difficult to justify legally in light of 29 U.S.C. 655(b)(5) and (b)(7) along with case law requiring OSHA to use ancillary provisions to reduce significant risk remaining at the PEL when these provisions result in more than a de minimis benefit to workers (see Section II, Pertinent Legal Authority). In any event, it should be noted that elimination of the ancillary provisions does not mean that all costs for ancillary provisions would disappear. In order to meet the PEL, employers would still commonly need to conduct exposure monitoring, train workers on the use of controls, and set up some kind of regulated areas (in general industry and maritime) to indicate where respirator use would be required. It is also likely that some employers would follow the many recommendations to provide medical surveillance for employees and establish a written exposure control plan. OSHA has not attempted to estimate the extent to which the costs of these activities would be reduced if they were not formally required.

OSHA finds that the benefits estimated under the final rule will not be fully achieved if employers do not implement the ancillary provisions of the final rule. For example, OSHA believes that the effectiveness of the final rule depends on regulated areas and the written exposure control plan to further limit exposures and on medical surveillance to identify disease cases when they do occur. For construction work, the written exposure control plan is an integral part of the overall scheme to protect workers engaged in activities covered by Table 1. Without this provision, workers would risk exposures from the activities of others and exposure monitoring would need to be significantly increased to ensure protection for those workers.

Both industry and worker groups have recognized that a comprehensive standard, as opposed to a PEL alone, is needed to protect workers exposed to respirable crystalline silica. For example, the industry consensus standards for crystalline silica, ASTM E 1132 – 06, Standard Practice for Health Requirements Relating to Occupational Exposure to Respirable Crystalline Silica, and ASTM E 2626 – 09, Standard Practice for Controlling Occupational Exposure to Respirable Crystalline Silica for Construction and Demolition Activities, as well as the draft proposed silica standard for construction developed by the Building and Construction Trades Department, AFL-CIO, have each included comprehensive programs. These recommended standards include provisions for methods of compliance, exposure monitoring, training, and medical surveillance (Document ID 1466; 1504; 1509.

A REGULATORY ALTERNATIVE THAT MODIFIES THE METHODS OF COMPLIANCE

The final standard in general industry and maritime requires employers to implement engineering and work practice controls to reduce employees' exposures to or below the PEL. Where engineering and/or work practice controls are insufficient, employers are still required to implement them to reduce exposure as much as possible, and to supplement them with a respiratory protection program. Under the final construction standard, employers are given two options for compliance. The first option specifies, in Table 1 of the final rule, the exposure control methods and respiratory protection required for compliance when performing the specified task or operating the specified machines. Employers choosing this option must fully and properly implement the control methods and respiratory protection on the table to be considered to be in compliance with Table 1. The second option largely follows the requirements in the general industry and maritime standard: employers must conduct exposure monitoring and provide sufficient controls to ensure that their workers are not exposed above the PEL.

One regulatory alternative (Regulatory Alternative #8) involving methods of compliance would be to eliminate Table 1 as a compliance option in the construction sector. This was suggested by one commenter (Document ID 1950), as a means of promoting innovation.

As discussed in the Summary and Explanation in detail, OSHA fashioned the final rule as a sensible compromise between providing clear direction for employers, in a manner that reduces compliance burdens, and allowing for flexibility and innovation when desired. Table 1 is an option in the final rule that promotes both goals. While OSHA assumes that most establishments will choose to follow Table 1, in part to avoid the cost of monitoring, it is not a requirement. Employers are free to follow the other option (paragraph (d) of the standard) and conduct the required monitoring and devise their own means of complying with the PEL if they choose. To eliminate Table 1, therefore, would actually provide less flexibility and impose additional costs upon employers. OSHA therefore did not quantify costs or benefits for eliminating Table 1. Nonetheless, the Agency seriously doubts that there would be any additional benefits under Alternative #8, and concludes that removing the Table 1 option would significantly increase exposure monitoring costs by taking away a carefully crafted "safe harbor" provision from employers.

REGULATORY ALTERNATIVES THAT AFFECT THE TIMING OF THE

STANDARD

The final rule will become effective 90 days following publication of the final rule in the Federal Register. The provisions outlined in the construction standard will become enforceable one year following the effective date, except for those governing sample analysis (two years). The provisions set forth in the general industry and maritime standards will become enforceable two years following the effective date, with the exception that the engineering and work practice control requirements in the hydraulic fracturing industry will become enforceable five years after the effective date.

There are many theoretical options that OSHA could explore with regard to compliance dates. These include: requiring the fracking industry to follow the same compliance schedule as all other general industry and maritime employers; going back to the dates originally proposed (one year for engineering controls, two years for laboratories, six months for all other provisions); allowing more time for all employers to comply with the final rule; or allowing less time for all employers to come into compliance. These options are explored in detail in the Summary and Explanation for "Dates." As indicated in that discussion, there are technical issues, and there may be additional costs, associated with advancing the compliance dates ahead of those laid out in the final rule; in all cases, pushing back the compliance deadlines will also push back the onset of benefits generated by the final rule. OSHA has not quantified the costs or benefits of either advancing or delaying any of the compliance dates because the timing of the effective dates has the same percentage effect on both benefits and costs.

Chapter IX: Final Regulatory Flexibility Analysis

The Regulatory Flexibility Act, as amended in 1996, requires an agency to prepare a Final Regulatory Flexibility Analysis (FRFA) whenever it promulgates a final rule that is required to conform to the notice-and-comment rulemaking requirements of section 553 of the Administrative Procedure Act (APA). See 5 U.S.C. 601-612. For OSHA rulemakings, the FRFA analysis must contain:

1. a statement of the need for, and objectives of, the rule;

2. a statement of the significant issues raised by the public comments in response to the initial regulatory flexibility analysis, a statement of the assessment of the agency of such issues, and a statement of any changes made in the proposed rule as a result of such comments;

3. the response of the agency to any comments filed by the Chief Counsel for Advocacy of the Small Business Administration (SBA) in response to the proposed rule, and a detailed statement of any change made to the proposed rule in the final rule as a result of the comments;

4. a description of and an estimate of the number of small entities to which the rule will apply or an explanation of why no such estimate is available;

5. a description of the estimated reporting, recordkeeping and other compliance requirements of the rule, including an estimate of the classes of small entities which will be subject to the requirement and the type of professional skills necessary for preparation of the report or record; and

6. a description of the steps the agency has taken to minimize the significant economic impact on small entities consistent with the stated objectives of applicable statutes, including a statement of the factual, policy, and legal reasons for selecting the alternative adopted in the final rule and why each one of the other significant alternatives to the rule considered by the agency which affect the impact on small entities was rejected; and for a covered agency, as defined in section 609(d)(2), a description of the steps the agency has taken to minimize any additional cost of credit for small entities. 5 U.S.C. 604.

The Regulatory Flexibility Act further states that the required elements of the FRFA may be performed in conjunction with or as part of any other agenda or analysis required by any other law if such other analysis satisfies the provisions of the FRFA. 5 U.S.C. 605.

In addition to these elements, OSHA also includes, in this section, the recommendations from the Small Business Advocacy Review (SBAR) Panel and OSHA's responses to those recommendations.

While a full understanding of OSHA's analysis and conclusions with respect to costs and economic impacts on small entities requires a reading of the complete FEA and its supporting materials, this FRFA summarizes the key aspects of OSHA's analysis as they affect small entities.

THE NEED FOR, AND OBJECTIVES OF, THE RULE

Exposure to crystalline silica has been shown to increase the risk of several serious diseases. Crystalline silica is the only known cause of silicosis, which is a progressive respiratory disease in which respirable crystalline silica particles cause an inflammatory reaction in the lung, leading to lung damage and scarring, and, in some cases, to complications resulting in disability and death. In addition, many well-conducted investigations of exposed workers have shown that exposure increases the risk of mortality from lung cancer, chronic obstructive pulmonary disease (COPD), and renal disease. OSHA's detailed analyses of the scientific literature and silica-related health risks were presented in OSHA's Review of Health Effects Literature and Preliminary QRA in the NPRM (Document ID 1711, pp. 7-229), and are included in Section VI Significance of Risk in the preamble to the final rule.

OSHA reviewed numerous studies and found that they all demonstrated positive, statistically significant exposure-response relationships between exposure to crystalline silica and lung cancer mortality. (See the Health Risk section in the preamble for more detail). In addition, OSHA noted that in 2009 the International Agency for Research on Cancer (IARC) reaffirmed its finding that respirable crystalline silica is a human carcinogen, identifying in its analysis an overall positive exposure-response relationship between cumulative exposure to crystalline silica and lung cancer mortality (see Section VI. Significance of Risk; Document ID 1711, pp. 269-292). Based on studies, OSHA estimates that the lifetime lung cancer mortality excess risk associated with 45 years of exposure to respirable crystalline silica ranges from 11 to 54 deaths per 1,000 workers at the preceding general industry PEL of 100 $\mu g/m^3$ respirable crystalline silica, with that risk reduced to 5 to 23 deaths per 1,000 workers at the new PEL of 50 $\mu g/m^3$ respirable crystalline silica.

OSHA has also quantitatively evaluated the mortality risk from non-malignant respiratory disease, including silicosis and COPD. Risk estimates for silicosis mortality are based on a study by Mannetje et al. (2002b, Document ID 1089), as reanalyzed by ToxaChemica, Inc. (2004, Document ID 0469), which pooled data from six worker cohort studies to derive a quantitative relationship between silica exposure and death rate for silicosis. For non-malignant respiratory disease generally, risk estimates are based on an epidemiologic study of diatomaceous earth workers, which included a quantitative exposure-response analysis (Park et al., 2002, Document ID 0405). For 45 years of exposure to the preceding general industry PEL, OSHA's estimates of excess lifetime risk are 11 silicosis deaths per 1,000 workers for the pooled analysis and 85 non-malignant respiratory disease deaths per 1,000 workers based on Park et al.'s (2002) estimates. At the new PEL, OSHA estimates silicosis and non-malignant respiratory disease mortality at 7 and 44 deaths per 1,000, respectively. As noted by Park et al. (2002), it is likely that silicosis as a cause of death is often misclassified as emphysema or chronic bronchitis; thus, Mannetje et al.'s analysis of deaths may tend to underestimate the true risk of silicosis mortality, while Park et al.'s (2002) analysis would more fairly capture the total respiratory mortality risk from all non-malignant causes, including silicosis and COPD.

OSHA also identified five studies that quantitatively described relationships between exposure to respirable crystalline silica and silicosis morbidity, as diagnosed from chest radiography. Based on the results of these studies, OSHA estimates a cumulative risk for silicosis morbidity of 60 to 773 cases per 1,000 workers for a 45-year exposure to the preceding general industry PEL of 100 μg/m^3 respirable crystalline silica, and 20 to 170 cases per 1,000 workers exposed at the new PEL of 50 μg/m^3 (see Section VI. Significance of Risk, Table VI-1).

OSHA's estimates of crystalline silica-related renal disease mortality risk are derived from an analysis by Steenland et al. (2002, Document ID 0448), in which data from three cohort studies were pooled to derive a quantitative relationship between exposure to silica and the relative risk of end-stage renal disease mortality. The cohorts included workers in the U.S. gold mining, industrial sand, and granite industries. OSHA's analysis for renal disease mortality shows estimated lifetime excess risk of 39 deaths per 1,000 workers at the preceding general industry PEL of 100 μg/m^3 respirable crystalline silica, and 32 deaths per 1,000 workers exposed at the new PEL of 50 μg/m^3 (see Section VI. Significance of Risk, Table VI-1).

The objective of the final rule is to reduce the numbers of fatalities and illnesses occurring among employees exposed to respirable crystalline silica in general industry, maritime, and construction sectors. This objective will be achieved by requiring employers to install engineering controls where appropriate and to provide employees with the equipment, respirators, training, exposure monitoring, medical surveillance, and other protective measures necessary for them to perform their jobs safely. The legal basis for the rule is the responsibility given to the U.S. Department of Labor through the Occupational Safety and Health Act of 1970 (OSH Act). The OSH Act provides that, in promulgating health standards dealing with toxic materials or harmful physical agents, the Secretary “shall set the standard which most adequately assures, to the extent feasible, on the basis of the best available evidence, that no employee will suffer material impairment of health or functional capacity even if such employee has regular exposure to the hazard dealt with by such standard for the period of his working life.” 29 U.S.C. 655(b)(5).

See Section II of the preamble for a more detailed discussion.

SUMMARY OF SIGNIFICANT ISSUES RAISED BY COMMENTS ON THE INITIAL REGULATORY FLEXIBILITY ANALYSIS (IRFA) AND OSHA’S ASSESSMENT OF, AND RESPONSE TO, THOSE ISSUES

Small business representatives commented on all aspects of this rule, and their comments and OSHA’s responses are covered throughout the preamble and this FEA. This section of the FRFA focuses only on comments that directly concern this FRFA or the screening analysis that precedes it.

One commenter questioned the use of SBA definitions for small businesses, arguing that some definitions include firms with 500 employees or more, which, according to the commenter, are too large to constitute “small” businesses. The commenter commended OSHA for also including an analysis of very small entities with fewer than 20 employees (Document ID 2351, Attachment 1, p. 8). OSHA determined that both the analysis of the impacts on SBA-defined small entities and the analysis of the impacts on very small entities (those with fewer than twenty employees) are useful and important for examining small business impacts.

Two commenters were concerned that their industries had not been covered in the IRFA. The American Railroad Association noted that small railroads had not been covered (Document ID 2366, Attachment 1, p. 4). The commenter is correct that OSHA did not examine small entities in this sector in the IRFA. For this FEA, OSHA has added a discussion of small entities in the railroad industry to Chapter VI, Economic Impacts. The Sorptive Minerals Institute also stated that their industry was not covered in the IRFA (Document ID 4230, Attachment 1, p. 16). As discussed in Chapter IV, the sorptive mineral industry was covered as part of a larger industry. In any case, OSHA has excluded exposures that result from the processing of sorptive clays from the scope of the final rule.

Many commenters were concerned that OSHA had not used economic data that included the effects of the recent “great recession”. This issue was addressed in the Chapter VI, Introduction, but some commenters specifically discussed this topic in reference to small entities (Document ID 1822, Attachment 1, p. 1; 2187, Attachment 1, p. 2; 2322, p. 13; 3433, p. 8; 4231, Attachment 1, pp. 15-17). Complete data of the kind that OSHA needs for a thorough analysis of economic impacts were not yet available at the time the PEA was developed. As discussed in Chapter II, Industrial profile, this FEA, including this FRFA, uses 2012, the most recent year with complete data, as a base year and used average profits from years including the recession and surrounding years.

Some commenters were concerned with OSHA's estimates of small business profits. One commenter pointed out that OSHA had relied entirely on C corporation data, even though many affected firms might be S corporations, partnerships or sole proprietorships (Document ID 2296, Attachment 1, p. 23). This is true, but there are no published data on S corporation, partnership, or sole proprietorship profits, and thus C corporation data is the best available data. As another commenter pointed out, reported profits of small business are generally lower than the total returns earned by owners who also act as executives for their firms. The same commenter explained that smaller firms have a great deal of flexibility in deciding what portions of entity gains are reported as profits, what portions are reported as management salaries, and what portions are reported as management bonuses (Document ID 2163, Attachment 1, p. 7). As a result, it is possible that OSHA has underestimated small firm profits and thus overestimated potential impacts on profits.

Stuart Sessions argued that OSHA should have analyzed whether smaller firms have higher or lower profits than larger firms (Document ID 4231, Attachment 1, pp. 11-12). The limited data supplied by Mr. Sessions, however, did not show that small firms either had larger or smaller profits than bigger firms on an across-industry basis (Document ID 4231, Attachment 1, p. 11). Mr. Sessions developed an economic model that used a combination of multiple data sources to determine profit rates of small firms (RMA and BizMiner). In Chapter III Industrial Profile, Revenue and Profit, OSHA discusses why the Agency's analysis does not use these alternate data sources suggested by Mr. Sessions. Mr. Sessions, testifying on behalf of the Construction Industry Safety Coalition, also testified that the use of data aggregated to the four-digit NAICS code level in OSHA's analysis shields small businesses from being captured properly in the analysis, and that "the analysis at the six-digit level would show substantial impacts for masonry contractors who are small business …, which the analysis currently doesn't show" (Document ID 3580, Tr. 1402). Mr. Sessions further claimed that, even though OSHA analyzed the costs to employers with 20 or fewer employees, the analysis still "hid" a lot of small businesses (Document ID 3580, Tr. 1402). The use of Internal Revenue Service's Corporation Source Book profit data at a four-digit NAICS code level is explained in Chapter III along with a discussion explaining why alternative data sources suggested by Mr. Sessions are not applied in this FEA.

At least one commenter argued that OSHA might have inaccurately estimated small firm revenues as a result of OSHA's method of estimating revenues for years when Census data are not available (Document ID 4231, Attachment 1, pp. 15-17). This argument is now moot, as OSHA is using data from the 2012 Economic Census, and is not using estimated revenues in this analysis.

Some commenters argued that OSHA had not adequately accounted for diseconomies of scale in small firms (Document ID 4231, Attachment 1, pp. 2-5; 2307, Attachment 10, p. 25; 2322, Attachment 1, pp. 15-16). During his testimony, Stuart Sessions testified that it was his "guess . . . that small businesses are substantially more likely to be noncompliant currently than large businesses," and requested that OSHA conduct additional analysis to "handle the differential compliance rates between small and large business" (Document ID 3580, Tr. 1399). As discussed in Chapter V, OSHA has changed its approach to estimating costs of small firms to account for diseconomies of scale in small firms. However, there is no evidence, other than Mr. Sessions's "guess," that small firms are less compliant than large firms.

Janet Kaboth, testifying on behalf of a small company in the brick manufacturing industry, stated that small businesses are more impacted by the rule because they have more difficulty accessing capital to upgrade engineering controls:

> "[Engineering controls] must be purchased and paid for in the first year of compliance. … It is extremely unlikely that a small entity such as Whitacre Greer would be able to obtain a bank loan … for something that does not reduce costs or increase revenue and additionally adds cost (Document ID 3589, Tr. 3397-3399).

As discussed in Chapter VI, Economic Impacts, small firms will typically be able to pay for the first year costs of engineering controls from a single year's profits. Thus, there is no need to account for possible difficulties in obtaining credit.

A different commenter requested that OSHA provide additional guidance in Table 1 of the construction standard as a way to mitigate the impact on small businesses (Document ID 2322, p. 6). OSHA has done so, and agrees that it will likely ease compliance for small construction businesses because it provides them with task-specific guidance that will allow them to avoid more complicated exposure monitoring processes.

