American Innovation and Manufacturing Act of 2020 – Subsection (h): Automatic Leak Detection Systems

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Acronyms and Abbreviations

AIM Act	American Innovation and Manufacturing Act of 2020
ALD	Automatic Leak Detection
CAA	Clean Air Act
CARB	California Air Resources Board
CC	Comfort Cooling
CPUC	California Public Utilities Commission
CR	Commercial Refrigeration
EPA	Environmental Protection Agency
GHG	Greenhouse Gas
GWP	Global Warming Potential
HFC	Hydrofluorocarbon
ppm	Parts Per Million
RACHP	Refrigeration, Air Conditioning, and Heat Pumps
IPR	Industrial Process Refrigeration
$MTCO_2e$	Metric Tons of Carbon Dioxide Equivalent
O&M	Operation and Maintenance
RMP	Refrigerant Management Program
TSD	Technical Support Document

1. Introduction

Subsection (h) of the American Innovation and Manufacturing (AIM) Act of 2020, titled "Management of Regulated Substances," directs the U.S. Environmental Protection Agency (EPA) to establish certain regulations for regulated substances[1] and their substitutes for the purposes of maximizing reclaiming and minimizing releases of regulated substances (used interchangeably with hydrofluorocarbons (HFCs) in this document) from equipment and ensuring the safety of technicians and consumers.

More specifically, subsection (h) directs EPA to promulgate regulations to control, where appropriate, any practice, process, or activity regarding the servicing, repair, disposal, or installation of equipment that involves: a regulated substance, a substitute for a regulated substance, the reclaiming of a regulated substance used as a refrigerant, or the reclaiming of a substitute for a regulated substance used as a refrigerant.

Subsection (h) also provides for the Agency to consider options to increase opportunities for reclaiming HFCs used as refrigerants and potential approaches to coordinate regulations carrying out subsection (h) of the AIM Act with other EPA regulations that involve the same or a similar practice, process, or activity regarding the servicing, repair, disposal, or installation of equipment, or reclaiming.

As part of implementing subsection (h), EPA is finalizing certain regulatory requirements[2] regarding the use of automatic leak detection (ALD) systems. This Technical Support Document (TSD), prepared for the purposes of subsection (h), provides background information on ALD systems. Specifically:

- Section 2 provides background information on ALD technologies, including manufacturers, market presence, and data logging techniques.
- Section 3 provides information on the subsectors affected by the ALD system requirements.

2. Background

For purposes of this TSD, ALD systems on refrigerant-containing appliances are refrigerant leak detection technologies calibrated to continuously monitor a refrigerant-based system(s) for evidence of leaks and alert an operator upon detection of a leak. ALD systems detect leaks either directly or indirectly. Direct ALD systems use technology (e.g., sensors) that automatically detects the presence of refrigerant leaked into the air from a refrigerant-based system. An indirect ALD system automatically analyzes operating conditions (e.g., temperature, pressure) within a refrigerant-based system and identifies changes that indicate a refrigerant leak has occurred. Both types of ALD systems help to ensure early detection of leaks and help identify the location and severity of a leak.

[1] The AIM Act lists 18 saturated HFCs, and by reference any of their isomers not so listed, that are covered by the statute's provisions, referred to as "regulated substances" under the Act (42 U.S.C. 7675(c)(1)).
[2] See final rule in Docket EPA-HQ-OAR-2022-0606 at www.regulations.gov.

2.1 Direct ALD Systems

2.1.1 Technology Overview

Direct refrigerant leak detection technologies use sensors to monitor the concentration of refrigerants in the air. Direct ALD systems are fixed hardware that can be used on refrigerant-containing equipment and send an “alarm” to maintenance and/or operations staff if the user-specified leak level threshold (measured, for example, in parts per million (ppm)) is exceeded. Both active and passive sensors are available for direct ALD system technologies – both types offer the ability to connect to a building management system which can provide remote notification capabilities (Emerson, 2017). Active detectors use a central system with tubing that samples multiple areas. Passive sensors utilize zone-specific infrared technology, which can add to the cost if many passive sensors are used. Direct ALD system sensors should be located at all leak-prone components of a refrigeration system and positioned in a manner which minimizes disruptions in air flow; otherwise, some leaks may go undetected.

