REGULATORY IMPACT ANALYSIS OF CONTROLS ON ASBESTOS AND ASBESTOS PRODUCTS

FINAL REPORT

VOLUME III
APPENDIX F

Prepared for:
Christine Augustyniak
Office of Toxic Substances
U.S. Environmental Protection Agency

Prepared by:
ICF Incorporated
Fairfax Virginia 22031-1207

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I. COMMERCIAL PAPER

A. Product Description

Asbestos commercial paper can be classified into two categories -- general insulation paper and muffler paper. Commercial papers are used to provide insulation against fire, heat, and corrosion at a minimum thickness. These papers are used in a variety of specialized applications and are, therefore, produced in many different weights and thicknesses. They usually consist of approximately 95 to 98 percent asbestos fiber by weight; the balance 2 to 5 percent is typically starch binder (Krusell and Cogley 1982).

Commercial papers are produced on conventional papermaking machines. The ingredients are combined with water to produce a mixture that is fed through a series of rollers. These rollers apply pressure and heat to produce a paper of uniform and desired thickness. The paper is then allowed to cool before it is cut, rolled, and packaged.

Muffler paper is used by the automotive industry for exhaust emission control systems. The paper is applied between the inner and outer skins of the muffler or converter to maintain the high temperature necessary for pollution control within the catalytic converter reaction chamber and to protect the outer layer from the heat (Krusell and Cogley 1982).

General asbestos insulation paper is used in a variety of industries. The steel and aluminum industries use it as insulation in furnaces, in trough linings, in the smelting process, and against hot metal and drippings of molten metal. Asbestos paper is also used in the glass and ceramic industry for kiln insulation, in foundries as mold liners, and in the electrical parts and appliance industry for electrical insulation.

B. Producers and Importers of Asbestos Commercial Paper

There were two primary processors of asbestos commercial paper in 1981: Johns-Manville Corporation (now Manville Sales Corporation) and Celotex

Corporation (TSCA 1982a). There were also three secondary processors of asbestos commercial paper in 1981: Metallic Gasket Division, Sepco Corporation (now Fluorocarbon Metallic Gasket Division), Parker Hannifan Corporation, and Lamons Metal Gasket Company (TSCA 1982b). All of these companies have stopped processing asbestos commercial paper, and there are currently no primary or secondary processors of this product (ICF 1986). However, a representative of Quin-T Corporation's Erie, PA plant stated that it is selling small amounts of commercial paper out of inventory. The official could not quantify the amount sold in 1985, but did state that production had been discontinued (ICF 1986). Because none of the other respondents to our survey indicated that they had begun the production of asbestos commercial paper in the period since the previous survey, or that they were aware of any other distributors or importer of this product, we have concluded that there are currently no domestic producers of asbestos commercial paper. In addition, a 1984 survey of importers failed to identify any importers of asbestos commercial paper (ICF 1984).

C. Trends

1981 production of asbestos commercial paper was 936 tons (TSCA 1982a). As described above, there was no production of this product in 1985.

D. Substitutes

Asbestos fiber has been used in commercial paper because of its corrosion resistance, fire resistance, chemical resistance, strength, and durability. Information on the advantages and disadvantages of asbestos commercial paper and its substitutes is summarized in Table 1.

The major substitute for asbestos commercial paper is ceramic paper (ICF 1985). Ceramic paper is manufactured by Carborundum Corporation, Cotronics Corporation, Babcock & Wilcox, and Lydall Corporation. This product shares many of the advantages of asbestos commercial paper such as corrosion, fire,

Table 1. Substitutes for Asbestos Commercial Paper

Product	Manufacturer	Advantages	Disadvantages	References
Asbestos Commercial Paper	None	Fire, heat, rot, and corrosion resistant. Low cost. Long service life.	Environmental and occupational health problems.	Krusell and Cogley (1982) ICF (1986)
Ceramic Paper	Carborundum Corp., NY Cotronics Corp., NY Babcock & Wilcox, GA Lydall Corp., NH	Heat, corrosion, and chemical resistant. High temperature use limit (2300°F).	Not as strong or resilient as asbestos. More expensive.	Carborundum (1986) Cotronics (1986) Babcock & Wilcox (1986)
Cellulose Paper	Hollingsworth & Vose, MA	Good electrical properties. Inexpensive	Not heat resistant. Low temperature use limit.	Hollingsworth & Vose (1983)
Fiberglass Paper	Lydall Corp., NH	Heat resistant. Temperature use limit of 1100°F.	Not as strong or dimensionally stable as asbestos.	Lydall (1983)

and chemical resistance. However, at extremely high temperatures the binders in the paper begin to burn and all that is left is the fiber. The strength differential becomes more important as the binder burns away because ceramic fibers are not as strong as asbestos fibers. In addition, ceramic paper is more expensive than commercial paper.

Despite these drawbacks, ceramic papers can substitute for asbestos commercial papers in any of the following applications: insulation for the aluminum and steel industries, foundry insulation, glass making, fire protecting barriers, mufflers, catalytic converters, kiln and furnace construction, and other high temperature uses.

Hollingsworth & Vose Company produces a cellulose electrical insulation paper. This product is a good substitute for asbestos commercial paper in the electrical parts and appliance industry. It is less expensive than the other substitutes, but it cannot be used in high temperature applications (Hollingsworth & Vose 1983).

Lydall Corporation also manufactures fiberglass commercial paper. This product is considered an inferior substitute because it can only operate at temperatures up to 1100°F and is not as strong or dimensionally stable as asbestos commercial paper (Lydall 1983).

E. Summary

Domestic production of asbestos commercial paper did not take place in 1985. A small amount was sold out of inventory, but there is currently no more consumption of this product. As a result, complete substitution of asbestos in commercial paper has taken place. The substitutes are more expensive than the asbestos product, but they have generally been able to match its performance along the critical dimensions.

REFERENCES

Babcock & Wilcox Co. T. Viverito. 1986 (October 14). Augusta, GA. Transcribed telephone conversation with Peter Tzanetos, ICF Incorporated, Washington, D.C.

Carborundum Corp. C. Demske. 1986 (October 14). Niagara Falls, NY. Transcribed telephone conversation with Peter Tzanetos, ICF Incorporated, Washington, D.C.

Cotronics Corp. Representative. 1986 (October 14). Brooklyn, NY. Transcribed telephone conversation with Peter Tzanetos, ICF Incorporated, Washington, D.C.

Hollingsworth & Vose. Stowte Ellsworth. 1983. East Walpole, MA. Transcribed telephone conversation with E. Malitz, ICF Incorporated, Washington, D.C.

ICF Incorporated. 1984. Imports of Asbestos Mixtures and Products. Washington, D.C.: Office of Pesticides and Toxic Substances, U.S. Environmental Protection Agency. EPA Doc. Control No. 20-8600681.

ICF Incorporated. 1985. Appendix H: Asbestos Products and Their Substitutes, in Regulatory Impact Analysis of Controls on Asbestos and Asbestos products. Washington, D.C.: Office of Pesticides and Toxic Substances, U.S. Environmental Protection Agency.

ICF Incorporated. 1986 (July-December). Survey of Primary and Secondary Processors of Asbestos Commercial Paper. Washington, D.C.

Krusell N, Cogley D. 1982. GCA Corp. Asbestos Substitute Performance Analysis. Revised Final Report. Washington, D.C.: Office of Pesticides and Toxic Substances, U.S. Environmental Protection Agency. Contract Number 68-02-3168.

Lydall Corporation. Mr. Devoe. 1983. Rochester, NH. Transcribed telephone conversation with E. Malitz, ICF Incorporated, Washington, D.C.

TSCA Section 8(a) submission. 1982a. Production Data for Primary Asbestos Processors, 1981. Washington, D.C.: Office of Pesticides and Toxic Substances, U.S. Environmental Protection Agency. EPA Document Control No. 20-8601012.

TSCA Section 8(a) submission. 1982b. Production Data for Secondary Asbestos Processors, 1981. Washington, D.C.: Office of Pesticides and Toxic Substances, U.S. Environmental Protection Agency. EPA Document Control No. 20-8670644.

II. ROLLBOARD

A. Product Description

Rollboard is a paper product that is used to protect against fire, heat, corrosion, and moisture. It is a thin and flexible material composed basically of two sheets of paper laminated together with sodium silicate. Rollboard can be cut, folded, wrapped, and rolled. In addition, it can be molded around sharp corners (Krusell and Cogley 1982).