Many companies, associations, and private individuals submitted comments requesting a new SBAR Panel based a number of changes that have occurred since the SBAR Panel for this rule was held in 2003. The first and most common concern was that the economic data and information gathered during the Panel have become outdated and do not represent the dramatic changes in economic conditions that have resulted from the boom and bust economic cycle that occurred in the years following 2003 (Document ID 2224, p. 2; 2004, p. 1; 3580, Tr. 1274-1276; 1779, p. 2; 1767, p. 2; 1783, p. 1; 2140, p. 1; 3495, p. 2; 1798, p. 6; 1811, pp. 1-2; 2023, p. 1; 2222, p. 1; 2224, p. 2; 2230, p. 1; 2248, Attachment 1, p. 5; 2294, p. 2; 2300, p. 2; 2305, p. 13; 2279, p. 11; 2289, p. 9; 2391, p. 2; 3275, pp. 2-3; 2075, p. 4; 2083, p. 1; 2114, Attachment 1, p. 2; 2150, p. 2; 2170, Attachment 1, p. 1; 2210, Attachment 1, pp. 1-2; 4194, p. 5; 4210, Attachment 1, p. 2; 4217, Attachment 1, p. 7). Some commenters claimed that their industries have not recovered from the recession of 2008 and feel that their economic circumstances as small entities have changed as a result (Document ID 1779, p. 2; 1767, p. 2; 1783, p. 1; 2140, p. 1; 3495, p. 2).

OSHA conducted the SBAR Panel early in the rulemaking process in order to address small business concerns during the development of the proposed rule. The Agency used information gathered during the SBAR Panel to make significant changes to the proposed rule itself, as well as to the cost, impact, and other analyses contained in the proposal. OSHA's proposal contained six pages of tables that described every recommendation from the SBAR Panel, along with the Agency's responses.

OSHA's extensive rulemaking process included small business feedback not only from the original SBREFA review in 2003, but also from the subsequent written comment period in 2013 and 2014, as well as from the public hearings held in 2014. The rulemaking record shows the major issues that arose with respect to technological feasibility, costs, economic feasibility, and possible alternatives to the proposed rule represented largely the same issues addressed by small entity representatives (SERs) in 2003. To the extent there may be new issues that have arisen since the SBAR Panel made its recommendations, OSHA is confident that commenters, including small entities and the Small Business Administration's Office of Advocacy, were able to raise those issues and express whatever concerns they had about them later in the rulemaking process. OSHA has addressed comments regarding recent and current economic conditions under which small businesses are operating by considering this information in developing the final rule and supporting analyses.

A second concern raised by commenters who were advocating for OSHA to hold a new SBAR Panel, related to the changes in technology and work practices that have taken place over the last ten years. For example, one commenter claimed that the comments of the SERs were not reflective of the greater use of tools with dust collection capability, and other devices currently being used that release water at the point of cutting, to control silica dust (Document ID 2210, Attachment 1, p. 1). However, the commenters who wanted OSHA to account for improved technology and work practices did not generally provide information to supplement or update the information OSHA received from the SERs, despite opportunities to do so.

While there has been progress in the development and adoption of technologies that reduce silica exposures, the record (including comments from the commenters calling for a new Panel) brought out few, if any, fundamentally new technologies for reducing silica exposure. In any event, the advancement of technologies that would improve silica control or reduce the cost impact of the final rule would not necessitate a new SBAR panel.

There were also a number of construction firms that expressed disappointment at not being able to comment on Table 1, as presented in the proposed rule, prior to the proposed rule being issued (Document ID 2187, p. 22; 4217, Attachment 1, p. 7; 3580, Tr. 1274-1276). It is typical for OSHA to modify a rule as a result of the SBREFA process. The SBREFA process is a one-time requirement, not a requirement to conduct a new Panel every time a rule is altered in response to SBAR Panel recommendations. The commenters, who did have the opportunity to comment on Table 1 once it was proposed, did not present any compelling argument regarding how the timing of their opportunity to comment impacted their ability to communicate their recommendations about Table 1 to OSHA. The Agency notes that it has made a number of significant changes to Table 1 since the proposal, most in response to post-proposal comments, so it is clear that commenters had ample opportunities to recommend improvements to Table 1.

No SERs from the hydraulic fracturing industry were included in the 2003 SBAR panel. OSHA did not determine that this industry would be affected by this rule until the preparation of the NPRM and the PEA. As a result, OSHA has received comments from associations and businesses requesting a new SBAR Panel that would allow a more detailed analysis of the potential impacts on small entities in this industry. Commenters pointed out that the unique economic circumstances of the hydraulic fracturing industry were not presented for public comment or analysis on regulatory alternatives and small business impacts during the Agency’s 2003 SBAR Panel (Document ID 2301, Attachment 1, p. 63; 3589, pp. 15-16; 2288, p. 5).

OSHA is not required to assure that every industry affected by a rule is represented on the Panel by a SER. The hydraulic fracturing industry had extensive opportunities to comment throughout this rulemaking process. In fact, a number of commenters, including several trade associations, submitted comments and testified at the hearing, providing extensive analysis of the hydraulic fracturing industry for the record. OSHA sees no indication that the record would be better developed by convening a different SBAR panel with a SER from the hydraulic fracturing industry. OSHA has, however, extended the compliance deadline for these firms to install the required engineering controls required by this final rule to five years; three more years than for establishments in general industry and four more years than for construction firms.

RESPONSE TO COMMENTS BY THE CHIEF COUNSEL FOR ADVOCACY OF THE SMALL BUSINESS ADMINISTRATION AND OSHA'S RESPONSE TO THOSE COMMENTS

The Chief Counsel for Advocacy of the Small Business Administration ("Advocacy") provided OSHA with comments on this rule on February 11, 2014 (Document ID 2349). Advocacy provided comment on OSHA's risk assessment and benefits analysis; technological feasibility analysis; cost analysis; current economic conditions; preferred alternatives; and procedural issues.

Risk Assessment and Benefits Issues

With respect to the risk assessment, Advocacy was concerned that OSHA was attributing benefits to reducing the PEL to 50 $\mu g/m^3$ that perhaps would better be attributed to eliminating exposures above the existing PEL of 100 $\mu g/m^3$ (Document ID 2349, pp. 3-4). OSHA does not think this is the case. As discussed in the section on significant risk, OSHA did not assess the risk of silica exposure by attributing existing known cases of silicosis or any other disease to various PELs. Rather, OSHA examined risk assessment studies that assessed the long term consequences of various levels of exposure to silica. Such studies focus on estimating the morbidity and mortality that result from changing lifetime exposure levels from the preceding PELs of 100 $\mu g/m^3$ in general industry and 250 $\mu g/m^3$ in construction to the new PEL of 50 $\mu g/m^3$.

Advocacy also expressed concerns about the accuracy of older exposure data (Document ID 2349, p. 4). OSHA's exposure profile, used for examining feasibility and benefits, now shows only exposures measured after 1990 and includes data from OSHA's OIS system for 2011 to 2014.

Advocacy was also concerned that OSHA might not have adequately accounted for varying risk levels associated with different types of silica (Document ID 2349, p. 4). OSHA carefully considered this issue in the risk assessment section and found there were insufficient data to demonstrate significant risk for silica exposures that result from processing sorptive clays. As a result, OSHA excluded this processing activity from the scope of the final standard. OSHA found that, while the risk from other forms of silica may vary, there is evidence of significant risk for all of the other forms of respirable crystalline silica.

Advocacy also reported that small business representatives were concerned that “OSHA’s assumption that silica exposure occurs over a working life of eight hours per day for 45 years does not reflect modern working conditions” (Document ID 2349, p. 4). OSHA is required by the OSH Act to consider the risk of a hazard over a worker’s entire working life. See 29 U.S.C. 655(b)(5). In Chapter VII of this FEA, OSHA also examined other possible average tenure assumptions and found that varying the tenure assumption made little difference to estimated benefits. With lower r tenure OSHA estimates lower morbidity but higher fatalities, such that the net effect was higher estimated benefits.

Advocacy also reported that small business representatives “noted the uncertainty of assessing silica-related risk because of confounding factors, such as smoking or exposure to other chemicals, and the long latency period for silica-related illness to appear” (Document ID 2349, p. 4). OSHA notes in Section VI, Significance of Risk, in the preamble to the final rule that study after study finds that incidence of the diseases caused by exposure to silica rises with increasing exposures to silica. In order to see this type of result, and for those results to be driven by smoking as a confounding factor, it would be necessary not just that the silica-using population smoke more than the comparable non-silica using population, but also that smoking rates rise as silica exposures increase. This seems very unlikely and there is no evidence in the record that this is the case.

Technological Feasibility Issues

Advocacy noted that small business representatives had raised many concerns about whether the controls OSHA indicated as appropriate to achieve the PEL were feasible in all circumstances and could, in fact, allow an employer to fully achieve the PEL (Document ID 2349, p. 4). OSHA has thoroughly examined all comments on this kind of issue across all affected industries in Chapter IV of this FEA, and OSHA notes that employers may raise infeasibility as a defense in enforcement actions[1]. Advocacy also noted that small business representatives were concerned about whether available methods of measuring exposure were sufficiently accurate to correctly measure the action level and PEL (Document ID 2349, p. 4). OSHA has explained in Chapter IV of this FEA why existing equipment is sufficiently accurate to correctly measure airborne respirable silica at the levels established by the new PEL and action level.

Advocacy said that one small business representative “noted that increasing the volume of air needed for additional ventilation could result in a violation of a facility’s air permit”

[1] An employer can establish an affirmative defense of infeasibility if it shows that: (1) compliance with the requirements of a standard is impossible or would prevent performance of required work; and (2) it took reasonable alternative steps to protect employees or there are no alternative means of employee protection available. Establishing this defense will excuse the employer from a citation that has otherwise been documented. *See Field Operations Manual*, CPL 02-00-159, Ch. 5, Sec. VI (Oct. 1, 2015).

(Document ID 2349, p. 5). While the Agency does not believe that most small employers exhaust large enough volumes of air that the additional ventilation required by this final standard will result in needing to alter air permits, OSHA does acknowledge that this may be an issue for some employers. In order to reduce the burden, should this be the case, OSHA has given general industry employers an additional year to meet the PEL, and has added costs for firms subject to air permitting requirements to alter their permits to more fully assess the economic feasibility of this rule.

Advocacy also said that one small business representative "noted that creating regulated areas is not feasible in many open-design facilities" (Document ID 2349, p. 5). Regulated area requirements have been a part of OSHA health standards for many years and employers have consistently found ways to make them work. The Agency does not expect that establishing a regulated area for silica would be any more difficult than establishing such an area for any of the other substances for which OSHA has regulated area requirements. In addition, OSHA does not have a regulated area requirement in construction where workplaces (such as in road building or repair) are more mobile.

Cost Issues

Advocacy stated that small business representatives generally felt that OSHA underestimated costs, and were particularly concerned about OSHA's "cost per exposed worker" approach and OSHA's estimates of the number of workers whose exposures are controlled per engineering control (Document ID 2349, p. 5). The specific methodological issues that Advocacy mentions are issues for OSHA's general industry and maritime cost estimates, but not for construction cost estimates because the cost estimation methodologies for the construction sector are quite different and do not use the "cost per exposed worker" approach. OSHA has provided detailed responses to comments on costs in Chapter V. In general industry and maritime, OSHA continues to use the cost per exposed worker approach and defends this approach in Chapter V. OSHA has lowered its estimate of the number of workers whose exposures are reduced per engineering control in response to comments from small business representatives and others.

Advocacy also noted that small business representatives objected to OSHA focusing on the incremental cost of moving from the preceding PELs to the new PEL. Advocacy reported that small business representatives believed OSHA should have included the costs of reaching the preceding PEL in its analysis (Document ID 2349, p. 5). Contrary to Advocacy's suggestion, OSHA did not conduct the analysis this way because it would require an assumption that employers are not complying with OSHA's existing requirements to meet the preceding PEL, but would now choose to comply with a more stringent requirement. OSHA's exposure profiles do indicate that many employers are failing to meet the preceding PELs, but the question that the Agency has to address with this analysis for this rulemaking is whether OSHA should require employers to meet a lower PEL than the preceding PEL. The costs of meeting the preceding PEL are not relevant to that decision.

Issues Concerning Current Economic Conditions

Advocacy reported that "small business representatives stated that OSHA was using older economic data that does not reflect current economic conditions, and [thus] that OSHA's cost pass-through assumptions are unrealistic" (Document ID 2349, p. 5). For this FEA, OSHA is using 2012 as the base year for economic data and includes data from the recent recession in analyzing average industry profits and historical changes in profits and prices. OSHA has updated its findings on the ability of firms to pass costs on to buyers in light of the updated data, resolving Advocacy's concern on this issue.

Regulatory Alternatives

Advocacy commended OSHA for following the advice of small business representatives and adopting the Table 1 approach for the construction sector, but urged OSHA to make the table clearer, more workable, and more specific, and to relieve employers of any remaining duty to conduct exposure monitoring when engaged in Table 1 tasks (Document ID 2349, p. 6). OSHA has revised Table 1, as Advocacy and small business representatives suggested, to provide employers with a clear alternative to exposure monitoring and to provide greater clarity and specificity in the descriptions of controls.

Advocacy also urged OSHA to consider the option of leaving the PEL unchanged and instead improving enforcement, noting that this was the option most favored by small business representatives (Document ID 2349, p. 3). However, the OSH Act commands OSHA to protect workers from harmful substances by setting

> the standard which most adequately assures, to the extent feasible, on the basis of the best available evidence, that no employee will suffer material impairment of health or functional capacity even if such employee has regular exposure to the hazard dealt with by such standard for the period of his working life." 29 U.S.C. 655(b)(5).

The record does not indicate that workers are currently protected in accordance with the Act. There are currently two entirely different PELs, 100 $\mu g/m^3$ in general industry and 250 $\mu g/m^3$ in construction. The record does not suggest either that employers in construction cannot feasibly reach a lower PEL or that there is no significant risk below 250 $\mu g/m^3$. The record shows that most employers in construction currently reach a PEL of 50 μg/m^3 most of the time (see Chapter IV) and that it is economically feasible to do so (see Chapter VI).

OSHA did consider the option of lowering the construction PEL to 100 μg/m^3 and leaving the general industry PEL unchanged. However, this action would not be in accordance with the OSH Act given that there is still significant risk at a PEL of 100 μg/m^3 and that a lower PEL is both technologically and economically feasible. Moreover, as discussed in the regulatory alternatives section, the adopted option of a PEL of 50 μg/m^3 for both general industry and construction results in greater estimated net benefits. As shown in OSHA's risk assessment, there is still significant risk of material impairment of health at levels all the way down to a lower PEL of 25 μg/m^3, but OSHA found compliance with the lower PEL of 25 μg/m^3 to be technologically infeasible for all industries.

Finally, Advocacy urged OSHA to consider the option of abandoning the hierarchy of controls, which is OSHA's longstanding policy of preferring engineering controls and administrative controls over personal protective equipment such as respirators (Document ID 2349, pp. 4-5). This issue is addressed in the summary and explanation section discussion of the methods of compliance provision. It should also be noted that OSHA defines technological feasibility in terms of what can be accomplished with engineering controls, not in terms of what can be accomplished with respirators.

Issues with Respect to Small Business Participation

Advocacy also expressed concern that small businesses did not have adequate opportunity for participation in the rulemaking process and that the SBAR panel was held over ten years before the proposed rule was issued (Document ID 2349, p. 7). OSHA responded to these concerns in section two of this FRFA.

A DESCRIPTION AND ESTIMATE OF THE NUMBER OF SMALL ENTITIES TO WHICH THE RULE WILL APPLY

OSHA has analyzed the impacts associated with this final rule, including the type and number of small entities to which the standard will apply. In order to determine the number of small entities potentially affected by this rulemaking, OSHA used the definitions of small entities developed by the Small Business Administration (SBA) for each industry.

OSHA estimates that approximately 646,000 small business or government entities would be affected by the silica standard. Within these small entities, roughly 1.4 million workers are exposed to crystalline silica and would be protected by this final standard. A breakdown, by industry, of the number of affected small entities is provided in Table III-6 in Chapter III of this FEA.

OSHA estimates that approximately 579,000 very small entities would be affected by the silica standard. Within these very small entities, roughly 785,000 workers are exposed to crystalline silica and would be protected by the standard. A breakdown, by industry, of the number of affected very small entities is provided in Table III-7 in Chapter III of this FEA.

A DESCRIPTION OF THE ESTIMATED REPORTING, RECORDKEEPING, AND OTHER COMPLIANCE REQUIREMENTS OF THE RULE

Tables IX-1 and IX-2 show the average costs of the silica standard and the costs of compliance as a percentage of profits and revenues by NAICS code for, respectively, small entities (classified as small by SBA) and very small entities (those with fewer than 20 employees). The costs for SBA defined small entities ranges from a low of $295 per entity for entities in NAICS 238200 Building Equipment Contractors, to a high of about $161,651for NAICS 213112 Support Activities for Oil and Gas Operations.

The cost for very small entities, ranges from a low of $223 for entities in NAICS 238200 Building Equipment Contractors, to a high of about $119,072 for entities in NAICS 213112 Support Activities for Oil and Gas Operations.

Table IX-3a and IX-3b shows the unit costs which form the basis for OSHA's cost estimates for the average small entity and very small entity.