The benefits of direct ALD systems include being able to pinpoint the location and severity of a leak. Direct ALD systems can operate independent of refrigerant-based system controllers, which is another benefit for users that have older, malfunctioning, or out-of-calibration control systems. A potential drawback of direct ALD systems is that a sensor would typically need to be near the source of a leak, depending on the alert threshold setting, to trigger a leak alert, i.e., if the ppm threshold is set too high and/or too far from the sensor, the leak may be missed. Installing many sensors, or “zones,” can alleviate this risk and provide comprehensive leak detection that can expedite repairs. However, additional sensors incur additional material and installation costs. Additionally, direct ALD systems are not intended for parts of a refrigerant-containing appliance that are not in an enclosed space (e.g., outside), since the sensors may not be able to pick up accurate readings given other potential sources of HFCs (e.g., other equipment that may be the source of the leak) and/or mixing with ambient air, which dilutes the reading.

Setting an appropriate leak level threshold, which triggers alerts to owners or operators, is important to detect leaks effectively. If a direct ALD system is installed with a leak level threshold that is too high, it is possible that only catastrophic leaks would be detected. On the other hand, if the leak level threshold is too low, the ALD system operation may result in false alarms. Existing leak repair programs, such as the California Air Resources Board (CARB) Refrigerant Management Program (RMP) and EPA Clean Air Act (CAA) Section 608, include guidance on the appropriate level of detection (i.e.,10 ppm) as well as the leak level threshold (i.e., 100 ppm) above which an alert is triggered. Installing and maintaining an ALD system with an appropriate leak level threshold setting could support accurate leak detection while avoiding expenditures on superfluous sensors.

2.1.2 Manufacturers and Market Presence

Information was gathered on direct ALD system manufacturers from manufacturers’ websites, products offered by online wholesale suppliers, and sample data from market research reports on refrigerant gas leak detection systems. EPA reviewed annual reports from manufacturers, news articles, and case studies for this TSD to understand the current market supply of direct ALD systems; however, publicly available data on annual sales were not found. In a public comment on the proposed rule, a direct ALD systems manufacturer attested to the direct ALD systems market’s ability to meet future demand (MSA, 2023). This manufacturer estimated that across their direct detection product portfolio and production locations, they alone have existing production volume levels and demonstrated capability of meeting the ALD system demand that would result from the proposed regulations. Therefore, there is a strong basis for EPA to determine that manufacturing can be scaled across the direct ALD systems industry to meet demand over time (MSA, 2023).

Many companies that manufacture direct refrigerant leak technologies manufacture handheld refrigerant leak detectors, but not fixed ALD systems. As such, it is important to distinguish between companies that manufacture direct refrigerant leak technologies generally from those that specifically manufacture fixed ALD systems. The companies identified below currently manufacture direct ALD systems for the U.S. market:

- Automated Logic
- CPS Products, Inc.
- Copeland (formerly Emerson Climate Technologies)
- Danfoss
- MSA/Bacharach Inc.
- NevadaNano
- Parker Hannifin
- RC Systems
- Sentech
- Senva
- Thermal Gas Systems
- Toshiba
- TQ Environmental
- Trane

The majority of EPA-identified ALD system manufacturers sell direct ALD products. Direct ALD systems are a more established technology compared to indirect ALD systems, which are a more recently developed technology. Direct leak detection technologies can also be applied to more than just refrigerant gases (e.g., carbon monoxide), which expands the market for these products. EPA is not aware of publicly available sources to estimate the number of direct ALD systems currently installed in refrigerant-based systems in the United States.