The primary constituent of asbestos rollboard is asbestos fiber. The balance consists of binders and fillers. The asbestos content can range from 60 to 95 percent by weight, but 70 to 80 percent is considered typical. Frequently used binders include starches, elastomers, silicates, and cement; common fillers are mineral wool, clay, and lime (Krusell and Cogley 1982).

Rollboard is manufactured in a process similar to that used for millboard production, but it is produced in a continuous sheet. The ingredients are mixed together and combined with water. This mixture is then fed into a conventional cylinder paper machine where heat and heavy rollers are applied to produce a uniform board. The material is then dried. The final steps are to laminate two of these sheets together, allow them to set, and to package the finished rollboard product.

Rollboard can be used in many industrial applications -- it can be used as a gasket and as a fire-proofing agent for security boxes, safes, and files. Its commercial uses include office partitioning and garage paneling, while its residential uss include linings for stoves and electric switch boxes.

B. Producers and Importers of Asbestos Rollboard

There were no domestic primary or secondary processors of asbestos rollboard in 1981, although a Johns-Manville Corp. (now Manville Sales Corp.) plant in Waukegan, IL was still selling the product out of inventory (TSCA 1982a, TSCA 1982b). In addition, a 1984 survey of importers failed to identify any importers of asbestos rollboard (ICF 1984). The Waukegan, IL plant no longer produces or sells asbestos rollboard (ICF 1986). Because none of the other respondents to our survey indicated either that they had begun the production of asbestos rollboard in the period since the previous survey, or that they were aware of any other distributors or importers of this product, we have concluded that there are currently no domestic producers or consumers of asbestos rollboard.

C. Trends

There was no production of asbestos rollboard in 1981 and there was still no production of asbestos rollboard in 1985. Small amounts of asbestos rollboard were being sold out of inventory in 1981, but this had ceased by 1985.

D. Substitutes

Most non-asbestos rollboards in the market today are made of ceramic fibers. Information on asbestos rollboard and its substitutes is summarized in Table 1.

Cotronics Corporation manufactures ceramic paper which is the primary substitute for asbestos rollboard (ICF 1985). It is made from high purity asbestos-free refractory fibers. Even though the product is sold in paper rolls, it can be made into free standing shapes such as rollboards. The continuous service temperature is 2300°F and applications include insulation materials and high temperature gaskets for furnaces, electrical wire insulation, kiln construction, and cushioning in furnace construction. Ceramic paper has low specific heat, low thermal conductivity, and has resistance to thermal shock and corrosion (Cotronics 1986).

Carborundum Corporation manufactures two asbestos rollboard substitutes. The first is Fiberfrax 550(R). It is a paper product made of alumina-silicate (ceramic) fiber and contains approximately 8 percent organic binder. It is

Table 1. Substitutes for Asbestos Rollboard

Product	Manufacturer	Advantages	Disadvantages	References
Asbestos Rollboard	None	Fire, heat, rot, and corrosion resistant. Long service life. Low cost.	Environmental and occupational health problems.	Krusell and Cogley (1982) ICF (1986)
Fiberfrax 550(R)	Carborundum Corp. Niagara Falls, NY	High temperature use limit (2300°F). Resistant to chemical attack. Good handling strength.	Poor resistance to acids and alkalies.	Carborundum (1986)
Fiberfrax 970(R)	Carborundum Corp. Niagara Falls, NY	High temperature use limit (2300°F). Resistant to chemical attack. Good handling strength.	Poor resistance to acids and alkalies. Lacks strength and rigidity.	Carborundum (1986)
Kaowool(R) Rollboard	Babcock & Wilcox, Inc. Augusta, GA	High temperature use limit (2300°F). Resistant to chemical attack. Good chemical stability.	Poor resistance to hydrofluoric and phosphoric acid and alkalies.	Babcock & Wilcox (1986)
Ceramic Paper	Cotronics Corp. Brooklyn, NY	High temperature use limit (2300°F). Thermal shock resistance. Corrosion resistance.		Cotronics (1986)

resistant to most chemical attacks with the exception of acids and alkalies. It also possesses good handling strength and has a continuous use temperature of 2300°F.* Fiberfrax 550(R) is designed specifically for applications where high temperature protection is more critical than heat retention. Typical applications of Fiberfrax 550(R) are industrial gasketing, liquid metal back-up insulation, brazing furnace insulation, and as an investment casting parting agent (Carborundum 1986).

The second asbestos rollboard substitute produced by Carborundum Corporation is Fiberfrax 970(R). It is also a ceramic paper product, and it contains approximately 6 percent organic binder. Fiberfrax 970(R) is noted for its exceptionally low thermal conductivity and good handling properties. Fiberfrax 970(R) is less suitable as an asbestos rollboard substitute because it lacks strength and rigidity; however, it does possess some of the favorable characteristics found in Fiberfrax 550(R) such as high temperature stability, resiliency, and excellent corrosion resistance. Typical applications of Fiberfrax 970(R) include high temperature gaskets, combustion chamber linings, thermal and electrical insulation, and glass furnace blow pipe insulation (Carborundum 1986).

Babcock & Wilcox produces non-asbestos ceramic rollboard made of Kaowool(R) which consists either of Kaolin, a natural occurring alumina-silica fireclay, or a blend of high purity alumina and silica. Kaowool(R) rollboard has a maximum temperature use limit of 2300°F, and it possesses good chemical stability with resistance to most chemicals. Kaowool rollboard is designed to replace asbestos rollboard in many non-furnace applications such as laundry and trough linings, gasketing between trough sections, glass conveyer rolls,

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* The continuous use temperature of asbestos rollboard could not be determined because the product is no longer produced. However, it is likely to have been approximately 1000°F, the continuous use temperature of standard asbestos millboard, a product with a very similar composition.

boiler jacket insulation, electrical appliance insulation, and radiator covers (Babcock & Wilcox 1986).

The use of asbestos rollboard was very limited and the substitutes are generally able to match or exceed the performance of the asbestos product. The price of asbestos rollboard in 1981 was approximately $1.00/lb. (ICF 1985). The current prices for the various substitutes are presented in Table 2. It is clear that the complete substitution away from asbestos rollboard has resulted in a higher price.

E. Summary

Domestic production or consumption of asbestos rollboard did not take place in 1985. This has resulted in complete substitution of asbestos rollboard with other substitute products. The substitute products are more expensive, but they have generally been able to match or exceed the performance of asbestos rollboard.

Table 2. Prices of Asbestos Rollboard and Its Substitutes
(in $/lb.)

Product	Manufacturer	Price	Reference
Asbestos Rollboard	None	N/A	ICF (1986)
Ceramic Paper	Cotronics Corp. Brooklyn, NY	$8.27-$12.40	Cotronics (1986)
Fiberfrax 550(R)	Carborundum Corp. Niagara Falls, NY	$5.92	Carborundum (1986)
Fiberfrax 970(R)	Carborundum Corp. Niagara Falls, NY	$10.24	Carborundum (1986)
Kaowool(R)	Babcock & Wilcox Augusta, GA	$5.70	Babcock & Wilcox (1986)

N/A: Not Applicable.

REFERENCES

Babcock & Wilcox Co. T. Viverito. 1986 (October 14). Augusta, GA. Transcribed telephone conversation with Peter Tzanetos, ICF Incorporated, Washington, D.C.

Carborundum Corp. C. Demske. 1986 (October 14). Niagara Falls, NY. Transcribed telephone conversation with Peter Tzanetos, ICF Incorporated, Washington, D.C.

Cotronics Corp. Representative. 1986 (October 14). Brooklyn, NY. Transcribed telephone conversation with Peter Tzanetos, ICF Incorporated, Washington, D.C.

ICF Incorporated. 1984. Imports of Asbestos Mixtures and Products. Washington, D.C.: Office of Pesticides and Toxic Substances, U.S. Environmental Protection Agency. EPA Doc. Control No. 20-8600681.

ICF Incorporated. 1985. Appendix H: Asbestos Products and Their Substitutes, in Regulatory Impact Analysis of Controls on Asbestos and Asbestos products. Washington, D.C.: Office of Pesticides and Toxic Substances, U.S. Environmental Protection Agency.