Table IX-1: Average Costs and Impacts for Small Entities Affected by the Final Silica Standard for General Industry, Maritime, and Construction (2012 dollars)

NAICS	Industry	Cost per Affected Entity	Cost to Profit	Cost to Revenue
213112	Support Activities for Oil and Gas Operations	$161,651	18.15%	1.29%
324121	Asphalt Paving Mixture and Block Manufacturing	$610	0.07%	0.00%
324122	Asphalt Shingle and Coating Materials Manufacturing	$10,782	0.81%	0.05%
325510	Paint and Coating Manufacturing	$887	0.29%	0.01%
327110	Pottery, Ceramics, and Plumbing Fixture Manufacturing	$8,161	38.57%	0.52%
327120	Clay Building Material and Refractories Manufacturing	$34,727	33.59%	0.45%
327211	Flat Glass Manufacturing	$3,282	1.72%	0.05%
327212	Other Pressed and Blown Glass and Glassware Manufacturing	$6,171	7.50%	0.20%
327213	Glass Container Manufacturing	$81,273	2.20%	0.06%
327320	Ready-Mix Concrete Manufacturing	$9,821	11.51%	0.16%
327331	Concrete Block and Brick Manufacturing	$9,363	13.11%	0.19%
327332	Concrete Pipe Manufacturing	$12,926	14.53%	0.21%
327390	Other Concrete Product Manufacturing	$9,139	18.59%	0.27%
327991	Cut Stone and Stone Product Manufacturing	$7,343	24.70%	0.43%
327992	Ground or Treated Mineral and Earth Manufacturing	$16,878	9.60%	0.17%
327993	Mineral Wool Manufacturing	$8,768	5.76%	0.10%
327999	All Other Miscellaneous Nonmetallic Mineral Product Manufacturing	$21,200	20.90%	0.37%
331110	Iron and Steel Mills and Ferroalloy Manufacturing	$1,194	0.16%	0.00%
331210	Iron and Steel Pipe and Tube Manufacturing from Purchased Steel	$1,262	0.17%	0.00%
331221	Rolled Steel Shape Manufacturing	$1,210	0.16%	0.00%
331222	Steel Wire Drawing	$1,254	0.38%	0.01%
331314	Secondary Smelting and Alloying of Aluminum	$1,249	0.17%	0.00%
331420	Copper Rolling, Drawing, Extruding, and Alloying	$1,280	0.11%	0.00%
331492	Secondary Smelting, Refining, and Alloying of Nonferrous Metal (except Copper and Aluminum)	$1,218	0.12%	0.00%
331511	Iron Foundries	$38,050	6.38%	0.28%
331512	Steel Investment Foundries	$26,727	4.64%	0.20%

Table IX-1: Average Costs and Impacts for Small Entities Affected by the Final Silica Standard for General Industry, Maritime, and Construction (2012 dollars) continued

NAICS	Industry	Cost per Affected Entity	Cost to Profit	Cost to Revenue
331513	Steel Foundries (except Investment)	$31,446	6.97%	0.30%
331524	Aluminum Foundries (except Die-Casting)	$8,437	4.06%	0.18%
331529	Other Nonferrous Metal Foundries (except Die-Casting)	$6,092	2.67%	0.12%
332111	Iron and Steel Forging	$1,199	0.19%	0.01%
332112	Nonferrous Forging	$1,186	0.19%	0.01%
332117	Powder Metallurgy Part Manufacturing	$1,174	0.35%	0.01%
332119	Metal Crown, Closure, and Other Metal Stamping (except Automotive)	$1,179	0.51%	0.02%
332215	Metal Kitchen Cookware, Utensil, Cutlery, and Flatware (except Precious) Manufacturing	$1,181	0.46%	0.02%
332216	Saw Blade and Handtool Manufacturing	$1,203	0.77%	0.03%
332323	Ornamental and Architectural Metal Work Manufacturing	$1,081	1.95%	0.05%
332439	Other Metal Container Manufacturing	$1,221	0.76%	0.02%
332510	Hardware Manufacturing	$1,178	0.40%	0.02%
332613	Spring Manufacturing	$1,245	0.42%	0.02%
332618	Other Fabricated Wire Product Manufacturing	$1,213	0.51%	0.02%
332710	Machine Shops	$1,147	1.36%	0.06%
332812	Metal Coating, Engraving (except Jewelry and Silverware), and Allied Services to Manufacturers	$1,851	1.91%	0.06%
332911	Industrial Valve Manufacturing	$1,213	0.17%	0.01%
332912	Fluid Power Valve and Hose Fitting Manufacturing	$1,211	0.18%	0.01%
332913	Plumbing Fixture Fitting and Trim Manufacturing	$1,198	0.13%	0.01%
332919	Other Metal Valve and Pipe Fitting Manufacturing	$1,193	0.17%	0.01%
332991	Ball and Roller Bearing Manufacturing	$1,237	0.21%	0.01%
332996	Fabricated Pipe and Pipe Fitting Manufacturing	$1,172	0.28%	0.02%
332999	All Other Miscellaneous Fabricated Metal Product Manufacturing	$1,153	0.56%	0.03%
333318	Other Commercial and Service Industry Machinery Manufacturing	$1,162	0.48%	0.01%
333413	Industrial and Commercial Fan and Blower and Air Purification Equipment Manufacturing	$1,202	0.58%	0.02%
333414	Heating Equipment (except Warm Air Furnaces) Manufacturing	$1,166	0.51%	0.02%

Table IX-1: Average Costs and Impacts for Small Entities Affected by the Final Silica Standard for General Industry, Maritime, and Construction (2012 dollars) continued

NAICS	Industry	Cost per Affected Entity	Cost to Profit	Cost to Revenue
333511	Industrial Mold Manufacturing	$1,161	0.92%	0.04%
333514	Special Die and Tool, Die Set, Jig, and Fixture Manufacturing	$1,150	1.17%	0.04%
333515	Cutting Tool and Machine Tool Accessory Manufacturing	$1,166	1.13%	0.04%
333517	Machine Tool Manufacturing	$1,169	0.45%	0.02%
333519	Rolling Mill and Other Metalworking Machinery Manufacturing	$1,171	0.52%	0.02%
333612	Speed Changer, Industrial High-Speed Drive, and Gear Manufacturing	$1,235	0.55%	0.01%
333613	Mechanical Power Transmission Equipment Manufacturing	$1,196	0.63%	0.01%
333911	Pump and Pumping Equipment Manufacturing	$1,195	0.29%	0.01%
333912	Air and Gas Compressor Manufacturing	$1,201	0.22%	0.01%
333991	Power-Driven Handtool Manufacturing	$1,160	0.44%	0.02%
333992	Welding and Soldering Equipment Manufacturing	$1,159	0.45%	0.02%
333993	Packaging Machinery Manufacturing	$1,170	0.50%	0.02%
333994	Industrial Process Furnace and Oven Manufacturing	$1,188	0.51%	0.02%
333995	Fluid Power Cylinder and Actuator Manufacturing	$1,210	0.32%	0.01%
333996	Fluid Power Pump and Motor Manufacturing	$1,158	0.38%	0.01%
333997	Scale and Balance Manufacturing	$1,184	0.65%	0.02%
333999	All Other Miscellaneous General Purpose Machinery Manufacturing	$1,156	0.64%	0.02%
334519	Other Measuring and Controlling Device Manufacturing	$1,163	0.46%	0.02%
335210	Small Electrical Appliance Manufacturing	$1,077	0.16%	0.01%
335221	Household Cooking Appliance Manufacturing	$968	0.13%	0.01%
335222	Household Refrigerator and Home Freezer Manufacturing	$1,005	0.08%	0.00%
335224	Household Laundry Equipment Manufacturing	$958	0.50%	0.02%
335228	Other Major Household Appliance Manufacturing	$986	0.12%	0.00%
336111	Automobile Manufacturing [1]	$1,031	-1.57%	0.01%
336112	Light Truck and Utility Vehicle Manufacturing	$1,017	-1.16%	0.01%
336120	Heavy Duty Truck Manufacturing	$1,164	-0.49%	0.00%
336211	Motor Vehicle Body Manufacturing	$1,207	0.91%	0.01%
336212	Truck Trailer Manufacturing	$1,220	0.95%	0.01%
336213	Motor Home Manufacturing	$1,139	0.97%	0.01%

Table IX-1: Average Costs and Impacts for Small Entities Affected by the Final Silica Standard for General Industry, Maritime, and Construction (2012 dollars) continued

NAICS	Industry	Cost per Affected Entity	Cost to Profit	Cost to Revenue
336310	Motor Vehicle Gasoline Engine and Engine Parts Manufacturing	$1,144	1.11%	0.01%
336320	Motor Vehicle Electrical and Electronic Equipment Manufacturing	$1,179	0.62%	0.01%
336330	Motor Vehicle Steering and Suspension Components (except Spring) Manufacturing	$1,151	0.42%	0.01%
336340	Motor Vehicle Brake System Manufacturing	$1,241	0.40%	0.01%
336350	Motor Vehicle Transmission and Power Train Parts Manufacturing	$1,178	0.41%	0.01%
336370	Motor Vehicle Metal Stamping	$1,254	0.41%	0.01%
336390	Other Motor Vehicle Parts Manufacturing	$1,199	0.49%	0.01%
336611	Ship Building and Repairing	$7,778	1.30%	0.08%
336612	Boat Building	$6,551	1.79%	0.11%
336992	Military Armored Vehicle, Tank, and Tank Component Manufacturing	$1,186	0.12%	0.00%
337110	Wood Kitchen Cabinet and Countertop Manufacturing	$900	3.24%	0.09%
337215	Showcase, Partition, Shelving, and Locker Manufacturing	$1,177	0.97%	0.03%
339114	Dental Equipment and Supplies Manufacturing	$6,215	1.95%	0.14%
339116	Dental Laboratories	$878	2.33%	0.17%
339910	Jewelry and Silverware Manufacturing	$988	1.28%	0.05%
339950	Sign Manufacturing	$1,088	1.69%	0.07%
423840	Industrial Supplies Merchant Wholesalers	$1,469	1.05%	0.03%
444110	Home Centers	$1,219	0.61%	0.04%
482110	Rail transportation [2]	NA	NA	NA
561730	Landscaping Services	$716	5.49%	0.16%
621210	Offices of Dentists	$312	0.51%	0.04%
236100	Residential Building Construction	$333	1.6%	0.04%
236200	Nonresidential Building Construction	$879	1.0%	0.02%
237100	Utility System Construction	$1,806	2.4%	0.08%
237200	Land Subdivision	$459	-1.7%	0.02%
237300	Highway, Street, and Bridge Construction	$2,449	1.9%	0.06%
237900	Other Heavy and Civil Engineering Construction	$1,368	2.2%	0.06%
238100	Foundation, Structure, and Building Exterior Contractors	$1,306	3.7%	0.13%

Table IX-1: Average Costs and Impacts for Small Entities Affected by the Final Silica Standard for General Industry, Maritime, and Construction (2012 dollars) continued

NAICS	Industry	Cost per Affected Entity	Cost to Profit	Cost to Revenue
238200	Building Equipment Contractors	$295	0.7%	0.03%
238300	Building Finishing Contractors	$581	2.5%	0.08%
238900	Other Specialty Trade Contractors	$1,241	3.0%	0.10%
221100	Electric Utilities	$458	0.2%	0.00%
999200	State Governments	NA	NA	NA
999300	Local Governments	NA	NA	NA

N/A = Not applicable.

[1] During the recession, some industries had a negative "net income." For example, NAICS code 3361, Motor Vehicle Manufacturing (the four digit NAICS industry that includes the six digit NAICS industries 336111 Automobile Manufacturing, 336112 Light Truck and Utility Vehicle Manufacturing, and 336120 Heavy Duty Truck Manufacturing), had a large negative "net income" for 2008 and 2009, pulling the average profit rate down to -7.76 percent. Similarly, NAICS code 237200, Land Subdivision, had a large negative "net income" for 2008 through 2010, pulling the average profit rate down to -2.7 percent. Such negative average profit rates resulted in negative cost to profit ratios for some of the industries in this table.

[2] Costs and impact to rail transportation were estimated separately. See the discussions in Chapter V and Chapter VI for more information

Source: OSHA, Directorate of Standards and Guidance, Office of Regulatory Analysis, based on OSHA, 2016.

Table IX-2: Average Costs for Very Small Entities (<20 employees) Affected by the Final Silica Standard for General Industry, Maritime, and Construction (2012 dollars)

NAICS	Industry [1]	Cost per Affected	Cost to Profit	Cost to Revenue
213112	Support Activities for Oil and Gas Operations	$119,072	29.46%	2.09%
324121	Asphalt Paving Mixture and Block Manufacturing	$234	0.07%	0.00%
324122	Asphalt Shingle and Coating Materials Manufacturing	$3,670	1.44%	0.09%
325510	Paint and Coating Manufacturing	$325	0.48%	0.02%
327110	Pottery, Ceramics, and Plumbing Fixture Manufacturing	$4,542	90.64%	1.21%
327120	Clay Building Material and Refractories Manufacturing	$8,136	58.51%	0.78%
327211	Flat Glass Manufacturing	$3,969	20.44%	0.54%
327212	Other Pressed and Blown Glass and Glassware Manufacturing	$3,951	22.66%	0.59%
327213	Glass Container Manufacturing	$3,927	6.66%	0.17%
327320	Ready-Mix Concrete Manufacturing	$4,291	15.91%	0.23%
327331	Concrete Block and Brick Manufacturing	$4,322	19.52%	0.28%
327332	Concrete Pipe Manufacturing	$4,612	22.11%	0.32%
327390	Other Concrete Product Manufacturing	$3,912	29.24%	0.42%
327991	Cut Stone and Stone Product Manufacturing	$3,835	30.81%	0.54%
327992	Ground or Treated Mineral and Earth Manufacturing	$6,671	16.33%	0.29%
327993	Mineral Wool Manufacturing	$3,966	17.42%	0.31%
327999	All Other Miscellaneous Nonmetallic Mineral Product Manufacturing	$12,216	51.05%	0.89%
331110	Iron and Steel Mills and Ferroalloy Manufacturing	NA	NA	NA
331210	Iron and Steel Pipe and Tube Manufacturing from Purchased Steel	NA	NA	NA
331221	Rolled Steel Shape Manufacturing	NA	NA	NA
331222	Steel Wire Drawing	NA	NA	NA
331314	Secondary Smelting and Alloying of Aluminum	NA	NA	NA
331420	Copper Rolling, Drawing, Extruding, and Alloying	NA	NA	NA
331492	Secondary Smelting, Refining, and Alloying of Nonferrous Metal (except Copper and Aluminum)	NA	NA	NA
331511	Iron Foundries	$6,324	10.03%	0.44%
331512	Steel Investment Foundries	$4,163	5.72%	0.25%
331513	Steel Foundries (except Investment)	$6,287	12.27%	0.53%

Table IX-2: Average Costs and Impacts for Very Small Entities (<20 employees) Affected by the Final Silica Standard for General Industry, Maritime, and Construction (2012 dollars) continued

NAICS	Industry	Cost per Affected Entity	Cost to Profit	Cost to Revenue
331524	Aluminum Foundries (except Die-Casting)	$3,776	11.29%	0.49%
331529	Other Nonferrous Metal Foundries (except Die-Casting)	$4,564	8.79%	0.38%
332111	Iron and Steel Forging	NA	NA	NA
332112	Nonferrous Forging	NA	NA	NA
332117	Powder Metallurgy Part Manufacturing	NA	NA	NA
332119	Metal Crown, Closure, and Other Metal Stamping (except Automotive)	NA	NA	NA
332215	Metal Kitchen Cookware, Utensil, Cutlery, and Flatware (except Precious) Manufacturing	NA	NA	NA
332216	Saw Blade and Handtool Manufacturing	NA	NA	NA
332323	Ornamental and Architectural Metal Work Manufacturing	$1,158	6.22%	0.17%
332439	Other Metal Container Manufacturing	NA	NA	NA
332510	Hardware Manufacturing	NA	NA	NA
332613	Spring Manufacturing	NA	NA	NA
332618	Other Fabricated Wire Product Manufacturing	NA	NA	NA
332710	Machine Shops	NA	NA	NA
332812	Metal Coating, Engraving (except Jewelry and Silverware), and Allied Services to Manufacturers	$1,158	5.51%	0.16%
332911	Industrial Valve Manufacturing	NA	NA	NA
332912	Fluid Power Valve and Hose Fitting Manufacturing	NA	NA	NA
332913	Plumbing Fixture Fitting and Trim Manufacturing	NA	NA	NA
332919	Other Metal Valve and Pipe Fitting Manufacturing	NA	NA	NA
332991	Ball and Roller Bearing Manufacturing	NA	NA	NA
332996	Fabricated Pipe and Pipe Fitting Manufacturing	NA	NA	NA
332999	All Other Miscellaneous Fabricated Metal Product Manufacturing	NA	NA	NA
333318	Other Commercial and Service Industry Machinery Manufacturing	NA	NA	NA
333413	Industrial and Commercial Fan and Blower and Air Purification Equipment Manufacturing	NA	NA	NA
333414	Heating Equipment (except Warm Air Furnaces) Manufacturing	NA	NA	NA
333511	Industrial Mold Manufacturing	NA	NA	NA

Table IX-2: Average Costs and Impacts for Very Small Entities (<20 employees) Affected by the Final Silica Standard for General Industry, Maritime, and Construction (2012 dollars) continued

NAICS	Industry	Cost per Affected Entity	Cost to Profit	Cost to Revenue
333514	Special Die and Tool, Die Set, Jig, and Fixture Manufacturing	NA	NA	NA
333515	Cutting Tool and Machine Tool Accessory Manufacturing	NA	NA	NA
333517	Machine Tool Manufacturing	NA	NA	NA
333519	Rolling Mill and Other Metalworking Machinery Manufacturing	NA	NA	NA
333612	Speed Changer, Industrial High-Speed Drive, and Gear Manufacturing	NA	NA	NA
333613	Mechanical Power Transmission Equipment Manufacturing	NA	NA	NA
333911	Pump and Pumping Equipment Manufacturing	NA	NA	NA
333912	Air and Gas Compressor Manufacturing	NA	NA	NA
333991	Power-Driven Handtool Manufacturing	NA	NA	NA
333992	Welding and Soldering Equipment Manufacturing	NA	NA	NA
333993	Packaging Machinery Manufacturing	NA	NA	NA
333994	Industrial Process Furnace and Oven Manufacturing	NA	NA	NA
333995	Fluid Power Cylinder and Actuator Manufacturing	NA	NA	NA
333996	Fluid Power Pump and Motor Manufacturing	NA	NA	NA
333997	Scale and Balance Manufacturing	NA	NA	NA
333999	All Other Miscellaneous General Purpose Machinery Manufacturing	NA	NA	NA
334519	Other Measuring and Controlling Device Manufacturing	NA	NA	NA
335210	Small Electrical Appliance Manufacturing	$1,165	1.62%	0.06%
335221	Household Cooking Appliance Manufacturing	NA	NA	NA
335222	Household Refrigerator and Home Freezer Manufacturing	NA	NA	NA
335224	Household Laundry Equipment Manufacturing	NA	NA	NA
335228	Other Major Household Appliance Manufacturing	NA	NA	NA
336111	Automobile Manufacturing	NA	NA	NA
336112	Light Truck and Utility Vehicle Manufacturing	NA	NA	NA
336120	Heavy Duty Truck Manufacturing	NA	NA	NA
336211	Motor Vehicle Body Manufacturing	NA	NA	NA
336212	Truck Trailer Manufacturing	NA	NA	NA
336213	Motor Home Manufacturing	NA	NA	NA
336310	Motor Vehicle Gasoline Engine and Engine Parts Manufacturing	NA	NA	NA

Table IX-2: Average Costs and Impacts for Very Small Entities (<20 employees) Affected by the Final Silica Standard for General Industry, Maritime, and Construction (2012 dollars) continued

NAICS	Industry	Cost per Affected Entity	Cost to Profit	Cost to Revenue
336320	Motor Vehicle Electrical and Electronic Equipment Manufacturing	NA	NA	NA
336330	Motor Vehicle Steering and Suspension Components (except Spring) Manufacturing	NA	NA	NA
336340	Motor Vehicle Brake System Manufacturing	NA	NA	NA
336350	Motor Vehicle Transmission and Power Train Parts Manufacturing	NA	NA	NA
336370	Motor Vehicle Metal Stamping	NA	NA	NA
336390	Other Motor Vehicle Parts Manufacturing	NA	NA	NA
336611	Ship Building and Repairing	$1,778	2.12%	0.13%
336612	Boat Building	$1,773	2.41%	0.15%
336992	Military Armored Vehicle, Tank, and Tank Component Manufacturing	NA	NA	NA
337110	Wood Kitchen Cabinet and Countertop Manufacturing	$828	7.03%	0.19%
337215	Showcase, Partition, Shelving, and Locker Manufacturing	NA	NA	NA
339114	Dental Equipment and Supplies Manufacturing	$2,919	5.92%	0.43%
339116	Dental Laboratories	$748	3.49%	0.26%
339910	Jewelry and Silverware Manufacturing	$534	2.17%	0.09%
339950	Sign Manufacturing	$1,211	6.21%	0.24%
423840	Industrial Supplies Merchant Wholesalers	$1,241	1.66%	0.05%
444110	Home Centers	$935	1.14%	0.07%
482110	Rail transportation [2]	NA	NA	NA
561730	Landscaping Services	$770	8.13%	0.24%
621210	Offices of Dentists	$308	0.57%	0.04%
236100	Residential Building Construction	$282	1.9%	0.04%
236200	Nonresidential Building Construction	$546	1.2%	0.03%
237100	Utility System Construction	$965	2.8%	0.09%
237200	Land Subdivision [3]	$388	-2.7%	0.04%
237300	Highway, Street, and Bridge Construction	$1,086	2.0%	0.06%
237900	Other Heavy and Civil Engineering Construction	$795	2.6%	0.07%
238100	Foundation, Structure, and Building Exterior Contractors	$828	3.9%	0.13%
238200	Building Equipment Contractors	$223	1.0%	0.04%

Table IX-2: Average Costs and Impacts for Very Small Entities (<20 employees) Affected by the Final Silica Standard for General Industry, Maritime, and Construction (2012 dollars) continued

NAICS	Industry	Cost per Affected Entity	Cost to Profit	Cost to Revenue
238300	Building Finishing Contractors	$448	2.9%	0.10%
238900	Other Specialty Trade Contractors	$825	3.3%	0.11%
221100	Electric Utilities	$451	1.0%	0.01%
999200	State Governments	NA	NA	NA
999300	Local Governments	NA	NA	NA

N/A = Not applicable.