2.2 Indirect ALD Systems

2.2.1 Technology Overview

Indirect ALD systems are a relatively newer technology than direct ALD systems and rely on predictive data analytics to detect leaks rather than physical detection of refrigerant gas. By gathering and identifying trends in data, indirect ALD systems monitor the operating conditions of a refrigerant-based system to infer whether a leak is present based on a deviation from "predicted" operating conditions. This method of leak detection is typically conducted using existing refrigerant-based system controllers and sensors that are already located on-site. An indirect ALD system is installed and connected to the controller(s) to record data and store it, often using cloud-based software. The technology then compares real-time operating conditions, such as liquid levels, pressures, temperatures, and ambient conditions, against historical trend data to determine if a leak may be occurring (Emerson, 2017). The system software can trigger leak alerts based on user settings. It is important that indirect ALD systems monitor multiple operating parameters to ensure accuracy in leak detection. Some older indirect ALD systems only use room temperature to determine whether a leak is present or not; newer indirect ALD systems often use multiple parameters working in tandem, such as temperature, pressure, liquid levels, etc., to help identify potential leaks (Axiom Cloud, 2023; CARB, 2023). Based on results from the CARB RMP, indirect ALD systems that rely on multiple data points are more accurate in identifying leaks, whereas systems utilizing only a single data point do not identify leaks as quickly or effectively (CARB, 2023).

Benefits of indirect ALD systems typically include the ability to monitor overall refrigeration system performance and identify potential maintenance issues that may otherwise go undetected until equipment fails and/or products spoil. Unlike a direct ALD system, the indirect ALD system is integrated into the refrigerant-based control system, so in addition to leaks, it is also monitoring for conditions such as high pressure. While most refrigerant-based controllers do this as well, the predictive analytics of an indirect ALD system may identify issues sooner than a controller alone would. Another benefit of indirect ALD systems is their ability to monitor all portions of a refrigerant-containing appliance, including portions of an appliance that are located outside of an enclosed space. Some indirect ALD systems can be utilized to monitor refrigeration system energy consumption and identify energy-saving measures as well (Hussmann Corporation, 2021). However, the features of an indirect ALD system beyond leak detection will vary by manufacturer/product.

A potential drawback of indirect ALD systems can be difficulty in locating a leak once it is identified. While these systems can identify leak events, the lack of physical gas sensors placed throughout a refrigerant-based system can make pinpointing individual leaks challenging and time-consuming. Once a leak event is identified, a service contractor or in-house technician would likely need to conduct a manual leak inspection of the entire refrigerant-based system using a handheld leak detector or bubble test. Another potential drawback of indirect ALD systems is that they rely on the existing refrigerant-based system controller and sensors. If the equipment is older, sensors may need to be recalibrated or replaced to ensure the accuracy of the leak detection methodology, which can be an additional expense. Regardless, when an indirect ALD system is installed, existing sensors and control systems should be checked to avoid false positives or negatives.

2.2.2 Manufacturers and Market Presence

Indirect ALD systems are an emerging technology. EPA is aware of four manufacturers with commercially available products in the United States – Axiom Cloud, Copeland (formerly Emerson Climate Technologies), Matalex, and Hussmann/Panasonic. Indirect ALD technologies have the potential to grow significantly in market share; because they are primarily a software-based system, indirect ALD systems can be deployed quickly and efficiently across many sites (Axiom Cloud, 2023).

In 2023, Axiom Cloud products were installed in 242 grocery stores and cold-storage facilities in the United States (NaturalRefrigerants.com, 2024). In a public comment on the proposed rule, Axiom Cloud expressed confidence in the indirect ALD market's ability to meet the anticipated demand, stating for example that their company's technology can be deployed to hundreds of facilities per week once access to corporate information technology systems is approved (Axiom Cloud, 2023).Matalex, another indirect ALD system manufacturer, has over 4,000 installations worldwide, and launched a pilot program in the United States in 2023 (Refrigeration Industry, 2023).

2.3 Data Logging and Reporting

The information generated and logged by ALD systems varies depending on the size and type of system. Smaller direct ALD systems (sometimes called “single-zone”) are intended to monitor only one location (e.g., a mechanical room containing compressors) and may not generate information other than alerting users of the presence of increased refrigerant levels (Automated Logic, 2024). These smaller systems tend to be used in targeted areas to detect large leaks in real-time and may not have logging capabilities. Some smaller systems may log and store data on-site or remotely depending on the model and brand (Senva, 2024).