ICF Incorporated. 1986 (July-December). Survey of Primary and Secondary Processors of Asbestos Rollboard. Washington, D.C.

Krusell N, Cogley D. 1982. GCA Corp. Asbestos Substitute Performance Analysis. Revised Final Report. Washington, D.C.: Office of Pesticides and Toxic Substances, U.S. Environmental Protection Agency. Contract Number 68-02-3168.

TSCA Section 8(a) submission. 1982a. Production Data for Primary Asbestos Processors, 1981. Washington, D.C.: Office of Pesticides and Toxic Substances, U.S. Environmental Protection Agency. EPA Document Control No. 20-8601012.

TSCA Section 8(a) submission. 1982b. Production Data for Secondary Asbestos Processors, 1981. Washington, D.C.: Office of Pesticides and Toxic Substances, U.S. Environmental Protection Agency. EPA Document Control No. 20-8670644.

III. MILLBOARD

A. Product Description

Asbestos millboard is essentially a heavy cardboard product that can be used for gasketing, insulation, fireproofing, and resistance against corrosion and rot. The primary constituent of this product is asbestos fiber, with the balance consisting of binders and fillers. The asbestos content ranges from 60 to 95 percent, but 70 to 80 percent is considered typical. Frequently used binders are starches, elastomers, silicates, and cement; common fillers include mineral wool, clay, and lime (Krusell and Cogley 1982).

Millboard is manufactured in essentially the same way as paper. The ingredients are mixed together and combined with water. This mixture is then fed into a conventional cylinder paper machine where heat and heavy rollers are applied to produce a uniform board. The material is cut lengthwise and then removed for final drying. Standard size millboards are 42 x 48 inches and 1/4 to 3/4 inches thick. The most popular millboards are 1/4 and 1/2 inch thick. Asbestos millboards are very similar to asbestos commercial paper and are differentiated primarily by their thickness and lower fiber composition than commercial paper.

Millboard is also sold in different grades. Differences between millboard grades reflect their ability to withstand elevated temperatures. Standard asbestos millboard is able to withstand temperatures of 1000°F, while premium millboard can withstand temperatures well above 2000°F (Quin-T 1986a).

The uses of asbestos millboard are numerous. Specific industrial applications include linings in boilers, kilns, and foundries; insulation in glass tank crowns, melters, refiners, and sidewalls in the glass industry; linings for troughs and covers in the aluminum, marine, and aircraft industries; and thermal protection in circuit breakers in the electrical industry. In addition, thin millboard is inserted between metal to produce gaskets. Commercial applications for millboard include fireproof linings for safes, dry-cleaning machines, and incinerators. Asbestos millboard had been used in residential applications, but this application has ceased (Quin-T 1986b).

B. Producers and Importers of Millboard

There were five primary processors of asbestos millboard in 1981: Celotex Corporation, GAF Corporation, Johns-Manville Corporation, Nicolet, Inc., and Quin-T Corporation (TSCA 1982a). Celotex Corporation, Johns-Manville Corporation (now Manville Sales Corporation), and Nicolet, Inc. have since stopped producing asbestos millboard. However, Nicolet, Inc. continues to sell the product out of inventory. GAF Corporation sold their plant in Erie, PA to Quin-T Corporation, and that plant is still producing asbestos millboard. The other Quin-T Corporation plant in Tilton, NH still produces an asbestos product, but they have decided to reclassify it as electrical paper. Therefore, there is currently only one domestic primary processor of asbestos millboard. That plant consumed 436 tons of asbestos fiber in producing 581 tons of asbestos millboard in 1985 (ICF 1986).

There were eight secondary processors of asbestos millboard in 1981 (TSCA 1982b). Since that time, four companies have stopped processing asbestos millboard. The four companies which still process asbestos millboard are: Capital Rubber & Specialty Company, Fluorocarbon Metallic Gasket Division of Sepco Company, Lamons Metal Gasket Company, and Parker Hannafin Corporation. All four companies process millboard for producing gaskets. Capital Rubber and Specialty Company imported millboard in 1985; no other importers of asbestos millboard were identified (ICF 1984; ICF 1986). The other three companies purchased approximately 120 tons of asbestos millboard (ICF 1986).

C. Trends

Total annual production of asbestos millboard has declined dramatically from 2,767 tons in 1981 to 581 tons in 1985. This decline may be somewhat overstated because Quin-T Corporation's plant in Tilton, NH believes that their 1981 millboard production should have been classified as electrical paper. Nonetheless, this decline is expected to continue, and Quin-T Corporation's plant in Erie, PA plans to stop producing asbestos millboard in 1988 (Quin-T 1986a).

D. Substitutes

The major advantages of asbestos millboard are its resistance to heat, fire, rot, and corrosion; its tensile strength, and its low price. In general, the substitutes can match or exceed the heat and fire resistance of asbestos millboard, but they do not offer as much rot or corrosion resistance or as much tensile strength. In addition, all the substitutes are more expensive. Despite these drawbacks, the substitutes are expected to perform adequately enough to replace asbestos millboard in all its current uses.

For the purposes of this analysis, the substitutes have been grouped into two categories -- standard boards and premium boards. This has been done because the performance characteristics of the boards within each category are similar, even though their exact chemical compositions are different. The performance characteristics across categories are, however, different. The advantages, disadvantages, and prices of asbestos millboard and its substitutes are presented in Table 1.

The major substitutes for asbestos millboard fall into the standard board category. The Quin-T Corporation produces a standard board known as mineral board which can replace asbestos millboard. This product is composed of a proprietary combination of inorganic fillers. It can withstand temperatures up to 1000°F and can replace millboard in many of its applications, even

Table 1. Substitutes for Asbestos Millboard

Product	Manufacturer	Advantages	Disadvantages	References
Asbestos Millboard	Quin-T Corp. Erie, PA	Fire, heat, and rot resistant. Corrosion resistant. Low cost.	Potential environmental and occupational health problems.	Krusell and Cogley (1982)
Standard Board	Quin-T Corp. Erie, PA; Nicolet, Inc. Ambler, PA	Temperature use limit of 850-1000°F. Not combustible.	Low tensile strength. High cost.	Quin-T (1986a) Nicolet (n.d.)
Premium Board	Babcock & Wilcox Co. Augusta, GA; Carborundum Corp. Niagara Falls, NY; Cotronics Corp. Brooklyn, NY; Janos Corp. Moonachie, NJ; Nicolet, IN. Ambler, PA	Temperature use limit of 1500-2300°F. Not combustible. Heat resistant.	Low tensile strength. High cost.	Babcock & Wilcox (1986) Carborundum (1986) Cotronics (n.d.) Janos (1986) Nicolet (n.d.

though it has a lower tensile strength. It costs over \$1.23/lb. (Quin-T 1986a).

Nicolet, Inc. produces a non-asbestos standard board known as Nampro 901(R). This product is a cement-bound millboard and can be used in gaskets, electric ovens, strong-box liners, and welding pads. It has a temperature use limit of 850°F (1200°F if strength loss is not detrimental) (Nicolet n.d.). It costs \$1.33/lb. (Nicolet 1986). It has been estimated that these two standard boards will combine to take 80 percent of the asbestos millboard market if asbestos is banned (Quin-T 1986a).

The remaining substitutes for asbestos millboard fall into the premium board category. They are more expensive, but they have much higher temperature resistance. Janos Industrial Insulation Corporation purchases a premium board called Nuboard 1800(R) from a British manufacturer and distributes it in the U.S. This board consists primarily of mineral fibers and silica. Nuboard 1800(R) can withstand temperatures up to 1800°F. This product can replace asbestos in many of its premium uses, even though it has a lower tensile strength. It costs \$2.92/lb. (Janos 1986).

Nicolet, Inc. produces a premium non-asbestos board known as Nampro 911(R). This product is an inorganic-bound millboard and can be used in kiln liners, incinerator liners, induction-furnace liners, and ingot-mold liners. It has a temperature use limit of 1500°F (2100°F if strength loss is not detrimental (Nicolet n.d.). It costs \$2.46/lb. (Nicolet 1986).

Babcock & Wilcox Company produces a premium non-asbestos board made of Kaowool(R). Kaowool(R) consists either of Kaolin, a naturally occurring alumina-silica fireclay or a blend of high purity alumina and silica. Kaowool board has a maximum temperature use limit of 2300°F and possesses good chemical stability with resistance to most chemicals. Kaowool can replace asbestos millboard in almost all its premium applications, and it costs $4.70/lb. (Babcock & Wilcox 1986).