[1] In the PEA, OSHA identified a number of industries as having captive foundries and estimated that some very small entities in those industries would have captive foundries. For this FEA, the Agency determined that this assumption was incorrect and that entities with fewer than 20 employees would not have enough workers to perform foundry operations as well as their primary business operations. For the sake of comparability between the PEA and FEA, OSHA has left those industries in this table but shows that very small entities in those industries will have no costs associated with this final rule.

[2] Costs and impact to rail transportation were estimated separately. See the discussions in Chapter V and Chapter VI for more information.

[3] During the recession some industries had a negative “net income”. For example, the NAICS code 237200, Land Subdivision, had a large negative “net income” for 2008 through 2011, pulling the average profit rate down to -2.7 percent. This negative average profit rate resulted in a negative cost to profit ratio for this industry.

Source: OSHA, Directorate of Standards and Guidance, Office of Regulatory Analysis, based on OSHA, 2016.

Table IX-3a: Source Information for the Unit Cost Estimates Used in OSHA's Final Cost Analysis for General Industry and Maritime

Control [a]	Description	Ventilation Airflow (cfm)	Capital Cost [b]	Operating Cost	Annualized Capital Cost	Comment or Source
Local exhaust ventilation (LEV)	Average capital and operating cost assumptions; per cfm	NA	$13.34	$3.70	$1.56	Estimated by industrial ventilation consultants, capital cost [a]; operating costs reflect current energy prices
Conveyor covers (unventilated)	Conveyor covers (2 ft. bed, including all hardware); per linear foot	NA	$20.73	NA	$2.43	$17.10 per linear foot for 100 ft. (Landola, 2003) [a]
Maintenance percentage	Standard rate for maintenance of capital equipment	NA	NA	NA	NA	10% - estimated as a percentage of capital cost
Dust suppressants	Kleen Products 50lb poly bag green sweeping compound	NA	NA	$676.47	$0.00	$0.28/lb, 2 lbs/day; 5 minutes/day (www.fastenal.com).
HEPA vacuum for housekeeping	NILFISK VT60 wet/dry hepa vac, 15 gal	NA	$3,632.58	$511.20	$793.19	Nilfisk, HEPA vacuum (http://www.sylvane.com/nilfisk.html)
HEPA vacuum for housekeeping	NILFISK, large capacity	NA	$8,002.49	$988.90	$1,747.38	Nilfisk, HEPA vacuum (McCarthy, 2003)
Saw enclosure	8x8x8 wood/plastic	NA	$526.90	$52.69	$115.05	Fabrication costs estimated by ERG, assuming in-plant work. Five-year life.
Cab enclosures	Enclosed cabs	NA	$15,762	$5,517	$3,441.81	ERG estimate based on vendor interviews.

Table IX-3a: Source Information for the Unit Cost Estimates Used in OSHA's Final Cost Analysis for General Industry and Maritime(continued)

Control [a]	Description	Ventilation Airflow (cfm)	Capital Cost [b]	Operating Cost	Annualized Capital Cost	Comment or Source
LEV for hand held grinders	Shrouds + vacuum	NA	$1,737.51	$608.13	$379.39	Vacuum plus shroud adapter (http://www.proventilation.com/products/productDetail.asp?id=15); 35% for maintenance and operating costs.
Upgraded abrasive blast cabinet	Improved maintenance and purchases for some	NA	$4,850	$1,000	$568.57	Assumes addit. maint. (of up to $2,000) or new cabinets ($8,000) (Norton, 2003) [a]
Yard dust suppression	100 ft, 1" contractor hose and nozzle	NA	$212.19	$0.00	$110.89	Contactor hose and nozzle; 2 year life; (www.pwmall.com) [a]
Wet methods to clean concrete mixing equip.	10 minutes per day per operator	NA	$0.00	$1,024.04	$0.00	10 mins per day per mixer operator
HEPA vacuum substitute for compressed air	Incremental time to remove dust by vacuum	NA	NA	$536.47	$0.00	5 min per day per affected worker
Spray system for wet concrete finishing	Shop-built sprayer system	NA	$213.42	$21.34	$111.54	Assumes $100 in materials and 4 hours to fabricate. Also 10% for maint.
Improved spray booth for pottery	Maintenance time & materials	NA	$121.25	$118.42	$239.67	Annual: $100 materials plus 4 hours maintenance time [a]
Improved LEV for ceramics spray booth	Increased air flow; per cfm	NA	$3.33	$0.92	$3.33	25% of installed CFM price
Exhaust for saw, cut stone industry	Based on saw LEV (e.g., pg. 10-158, 159, 160, ACGIH, 2001)	645	$8,602.67	$2,385.88	$1,008.50	Includes 545 cfm for saw base and 100 cfm for blade guard; updated to ACGIH 2013; VS-65-02, pg. 13-79
LEV for hand chipping in cut stone	Granite cutting and finishing; (pg. 10-94, ACGIH, 2001)	600	$8,002.49	$2,219.43	$938.14	ERG estimate of CFM requirements
Exhaust trimming machine	Based on abrasive cut-off saw; (pg. 10-134) (ACGIH, 2001)	500	$6,668.74	$1,849.52	$781.78	Opening of 2 sq ft assumed, with 250 cfm/sq.ft

Table IX-3a: Source Information for the Unit Cost Estimates Used in OSHA's Final Cost Analysis for General Industry and Maritime(continued)

Control [a]	Description	Ventilation Airflow (cfm)	Capital Cost [b]	Operating Cost	Annualized Capital Cost	Comment or Source
Bag opening	Bag opening station; (pg. 10-19, ACGIH, 2001)	1,513	$20,179.60	$5,596.66	$2,365.66	3.5'x1.5' opening; with ventilated bag crusher (200 cfm)
Conveyor ventilation	Conveyor belt ventilation; (pg. 10-70, ACGIH, 2001)	700	$9,336.23	$2,589.33	$1,094.49	Per take-off point, 2' wide belt.
Bucket elevator ventilation	Bucket elevator ventilation (pg. 10-68; ACGIH,2001)	1,600	$21,339.96	$5,918.47	$2,501.69	2'x3'x30' casing; 4 take-offs @250 cfm; 100 cfm per sq ft of cross section
Bin and hopper ventilation	Bin and hopper ventilation (pg. 10-69; ACGIH, 2001)	1,050	$14,004.35	$3,884.00	$1,641.74	350 cfm per ft2; 3' belt width
Screen ventilation	Ventilated screen (pg. 10-173, ACGIH, 2001)	1,200	$16,004.97	$4,438.86	$1,876.27	4'x6' screen; 50 cfm per ft2
Batch operator workstation	Bin & hopper ventilation for unvented mixers (pg. 10-69, ACGIH, 2001)	1,050	$14,004.35	$3,884.00	$1,641.74	ERG estimate of CFM requirements
LEV for hand grinding operator (pottery)	Hand grinding bench (pg. 10-135, ACGIH, 2001)	3,750	$50,015.54	$13,871.42	$5,863.35	ERG estimate of CFM requirements
LEV, mixer and muller hood	Mixer & muller hood (pg. 10-87, ACGIH, 2001)	1,050	$14,004.35	$3,884.00	$1,641.74	ERG estimate of CFM requirements
LEV for bag filling stations	Bag filling station (pg. 10-15, ACGIH, 2001)	1,500	$20,006.21	$5,548.57	$2,345.34	Includes costs for air shower
Installed manual spray mister	Manual controls, system covers 100 ft of conveyor	NA	$10,609.36	$1,060.94	$1,243.74	National Environmental Services Company (Kestner, 2003). [a]
Install cleaning hoses, reslope floor, drainage	Plumbing for hose installations, floor resloping and troughs	NA	$36,412.40	$3,323.52	$4,268.64	ERG estimate. Includes cost of water and labor time.
Substitute alt., non-silica, blasting media	Alternative media estimated to cost 22 percent more	NA	$0.00	$5,156.25	$0.00	Based on 220,000 square feet of coverage per year per crew
Shakeout conveyor enclosure	Ventilated shakeout conveyor enclosure	10,000	$133,374.76	$36,990.46	$15,635.59	ERG estimate

Table IX-3a: Source Information for the Unit Cost Estimates Used in OSHA's Final Cost Analysis for General Industry and Maritime(continued)

Control [a]	Description	Ventilation Airflow (cfm)	Capital Cost [b]	Operating Cost	Annualized Capital Cost	Comment or Source
Shakeout side-draft ventilation	Shakeout double side-draft table (pg. 10-23, ACGIH, 2001)	28,800	$384,119.32	$106,532.52	$45,030.50	ERG estimate of CFM requirements
Shakeout enclosing hood	Ventilated enclosing hood (pg. 10-23, ACGIGH, 2001); 4'x4' openings	7,040	$93,895.83	$26,041.28	$11,007.46	ERG estimate of opening size required
Small knockout table	Portable grinding table pg. 10-136), ACGIH, 2001), 3'x3' opening	1,350	$18,005.59	$4,993.71	$2,110.80	ERG estimate of opening size required
Large knockout table	Hand grinding table (pg. 10-135), ACGIH, 2001), 4'x6' surface	4,800	$64,019.89	$17,755.42	$7,505.08	ERG estimate of bench surface area
Ventilated abrasive cutoff saw	Ventilated cut-off saw (pg. 10-134, ACGIH, 2001, 2'x3' opening	1,500	$20,006.21	$5,548.57	$2,345.34	ERG estimate of opening size required
Hand grinding bench (foundry)	Bench with LEV (pg. 10-135, ACGIH, 2001); 3'x5'	3,750	$50,016	$13,871.42	$5,863.35	ERG estimate of CFM requirements; 250 cfm/sq. ft.
Forming operator bench (pottery)	Bench with LEV (pg. 10-149, ACGIH, 2001), 3'x4'	1,400	$18,672	$5,178.66	$2,188.98	ERG estimate of CFM requirements; 125 cfm per linear foot
Hand grinding bench (pottery)	Bench with LEV (pg. 10-135, ACGIH, 2001); 3'x4'	2,400	$32,010	$8,877.71	$3,752.54	ERG estimate of CFM requirements; 200 cfm/sq. ft.
Hand tool hardware	Retrofit suction attachment	200	$464	$739.81	$54.42	ERG estimate of CFM requirements [a]
Clean air island	Clean air supplied directly to worker	2,500	$33,343.69	$9,247.61	$3,908.90	ERG estimate of CFM requirements; 125 cfm/sq. ft. for 20 square feet
Water fed chipping equipment drum cleaning	Shop-built water feed equipment	NA	$242.50	$0.00	$242.50	ERG estimate. $200 in annual costs [a]
Ventilation for drum cleaning	Ventilation blower and ducting	NA	$823.98	$205.99	$179.92	Electric blower (1,277 cfm) and 25 ft. of duct. Northern Safety Co. (p. 193) [a]

Table IX-3a: Source Information for the Unit Cost Estimates Used in OSHA's Final Cost Analysis for General Industry and Maritime(continued)

Control [a]	Description	Ventilation Airflow (cfm)	Capital Cost [b]	Operating Cost	Annualized Capital Cost	Comment or Source
Control room	10'x10' ventilated control room with HEPA filter	200	$20,327.53	$739.81	$2,383.01	ERG estimate based on Means, 2003, ACGIH, 2001
Control room improvement	Repair and improve control room enclosure	NA	$2,240	NA	$262.60	ERG estimate. Assumes repairs are 20% of new control room cost.
Improved bag valves	Bags with extended polyethylene valve, incremental cost per bag	NA	$0.01	NA	NA	Cecala et. al., 1986 [a]
Respirator	Half-mask respirator	NA	NA	NA	$520.32	ERG, 2003 [Economic Analysis of APF rule], Updated to 2012
Improved maintenance on process equipment enclosures (concrete II)	Maintenance time & materials	NA	$303.12	$250.59	$553.71	Annual: $250 materials plus 8 hours maintenance time [a]
Improved maintenance on process equipment enclosures (Mineral Proc.)	Maintenance time & materials	NA	$303.12	$257.08	$560.21	Annual: $250 materials plus 8 hours maintenance time [a]
Initial cleaning	Thorough initial cleaning, per square foot	NA	$0.00	$0.15	$0.15	ERG estimate
Self-contained dust collection system			$800.00	$80.00	$93.78	Self-contained dust collection system. Darby Dental Lab Supply, 2005 (www.darbylab.com)

[a] For local exhaust ventilation (LEV), maintenance, and conveyor covers, OSHA applied the following estimates:

LEV: capital cost=$13.34 per cfm; operating cost=$3.70 per cfm; annualized capital cost=$1.56 per cfm; based on current energy prices and the estimates of consultants to ERG (OSHA, 2016).

Maintenance: estimated as 10% of capital cost

Conveyor Covers: estimated as $17.10 per linear foot for 100 ft. (Landola, 2003); capital cost=$20.73 per linear ft., including all hardware; annualized capital cost=$2.84 per linear ft.

[b] Adjusted from 2003 price levels using an inflation factor of 1.212 based on GDP Implicit price deflator for 2003 and 2012.

[c] Mean expense per office-based physician visit to a pulmonary specialist for diagnosis and treatment, based on data from the 2004 MEPS. Inflated to 2012 levels using the consumer price index for medical services. Inflation based on the BLS Consumer Price Index for Urban Consumers for medical services.

Source: OSHA, Directorate of Standards and Guidance, Office of Regulatory Analysis, based on OSHA, 2016.

Table IX-3b: Source Information for the Unit Cost Estimates Used in OSHA's Final Cost Analysis for Construction

Control Equipment	Equipment Cost	Average Lifetime (yrs)	Average Annualized Cost	Average Ann. Cost/Day of Use [a]	Maintenance and Operating Cost/Day [b]	Total Ann. Cost/Day of Use	Source; Comments
Wet kit, with water tank	$227	2	$118.49	$0.79	$0.17	$0.96	Contractors Direct, 2009; Bertland Tools Outlet, 2009; Mytoolstore, 2009
Dust shrouds: grinder	$97	1	$97.33	$0.65	$0.14	$0.79	Contractors Direct, 2009; Bertland Tools Outlet, 2009; DustBuddy, 2009; Martin 2008
Water tank, portable (unspec. capacity)	NA	NA	NA	$15.50 [c]	$0.00 [c]	$15.50	RS Means - based on monthly rental cost
Water tank, small capacity (hand pressurized)	$74	1	$76.09	$0.51	$0.11	$0.61	Contractors Direct, 2009; Mytoolstore, 2009
Hose (water), 20', 2" diameter	NA	NA	NA	$1.65 [c]	$0.00	$1.65	RS Means - based on monthly cost
Custom water spray nozzle and attachments	$363	1	$374.15	$2.49	$0.52	$3.02	New Jersey Laborers' Health and Safety Fund, 2007
Hose (water), 200', 2" diameter	NA	NA	NA	$16.45 [c]	$0.00 [c]	$16.45	RS Means - based on monthly rental cost
Vacuum, 10-15 gal with HEPA	$725	2	$378.89	$2.53	$0.53	$3.06	ICS, 2009; Dust Collection, 2009; Edco, 2009; CS Unitec, 2009
Vacuum, 10-15 gal with HEPA (infrequent use)	$725	2	$378.89	$5.05	$0.53	$5.58	ICS, 2009; Dust Collection, 2009; Edco, 2009; CS Unitec, 2009
Vacuum, large capacity with HEPA	$2,108	2	$1,101.66	$7.34	$1.54	$8.89	ICS, 2009; Edco, 2009; Aramsco, 2009
Electric blower (1,277 cfm) and 25 ft. of duct	$950	5	$207.44	$1.38	$0.29	$1.67	Northern Safety Co., 2003. Inflated to 2009 dollars.
Dust extraction kit (rotary hammers)	$215	1	$214.81	$1.43	$0.30	$1.73	Grainger 2009; Mytoolstore, 2009; Toolmart, 2009
Dust extraction kit (rotary hammers) (infrequent use)	$215	1	$214.81	$2.86	$0.30	$3.16	Grainger 2009; Mytoolstore, 2009; Toolmart, 2009
Dust control/quarry drill	NA	NA	NA	$17.33 [c]	$0.00	$17.33	RS Means Heavy Construction Cost Data 2008

Table IX-3b: Source Information for the Unit Cost Estimates Used in OSHA's Final Cost Analysis for Construction (continued)

Control Equipment	Equipment Cost	Average Lifetime (yrs)	Average Annualized Cost	Average Ann. Cost/Day of Use [a]	Maintenance and Operating Cost/Day [b]	Total Ann. Cost/Day of Use	Source; Comments
Dustless drywall sander	$133	1	$133.33	$0.89	$0.19	$1.08	Home Depot, 2009; LSS 2009; Dustless Tech, 2009
Water misting cannon	$19,190	10	$2,249.65	$15.00	$3.15	$18.15	New Jersey Used Equipment, 2015
Cab enclosure /w ventilation and air conditioning	$13,000	10	$1,524.00	$10.16	$2.13	$12.29	Estimates from equipment suppliers and retrofitters
Foam dust suppression system	$14,550	10	$1,706	$11.37	$2.39	$13.76	Midyett, 2003.
Water tank, engine driven discharge, 5000 gal.	NA	NA	NA	$121.50 [c]	$0.00 [c]	$121.50	RS Means - based on monthly rental cost
Water tank, engine driven discharge, 10,000 gal	NA	NA	NA	$168.38 [c]	$0.00 [c]	$168.38	RS Means - based on monthly rental cost
Half-face respirator	$27	2	$468.74	$3.12	$0.66	$3.78	[d]
Dust booth	$10,605	10	$1,243	$8.29	$1.74	$10.03	ERG estimate based on Cerala, et al, 2002 & 2005
Tunnel dust suppression system supplement	$7,928	5	$1,731.03	$11.54	$2.42	$13.96	Raring, 2003.

NA=Not applicable. For cost items that are assumed to be leased or rented (as on a per job basis), equipment lifetimes are not relevant and have not been defined.

[a] Except where noted, daily equipment cost is based on the annualized equipment cost divided by 150 to reflect the assumed average number days of use per year.