More extensive direct ALD systems may record and store refrigerant-based system operating pressures and temperatures, refrigerant concentrations at each sensor, as well as alarm and fault statuses in one or more locations (Copeland, 2024). Raw concentration data for leaked refrigerant may be adjusted based on factors, such as temperature, to adjust for a range of conditions and provide more accurate leak concentration data. Direct ALD systems may also provide historical trend data for a given location, displayed as a time series of concentration measurements. Both passive and active direct ALD system types generally offer the ability to connect to a building management system or refrigerant-based system controller which can provide remote leak notification capabilities (Emerson, 2017). Data may be sent to connected or centralized data displays. The quality of data collection for direct ALD systems also depends on the proper calibration and maintenance of devices. The collection and categorization of data may also depend on preset or user-determined refrigerant detection limits as well as thresholds for leak or evaluation levels (Copeland, 2024). Direct ALD systems are allowed under existing leak repair programs, such as the CARB RMP, and can be used as a compliance option in lieu of leak inspections under CAA Section 608, as long as they are calibrated and configured according to compliance requirements.

Inherent to indirect ALD system functionality is “predictive analytics;” therefore, all indirect systems log historical refrigerant-based system operational data to develop trend analytics that can be used to infer when a leak has occurred based on a deviation from “predicted” data. To acquire the necessary data, the hardware component of an indirect ALD system is connected to an existing refrigerant-based system controller on-site to collect data points being monitored by the controller. Such data can include receiver levels, pressures, temperatures, condenser heat rejection calculations, weather data, heat reclaim status, condenser split status, and other available data (Axiom Cloud, 2024). The data logged by the indirect ALD system are commonly stored in a cloud-based system. The data are accessible remotely to manufacturers and refrigerant-based system owners/operators, and leak alerts can be set up based on various parameters. Some indirect ALD systems can also produce reports that include a summary of prioritized leak events at a single location or multiple locations. While the specifics of indirect ALD system logging and reporting can be proprietary, these systems are allowed under existing leak repair programs, such as the CARB RMP, and can also be used as a compliance option in lieu of leak inspections under CAA section 608.

3. Subsector Characterizations Affected by ALD Requirements

3.1 Commercial Refrigeration

Commercial refrigeration systems are the refrigerant-containing appliances used in the retail food and cold storage warehouse subsectors. Retail food appliances include the refrigeration equipment found in supermarkets, restaurants, convenience stores, and other food service establishments. Cold storage includes the refrigeration equipment used to store meat, produce, dairy products, and other perishable goods.

Commercial refrigeration is the most common subsector where ALD systems are utilized. Food retail applications such as supermarket systems often contain distributed refrigeration equipment with extensive piping networks and many valves and connections. These systems can be extremely leak prone.

Current and anticipated federal and state requirements as well as partnership programs have incentivized the food retail sector to reduce refrigerant leak rates, and ALD systems have become one of the strategies used to reduce leaks (AHRI, 2022; EPA GreenChill, Hussmann Corporation, 2022). Of the commercially available direct and indirect ALD systems in the United States, all are marketed primarily towards the food retail sector for both supermarket systems and cold storage systems.

3.2 Industrial Process Refrigeration

Industrial process refrigeration (IPR) systems are complex, customized refrigerant-containing appliances that are directly linked to the processes used in, for example, the chemical, pharmaceutical, petrochemical, and manufacturing industries. IPR systems also include industrial ice machines, appliances used directly in the generation of electricity, and ice rinks. In some situations, one appliance may be used both for IPR and other applications.

IPR systems utilize ALD systems, but to a lesser extent than commercial refrigeration. IPR equipment often is configured as a packaged chiller containing refrigerant that is connected via a heat exchanger to a glycol loop that is distributed throughout the site. In this configuration, refrigerant is contained to a packaged piece of equipment, making refrigerant leaks less likely than in commercial refrigeration applications. When IPR systems use a direct exchange refrigeration system, carbon dioxide (CO_2) or ammonia (NH_3) are the most common refrigerants used. Ammonia systems have distinct requirements to prevent leaks and ensure human health and safety that are met by systems other than conventional ALD systems.

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