Cotronics Corporation produces a premium non-asbestos board called Ceramic Board 360(R). This product is made from high purity refractory fibers which are interlaced and bonded with an inorganic binder. It is resistant to oxidizing and reducing atmospheres, molten non-ferrous metals, steam, and most chemicals and solvents. It also has a continuous use temperature of 2300°F. it can be used in rigid high temperature gaskets, heat shields, chemical reactor insulation, and brazing fixture supports; it costs $1.88/lb. (Cotronics n.d.).

Carborundum Corporation produces a premium non-asbestos board called GH Board made of Fiberfrax(R). Fiberfrax(R) consists mainly of ceramic fibers and has a temperature use limit of 2300°F. In addition, Fiberfrax(R) will work well in electrical insulating applications because it has a low dielectric constant and does not conduct electricity. GH board can substitute for asbestos in all applications where tensile strength is not important, and it costs $5.05/lb. (Carborundum 1986). The premium boards are estimated to take the remaining 20 percent of the asbestos millboard market if asbestos is banned (Quin-T 1986a). All the inputs for the Regulatory Cost Model are presented in Table 2.

E. <u>Summary</u>

Asbestos millboard is essentially a heavy cardboard product which can be used for gasketing, insulation, fireproofing, and resistance against corrosion and rot. It is typically used in gasketing applications and as a liner in industrial boilers, furnaces, and kilns.

The only processor of asbestos millboard in 1985 was Quin-T Corporation's Erie, PA plant. This plant consumed 435 tons of asbestos and produced 581

Table 2. Data Inputs for Asbestos Regulatory Cost Model

Product	Output	Product Asbestos Coefficient	Consumption/ Production Ratio	Price[a]	Useful Life	Equivalent Price	Market Share	Reference
Asbestos Millboard	581 tons	$0.75 tons/ton	1.005	$1,760/ton	25 years	$1,760/ton	N/A	Quin-T (1986a)
Standard Board	N/A	N/A	N/A	$2,560/ton[b]	25 years	$2,560/ton	80%[b]	Quin-T (1986a) Nicolet (1986)
Premium Board	N/A	N/A	N/A	$6,800/ton[b]	25 years	$6,800/ton	20%[b]	Babcock & Wilcox (1986) Carborundum (1986) Cotronics (n.d.) Janos (1986) Nicolet (1986)

N/A: Not Applicable.

[a]Prices in the text are given per pound, but they have been converted to prices per ton for use in the ARCM.

[b]See Attachment for explanations.

tons of millboard. Quin-T Corporation plans to stop processing asbestos in 1988.

The major substitutes for asbestos millboard are mineral boards. If asbestos were banned, it is estimated that standard mineral boards would capture 80 percent of the market and that premium mineral boards would capture the remaining 20 percent. The price of asbestos millboard is $0.88/lb. The average price of standard mineral board is $1.28/lb. and the average price of premium mineral board is $3.40/lb.

ATTACHMENT

The projected market shares for standard board and for premium board were estimated by Ray Heidt, Sales Manager, Quin-T Corporation (the only domestic producer of asbestos millboard).

The price of standard board was computed by averaging the prices of the two standard board products. The average of Quin-T Corporation's mineral board ($1.23/lb.) and Nicolet, Inc.'s Nampro 901(R) ($1.33/lb.) is $1.28/lb.

The price of premium board was computed by averaging the prices of the five premium board products. The average of Janos Corporation's Nuboard 1800(R) ($2.92/lb.), Nicolet Inc.'s Nampro 911(R) ($2.46/lb.), Cotronics Corporation's Ceramic Board 360(R) ($1.88/lb.), Babcock & Wilcox Company's Kaowool(R) board ($4.70/lb.), and Carborundum Corporation's GH Board(R) ($5.05/lb.) is $3.40/lb.

REFERENCES

Babcock & Wilcox Co. T. Viverito. 1986 (October 14). Augusta, GA. Transcribed telephone conversation with Peter Tzanetos, ICF Incorporated, Washington, D.C.

Carborundum Corp. Applications Engineer. 1986 (November 10). Niagara Falls, NY. Transcribed telephone conversation with Peter Tzanetos, ICF Incorporated, Washington, D.C.

Cotronics Corp. (n.d.) Product Literature. Ceramic Board. Brooklyn, NY.

ICF Incorporated. 1984. Imports of Asbestos Mixtures and Products. Washington, D.C.: Office of Pesticides and Toxic Substances, U.S. Environmental Protection Agency. EPA Doc. Control No. 20-8600681.

ICF Incorporated. 1986 (July-December). Survey of Primary and Secondary Processors of Asbestos Millboard. Washington, D.C.

Janos Industrial Insulation Corp. Sales Representatives. 1986 (November 10 and December 5). Moonachie, NJ. Transcribed telephone conversations with Peter Tzanetos, ICF Incorporated, Washington, D.C.

Krussel N, Cogley D. 1982. GCA Corporation. Asbestos Substitute Performance Analysis. Revised Final Report. Washington, DC: Office of Pesticides and Toxic Substances, U.S. Environmental Protection Agency. Contract 68-02-3168.

Nicolet, Inc. (n.d.) Product Literature. Asbestos-Free Millboard. Ambler, PA 19002.

Nicolet, Inc. Sales Representative. 1986 (December 4). Transcribed telephone conversation with Peter Tzanetos, ICF Incorporated, Washington, D.C.

Quin-T Corp. R. Heidt. 1986a (July-November). Erie, PA. Transcribed telephone conversations with Peter Tzanetos and Eric Crabtree, ICF Incorporated, Washington, D.C.

Quin-T Corp. E. Kovykio. 1986b (November 11). Erie, PA. Transcribed telephone conversation with Peter Tzanetos, ICF Incorporated, Washington, D.C.

TSCA Section 8(a) submission. 1982a. Production Data for Primary Asbestos Processors, 1981. Washington, D.C.: Office of Pesticides and Toxic Substances, U.S. Environmental Protection Agency. EPA Document Control No. 20-8601012.

TSCA Section 8(a) submission. 1982b. Production Data for Secondary Asbestos Processors, 1981. Washington, D.C.: Office of Pesticides and Toxic Substances, U.S. Environmental Protection Agency. EPA Document Control No. 20-8670644.

IV. ASBESTOS PIPELINE WRAP

A. Product Description

Pipeline wrap is an asbestos felt product. It is composed of at least 85 percent asbestos with the balance being cellulose fibers and binders such as starch and latex. It is manufactured on conventional papermaking machines in a process similar to that of asbestos roofing felt. The ingredients are combined and mixed with water. This mixture is then fed through a series of machines that apply heat and heavy rollers to produce a felt of uniform thickness. The felt is then coated by pulling it through a bath of hot asphalt or coal tar until it is thoroughly saturated. The paper then passes over another series of rollers which set the coal tar or asphalt onto the felt. Next, it passes over a series of cooling rollers that reduce the temperature and provide a smooth surface finish. The felt is finally air-dried, rolled, and packaged for marketing (Krusell and Cogley 1982).

Pipeline wrap is primarily used by the oil and gas industry for coating its pipelines.[1] There is also some use by the chemical industry for underground hot water and steam piping. Pipeline wrap is occasionally used in above-ground applications, such as for special piping in cooling towers.

Pipeline wrap itself is only one product used in the coal tar enamel method of coating pipes. The coal tar enamel process involves five steps. First, a primer is applied directly onto the pipe. Second, when the primer dries, heated coal tar is applied to the pipe as it is rotated. Third, a glass mat is applied over the coal tar. Fourth, the asbestos felt is wrapped onto the pipe by high-speed wrapping machines. Finally, the pipe is coated

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[1]The Department of Transportation has mandated that all oil and gas pipelines be coated.

with kraft paper[2] (Power 1986a). The asbestos felt helps protect the pipe from moisture, corrosion, rot, and abrasion.