[b] Except where noted, daily operating and maintenance costs are calculated as 10% and 25%, respectively, of annualized equipment costs divided by 250.

[c] Daily equipment costs derived from RS Means monthly rental rates which include maintenance and operating costs.

[d] Derived by ERG based on vendor-derived capital cost of $27.00, 2 year equipment life, accessory cost of $295.52. Also includes annualized training cost of $50.34, fit test cost of $26.45, and respirator cleaning cost of $81.49 to derive total annual costs of $468.74.

Source: OSHA, Directorate of Standards and Guidance, Office of Regulatory Analysis, based on OSHA, 2016, vendors' equipment prices and R.S. Means, Heavy Construction Cost Data, 2009.

DESCRIPTION OF THE STEPS OSHA HAS TAKEN TO MINIMIZE THE SIGNIFICANT ECONOMIC IMPACT ON SMALL ENTITIES CONSISTENT WITH THE STATED OBJECTIVES OF APPLICABLE STATUTES AND STATEMENT OF THE REASONS FOR SELECTING THE ALTERNATIVE ADOPTED IN THE FINAL RULE

OSHA has made a number of changes in the final silica rule that will serve to minimize significant impacts on small entities consistent with the objectives of the OSH Act.

First, OSHA has made two changes to the scope of the rule that will minimize impacts for small business. OSHA has eliminated from the scope of the rule exposures that result from the processing of sorptive clays. OSHA's analysis did not determine whether any or all of the processers of sorptive minerals are small businesses, but to the extent they are, this change will reduce impacts on such entities. OSHA has also rewritten the scope of the rule with respect to the coverage of employers whose employees are exposed to silica at levels below the action level. The final rule does not apply to employers in general industry and maritime where the employer has objective data demonstrating that employee exposure to respirable crystalline silica will remain below 25 μg/m^3 as an 8-hour time-weighted average under any foreseeable conditions, and does not apply in construction where employee exposure will remain below 25 μg/m^3 as an 8-hour time-weighted average under any foreseeable conditions (see Scope in Section XV of the preamble). OSHA expects that these changes may remove all compliance duties for some small businesses, possibly including carpenters, plumbers, and electricians, whose employees' only exposures to respirable crystalline silica is in small amounts for short-duration tasks that are performed infrequently.

OSHA also revised Table 1 for the construction industry in ways that will minimize impacts on small businesses. OSHA requested comment on the approach for construction in the NPRM. After carefully reviewing the comments received on this issue, the Agency significantly revised the structure of the construction rule to focus on the tasks known to generate high exposures to respirable crystalline silica and to expand Table 1 to cover almost all of them (tunnel boring and abrasive blasting are the exceptions). Under this final rule, where employers fully and properly implement the specified engineering controls, work practices, and respiratory protection for each employee engaged in a task identified on Table 1, the employer is not also required to conduct exposure assessments to determine compliance with the PEL. Specifying the kinds of dust controls for construction tasks that are expected to reduce exposures to the 50 μg/m^3 target, as an option in lieu of a performance-oriented approach involving a PEL and regular exposure assessment, will make compliance easier for construction employers. Some commenters indicated that this specific guidance is particularly beneficial to small businesses that may not have as many resources to develop their own compliance plans (see, e.g., Document ID 2322-A1, p. 16). The Agency also revised the notes and specifications on Table 1 to clarify what is required for employers to fully and properly implement the specified engineering controls, work practices, and respiratory protection for tasks on Table 1 (see Specified Exposure Control Methods in Section XV of the preamble).

After carefully reviewing the comments received on respiratory protection requirements for the construction standard and the exposure data in the record (described in Chapter IV of the FEA), OSHA identified those situations where respiratory protection is necessary and made significant revisions to the respiratory protection requirements specified on Table 1 based on those findings. The result is that respiratory protection is not required for most of the tasks covered by Table 1 (see Specified Exposure Control Methods in Section XV of the preamble).

For this final rule, the Agency has significantly revised the requirements for initial exposure assessment and periodic exposure assessment in order to provide employers with greater flexibility. The standard allows the employer to use either the performance option or the scheduled monitoring option for initial and periodic exposure assessments. OSHA also clarified that the performance option provides employers with flexibility in the methods used to assess employee exposures, and provided examples of how employers can accurately characterize employee exposures using the performance option (see Exposure Assessment discussion in the Summary and Explanation (Section XV) of the preamble).

At the suggestion of many commenters, OSHA has eliminated regulated area/access control plan requirements in construction. Employers in construction now have more flexibility in determining the best way to control exposures through a written exposure control plan.

In the final rule, OSHA has agreed with many commenters to eliminate the requirements for protective clothing, and thus has reduced costs to small businesses.

OSHA requested comment on the use of wet methods as a substitute for dry sweeping in the NPRM. After carefully reviewing the comments received on this issue, the Agency revised the provision to prohibit dry sweeping only where such activity could contribute to employee exposure to respirable crystalline silica. Moreover, the standard contains an exception to the prohibition on dry sweeping in such circumstances if wet sweeping, HEPA-filtered vacuuming, or other methods that minimize the likelihood of exposure are not feasible (see Housekeeping in Section XV of the preamble).

In the NPRM, OSHA requested comment on the prohibition of employee rotation to achieve compliance when exposure levels exceed the PEL. After carefully reviewing the comments received on this issue, OSHA removed the prohibition on employee rotation from the rule (see Methods of Compliance in Section XV of the preamble).

OSHA examined the issue of a 30-day exemption in the NPRM. After carefully reviewing the comments received on this issue, the Agency decided not to include a 30-day exemption from the requirement to implement engineering and work practice controls. However, OSHA clarified that where engineering controls are not feasible, such as for certain maintenance and repair activities, the use of respirators is permitted (see Methods of Compliance and Respiratory Protection in Section XV of the preamble).

OSHA adopted these alternatives to reduce costs and regulatory burdens consistent with the requirements of the OSH Act and court interpretations of the Act. For health standards issued under section 6(b)(5) of the OSH Act, OSHA is required to promulgate a standard that reduces significant risk to the extent that it is technologically and economically feasible to do so. See Section II of the Preamble to the final rule, Pertinent Legal Authority, for a full discussion of OSHA legal requirements.

OSHA has conducted an extensive review of the literature on adverse health effects associated with exposure to respirable crystalline silica. The Agency has also developed estimates of the risk of silica-related diseases assuming exposure over a working lifetime at the proposed PEL and action level, as well as at OSHA's preceding PELs. These analyses are summarized in the preamble in Section V, Health Effects and Quantitative Risk Analysis. The available evidence indicates that employees exposed to respirable crystalline silica well below the preceding PELs are still at increased risk of lung cancer mortality and silicosis mortality and morbidity. Occupational exposures to respirable crystalline silica also may result in the development of kidney and autoimmune diseases and in death from other nonmalignant respiratory diseases, including chronic obstructive pulmonary disease (COPD).

As discussed in Section VI, Significance of Risk, in the preamble, OSHA determined that worker exposure to respirable crystalline silica constitutes a significant risk and that the final standard will substantially reduce this risk. Further, there is significant risk well below the new PEL of 50 $\mu g/m^3$, but OSHA has determined that achieving a PEL of 25 $\mu g/m^3$ is not technologically feasible.

Section 6(b) of the OSH Act requires OSHA to determine that its standards are technologically and economically feasible. OSHA's examination of the technological and economic feasibility of the final rule is presented in this FEA and FRFA. OSHA has concluded that the new PEL of 50 μg/m^3 is technologically feasible for all affected sectors in general industry and maritime and that Table 1 is technologically feasible for construction.

For those few operations where the new PEL is not technologically feasible, even when workers use recommended engineering and work practice controls, employers can supplement controls with respirators to achieve exposure levels at or below the new PEL.

OSHA developed quantitative estimates of the compliance costs of the final rule for each of the affected industry sectors in Chapter V of this FEA. The estimated compliance costs were compared with industry revenues and profits to provide a screening analysis of the economic feasibility of complying with the revised standard and an evaluation of the potential economic impacts in Chapter VI of this FEA. Industries with unusually high costs as a percentage of revenues or profits were further analyzed for possible economic feasibility issues. After performing these analyses, OSHA has concluded that compliance with the requirements of the final rule will be economically feasible in every affected industry sector.

OSHA has also provided analyses of the costs and benefits of alternative PELs, though it should be pointed out these are for informational purposes only. Benefit cost analysis cannot be used as a decision criteria for OSHA health standards under the OSH Act. OSHA has examined two regulatory alternatives (named Regulatory Alternatives #1 and #2) that would have modified the PEL for the final rule. Under Regulatory Alternative #1, the PEL would have been 100 μg/m^3 for all affected industry sectors, and the action level would have been 50 μg/m^3 (thereby keeping the action level at one-half of the PEL). For the construction sector under Regulatory Alternative #1, Table 1 requirements for respirator use would have been eliminated for all workers performing Table 1 tasks. Under this alternative, only abrasive blasters and underground construction workers would have been required to wear respiratory protection, and only workers wearing respirators in these operations would have been subject to the medical surveillance provision. Under Regulatory Alternative #2, the PEL would have been 25 μg/m^3 for all affected industry sectors, while the action level would have remained at 25 μg/m^3 (because of difficulties in accurately measuring exposure levels below 25 μg/m^3). For the construction sector under Regulatory Alternative #2, Table 1 requirements would have been modified to include respiratory protection for all workers covered under Table 1, and all these covered workers would have been subject to the medical surveillance provision.

Table IX-4 presents, for informational purposes, the estimated costs, benefits, and net benefits of the final rule under Regulatory Alternatives #1 and #2, using alternative discount rates of 3 and 7 percent. The tables also present the incremental costs, the incremental benefits, and the incremental net benefits of going from a PEL of 100 μg/m^3 to the new PEL of 50 μg/m^3 and then of going from the new PEL of 50 μg/m^3 to a PEL of 25 μg/m^3 for general industry and maritime, as well as the effects in construction of the corresponding changes to Table 1 under Regulatory Alternatives #1 and #2. Table IX-4 breaks out costs by provision and benefits by type of disease and by morbidity/mortality.

Because OSHA determined that a PEL of 25 μg/m^3 would not be feasible (that is, engineering and work practices would not be sufficient to reduce and maintain silica exposures to a PEL of 25 μg/m^3 or below in most operations most of the time in the affected industry sectors in general industry and maritime), the Agency did not attempt to identify engineering controls or their costs for this alternative PEL. Instead, for purposes of estimating the costs of going from a PEL of 50 μg/m^3 to a PEL of 25 μg/m^3, OSHA assumed that all workers exposed between 50 μg/m^3 and 25 μg/m^3 would have to wear respirators to achieve compliance with a PEL of 25 μg/m^3. OSHA then estimated the associated additional costs for respirators, exposure assessments, medical surveillance, and regulated areas (the latter three for ancillary requirements specified in the final rule). For the construction sector under Regulatory Alternative #2, as previously indicated, Table 1 requirements would be modified to include respiratory protection for all covered workers, and all covered workers would be subject to the medical surveillance provision.

As shown in Tables IX-4, going from the final rule to Regulatory Alternative #2 would prevent, annually, an additional 295 silica-related fatalities and an additional 122 cases of silicosis. These estimates support OSHA's finding that there is significant risk remaining at the new PEL of 50 μg/m^3. However, the Agency has determined that it cannot select Regulatory Alternative #2 because a PEL of 25 μg/m^3 is not technologically feasible and this alternative would require extensive use of respirators for those using Table 1 under the construction standard (see the Technological Feasibility Summary in the preamble for a further discussion of the feasibility of a PEL of 25 μg/m^3).

Table IX-4: Annualized Costs, Benefits and Incremental Benefits of OSHA's Regulatory Alternatives

Millions ($2012)

	Regulatory Alternative #2						Final Rule						Regulatory Alternative #1		
	25 $\mu g/m^3$			Incremental Costs Between 50 and 25 $\mu g/m^3$			50 $\mu g/m^3$			Incremental Costs Between 100 and 50 $\mu g/m^3$			100 $\mu g/m^3$		
Discount Rate		3%	7%		3%	7%		3%	7%		3%	7%		3%	7%
Annualized Costs															
Engineering Controls		$661	$674		$0	$0		$661	$674		$241	$261		$421	$413
Respirators		$82	$82		$49	$49		$33	$33		$32	$32		$1	$1
Exposure Assessment		$141	$142		$45	$53		$96	$98		$32	$32		$64	$65
Medical Surveillance		$485	$492		$388	$392		$96	$100		$73	$75		$24	$24
Familiarization and Training		$96	$100		$0	$0		$96	$102		$0	$2		$96	$100
Regulated Area		$12	$12		$9	$9		$3	$3		$3	$3		$0	$0
Written Control Plan		$44	$47		$0	$0		$44	$47		$0	$1		$44	$47
Total Annualized Costs (point estimate)		**$1,521**	**$1,552**		**$491**	**$496**		**$1,030**	**$1,056**		**$381**	**$406**		**$649**	**$650**
Annual Benefits: Number of Cases Prevented	**Cases**			**Incremental Benefits Between 50 and 25 $\mu g/m^3$--Cases**			**Cases**			**Incremental Benefits Between 100 and 50 $\mu g/m^3$--Cases**			**Cases**		
Fatal Lung Cancers (midpoint estimate) **	178			54			123			62			62		
Fatal Silicosis & other Non-Malignant Respiratory Diseases**	438			113			325			154			170		
Fatal Renal Disease**	321			128			193			110			83		
Silica-Related Mortality**	937	9,340	5,119	295	**$2,942**	**$1,612**	642	$6,398	$3,507	326	$3,248	$1,783	316	$3,151	$1,724
Silicosis Morbidity**	1,040	2,593	1,478	122	**$304**	**$173**	918	$2,289	$1,305	440	$1,098	$626	477	$1,191	$679
Monetized Annual Benefits (midpoint estimate) **		**$11,933**	**$6,597**		**$3,246**	**$1,786**		**$8,687**	**$4,812**		**$4,346**	**$2,409**		**$4,341**	**$2,403**
Net Benefits**		**$10,412**	**$5,046**		**$2,755**	**$1,290**		**$7,657**	**$3,756**		**$3,965**	**$2,003**		**$3,692**	**$1,753**

Source: OSHA, Directorate of Standards and Guidance, Office of Regulatory Analysis, based on OSHA, 2016.

RECOMMENDATIONS FROM THE SBAR PANEL AND OSHA'S RESPONSES

Table IX-5 lists all of the SBAR Panel recommendations and OSHA's responses to these recommendations.

Table IX-5: SBAR Panel Recommendations and OSHA Responses

SBAR Panel Recommendation	**OSHA Response**
The Panel recommended that OSHA give consideration to the alternative of improved enforcement of and expanded outreach for the existing rule rather than a new rule. In addition, the Panel recommended that OSHA carefully study the effects of existing compliance and outreach efforts, such as the Special Emphasis Program on silica, with a view to better delineating the effects of such efforts. This examination should include (1) a year-by-year analysis of the extent of noncompliance discovered in OSHA compliance inspections, and (2) the kinds of efforts OSHA made to improve enforcement and outreach.	As discussed in Chapter II of this FEA, Need for Regulation (and summarized in Section II of the preamble), OSHA has reviewed existing enforcement and outreach programs, as well as other legal and administrative remedies, and believes that a standard is the most effective means to protect workers from exposure to silica. The rulemaking record indicates that workers did not receive adequate protection from silica hazards under OSHA's previous standards. A review of OSHA's compliance assistance and enforcement efforts and their effects on preceding PELs for respirable crystalline silica are discussed in Section III of the preamble, Events Leading to the Final Standards.

Table IX-5: SBAR Panel Recommendations and OSHA Responses (continued)	
SBAR Panel Recommendation	**OSHA Response**
(General Industry) The Panel recommended that OSHA revise its economic and regulatory flexibility analyses as appropriate to reflect the SERs' comments on underestimation of costs, and that the Agency compare OSHA's revised estimates to alternative estimates provided and methodologies suggested by the SERs. For those SER estimates and methodological suggestions that OSHA does not adopt, the Panel recommends that OSHA explain its reasons for preferring an alternative estimate and solicit comment on the issue.	OSHA reviewed its cost estimates in response to the comments received from the SERs and evaluated the alternative estimates and methodologies suggested by the SERs. In some cases (such as for exposure monitoring, medical surveillance, and training) OSHA revised its cost estimates in response to SER comments. However, OSHA has not made all cost changes suggested by the SERs. OSHA has retained (or simply updated) those cost estimates that it determined reflect sound methodology and reliable data. OSHA requested comments on the Agency's estimated costs and on the assumptions applied in the preliminary cost analysis. OSHA's final analysis of costs is presented in Chapter V of this FEA and reflects the final Agency response to comments from SERs and other small entities who participated in the rulemaking.
The Panel recommended that prior to publishing a proposed standard, OSHA should carefully consider the ability of each potentially affected industry to meet any proposed PEL for silica, and that OSHA should recognize, and incorporate in its cost estimates, specific issues or hindrances that different industries may have in implementing effective controls.	This FEA reflects OSHA's judgment on technological feasibility and includes responses to specific issues raised by the Panel, SERs, and other small entities who participated in the rulemaking. OSHA solicited comment on the accuracy and reasonableness of its preliminary judgments and included this topic in the NPRM. OSHA's final analysis of technological feasibility presented in Chapter IV of the FEA includes the final Agency response to comments from SERs and the other small entities who participated in the rulemaking.

Table IX-5: SBAR Panel Recommendations and OSHA Responses (continued)	
SBAR Panel Recommendation	**OSHA Response**
The Panel recommended that OSHA carefully review the basis for its estimated exposure monitoring costs, consider the concerns raised by the SERs, and ensure that its estimates are revised, as appropriate, to fully reflect the costs likely to be incurred by potentially affected establishments.	Table 1 in the final construction standard is designed to relieve establishments in construction from requirements for exposure assessment for identified tasks. For the final rule, OSHA clarified that Table 1 provides an alternative method of compliance, not just a partial safe-harbor as in the NPRM. OSHA also further expanded the tasks covered by Table 1 in recognition of the exposure control challenges facing many construction employers, including small entities. As a result, OSHA estimates that monitoring costs in construction will be minimal. For general industry, OSHA developed cost estimates in this FEA for exposure monitoring as a function of the size of the establishment. OSHA's cost estimates now reflect the fact that smaller entities will tend to experience larger unit costs. In the PEA and in this FEA, OSHA estimated higher exposure monitoring costs for small entities because an industrial hygienist could not take as many samples a day in a small establishment as in a large one. For the FEA, in response to public comment, OSHA raised the unit fee for industrial hygiene technician and revised other unit estimates (primarily as a result of converting to 2012 dollars). See Chapter V of this FEA for details of OSHA's unit costs for exposure monitoring in general industry and maritime.

Table IX-5: SBAR Panel Recommendations and OSHA Responses (continued)	
SBAR Panel Recommendation	**OSHA Response**
The Panel recommended that OSHA carefully review the basis for its estimated health screening compliance costs, consider the concerns raised by the SERs, and ensure that its estimates are revised, as appropriate, to fully reflect the costs likely to be incurred by potentially affected establishments.	OSHA's cost estimates for health screening are a function of the size of the establishment. OSHA's cost estimates now reflect the fact that smaller entities will tend to experience larger unit costs. In the PEA, OSHA estimated higher medical surveillance costs (than was estimated in the Preliminary Initial Regulatory Flexibility Analysis (PIRFA)) for small entities because smaller establishments would be more likely to send the workers off-site for medical testing. OSHA has carried forward that methodology for this FEA. In addition, for the PEA and this FEA, OSHA significantly increased the total costs of exposure sampling and x-rays in medical surveillance by assuming no existing compliance with those provisions in the proposed and final rule (as compared to an average of 32.6 percent and 34.8 percent existing compliance, respectively, in the PIRFA). A full discussion of OSHA's consideration of medical surveillance costs is included in Chapter V of this FEA and in the preamble.

Table IX-5: SBAR Panel Recommendations and OSHA Responses (continued)	
SBAR Panel Recommendation	**OSHA Response**
(Construction) The Panel recommended that OSHA carefully review the basis for its estimated hygiene compliance costs, consider the concerns raised by the SERs, and ensure that its estimates are revised, as appropriate, to fully reflect the costs likely to be incurred by potentially affected establishments.	OSHA removed the specific hygiene provisions presented in the PIRFA from the proposed and final rules, which has resulted in the elimination of compliance costs for change rooms, shower facilities, lunch rooms, and hygiene-specific housekeeping requirements. In the NPRM, OSHA requested comment on the requirements for use of protective clothing. After carefully reviewing the comments received on this issue, the Agency removed the requirement for protective clothing from the rule (see Regulated Areas in Section XV of the preamble).

Table IX-5: SBAR Panel Recommendations and OSHA Responses (continued)	
SBAR Panel Recommendation	**OSHA Response**
(General Industry) While some SERs currently provide both protective clothing and hygiene facilities, others provide neither. Those SERs that do not currently provide either felt that these provisions were both highly expensive and unnecessary. Some SERs stated that these provisions were pointless because silica is not a take-home hazard or a dermal hazard. Others suggested that such provisions only be required when the PEL is exceeded. The Panel recommended that OSHA carefully consider the need for these provisions, and solicit comment on the need for these provisions, and how they might be limited.	OSHA removed the specific hygiene provisions presented in the PIRFA from the proposed and final rules, which has resulted in the elimination of compliance costs for change rooms, shower facilities, lunch rooms, and hygiene-specific housekeeping requirements. In the NPRM, OSHA requested comment on the requirements for use of protective clothing. After carefully reviewing the comments received on this issue, the Agency removed the requirement for protective clothing from the rule (see Regulated Areas in Section XV of the preamble).

Table IX-5: SBAR Panel Recommendations and OSHA Responses (continued)	
SBAR Panel Recommendation	**OSHA Response**
The Panel recommended that OSHA carefully review the issue of dry sweeping in the analysis, consider the concerns raised by the SERs, and ensure that its estimates are revised, as appropriate, to fully reflect the costs likely to be incurred by potentially affected establishments.	In the NPRM, OSHA requested comment on the use of wet methods as a substitute for dry sweeping. After carefully reviewing the comments received on this issue, the Agency revised the provision to prohibit dry sweeping where such activity could contribute to employee exposure to respirable crystalline silica, but provided an exception for situations in which wet sweeping, HEPA-filtered vacuuming or other methods that minimize the likelihood of exposure are not feasible (see Housekeeping in Section XV of the preamble). As a result, OSHA has mitigated the potential burden the prohibition on dry sweeping might have imposed on affected employers.
(General Industry) Some SERs were concerned that the prohibition on dry sweeping was not feasible or cost effective in their industries. The Panel recommended that OSHA consider this issue and solicit comment on the costs and necessity of such a prohibition.	In the NPRM, OSHA requested comment on the prohibition on dry sweeping. After carefully reviewing the comments received on this issue, the Agency revised the provision to prohibit dry sweeping where such activity could contribute to employee exposure to respirable crystalline silica, unless wet sweeping, HEPA-filtered vacuuming or other methods that minimize the likelihood of exposure are not feasible (see Housekeeping in Section XV of the preamble). As a result, OSHA has mitigated the potential burden the prohibition on dry sweeping might have imposed on affected employers.

The Panel recommended that OSHA carefully review the basis for its training costs, consider the concerns raised by the SERs, and ensure that its estimates are revised, as appropriate, to fully reflect the costs likely to be incurred by potentially affected establishments.	One participant in the silica SBAR process objected to ERG's analytical assumption (used in the PIRFA) that training is needed only for those workers exposed above the action level and suggested that training might be necessary for all at-risk workers. For the proposed rule, the scope of this requirement was revised so that the provision would apply to all workers with any potential occupational exposure to respirable crystalline silica; OSHA estimated training costs in the PEA accordingly. The final rule requires training for each covered employee. However, the rule does not apply in general industry and maritime where the employer has objective data demonstrating that employee exposure to respirable crystalline silica will remain below 25 μg/m^3 as an 8-hour time-weighted average under any foreseeable conditions and does not apply in construction where employee exposure will remain below 25 μg/m^3 as an 8-hour time-weighted average under any foreseeable conditions. For the PEA and this FEA, for employers where the rule applies, OSHA estimated higher training costs for small entities because of smaller-sized training classes and significantly increased training costs by assuming zero current compliance for all of the affected establishments (compared to an average of 56 percent existing compliance for all establishments in the PIRFA).
(Construction) SERs raised cost issues similar to	The cost estimates in this FEA reflect OSHA's best judgment and take the much

Table IX-5: SBAR Panel Recommendations and OSHA Responses (continued)	
SBAR Panel Recommendation	**OSHA Response**
those in general industry, but were particularly concerned about the impact in construction, given the high turnover rates in the industry. The Panel recommended that OSHA carefully review the basis for its estimated compliance costs, consider the concerns raised by the SERs, and ensure that its estimates are revised, as appropriate, to fully reflect the costs likely to be incurred by potentially affected establishments.	higher labor turnover rates in construction into account when calculating costs. For this analysis of the final rule, OSHA used the most recent BLS turnover rate of 70 percent for construction (versus a turnover rate of 25 percent for general industry). OSHA believes that the estimates in this FEA capture the effect of high turnover rates in construction, and in Chapter III, Profile of Affected Industries the Agency addresses the comments received on this issue in response to the NPRM.

(Construction) The Panel recommended that OSHA (1) carefully review the basis for its estimated labor costs, and issues related to the use of FTEs in the analysis, (2) consider the concerns raised by the SERs, and (3) ensure that its estimates are revised, as appropriate, to fully reflect the costs likely to be incurred by potentially affected establishments.	OSHA used the exposure profiles to estimate the number of full-time-equivalent (FTE) workers in construction who are exposed above the PEL. This would be the exposure profile if all exposed workers worked full-time only at the specified silica-generating tasks. In OSHA's preliminary analysis, the actual number of workers exposed above the PEL was estimated to be from two to five times the number of FTE workers, depending on the activity. For this FEA, OSHA developed a more nuanced approach to estimating the number of affected workers. OSHA first divided the construction sector into four subsectors in order to account for likely differences among them with respect to the frequency with which such silica-related tasks are performed. OSHA calculated that there are an estimated 387,710 FTE workers affected by the rule. In Chapter V, Costs of Compliance, OSHA converts these FTEs to 2.02 million affected construction workers disaggregated by occupation, thus resulting in an average ratio of over 5 workers per FTE. The estimate of the total number of at-risk workers takes into account the fact that most workers, regardless of construction occupation, spend some time working on jobs where no silica contamination is present. For the control cost analysis, however, it matters only how many worker-days there are in which exposures are above the PEL. These are the worker-days in which controls are required. The control costs (as opposed to the program costs) are independent of the number of at-risk workers associated with these worker-days. OSHA emphasizes that the use of FTEs does not "discount" its estimates of aggregate control costs.
(Construction) Some SERs requested that OSHA	In the NPRM, OSHA requested comment on the issue of a 30-day exemption.

Table IX-5: SBAR Panel Recommendations and OSHA Responses (continued)	
SBAR Panel Recommendation	**OSHA Response**
apply a 30-day exclusion for implementing engineering and work practice controls, as was reflected in the draft standard for general industry and maritime. The Panel recommended that OSHA consider this change and request comment on the appropriateness of exempting operations that are conducted fewer than 30 days per year from the hierarchy requirement.	After carefully reviewing the comments received on this issue, the Agency decided, with respect to general industry, maritime, and construction, that permitting employers to use respirators instead of feasible engineering and work practice controls for exposures occurring for 30 days or less per year would not best effectuate the purpose of the rule. OSHA also determined that it is reasonably necessary and appropriate to require the use of all feasible engineering and work practice controls in the construction industry, even for tasks of short duration, in order to protect employees from exposures to respirable crystalline silica. However, OSHA clarified in the final rules for construction, general industry, and maritime, that where engineering controls are not feasible to reduce exposures to or below the PEL, such as for certain maintenance and repair activities, respirators may be used instead (see Methods of Compliance and Respiratory Protection in Section XV of the preamble).

Table IX-5: SBAR Panel Recommendations and OSHA Responses (continued)	
SBAR Panel Recommendation	**OSHA Response**
(Construction) The Panel recommended that OSHA consider and seek comment on the need to prohibit employee rotation as a means of complying with the PEL and the likelihood that employees would be exposed to other serious hazards if the Agency were to retain this provision.	In the NPRM, OSHA requested comment on the prohibition of employee rotation to achieve compliance when exposure levels exceed the PEL. After carefully reviewing the comments received on this issue, OSHA removed the prohibition on employee rotation from the rule (see Methods of Compliance in Section XV of the preamble).
(Construction) Some SERs questioned the scientific and legal basis for the draft prohibitions on the use of compressed air, brushing, and dry sweeping of silica-containing debris. Others raised feasibility concerns such as in instances where water or electric power was unavailable or where use of wet methods could damage construction materials. The Panel recommended that OSHA carefully consider the need for and feasibility of these prohibitions given these concerns, and that OSHA seek comment on the appropriateness of such prohibitions.	OSHA requested comment on the prohibitions against the use of compressed air, brushing, and dry sweeping of silica-containing debris in the NPRM. After carefully reviewing the comments received on this issue, the Agency revised the rule to (1) prohibit dry sweeping where such activity could contribute to employee exposure to respirable crystalline silica, unless wet sweeping, HEPA-filtered vacuuming or other methods that minimize the likelihood of exposure are not feasible and (2) prohibit the use of compressed air where such an activity could contribute to employee exposures to respirable crystalline silica, unless it is used in conjunction with a ventilation system that effectively captures the dust cloud or no alternative method is feasible (see Housekeeping in Section XV of the preamble).

Table IX-5: SBAR Panel Recommendations and OSHA Responses (continued)	
SBAR Panel Recommendation	**OSHA Response**
(Construction) The Panel recommended that OSHA carefully consider whether regulated area provisions should be included in the draft proposed standard, and, if so, where and how regulated areas are to be established. OSHA should also clarify in the preamble and in its compliance assistance materials how compliance is expected to be achieved in the various circumstances raised by the SERs.	After carefully reviewing the comments received on the requirement for regulated areas in construction, OSHA removed the requirement from the construction standard and instead requires a written exposure control plan (see Regulated Areas and Written Exposure Control Plan in Section XV of the preamble).
(Construction) The Panel recommended that OSHA clarify how the regulated area requirements would apply to multi-employer worksites in the draft standard or preamble, and solicit comments on site control issues.	In the NPRM, OSHA requested comment on the applicability of the regulated area requirements to multi-employer worksites in construction. After carefully reviewing the comments received on this issue, OSHA removed the requirement for regulated areas from the construction standard and instead, requires a written exposure control plan that provides for a competent person to restrict access to work areas when necessary (see Regulated Areas and Written Exposure Control Plan in Section XV of the preamble). In addition, OSHA has added costs to account for additional controls for sole proprietors (self-employed workers) whose activities on a multi-employer site could expose others to silica. OSHA also amended the written exposure control plan provisions to clarify the employer's responsibility to account for silica exposures caused by sole proprietors and others when it develops its exposure control plan.

Table IX-5: SBAR Panel Recommendations and OSHA Responses (continued)	
SBAR Panel Recommendation	**OSHA Response**
(Construction) Many SERs were concerned with the extent to which they felt the draft proposed standard would require the use of respirators in construction activities. The Panel recommended that OSHA carefully consider its respiratory protection requirements, the respiratory protection requirements in Table 1, and the PEL in light of this concern.	In the NPRM, OSHA requested comment on the use of respirators in construction activities. After carefully reviewing the comments received on this issue and the exposure data in the record (described in Chapter IV of this FEA), OSHA identified those situations where respiratory protection is necessary and made significant revisions to the respiratory protection requirements specified in Table 1 based on those findings. The result is that respiratory protection is not required for most of the tasks covered by Table 1 (see Specified Exposure Control Methods in Section XV of the preamble).

Table IX-5: SBAR Panel Recommendations and OSHA Responses (continued)	
SBAR Panel Recommendation	**OSHA Response**
(Construction) The Panel recommended that OSHA carefully address the issues of reliability of exposure measurement for silica and laboratory requirements. The Panel also recommended that OSHA seek approaches to a construction standard that can mitigate the need for extensive exposure monitoring to the extent possible.	In the NPRM and PEA, OSHA raised the issue of reliability of exposure measurement and laboratory requirements for silica, and in Chapter IV of this FEA the Agency addresses comments on the issue. In the NPRM, the Agency also requested comment on the requirement for exposure assessment in the construction standard. After carefully reviewing the comments received on this issue, OSHA is not requiring employers to conduct exposure assessments for employees engaged in a task identified in Table 1, where the specified engineering controls, work practices, and respiratory protection are fully and properly implemented (see Specified Exposure Control Methods in Section XV of the preamble). Where construction employers are required to conduct exposure assessments, the Agency revised the rule to provide employers with greater flexibility for meeting this requirement using the performance option (see Exposure Assessment in Section XV of the preamble).

Table IX-5: SBAR Panel Recommendations and OSHA Responses (continued)	
SBAR Panel Recommendation	**OSHA Response**
(Construction) As in general industry, many SERs were concerned about all of these [protective clothing requirement] provisions because, they contended, silica is not recognized as either a take-home or dermal hazard. Further, many said that these provisions would be unusually expensive in the context of construction work. Other SERs pointed out that protective clothing could lead to heat stress problems in some circumstances. The Panel recommended that OSHA carefully re-examine the need for these provisions in the construction industry and solicit comment on this issue.	In the NPRM, OSHA requested comment on the requirements for use of protective clothing. After carefully reviewing the comments received on this issue, the Agency removed the requirement for protective clothing from the rule (see Regulated Areas in Section XV of the preamble).

Table IX-5: SBAR Panel Recommendations and OSHA Responses (continued)	
SBAR Panel Recommendation	**OSHA Response**
(Construction) The Panel recommended that OSHA explicitly examine the issue of availability of specialists called for by these [medical surveillance] provisions, and re-examine the costs and feasibility of such requirements based on their findings with respect to availability, as needed.	In the NPRM, OSHA requested comment on the availability of B Readers and pulmonary specialists to enable employers to achieve compliance with the medical surveillance provisions. After carefully reviewing the comments received on this issue, the Agency retained the requirement for B Readers given the ample evidence of sufficient numbers of B Readers and the value of B Reader interpretation according to ILO methods. The Agency also retained the requirement for examination by a specialist based on X-ray evidence of silicosis or if otherwise deemed appropriate by the physician or other licensed health care professional (PLHCP). OSHA expanded the definition of specialist to include occupational medicine specialists, in addition to pulmonary disease specialists. The record indicates a substantial number of pulmonary disease specialists are available in the U.S., and the addition of occupational medicine specialists should increase the number of qualifying specialists by about 20 percent (see Medical Surveillance in Section XV of the preamble). OSHA also requested comment on the costs for medical examinations and re-examined its estimates, as discussed in more detail in Section XV Medical Surveillance.

Table IX-5: SBAR Panel Recommendations and OSHA Responses (continued)	
SBAR Panel Recommendation	**OSHA Response**
(General Industry) The Panel recommended that OSHA explicitly examine and report on the availability of specialists called for by these [medical surveillance] provisions, and re-examine the costs and feasibility of such requirements based on their findings with respect to availability, as needed.	In the NPRM, OSHA requested comment on the availability of B Readers and pulmonary specialists. After carefully reviewing the comments received on this issue, the Agency retained the requirement for B Readers given the ample evidence of sufficient numbers of B Readers and the value of B Reader interpretation according to ILO methods. The Agency also retained the requirement for examination by a specialist based on X-ray evidence of silicosis or if otherwise deemed appropriate by the PLHCP. OSHA expanded the definition of specialist to include occupational medicine specialists, in addition to pulmonary disease specialists. The record indicates a substantial number of pulmonary disease specialists are available in the U.S., and the addition of occupational medicine specialists should increase the number of qualifying specialists by about 20 percent (see <u>Medical Surveillance</u> in Section XV of the preamble).

Table IX-5: SBAR Panel Recommendations and OSHA Responses (continued)	
SBAR Panel Recommendation	**OSHA Response**
(Construction) The Panel recommended that OSHA carefully consider the need for pre-placement physicals in construction, the possibility of delayed initial screening (so only employees who had been on the job a certain number of days would be required to have initial screening), and solicit comment on this issue.	OSHA does not require pre-placement physicals in the rule. In the NPRM, OSHA requested comment on the timing for initial examinations. After carefully reviewing the comments received on this issue, the Agency continued to only require medical surveillance in the construction standard for employees required to use a respirator for 30 or more days a year, and with respect to that group of employees, OSHA retained the requirement for employers to provide initial examinations within 30 days after initial assignment. Giving employers a 30-day period to offer medical surveillance offers them flexibility in accomplishing the screening (see Medical Surveillance in Section XV of the preamble). OSHA has also clarified that employees do not need a second "initial" screening when they switch employers but are still within the valid time period (3 years) for their initial screening.

Table IX-5: SBAR Panel Recommendations and OSHA Responses (continued)	
SBAR Panel Recommendation	**OSHA Response**
(Construction) Like the general industry SERs, construction SERs raised the issue that they would prefer a warning label with wording similar to that used in asbestos and lead. The Panel recommended that OSHA consider this suggestion and solicit comment on it.	In the NPRM, OSHA requested comment on the requirements for warning labels. After carefully reviewing the comments received on this issue, the Agency has not included new requirements or specifications for warning labels in this standard. Warning labels are specified by OSHA's hazard communication standard (HCS) (29 CFR 1926.59;29 CFR 1910.1200). OSHA has structured the hazard communication requirements in the silica rule to be as consistent as possible with HCS to avoid a duplicative administrative burden on employers who must comply with both HCS and this rule (see Communication of Respirable Crystalline Silica Hazards to Employees in Section XV of the preamble).
(Construction) Some SERs questioned whether hazard communication requirements made sense on a construction site where there are tons of silica-containing dirt, bricks, and concrete. The Panel recommended OSHA consider how to address this issue in the context of hazard communication.	In the NPRM, OSHA requested comment on the applicability of hazard communication requirements to construction. After carefully reviewing the comments received on this issue, the Agency retained the requirements for hazard communication in the construction standard (see Communication of Respirable Crystalline Silica Hazards to Employees in Section XV of the preamble).