B. Producers and Importers of Asbestos Pipeline Wrap

There were three primary processors and one secondary processor of asbestos pipeline wrap in 1981. The primary processors were: Celotex Corporation, Johns-Manville Corporation (now Manville Sales Corporation), and Nicolet, Incorporated (TSCA 1982a). The secondary processor was Aeroquip Corporation (TSCA 1982b). There are currently no domestic processors of asbestos pipeline wrap (ICF 1986). However, Nicolet, Inc. is selling the product out of inventory and may restart production if demand warrants it (Nicolet 1986a). In addition, Power Marketing Group distributes asbestos pipeline wrap which it imports from Manville Sales Corp. (formerly Johns-Manville Corp.) plants in Canada. No other importers of asbestos pipeline wrap were identified, and neither firm is aware of any other producers or distributors of this product in the U.S. (ICF 1984; ICF 1986).

C. Trends

In 1981, 2,150,615 squares of asbestos pipeline wrap were produced (TSCA 1982b). Nicolet, Inc. has refused to divulge information on 1985 fiber consumption or pipeline wrap output. Power Marketing Group has provided information from which one can estimate output and fiber consumption for both companies. Total fiber consumption and pipeline wrap production are presented in Table 1. Finally, it should be noted that 1986 output may be much lower because Nicolet, Inc. has stopped producing the product and is only selling it out of inventory.

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[2]Kraft paper consists of wood and cellulose fibers.

Table 1. 1985 Asbestos Fiber Consumption and Asbestos Pipeline Wrap Production[a]

	Fiber Consumption (in short tons)	Pipeline Wrap Production (in squares)[b]
Total	3,333.3	742,383

[a]Computations underlying these estimates are in the Attachment.

[b]1 square = 100 square feet

D. Substitutes

The use of asbestos in pipeline wrap is desirable because of its resistance to chemicals, rotting, and decay; its dimensional stability; and its heat resistance (Rood 1986). It is also unaffected by corrosive environments, cannot be attacked by vermin, and performs in the most severe salt water conditions (Power 1986a). These qualities are important for underground pipeline wrap that is used to prevent the deterioration of pipeline buried in earth or under water.

Power Marketing Group and Nicolet, Inc. both sell a non-asbestos mineral felt which can be used instead of asbestos pipeline wrap. Power Marketing Group sells its mineral felt for $5.80/100 square feet, the same price as its asbestos felt. This product appears to have the same advantages as the asbestos product -- resistance to chemicals, rotting, and decay; dimensional stability; and heat resistance (Power 1986b). However, it does not have the proven track record of asbestos felt because it is a new product. There are instances of asbestos pipeline wrap being in the ground for over fifty years, a track record which makes companies reluctant to replace this successful and proven product.

Nicolet, Inc. refers to its mineral felt as Safelt(R). Safelt(R) is a combination of minerals, fibers, and binders. It contains a minimum of 75 percent non-biodegradable components. Safelt(R) is available in two types -- 960 and 966. Safelt 966 is more dense and is therefore sold in a thinner layer (Nicolet n.d.). They are both priced $6.20/100 square feet (Nicolet 1986a), but product literature states that application costs are lower than asbestos wrap because of their superior wrapping characteristics (Nicolet n.d.). This characteristic is not modeled because Nicolet officials would not quantify this advantage and coaters could neither confirm or deny its existence.

Power Marketing Group also sells a fiberglass felt called Duraglass(R). It is priced \$5.80/100 square feet. They have had problems, however, in using it in the coal tar enamel method because it does not seem to bond well. Power Manufacturing is currently in the process of reformulating the product in order to rectify this problem (Power 1986b). A summary of the characteristics of the asbestos substitutes is presented in Table 2.

The All American crude oil pipeline, a major cross-country pipeline, is being coated with a new coal tar system which does not use any asbestos or mineral felt. A 20 mil thickness of coal tar enhanced urethane is applied first. It is followed by a 1.5 inch urethane foam layer. The final step is to apply a covering of Polykin tape (Pipeline Digest 1986). Since this method has no history, we do not know its advantages and disadvantages.

These are the only direct substitutes for asbestos pipeline wrap in the coal tar enamel method of coating pipes. However, there are seven other methods of coating pipes: asphalt enamel, thin-film powder, bonded polyethylene, tape, extruded polyethylene, sintered polyethylene, and insulation (Pipeline Digest 1986). The 1985 market shares and output levels for these processes are presented in Table 3.

The coal tar enamel method is the only method of coating pipes that presently uses asbestos pipeline wrap. In 1985 it accounted for 14.39 percent of the pipeline coating market (Pipeline Digest 1986). In the event of an asbestos ban, pipeline coaters and oil industry representatives believe that asbestos felt used in the coal tar enamel method will be replaced by mineral and fiberglass felts, both of which are good substitutes (Arco 1986, Energy Coatings 1986). They do not expect the market share (14.39 percent) held by the coal tar enamel method to be taken over by any one or all of the other seven methods just because asbestos felt will be unavailable. Thus, it has

Table 2. Substitutes for Asbestos Pipeline Wrap

Product	Manufacturer	Advantages	Disadvantages	References
Asbestos Felt	Nicolet, Inc. Ambler, PA; Power Marketing Group Houston, TX	Historical performance. Chemical resistance. Dimensional stability. Heat and rot resistance. Resistant to salt water and vermin attack.	Potential environmental and occupational health hazards.	Krusell and Cogley (1982) Power (1986b)
Mineral Felt	Nicolet, Inc. Ambler, PA; Power Marketing Group Houston, TX	Low application cost. Chemical resistance. Dimensional stability Heat and rot resistance.	Unproven in the marketplace.	Power (1986a)
Fiberglass Felt	Power Marketing Group Houston, TX	Chemical resistance. Dimensional stability. Heat and rot resistance.	Does not bond well. Unproven in the marketplace.	Power (1986a)

Table 3. 1985 Market Shares and Output of Pipeline Coating Processes

Process	Output (square feet)	Market Share (percent)
Asphalt Enamel	200,000	0.03
Coal Tar Enamel	88,439,891	14.39
Thin-Film Powder	263,807,418	42.39
Bonded Polyethylene	28,293,723	4.60
Tape 8,251,037	1.34	
Extruded Polyethylene	196,255,978	31.93
Sintered Polyethylene	13,704,375	2.23
Insulation 15,602,441	2.54	

Source: Pipeline Digest (1986).

been assumed that substitution will be entirely for asbestos felt rather than for the coal tar enamel method.

The inputs for the Regulatory Cost Model are presented in Table 4. It has been assumed that Power Marketing Group or some other company will formulate a more successful fiberglass felt which will take 20 percent of the market (Arco 1986). The remaining 80 percent of the market will be taken by mineral felt. Because this is a new product, there is no data on projected market shares. As a result, it is assumed that the current market shares of the producers of the asbestos product will apply to the substitutes as well.[3] This will result in a 48 percent (0.80 x 0.60) projected market share for Power Marketing Group's mineral felt and a 32 percent (0.80 x 0.40) projected market share for Safelt(R) (Nicolet's mineral felt).

E. Summary

Asbestos pipeline wrap is a felt product used in the coal tar enamel method of coating pipes. This product is not being produced in the U.S., although one company was selling it out of inventory and another company was importing it from Canada and distributing it. Total domestic production of this product is estimated to have been 296,949 squares in 1985.

It has been assumed that adequate substitutes exist for asbestos felt, and, therefore, pipeline coaters will not switch to alternate methods of coating pipes in the case of a complete asbestos ban. It is estimated that 20 percent of the market will be taken by fiberglass felt that costs $5.80/square. The remaining 80 percent will be taken by mineral felts. Because the two distributors of asbestos felt are also the major distributors of mineral felt, it is assumed that they will both retain their current market shares. Hence Power Marketing's mineral felt will capture 48 percent of the

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[3]We cannot look at the trends in market shares because 1981 data for Power Marketing Group are not available.

Table 4. Data Inputs for Asbestos Regulatory Cost Model

Product	Output	Product Asbestos Coefficient	Consumption/ Production Ratio	Price	Useful Life	Equivalent Price	Market Share	Reference
Asbestos Felt	296,949 squares[a]	0.0044900 tons/square	2.5	$5.80/square	25 years	$5.80/square	N/A	Power (1986b) Power (1987)
Mineral Felt	N/A	N/A	N/A	$5.80/square	25 years	$5.80/square	48%[a]	Power (1987)
Safelt(R)	N/A	N/A	N/A	$6.20/square	25 years	$6.20/square	32%[a]	Nicolet (1986)
Duraglass(R)	N/A	N/A	N/A	$5.80/square	25 years	$5.80/square	20%[a]	Power (1987)

N/A: Not Applicable.