Table IX-5: SBAR Panel Recommendations and OSHA Responses (continued)	
SBAR Panel Recommendation	**OSHA Response**
(Construction) The Panel recommended that OSHA carefully review the recordkeeping requirements with respect to both their utility and burden.	In the NPRM, OSHA requested comment on the recordkeeping requirements. After carefully reviewing the comments received on this issue, the Agency retained the recordkeeping requirements in the rule (see Recordkeeping in Section XV of the preamble). OSHA has also reviewed the recordkeeping requirements as required by the Paperwork Reduction Act. Detailed analysis of the recordkeeping requirements can be found in OSHA's information collection request submitted to OMB.
The Panel recommended that OSHA, to the extent permitted by the availability of economic data, update economic data to better reflect recent changes in the economic status of the affected industries consistent with its statutory mandate.	OSHA has prepared this FEA using the most current economic data available, including data introduced into the record by SERs and other small entities who participated in the rulemaking. The profits data now encompasses a time period that includes 2008 and reflects the economic effects of the great recession.

SERs in construction, and some in general industry, felt the estimate of affected small entities and employees did not give adequate consideration to workers who would be subject to exposure at a site but were not directly employed by firms engaged in silica-associated work, such as employees of other subcontractors at a construction site, visitors to a plant, etc. The Panel recommended that OSHA carefully examine this issue, considering both the possible costs associated with such workers, and ways of clarifying what workers are covered by the standard.	The OSH Act authorizes OSHA to protect employees. OSHA does not have authority to regulate sole proprietors without employees (self-employed workers). Therefore it would not be appropriate to include them in the estimates of entities regulated by the rule. Nevertheless, the final cost analysis for construction accounts for costs related to the presence of self-employed workers on or near multi-employer work sites. OSHA also adjusted the written exposure control plan requirements in construction to account for exposures to an employer's employees caused by the activities of another entity. To address concerns about the number of entities who might be impacted by the rule as the result of tasks that produce low levels of silica exposure and do not comprise a significant portion of their employees' work days, OSHA adjusted the scope of both the general industry and construction standards. The rule does not apply in general industry and maritime where the employer has objective data demonstrating that employee exposure to respirable crystalline silica will remain below 25 μg/m^3 as an 8-hour time-weighted average under any foreseeable conditions, and does not apply in construction where employee exposure will remain below 25 μg/m^3 as an 8-hour time-weighted average under any foreseeable conditions (see Scope in Section XV of the preamble).
The Panel recommended that OSHA clarify in any	The contents of OSHA's final rule have no direct bearing on whether silica waste

Table IX-5: SBAR Panel Recommendations and OSHA Responses (continued)	
SBAR Panel Recommendation	**OSHA Response**
rulemaking action how its action is or is not related to designating silica-containing materials as hazardous wastes.	is classified as hazardous for EPA purposes. The relationship between the final rule and EPA requirements is discussed in Chapter X, Environmental Impacts, in this FEA and in Section XIV, Environmental Impacts, of the preamble.
Some SERs also noted the issue that the use of wet methods in some areas may violate EPA rules with respect to suspended solids in runoff unless provision is made for recycling or settling the suspended solids out of the water. The Panel recommended that OSHA investigate this issue, add appropriate costs if necessary, and solicit comment on this issue.	In the PEA, a preliminary analysis of wet methods for dust controls indicated that in most cases the amount of slurry discharged is not sufficient to cause a run off to storm drains. OSHA solicited comment on this topic in the NPRM. The comments received corroborated OSHA's preliminary finding. OSHA's final analysis of environmental impacts in Chapter X of this FEA contains the Agency's response to comments on this issue.

Table IX-5: SBAR Panel Recommendations and OSHA Responses (continued)	
SBAR Panel Recommendation	**OSHA Response**
The Panel recommended that OSHA (1) carefully consider and solicit comment on the alternative of improved outreach and support for the existing standard; (2) examine what has and has not been accomplished by existing outreach and enforcement efforts; and (3) examine and fully discuss the need for a new standard and if such a standard can accomplish more than improved outreach and enforcement.	OSHA analyzed past outreach and compliance initiatives and their effects on compliance with current PELs in Section III, Events Leading to the Final Standard, of the preamble. An explanation of OSHA's choice of the new PEL is provided in several places, including in this FRFA in the section preceding this one.

Table IX-5: SBAR Panel Recommendations and OSHA Responses (continued)	
SBAR Panel Recommendation	**OSHA Response**
(Construction) The Panel recommended, if there is to be a standard for construction, that OSHA: (1) seek ways to greatly simplify the standard and restrict the number of persons in respirators; (2) consider the alternative of a standard oriented to engineering controls and work practices in construction; and (3) analyze and solicit comment on ways to simplify the standard.	In the NPRM, OSHA requested comment on the approach for construction in the NPRM. After carefully reviewing the comments received on this issue, the Agency significantly revised the structure of the construction rule to focus on the tasks known to generate high exposures to respirable crystalline silica. Where employers fully and properly implement the specified engineering controls, work practices, and respiratory protection for each employee engaged in a task identified in Table 1, the employer is not also required to conduct exposure assessments to determine compliance with the PEL. The Agency also revised the notes and specifications in Table 1 to clarify what is required for employers to fully and properly implement the specified engineering controls, work practices, and respiratory protection for tasks in Table 1 (see Specified Exposure Control Methods in Section XV of the preamble). The clear and specific guidance in Table 1, along with the opportunity Table 1 provides for employers to avoid exposure monitoring costs will make compliance easier and less expensive. After carefully reviewing the comments received on respiratory protection requirements for the construction standard and the exposure data in the record (described in Chapter IV of this FEA), OSHA identified those situations where respiratory protection is necessary and made significant revisions to the respiratory protection requirements specified in Table 1 based on those findings. The result is that respiratory protection is not required for most of the tasks covered by Table 1 (see Specified Exposure Control Methods in Section XV of the preamble).

Table IX-5: SBAR Panel Recommendations and OSHA Responses (continued)	
SBAR Panel Recommendation	**OSHA Response**
The Panel recommended that, if there is to be a standard, OSHA consider and solicit comment on maintaining the existing PEL. The Panel also recommends that OSHA examine each of the ancillary provisions on a provision-by-provision basis in light of the comments of the SERs on the costs and lack of need for some of these provisions.	In the NPRM, OSHA requested comment on the PEL and ancillary requirements. After carefully reviewing the comments received on this issue, OSHA retained the proposed PEL because it is necessary for any new rule to meet the legal requirement to reduce significant risk to the extent feasible. Because the new PEL is a fixed value, OSHA also believes that it is easier to understand when compared to the preceding PELs, which differed between Construction and General Industry (see Permissible Exposure Limit in Section XV of the preamble). OSHA has reexamined the costs of the ancillary provisions in light of further comments (see Chapter V of this FEA) and addresses the need for the ancillary provisions in their respective sections in Section XV Summary and Explanation of the preamble.
(General Industry) The Panel recommended that OSHA carefully examine the technological and economic feasibility of the draft proposed standard in light of these SER comments.	This FEA reflects OSHA's judgments on the technological and economic feasibility of the final standard and includes responses to specific issues raised by the Panel and other rulemaking participants. In the NPRM, OSHA solicited comment on the accuracy and reasonableness of the Agency's preliminary judgments; this final analysis reflects the Agency's review of and response to all issues raised by SERs and other small entities who participated in the rulemaking.

Table IX-5: SBAR Panel Recommendations and OSHA Responses (continued)	
SBAR Panel Recommendation	**OSHA Response**
(General Industry) The Panel recommended that OSHA carefully consider whether regulated area provisions should be included in the draft proposed standard, and, if so, where and how regulated areas are to be established. OSHA should also clarify in the preamble and in its compliance assistance materials how compliance is expected to be achieved in the various circumstances raised by the SERs.	After carefully reviewing the comments received on the requirement for regulated areas in general industry and maritime, OSHA retained the requirement to establish regulated areas where exposures are or are reasonably expected to be above the PEL and removed the access control plan option from the standard. The provision requires employers to demarcate the regulated area, post signs with specified language at all entrances, limit access to the area, and provide appropriate respiratory protection to any employee or designated representative entering the area (see Regulated Areas and Written Exposure Control Plan in Section XV of the preamble).
(General Industry) The Panel recommended that OSHA carefully examine the issues associated with reliability of monitoring and laboratory standards in light of the SER comments, and solicit comment on these issues.	In the NPRM, OSHA requested comment on the specified sampling and analytical methods. After carefully reviewing the comments received on this issue, the Agency retained the sampling and analytical methods requirements (see Appendices in Section XV of the preamble and Chapter IV of this FEA).

Table IX-5: SBAR Panel Recommendations and OSHA Responses (continued)	
SBAR Panel Recommendation	**OSHA Response**
(General Industry) Some SERs preferred the more performance-oriented Option 2 provision included in the draft exposure assessment requirements, stating that fixed-frequency exposure monitoring can be unnecessary and wasteful. However, other SERs expressed concern over whether such a performance-oriented approach would be consistently interpreted by enforcement officers. The Panel recommended that OSHA continue to consider Option 2 but, should OSHA decide to include it in a proposed rule, clarify what would constitute compliance with the provision. Some SERs were also concerned about the wording of the exposure assessment provision	In the NPRM, OSHA requested comment on the exposure assessment requirements for general industry and maritime. After carefully reviewing the comments received on this issue, the Agency significantly revised the requirements for initial exposure assessment and periodic exposure assessment in order to provide employers with the greater flexibility they had requested. The standard allows the employer to use either the performance option or the scheduled monitoring option for exposure assessments. OSHA also clarified that the performance option provides employers with flexibility in the methods used to assess employee exposures and provided examples of how employers can accurately characterize employee exposures using the performance option (see Exposure Assessment in the Summary and Explanation Section of the preamble, Section XV).

Table IX-5: SBAR Panel Recommendations and OSHA Responses (continued)	
SBAR Panel Recommendation	**OSHA Response**
(General Industry) Some SERs were also concerned about the wording of the exposure assessment provision of the draft proposed standard. These SERs felt that the wording could be taken to mean that an employer needed to perform initial assessments annually. The Panel recommended that OSHA clarify this issue.	In the final rule, OSHA has clarified the regulatory text to ensure it does not suggest that employers must repeat initial assessments annually. OSHA has also provided employers with greater flexibility to use either the performance option or the scheduled monitoring option to meet their ongoing exposure assessment obligations (see Exposure Assessment in Section XV of the preamble).
(General Industry) The SER comments included several suggestions regarding the nature and wording of the health screening requirements. (See, e.g., OSHA, 2003, Document ID 0937, pp. 25-28.) The Panel recommended that OSHA consider revising the standard in light of these comments, as appropriate.	OSHA has considered these comments and revised the standard where appropriate. Revisions included naming this section of the rule medical surveillance; removing the symptom trigger for medical exams; removing the requirement for the medical and work history to be administered by a health care provider and adding smoking history as a requirement of histories; redefining the size of allowable X-ray films and limiting X-ray readings to only B Readers; defining who can offer medical exams as physicians or other licensed health care providers (PLHCPs); and decreasing the frequency for periodic examinations (see Medical Surveillance in Section XV of the preamble).

Table IX-5: SBAR Panel Recommendations and OSHA Responses (continued)	
SBAR Panel Recommendation	**OSHA Response**
(General Industry) Though the provision for hazard communication simply repeats such provisions already in existence, some SERs urged OSHA to use this opportunity to change the requirement so that warning labels would only be required of substances that were more than 1% (rather than the current 0.1%) by weight of silica. The Panel recommended that OSHA consider this suggestion and solicit comment on it.	In the NPRM, OSHA requested comment on the requirement for warning labels. After carefully reviewing the comments received on this issue, the Agency has not included new requirements or specifications for warning labels in this standard. OSHA has structured the hazard communication requirements in the silica rule to be as consistent as possible with HCS to promote the harmonization of the classification and labelling of chemicals and avoid duplicative administrative burden on employers who must comply with both the HCS and this rule (see Communication of Respirable Crystalline Silica Hazards to Employees in Section XV of the preamble).
(General Industry) The Panel recommended that OSHA carefully review the recordkeeping requirements with respect to both their utility and burden.	In the NPRM, OSHA requested comment on the recordkeeping requirements. After carefully reviewing the comments received on this issue, the Agency retained the recordkeeping requirements in the rule (see Recordkeeping in Section XV of the preamble). OSHA has also reviewed the recordkeeping requirements as required by the Paperwork Reduction Act. Detailed analysis of the recordkeeping requirements can be found in OSHA's information collection request submitted to OMB.

Table IX-5: SBAR Panel Recommendations and OSHA Responses (continued)	
SBAR Panel Recommendation	**OSHA Response**
(Construction) The Panel recommended that OSHA continue to evaluate the appropriateness of and consider modifications to scope Option 2 [the standard would apply whenever employees perform a list of activities that involve the application of certain forces to concrete, brick, block, mortar, rock, soil or other material containing crystalline silica, and to abrasive blasting operations where there is potential for exposure to crystalline silica] that can more readily serve to limit the scope of the standard.	OSHA retained Scope Option 1 [the rule would apply wherever there is occupational exposure to airborne respirable crystalline silica in construction workplaces], but revised the provision to exempt situations in which employee exposure will remain below 25 μg/m^3 as an 8-hour time-weighted average under any foreseeable conditions. (see Scope in Section XV of the preamble).

Table IX-5: SBAR Panel Recommendations and OSHA Responses (continued)	
SBAR Panel Recommendation	**OSHA Response**
(Construction) Many SERs found the requirements for a competent person hard to understand. Many SERs took the competent person requirement as requiring a person with a high level of skills, such as the ability to conduct monitoring. Other SERs said this requirement would require training a high percentage of their employees as competent persons because they typically had many very small crews at many sites. In general, the SERs thought this requirement as written would be difficult to comply with and costly. The Panel recommended that OSHA seek ways to clarify OSHA's intent with respect to this requirement and more clearly delineate the responsibilities of competent persons.	OSHA clarified the role and responsibilities of the competent person in the construction standard. In paragraph (b) of the construction standard for respirable crystalline silica, OSHA defines competent person as an individual who is capable of identifying existing and foreseeable respirable crystalline silica hazards in the workplace and who has authorization to take prompt corrective measures to eliminate or minimize them. The definition also specifies that the competent person have the knowledge and ability necessary to fulfill the responsibilities set forth in paragraph (g). In paragraph (g)(4) of the construction standard, the employer is required to designate a competent person to make frequent and regular inspections of job sites, materials, and equipment to implement the written exposure control plan. None of these provisions require the competent person to have the ability to conduct air monitoring (see <u>Definitions</u> and <u>Written Exposure Control Plan</u> in Section XV of the preamble).

Table IX-5: SBAR Panel Recommendations and OSHA Responses (continued)	
SBAR Panel Recommendation	**OSHA Response**
(Construction) Many SERs did not understand that Table 1 was offered as an alternative to exposure assessment and demonstration that the PEL is being met. Some SERs, however, understood the approach and felt that it had merit. These SERs raised several issues concerning the use of Table 1, including: • The Table should be expanded to include all construction activities covered by the standard, or the scope of the standard should be reduced to only those activities covered by Table 1; • The control measures endorsed in Table 1 need to be better established, as necessary; and • Table 1 should require less use of, and possibly no use of, respirators. The Panel recommended that OSHA carefully consider these suggestions, expand Table 1, and make other modifications, as appropriate.	In the NPRM, OSHA requested comment on the approach for construction. After carefully reviewing the comments received on this issue, the Agency significantly revised the structure of the construction rule to focus on the tasks known to generate high exposures to respirable crystalline silica. Where employers fully and properly implement the specified engineering controls, work practices, and respiratory protection for each employee engaged in a task identified in Table 1, the employer is not required to also conduct exposure assessments to determine compliance with the PEL. The Agency also revised the notes and specifications in Table 1 to clarify what is required for employers to fully and properly implement the engineering controls, work practices, and respiratory protection for tasks in Table 1 (see Specified Exposure Control Methods in Section XV of the preamble). The clear and specific guidance in Table 1, along with the opportunity Table 1 provides for employers to avoid monitoring costs, will make compliance easier and less expensive. After carefully reviewing the comments received on respiratory protection requirements for the construction standard and the exposure data in the record (described in Chapter IV of this FEA), OSHA identified those situations where respiratory protection is necessary and made significant revisions to the respiratory protection requirements specified in Table 1 based on those findings. The result is that respiratory protection is not required for most of the tasks covered by Table 1 (see Specified Exposure Control Methods in Section XV of the preamble).

Table IX-5: SBAR Panel Recommendations and OSHA Responses (continued)	
SBAR Panel Recommendation	**OSHA Response**
The Panel recommends that OSHA thoroughly review the economic impacts of compliance with a proposed silica standard and develop more detailed feasibility analyses where appropriate.	OSHA significantly expanded its economic impact and economic feasibility analyses in Chapter VI of the PEA. As part of that impact analysis, OSHA added data on normal year-to-year variations in prices and profit rates in affected industries to provide a context for evaluating potential price and profit impacts of the proposed rule. Sections were also added to estimate the potential international trade impacts and macroeconomic impacts of the proposed rule. OSHA invited comment in the PEA on the issues of the economic impacts and the economic feasibility of the proposed rule. Chapter VI in this FEA discusses comments on economic impacts, OSHA's response to those comments, and the Agency's final analysis of economic impacts and regulatory flexibility.
(Construction) The panel recommends that OSHA re-examine its cost estimates for respirators to make sure that the full cost of putting employees in respirators is considered.	For the PEA, OSHA re-examined and updated its cost estimates for each type of respirator. Unit respirator costs included the cost of the respirator itself and the annualized cost of respirator use, to include accessories (e.g., filters), training, fit testing, and cleaning. In addition, OSHA added a cost for employers to establish a respirator program. For this FEA, all costs have been updated to 2012 dollars. OSHA solicited comment on this issue in the PEA; in this FEA, OSHA's final estimate of costs for respiratory protection (see Chapter V) conveys the Agency's response to public comment.

Table IX-5: SBAR Panel Recommendations and OSHA Responses (continued)	
SBAR Panel Recommendation	**OSHA Response**
(Construction) Some SERs indicated that the unit costs were underestimated for monitoring, similar to the general industry issues raised previously. In addition, special issues for construction were raised (i.e., unpredictability of exposures), suggesting the rule would be costly, if not impossible to comply with. The Panel recommends that OSHA carefully review the basis for its estimated compliance costs, consider the concerns raised by the SERs, and ensure that its estimates are revised, as appropriate, to fully reflect the costs likely to be incurred by potentially affected establishments.	To reflect the fact that an industrial hygienist could not typically take as many samples a day in a small establishment as in a large one, OSHA developed cost estimates for exposure monitoring as a function of the size of the establishment. OSHA's cost estimates therefore now reflect the fact that smaller entities will tend to experience larger unit costs for exposure monitoring. To address concerns about unpredictability of exposure in construction, as well as to provide more specific guidance to employers, OSHA designed Table 1 in the final standard to allow establishments in construction the option, for many common tasks, to implement engineering controls, work practices, and respiratory protection without the need for exposure assessment. OSHA has carefully reviewed the basis for its exposure monitoring cost estimates and considered the concerns raised by the SERs. OSHA solicited comments on this issue in the PEA, and in Chapter V of this FEA the final analysis of costs for exposure monitoring reflects the Agency's response to public comment.