[a]See Attachment for explanation.

market at a price of $5.80/square, and Nicolet's Safelt(R) will capture 32 percent of the market at a price of $6.20/square.

ATTACHMENT

The asbestos fiber consumption and asbestos pipeline wrap output for Power Marketing Group and Nicolet, Inc. were computed using the following methodology. Power Marketing Group estimated that 100 square feet of saturated pipeline felt weigh 13 lbs. Because the saturated felt is 23 percent asphalt or tar coating, the unsaturated felt weighs 10.57 lbs. (13/1.23). Because the unsaturated felt is approximately 85 percent asbestos, 100 square feet of pipeline wrap contain 8.98 lbs. of asbestos (10.57 * .85). Therefore, the asbestos product coefficient is 0.00449 (8.98 lbs./square / 2,000 lbs./ton) tons square.

REFERENCES

Arco Oil & Gas Company. J. Murray. 1986 (November 24). Transcribed telephone conversation with Peter Tzanetos, ICF Incorporated, Washington, D.C.

Energy Coating Company. W. Heineman. 1986 (November 3). Transcribed telephone conversation with Peter Tzanetos, ICF Incorporated, Washington, D.C.

ICF Incorporated. 1984. Imports of Asbestos Mixtures and Products. Washington, D.C.: Office of Pesticides and Toxic Substances, U.S. Environmental Protection Agency. EPA Doc. Control No. 20-8600681.

ICF Incorporated. 1986 (July-December). Survey of Primary and Secondary Processors of Asbestos Pipeline Wrap. Washington, D.C.

Krusell N, Cogley D. 1982. GCA Corp. Asbestos Substitute Performance Analysis. Revised Final Report. Washington, D.C.: Office of Pesticides and Toxic Substances, U.S. Environmental Protection Agency. Contract Number 68-02-3168.

Nicolet, Inc. Sales Representative. 1986a (November 11). Transcribed telephone conversation with Peter Tzanetos, ICF Incorporated, Washington, D.C.

Nicolet, Inc. R. Hittinger. 1986b (November 5). Transcribed telephone conversation with Peter Tzanetos, ICF Incorporated, Washington, D.C.

Nicolet, Inc. (n.d.). Product Literature. Safelt. Ambler, PA 19002.

Pipeline Digest. 1986 (April 7). Pipe Coating Survey. Houston, TX.

Power Marketing Group. 1986a. Public comment brief on asbestos pipeline wrap submitted to U.S. Environmental Protection Agency, Washington, D.C.

Power Marketing Group. J. Toerner. 1986b (October 24 and October 31). Houston, TX. Transcribed telephone conversations with Peter Tzanetos, ICF Incorporated, Washington, D.C.

Power Marketing Group. G. Pytko. 1987 (January 30). Denver, CO 80231. Letter to Peter Tzanetos, ICF Incorporated, Washington, D.C. 20006.

Rood K. 1986 (October 31). Independent consultant (former employee of Johns-Manville Corporation). Transcribed telephone conversation with Peter Tzanetos, ICF Incorporated, Washington, D.C.

TSCA Section 8(a) Submission. 1982a. Production Data for Primary Asbestos Processors, 1981. Washington DC: Office of Toxic Substances, U.S. Environmental Protection Agency. EPA Document Control No. 20-8601012.

TSCA Section 8(a) Submission. 1982b. Production Data for Secondary Asbestos Processors, 1981. Washington DC: Office of Toxic Substances, U.S. Environmental Protection Agency. EPA Document Control No. 20-8670644.

V. BEATER-ADD GASKETS

A. Product Description

Gaskets can be described as materials used to seal one compartment of a device from another in non-dynamic applications such as engine and exhaust manifolds. Asbestos gaskets, used mainly to seal connections and prevent leakage of fluids between solid surfaces, can be classified into two categories: beater-add and compressed sheet. Compressed sheet gaskets are discussed in Section XXVII.

Asbestos beater-add gaskets, are less dense, use shorter asbestos fibers, and have lower tensile strength than compressed asbestos sheet gaskets. Consequently, beater-add gaskets are used in less severe applications and at temperatures ranging up to 750°F. At temperatures between 250-750°F asbestos beater-add gasketing can withstand pressure ranging between vacuum and 1,000 psi (Union Carbide 1987). Beater-add gasketing comes in a continuous roll form (reducing waste during die cutting), is more dimensionally uniform, and is less expensive than sheet gasketing (ICF 1986).

Asbestos beater-add gasketing is manufactured[1] by a technique employing a paper making process, using fourdrinier or cylindrical paper machines to make paper from a viscous slurry of asbestos and liquid binders. The asbestos fibers are incorporated within various elastomeric binders and other fillers to form the beater-add paper. These products are used extensively for internal combustion applications and for the sealing component of spiral wound gaskets (Union Carbide 1987). Beater-add gaskets generally contain 60 to 80 percent asbestos in combination with 20 to 40 percent binders and are used primarily in the transportation and chemical industries as:

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[1]The binder is added during the beater process, hence the name "beater-add".

- head, carburetor, exhaust manifold, and transmission gaskets to prevent leakage of oil, fuel, water, gas, or low pressure steam in automobiles, trains, airplanes, and ships; and,

- flange, spiral wound, and general service industrial gaskets to prevent leakage and potential reactions of chemicals in reactors, compressors, heat exchangers, distillation columns, and similar apparatus (ICF 1986).

The particular binder used in a beater-add paper determines the material's suitability for use in water, oil, fuel, or chemical environments. Since the proportion of fiber to binder determines the intended temperature range, different grades of asbestos beater-add gaskets are available for different temperature use limits. Latex is the most popular binder, but styrene-butadiene, acrylic, acrylonitrile, neoprene, fluoroelastomeric polymers, rubber, polytetrafluoroethylene (PTFE), and silicone polymers are also used (Krusell and Cogley 1982).

Gasketing paper is usually produced in a sheet or sheet roll that varies in thickness from approximately 1/64 inch to 3/16 inch. Gaskets are fabricated to customer-specified sizes and dimensions from these sheet rolls. They may be used in this form with no further fabrication required, or they may be processed further by reinforcing them with wire insertions or by jacketing the paper with various metal, foils, plastics, or cloth (ICF 1986).

B. Producers and Importers of Asbestos Beater-Add Gasketing

In 1985, four companies, at five locations, Armstrong World Industries (Fulton, NY), Hollingsworth & Vose (East Walpole, MA), Lydall Corp. (Hoosick Falls, NY and Covington, TN), and Quin-T Corporation (Erie, PA) produced asbestos beater-add gasketing. A fifth company, Boise Cascade Corporation (Beaver Falls, NY) produced beater-add gaskets in 1981, but did not supply information for the ICF survey. In order to account for the estimated production of this company, a methodology was developed to allocate the industry averaged trend to the non-responding companies (Appendix A). The consumption in this category for 1985 is estimated, therefore, to be 12,436.4 tons of fibers used to produce 16,505 tons of beater-add gasketing. Table 1 lists the total production of beater-add gaskets. The beater-add gasketing market was estimated to be worth $24.8 million in 1985, based on an average price of $0.75 per pound (ICF 1986).

Beater-add gasketing is not imported to the United States. Beater-add gaskets[2] were, however, imported by foreign automobile manufacturers. Kawasaki, Toyota, and Suzuki have in total reported imports of 361.35 tons. Other auto makers also imported beater-add gaskets, but the actual import volume for 1985 was not available (ICF 1986).

C. Trends

Between 1981 and 1985, Rogers Corp. (Rogers, CT), Nicolet, Inc. (Norristown, PA), and Celotex (Lockland, OH), three manufacturers that formerly produced asbestos beater-add gasketing, either substituted for asbestos with other materials or discontinued their operations. During those four years one company, Lydall Corp. (Hoosick Falls, NY), initiated production.[3] Total production of asbestos beater-add gasketing paper declined by 37 percent between 1981 and 1985 resulting in a reduction from 26,039 tons to 16,505 tons (ICF 1986, ICF 1985).

All six manufacturers are currently producing substitutes for their products. The substitutes currently hold about a 50 percent share of the gasket market (ICF 1986), but as concern about asbestos grows and substitutes gain wider acceptance, the production of beater-add asbestos gaskets is likely to decline further (ICF 1986).

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[2]Gaskets, as opposed to gasketing, are custom made by secondary processors for their customers.