Table IX-5: SBAR Panel Recommendations and OSHA Responses (continued)	
SBAR Panel Recommendation	**OSHA Response**
(General Industry) The Panel recommends that OSHA use the best scientific evidence and methods available to determine the significance of risks and magnitude of benefits for occupational exposure to silica. The Panel further recommends that OSHA evaluate existing state silicosis surveillance data to determine whether there are industry-specific differences in silicosis risks, and whether or how the draft standard should be revised to reflect such differences.	OSHA has conducted a comprehensive review of the scientific evidence from toxicological and epidemiological studies on adverse health effects and baseline estimates of the risks of developing silica-related diseases associated with occupational exposure to respirable crystalline silica. This review is summarized in Section V of the preamble, Health Effects and Quantitative Risk Assessment. The significance of these risks is examined in Section VI, Significance of Risk. The benefits associated with the final rule are summarized in Chapter VII of this FEA. Although OSHA's final analysis indicates that a variety of factors may affect the toxicological potency of crystalline silica found in different work environments, OSHA has not identified information that would allow the Agency to calculate how these influences may affect disease risk to workers in any particular workplace setting.

Table IX-5: SBAR Panel Recommendations and OSHA Responses (continued)	
SBAR Panel Recommendation	**OSHA Response**
The SERs, however, also had many specific issues concerning what OSHA should do if it chooses to go forward with a proposed rule. In order to reflect these specific issues, the Panel has made many recommendations concerning issues to be considered if the Agency goes forward with a rule. The Panel also recommends that OSHA take great care in reviewing and considering all comments made by the SERs.	OSHA has carefully considered the Panel recommendations, and the Agency's responses are listed in this table. In addition, specific issues raised in comments by individual SERs are addressed throughout the preamble.

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Chapter X: Environmental Impacts

INTRODUCTION

OSHA has reviewed the final rule according to the National Environmental Policy Act (NEPA) of 1969 (42 U.S.C. 4321 *et seq*.), the regulations of the Council on Environmental Quality (40 CFR part 1500 *et seq.*), and the Department of Labor's NEPA procedures (29 CFR part 11). The Agency has determined that the final rule will have no significant impact on air, water, or soil quality; plant or animal life; the use of land; or other aspects of the external environment. Therefore, OSHA concludes that the final standard will have no significant environmental impacts. This conclusion reaffirms the conclusions set forth in the Preliminary Economic Analysis (PEA).

To reach this conclusion, OSHA examined comments received about the potential environmental impacts posed by the final rule. Comments addressed two main issues: (1) potential water runoff from construction tasks; and (2) costs associated with federal, state, and local environmental permits employers could be required to obtain as a result of the final rule. There were no specific comments regarding soil quality, plant or animal life, or land use. This section first lays out OSHA's preliminary conclusions regarding environmental impacts and then shows why the best available evidence in the rulemaking record reaffirms those conclusions.

SBREFA AND CONCLUSIONS CONTAINED IN THE PEA

Pursuant to the recommendations from the Small Business Advocacy Review Panel, the Agency investigated potential environmental impacts and articulated its findings in the PEA. As noted in the SBREFA report (OSHA-H006A-2006-0800-0025, p. 77), the Panel requested that OSHA clarify how its silica rulemaking was related to designating silica-containing materials as hazardous wastes. In the PEA, OSHA explained that it did not believe silica wastes are classified as hazardous wastes for purposes of the Environmental Protection Agency (EPA) (Document ID 1720, p. IX-68). And the contents of OSHA's final rule on silica have no direct bearing on whether silica waste is classified as hazardous for EPA purposes.

In addition, some Small Entity Representatives (SERs) raised the possibility that the use of wet methods to limit silica exposures in some areas could violate EPA rules with respect to suspended solids in runoff unless provisions are made for recycling or settling the suspended solids out of the water. The SBAR Panel recommended that OSHA investigate this issue, add appropriate costs if necessary, and solicit comment. In response, the Agency identified six construction tasks where wet methods were utilized and found negligible costs related to controlling excess water because the amount of water used to control silica dust was minimal and typically did not produce runoff. OSHA's estimate of the potential environmental impact of each of these six equipment types was summarized in the PEA as follows:

- Stationary masonry saws: Most stationary saws come equipped with a water basin that typically holds several gallons of water and a pump for recycling water for wet cutting. The water is recirculated and, thus, not continually discharged. When emptied, the amount of water is not sufficient to produce a runoff.

- Hand-held masonry saws: Large quantities of water typically are not required in order to control dust. With these saws, water is supplied from a small capacity water tank. Any slurry residue after cutting could be dealt with by sweeping or vacuuming.

- Walk-behind and other large concrete saws: Larger concrete saws are equipped with a tank to supply water to the blade while cutting. These saws leave a slurry residue, but do not require so much water as to create a runoff.

- Walk-behind concrete grinders and millers: Some tools are equipped with a water-feed system. In these, a water line from a tank, a garden hose, or other water supply leads to the grinding head and delivers water to spray or flood the cutting tool and/or the work surface. When an automatic water feed is not available, a helper can apply water directly to the cutting surface. While such wet methods might generate enough water to create a runoff, these grinding and milling activities are typically done during the finishing stages of structure construction (e.g., parking garages) and are often performed inside the structure. Thus, direct discharges to storm drains or surface waters are unlikely.

- Asphalt millers for pavement resurfacing: A typical asphalt milling machine has a built-in reservoir from which water is applied to the cutting drum. The amount of water used, however, is insufficient to produce a runoff.

- Impact drillers/pavement breakers: Water for dust suppression can be applied manually or by using a semi-automated water-feed device. In the simplest method for suppressing dust, a dedicated helper directs a constant spray of mist at the impact point while another worker operates the jackhammer. The helper can use a hose with a garden-style spray nozzle to maintain a steady and carefully directed mist at the impact point where material is broken and crushed. Jackhammers retrofitted with a focused water mist aimed at the tip of the blade offer a dramatic decrease in silica exposure. Although water-fed jackhammers are not

> commercially available, it is neither expensive nor difficult to retrofit equipment. Studies suggest that a water flow rate of 1/8 to 1/4 gallon per minute is best for silica dust control. At this rate, about 7.5 to 15 gallons of water per hour would be applied to (i.e., sprayed on) the work area. It is unclear whether this quantity of water applied to a moveable work area at a constant rate would produce a runoff. If the work were in sufficient proximity to a storm drain or surface water, the contractor might need to use a simple barrier to prevent the water from entering the drain, or otherwise filter it. Because the volume of water is relatively small, the costs for such barriers are likely insubstantial and would typically overlap with the contractor's existing obligations for a site-control plan to prevent unwanted runoff from other causes.

In the PEA, OSHA found that employers typically have pre-existing obligations to limit runoff of solid waste, such as from rainfall, into storm drains. The Agency preliminarily concluded that: (1) the use of wet methods for certain construction tasks would not cause significant environmental problems from water runoff; and (2) employers should be able to comply with non-OSHA environmental regulations because runoff from wet methods can be easily controlled. As explained below, in light of the best available evidence contained in the record, OSHA reaffirms its preliminary conclusions.

Potential Water Runoff from Construction Tasks

While the Agency did not receive any comments directly addressing the PEA's discussion of environmental impacts, it did receive several comments on the water runoff issue. Most of the concerns expressed related to construction work, although a few comments came from entities in general industry. The construction and general industry commenters that addressed the issue of water runoff from the use of wet methods to comply with the final PEL included James Hardie Building Products, Inc.; the Unified Abrasives Manufacturers' Association; American Road & Transportation Builders Association; the General Contractors Association of New York; the Masonry & Concrete Saw Manufacturers Institute; and the Fertilizer Institute. None of the commenters to raise this issue provided any evidence to establish that runoff created by wet methods would actually create a problem (Document ID 2322, Attachment A, p. 174; 2243, p. 2; 2245, p. 4; 2314, p. 2; 2316, Attachment 1, pp. 2-3; 2101, pp. 6-7 and 11-12). For example, one commenter, the Construction Industry Safety Coalition, advanced a theoretical argument that wet methods would either: (a) require "tremendous" amounts of water; or (b) fail to effectively control silica. It stated:

> For employers using wet methods, even attempting to meet this "no visible dust" standard will require a tremendous amount of water - many studies discussed in the technological feasibility analysis certainly support this

> notion. Such large amounts of water run counter to OSHA's contractor's assessment that "minimal" water should be used to avoid environmental contamination issues. The Agency contends that construction employers can mitigate any environmental concerns by utilizing as little water as possible to prevent accumulations from occurring or potentially damaging residential or commercial buildings. Even if utilizing only a little water will effectively reduce exposures to below the proposed PEL, the CISC has significant concerns that it will prevent *all* visible dust from being emitted (Document ID 2320, Attachment 1, pp. 9-10).

In light of the discussion set forth in Chapter VI of this FEA, Technological Feasibility, and evidence in the record, OSHA's preliminary findings regarding water runoff are affirmed. The Agency concludes that the comments it received expressing concerns about the runoff issue are unsubstantiated and theoretical and do not provide a sufficient justification for OSHA to alter its preliminary conclusions. As discussed in the Technological Feasibility section, OSHA finds that appropriate wet methods will typically require only limited application of water, possibly as little as a mist. In such conditions, the water will evaporate before collecting into a body of water. Where a greater water flow is necessary to suppress airborne silica, the runoff, rather than forming a free-flowing stream, will typically consolidate into slurry. In addition, because employers want to keep nearby structures and materials dry, they will typically use as little water as necessary.

OSHA finds support for these findings in the hearing testimony compilation assembled by the Building and Construction Trades Department. That evidence demonstrates the practical reality that water runoff from construction tasks is insignificant (Document ID 4223, pp. 28-30). Indeed, Deven Johnson, of the Operative Plasterers' and Cement Masons' International Association, stated that in her years of experience in using wet methods to control relatively dusty situations involving demolition, she had never had a problem with runoff-related issues. She indicated that runoff tends to create a slurry, which is easily vacuumed up (Document ID 3581, pp. 1695-1696). Gary Fore, a consultant and former Vice President for the American National Asphalt Pavement Association, likewise said that runoff was never a problem. He confirmed the PEA's preliminary conclusion for asphalt milling operations. While there may be a substantial amount of water used in the course of a day, it is applied as an aerosol. Further, although the pavement surface may be temporarily moist, it does not produce runoff from the construction site (Document ID 3583, p. 2209). Finally, Donald Hulk, Safety Director for Manafort, a construction contractor, testified that contrary to hypothetical assertions about potential runoff issues, his company did not find managing potential runoff from wet methods to be a problem. His reasoning confirmed the PEA's finding that the amount of water required for typical silica-containing dust suppression will not create substantial runoff. Moreover, he testified that in the case of demolition related to roadway construction, excess water is typically absorbed into demolition debris or evaporates—which is aided by the fact that most construction activity occurs during the warmer parts of the year (Document ID 3583, Tr. 2384-2385).

Certain industries voiced water runoff concerns specific to their workplaces. For example, the fertilizer industry stated its apprehension about OSHA's "preference" for wet methods to control silica exposure and indicated that such methods would be potentially problematic from an environmental standpoint at its facilities (Document ID 2101, pp. 6-7 and11-12). OSHA finds the fertilizer industry's concern misplaced because the final standard does not require the use of wet methods in general industry. Additionally, as discussed in Chapter III, the Agency estimates that exposures to respirable crystalline silica in the fertilizer industry are sufficiently low that most fertilizer-related manufacturing industries will not be affected by the final standard; the mixing-only fertilizer industry, NAICS 325314, was the only one judged to be affected.

The coal-fired electric industry also raised the issue of water runoff in its industry. The Edison Electric Institute and Alabama Power Company indicated a potential for conflict between an EPA rulemaking regarding ash ponds at the site of coal-fired electric utilities and this rulemaking (Document ID 2357, pp. 28-29; 2185, Attachment 1, p. 11). OSHA considered this concern, but has concluded that this will not be a problem in practice. The commenters never explained how the wet methods that might be required in Table 1 for construction activities (e.g., cutting concrete for transmission and distribution) would result in water flowing into fly ash ponds. In any event, the Agency has found that the proper use of wet methods will not result in significant runoff issues for any of the industries covered by the standard.[1]

Air Quality/Permit Concerns

Regulations that will reduce the atmospheric concentration of respirable crystalline silica in the air within industrial and other facilities and workplaces have the potential to affect, either positively or negatively, the amount of respirable crystalline silica emitted by these sources into the ambient (external) environment. In most cases, the change will be small. As discussed in Chapter 5 most ventilation is needed to reach the preceding PEL rather than the new PEL. The extent to which the reduction in the PEL – and, hence, occupational exposures – under the OSHA standard will impact air quality depends on how employers handle the increased volume of respirable crystalline silica captured by the relevant control technologies. Taking into account the measures employers are already using to comply with the existing silica PEL, and the fact that the baghouses

[1] Alabama Power also referred to problems with environmental permits, but did not specify to which environmental permits they were referring. Permit issues are addressed later in this section.

employers are already using capture at least 99 percent of silica emissions (Document ID 3641, p. VII-19), OSHA concludes that the final rule will not have a significant impact on air quality

A number of commenters raised concerns that the final rule would create an onerous and cost-increasing administrative burden because it would necessitate obtaining EPA environmental permits, notably with regard to air quality regulations and related permits and process approvals at the state and local level. The concern was not an adverse environmental impact, per se, but rather the burden of complying with existing environmental rules in the context of the new OSHA standard (See, e.g., Document ID 2291, Attachment 1, p. 12; 2379, Appendix 1, p. 14; 2380, Attachment 2, p. 19; 2317, pp. 2-3). OSHA's response to these cost concerns is addressed in Chapter V in the section on general industry engineering control costs.

A prime concern voiced by the commenters was having to comply with OSHA compliance deadlines while simultaneously meeting deadlines under applicable air quality permitting regulations.

For example, the Asphalt Roofing Manufacturers Association (ARMA) raised the issue of EPA permits related to changes in ventilation systems.

> …the proposal appears to completely disregard environmental permitting requirements, which will present a significant time demand in almost every case because the standard will require increased dust collection, and releases to outside air will trigger air pollution limitations and permitting requirements for both State and or Federal agencies. Recent experience of ARMA members relating to implementation of the new National Ambient Air Quality Standards (NAAQS) for particulate matter (PM2.5) reveals that, even in the case of minor facility modifications which emit particulate matter, authorization to construct or modify a control device can take more than a year to obtain. Even longer permitting times will be experienced in cases requiring complex modeling of nearby sources, or State or Federal approval of modeling methods and protocol inputs. These factors could further delay the issuance of permits by an additional twelve months, assuming the facility is able to develop a passing model. If the model does not pass, further modeling and review by permitting agencies, or additional emissions abatement, may be required to obtain the permits, extending still further this step in the process (Document ID 2291, Attachment 1, p. 12).

As the Agency explains in the Summary & Explanation section of the preamble dealing with paragraph (j), dates, the final rule's effective and enforcement dates have been tailored to allow a sufficient period of time for employers to meet requirements for approval by other regulatory agencies. (A discussion of various state permitting times can be found in "Examples of State Environmental Agency Permit Turnaround Times," ERG, 2015). The Agency believes providing longer compliance deadlines should address the primary concerns expressed by commenters regarding the time necessary to obtain any required environmental permit approvals. Ultimately, as discussed in the Summary and Explanation, cases that are unusually problematic can be addressed through OSHA's enforcement discretion if the employer can show that it has made good faith efforts to implement engineering controls, but has been unable to implement such controls due to the time needed for environmental permitting.

Some industries raised permit concerns unique to their operations. The Association of American Railroads and American Short Line and Regional Railroad Association stated that it foresaw a need for a permit under the Clean Water Act if a ballast was sprayed with a chemical, which, through run off or by another means, reached a body of water (Document ID 2366, p. 7).

OSHA considers the railroad industry's concern about the threat of significant water contamination from chemical dust suppressant speculative because of the limited amount of water potentially used. Consequently, the Agency does not foresee a significant environmental impact. Additionally, no current OSHA standard governs the use of chemical dust suppressants. While some state or local governments may require a permit, it is not clear this would pose a new issue for the railroads, as OSHA believes it is likely that they already have to deal with such issues in the context of runoff from deicing chemicals, as well as oil and metal particles from normal operations. OSHA notes, however, that the analysis in the railroad section of Chapter IV of this FEA, Technological Feasibility, discusses chemical suppressants merely as a possibility for reducing exposures, but it is not ultimately identified as necessary to enable employers in the industry to meet the PEL of 50 $\mu g/m^3$. Accordingly, the FEA's cost analysis for the railroad industry does not include chemical suppressants, but assumes the industry will use wet methods to reduce exposures, and estimates the costs accordingly. To the extent chemical dust suppressants are more cost-effective than water, the FEA has overestimated the cost to the industry. And to the extent suppressants pose an environmental air quality permitting issue, OSHA notes that suppressants are not required under the final rule and is not including relevant permitting costs in its analysis.

The Shipbuilders Council of America (SCA) stated that if the final silica rule altered blasting technologies and/or facility equipment, the data currently used for shipyard permits in certain states (e.g. state air and water permits) would be invalid, necessitating permit and plan updates and creating additional costs for the industry (Document ID 2255, p. 2). The final rule does not specify engineering control changes in this area; nor does the Agency believe the lower PEL will require a change in engineering controls for abrasive blasting, relative to current standards. As laid out in Chapter V in this FEA, employers complying with the hierarchy of controls under the existing silica PEL and ventilation standards will already be using engineering controls to limit exposures. OSHA has found that the only additional feasible engineering controls employers in shipyards can implement to reduce exposures is the use of HEPA vacuums (in lieu of dry sweeping). Implementation of this control will reduce potential environmental problems because the use of HEPA vacuums raises less dust than dry sweeping.

Positive Environmental Effects

Based on its review of the record, OSHA concludes that the final rule will potentially have a positive environmental impact. At least one industry commenter, in the context of the hydraulic fracturing industry, suggested that its technology, the adoption of which would presumably be hastened by the promulgation and enforcement of the final rule, would reduce potential environmental impacts (Document ID 3589, Tr. 4140). In a similar vein, as discussed in both Chapters IV and V of this FEA, the final standard actually helps construction employers' reduce fugitive and co-generated dust, aiding in their compliance with environmental standards related to the dust. (The issue of controlling fugitive dust overlaps with the issue of existing employer obligations to minimize the runoff of solid waste into public water, discussed previously in this chapter, as well as the general expectation that employers clean up their work sites after their work is completed, as discussed in Chapter V).

CONCLUSION

As a result of this review, OSHA has reaffirmed its conclusions in the PEA, that the silica final rule will have no significant impact on air, water, or soil quality; plant or animal life; the use of land; or aspects of the external environment. It finds that the final standard is in compliance with NEPA and will have no significant environmental impact.