[3]Lydall Corp. purchased the beater-add gasketing business of Rogers Corp. in 1984, and subsequently moved the operation to their Hoosick Falls, NY location.

Table 1. Production of Asbestos Beater-Add Gasketing and Asbestos Fiber Consumption

	1985 Fiber Consumption (short tons)	1985 Production (short tons)	Reference
Total	12,436.4	16,505	ICF (1986)

D. Substitutes

Asbestos is a chemically inert, nearly indestructible substance that can be processed into fibers. Asbestos fibers partially adsorb the binder with which they are mixed during processing, and subsequently intertwine within it and become the strengthening matrix of the product. Gaskets made using asbestos contain as much as 80 percent asbestos fiber, some of which has been employed as a filler. The balance of the product is the binder which holds the asbestos in the matrix. Industry leaders indicate that they have been unable to find a single substitute for asbestos that can reproduce all of its qualities and have been forced to replace asbestos fiber with a combination of substitute materials, including cellulose, aramid, glass, PTFE, graphite, and ceramic fibers. Asbestos used as a filler has been replaced by other fillers (e.g., clay, mica).

Formulations of substitute products most often include a combination of substitute fibers and fillers in order to reproduce the properties of asbestos necessary for a particular application. Formulation of substitute products is done so as to meet the performance requirements on an application-by-application basis (ICF 1986). For the purposes of this analysis, the substitute products have been grouped into six major categories according to the type of asbestos substitute used:

- cellulose fiber,
- aramid,
- fibrous glass,
- polytetrafluoroethylene (PTFE),
- graphite, and,
- ceramic fiber mixtures (ICF 1986; Palmetto Packing 1986).

Table 2 presents the characteristics of the substitute materials.

The estimated current market shares for the different substitute formulations are presented in Table 3. For all beater-add applications, asbestos-based producers still occupy 50 percent of the market. It is evident

Table 2. Substitutes for Asbestos Beater-Add Gasketing Paper

Product	Advantages	Disadvantages	Remarks	Reference
Cellulose	Inexpensive. Good carrier web.	Not heat resistant. Useful to 350°F. Not chemically resistant.	Useful for low temperature applications only.	ICF 1986; ICF 1985; Mach. Des., July 10, 1986.
Aramid	Very strong. Tear resistant. High tensile strength.	Hard to cut. Wears out cutting dyes quickly. 800°F temperature limit.		ICF 1986; ICF 1985; Mach. Des., July 10, 1986.
Glass Fibers	Good tensile properties. Chemical resistant.	More expensive than asbestos.	Often used in the auto industry.	ICF 1986; ICF 1985; Mach. Des., July 10, 1986.
PTFE	Low friction. Chemical resistant. FDA approved to contact food and medical equipment.	Not as resilient as asbestos. Deforms under heavy loads.	Used primarily in the chemical industry.	ICF 1986; Palmetto Packing 1986a.
Graphite	Heat resistant to 5000°F. Chemical resistant. Light weight.	More expensive. Brittle. Frays.	Fastest growing substitute in the auto market in high temperature seals.	ICF 1986; ICF 1985; Mach. Des., July 10, 1986; Union Carbide 1987.
Ceramic Paper	High heat resistance. Chemical resistant. Strong.	Not oil resistant. Not resilient. More expensive than asbestos.		ICF 1986; ICF 1985; Mach. Des., July 10, 1986.

Table 3. Estimated Market Share for Asbestos Substitute Fibers in Beater-Add Gasketing

Fiber	Estimated Market Share (percent)	References
Cellulose	25	ICF 1986 Palmetto Packing 1986
Aramid	30	ICF 1986 Palmetto Packing 1986
Glass	20	ICF 1986 Palmetto Packing 1986
PTFE	10	ICF 1986 Palmetto Packing 1986
Graphite	10	Union Carbide 1987
Ceramic	5	ICF 1986

from the survey of asbestos processors, however, that the market share of asbestos-free beater-add gaskets is increasing rapidly as companies replace asbestos in some applications. One obstacle to complete replacement of asbestos gaskets by substitute products is military contract specifications that require asbestos gaskets.

1. <u>Cellulose Fiber Mixtures</u>

Cellulose fibers are generally milled from newsprint or other waste forms of cellulose (e.g., vegetable matter) in the presence of additives which ease grinding and prevent fires during processing. Cellulose fiber gaskets usually contain between 20 and 25 percent cellulose fiber and 50 to 55 percent fillers and thickeners. The remaining 25 percent is usually an elastomeric binder (ICF 1986).

Traditionally, cellulose fibers do not resist pressure well and crush easily. However, proprietary methods have been found to reinforce fibers. This results in excellent crush resistance, excellent dimensional stability, and good sealability below 350°F. Cellulose gaskets can substitute for asbestos beater-add gaskets in low temperature applications (below 350°F) such as with oil, gas, organic solvents, fuels, and low pressure steam.

Three producers of asbestos beater-add gaskets also produce cellulose based gaskets. They are Armstrong World Industries, Hollingsworth & Vose, and Lydall Corporation (ICF 1986).

Armstrong World Industries of Fulton, NY, the largest producer of asbestos containing beater-add gaskets, produces a line of asbestos-free, cellulose based gaskets, Syntheseal(R). Armstrong indicated that the asbestos-free formulation costs more to produce and yields a product comparable in quality to the asbestos product for applications with an operating temperature under 350°F (Armstrong 1985).

Hollingsworth & Vose also produces a line of cellulose based, asbestos-free gaskets. The formulation includes mineral fillers and an elastomeric binder. The company cited no quality problems with their asbestos-free gasket line that costs more to produce (ICF 1986a).

The Lydall Corporation also produces cellulose based gaskets that cost more than the asbestos formulation. Company officials indicated that these cellulose based products can only be used in temperatures below 350°F (ICF 1986).

Reinforced cellulose based gaskets have increased in popularity in the past few years. These gaskets can duplicate all asbestos performance parameters, except high temperature resistance. Although they can be used at a maximum continuous operating temperature of 350°F, their life is substantially shortened in temperatures over 95°F and they cannot be used in even mild pressure applications (Union Carbide 1987). But in the right operating environment, manufacturers indicate that the service life of these asbestos-free gaskets is the same as that of asbestos gaskets (ICF 1986).

In the event of an asbestos ban, cellulose fiber formulations in combination with clay and mineral thickeners are estimated to capture 25 percent of the gasketing market (Table 3). Prices would be expected to rise 20 percent to $0.90 per pound due to increased material and production costs (ICF 1986, Palmetto Packing 1986).

2. Aramid Mixture

Aramid fibers are used in asbestos-free gaskets because they are highly heat resistant and strong (ten times stronger than steel, by weight). Aramids are at least seven times more expensive than asbestos, by weight, but as they are less dense and stronger, less is needed for reinforcement purposes. At high temperatures (above 800°F), the fiber physically degrades, and it can only be used in applications where pressure service is below 1,000 psi (Union Carbide 1987).

Aramid gaskets are usually 20 percent aramid fiber, by weight, and 60 to 65 percent filler. The remaining 20 to 25 percent is binder that keeps the fibers in a matrix. Typical applications include gasketing for internal combustion engines in off-highway equipment, diesel engines, and compressors. These applications require a very strong gasketing material that will withstand moderate temperatures (ICF 1986).

Thermo-Tork (R) is a trade name for the line of aramid-containing gaskets that Armstrong World Industries markets for operating temperatures over 350°F (Armstrong 1987). The content is a proprietary mixture of aramid fibers and other fibers and fillers that changes according to intended operating parameters. Many types of Thermo-Tork (R) gaskets are available, each with different combinations of suitable operating temperature and pressure ranges (Armstrong 1987). The various types of gasket were designed for specific applications, such as:

- small engines and motors,
- sealing fuels, fluids, and hot oils,
- sealing gases, water, and low pressure steam, and
- compressors and transmissions (Armstrong 1985).

Suitable temperatures can range up to 800°F, and pressures can range up to 1500 pounds per square inch. Armstrong indicated no diminished quality with the non-asbestos gaskets. In fact, greater sealability is often found with the Thermo-Tork (R) gaskets.

Hollingsworth & Vose identified strength and high temperature resistance as the reasons for selecting aramids for asbestos beater-add replacement. Their formulation includes mineral fillers and elastomeric binders. The estimated cost of the aramid product was 1.5 to 3 times as much as the asbestos product resulting in gaskets that cost $1.69 per pound (ICF 1986).

Although aramid products are expensive, their high temperature and pressure limits make them very attractive for gasket applications. Thus, the estimated market share for aramid products would be about 30 percent of the total asbestos market in the event of an asbestos ban (ICF 1986).

3. Fibrous Glass Mixtures

Fibrous glass is generally coated with a binder such as neoprene, tetrafluoroethylene (TFE), or graphite in the manufacturing process to make gaskets. The glass fibers are relatively easy to manufacture into this material.

Fibrous glass gaskets can be divided into two groups, "E" glass gaskets, and "S" glass gaskets, depending upon the type of glass fiber used in the formulation. "E" glass is one of the more common glass fibers, and it is occasionally manufactured into a gasketing which is used as a jacket around a plastic core of carbon or aramid fibers and other material (OGJ 1986).

"E" glass gaskets are suitable for applications where the operating temperature is below 1000°F. Above this temperature, the gasketing loses 50 percent of its tensile strength. The material can be used with most fluids except strong caustics.

The second type of fiber, "S" glass, was developed by NASA and is recognized as the superior glass fiber in use today (OGJ 1986). This material is occasionally used as a jacket around a core of graphite and other fibers. This beater-add gasketing is caustic resistant and can be used in applications with operating temperatures that reach 1500°F (OGJ 1986).

It is estimated that glass gaskets will capture 20 percent of the total asbestos beater-add gasketing market and will cost twice as much as the asbestos material. Thus, the price will be $1.50 per pound (Palmetto Packing 1986, ICF 1986).

4. Polytetrafluoroethylene (PTFE)

Fibers of polytetrafluoroethylene (PTFE) are used as substitutes for asbestos in gaskets because of their chemical resistance to all but the most powerful oxidizing agents, acids, and alkalies in temperatures ranging from -450°F to 500°F (Chem. Eng. News 1986). PTFE also has good dielectric strength and impact resistance.

PTFE can be used in specialized applications because it has been approved by the FDA for contact with food and in medical equipment. In addition, it does not stain the fluid with which it has contact (Krussel and Cogley 1982). The finished product is 3.5 times as expensive as the asbestos product resulting in gasketing material costs of $2.62 per pound. PTFE gaskets will capture an estimated 10 percent of the total asbestos market in the case of an asbestos ban (Palmetto Packing; ICF 1986).

5. Graphite

Flexible graphite[4] is made from natural flake graphite, expanded several hundred times into a light, fluffy material by mixing with nitric or sulfuric acid. It is then calendered into a sheet (without additives or binders) (Chem. Eng. News 1986). It is extremely heat resistant and inherently fire-safe (because it does not contain binders). Graphite gaskets are suitable for applications where the operating temperatures reach 5000°F in non-oxidizing atmospheres. In the presence of oxygen, the material is limited to use below 800°F (Chem. Eng. News 1986). The gaskets have excellent

[4] Other forms of graphite with similar properties are also available (e.g., carbonized viscose rayon), but are grouped in the category for convenience.

chemical resistance with the exception of strong mineral acids and can be used up to 1,500 psi[5] (Union Carbide 1987).

Graphite material is often used in oil refineries and oil field applications because of its high temperature resistance. A wire can be added to increase strength in high temperature, high pressure applications. (OGJ 1986).

Graphite is an expensive material, but the addition of various fillers helps keep the cost competitive with other substitute materials. Graphite gaskets are estimated to cost twice as much as asbestos beater-add gaskets, resulting in a cost of $1.50 per pound. This substitute's market share is estimated to be 10 percent of the total asbestos gasketing market, but this value is likely to rise to 50 percent for internal combustion engines, and to 20 percent for all applications (Union Carbide 1987).

6. Ceramic Mixtures

Ceramic mixtures are made from high purity silica/alumina fibers that are thoroughly interlaced in the production process and bonded with either an elastomeric or inorganic binder. The elastomeric binder can be used when operating temperatures do not rise above 800°F, while inorganic binders can be used for all operating temperatures. Ceramic fiber products are heat resistant, chemical resistant, and very strong; this enables them to be used under stressful operating conditions.

Three major companies that produce ceramic paper used for gasketing purposes are: Cotronics Corporation, Carborundum Corporation, and Quin-T Corporation. Only Quin-T is also an asbestos beater-add gasketing producer. Quin-T indicated that their formulation for asbestos free gaskets was

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[5]Unlike other gasketing materials that exhibit a temperature/pressure dependence, flexible graphite is able to withstand high pressures independent of temperatures.

proprietary, but did state that the ceramic mixture products could capture 5 percent of the asbestos gasketing market.

The manufacturer stated that the ceramic mixture is not as resilient as asbestos and not as resistant to oil, but claimed that this was not detrimental to the function of gaskets in most applications.

The price of ceramic gaskets is estimated to be three times that of the asbestos products they replace, resulting in a cost of $2.25 per pound. The service life of the substitute product is 5 years, as is that of the asbestos gasket (ICF 1986).

E. Summary

It appears that substitutes for asbestos containing gaskets currently exist. These products cost more to produce, however, and may not perform as well in all applications. Because no single substitute fiber exists, manufacturers have been forced to replace asbestos with a combination of substitute materials, including cellulose, aramid, glass, graphite, PTFE and ceramic fibers. The substitute materials are a combination of fibers and fillers designed on an application-by-application basis.

The estimation of market shares and prices of the substitute formulations in the event of an asbestos ban relies to a large extent upon educated judgments of industry experts. Table 4 summarizes the findings of this analysis, and presents the data inputs for the Asbestos Regulatory Cost Model.

Table 4. Data Inputs for Asbestos Regulatory Cost Model
(005) Beater-Add Gasketing Paper

Product	Output	Product Asbestos Coefficient	Consumption/ Production Ratio	Price	Useful Life	Equivalent Price	Market Share	Reference
Asbestos Gasketing	16,505 tons	0.75349 tons/ton	1.02	$1,500/ton	5 years	$1,500/ton	N/A	ICF 1986.
Cellulose	N/A	N/A	N/A	$1,800/ton	5 years	$1,800/ton	25%	ICF 1986.
Aramid	N/A	N/A	N/A	$3,380/ton	5 years	$3,380/ton	30%	ICF 1986.
Fibrous Glass	N/A	N/A	N/A	$3,000/ton	5 years	$3,000/ton	20%	ICF 1986; Palmetto Packing.
PTFE	N/A	N/A	N/A	$5,240/ton	5 years	$5,240/ton	10%	ICF 1986; Palmetto Packing.
Graphite	N/A	N/A	N/A	$9,740/ton	5 years	$3,000/ton	10%	ICF 1986; Union Carbide 1987.
Ceramic	N/A	N/A	N/A	$4,500/ton	5 years	$4,500/ton	5%	ICF 1986.

REFERENCES

Armstrong World Industries. 1985. Product literature on Thermo-tork(R) gasketing material.

Armstong World Industries. L. Creech. 1987 (July 1). Fulton, NY. Transcribed telephone conversation with Mark Wagner, ICF Incorporated, Washington, D.C.

Chemical Engineering News, October 27, 1986. Asbestos Users Step Up Search for Substitutes. McGraw-Hill.

ICF Incorporated. 1985. Appendix H: Asbestos Products and Their Substitutes, in Regulatory Impact Analysis of Controls on Asbestos and Asbestos Products. Washington DC: Office of Pesticides and Toxic Substances, U.S. Environmental Protection Agency.

ICF Incorporated. 1986 (July-December). Survey of Primary and Secondary Processors of Asbestos Beater-Add Gasketing. Washington, DC.

Krusell N, Cogley D. 1982. GCA Corp. Asbestos Substitute Performance Analysis. Revised Final Report. Washington DC: Office of Pesticides and Toxic Substances, U.S. Environmental Protection Agency. Contract 68-02-3168.

Oil and Gas Journal. May 26, 1986. Refining Technology: Substitute Materials to Replace Asbestos in Refinery-Service Gaskets and Packings. PennWell Publication. Tulsa, OK. Pp.47-51.

Machine Design. 1986 (July 10). Better Gaskets Without Asbestos. Volume 58, pp. 67-71.

Palmetto Packing. S. Matt. 1986 (January 8 and 19). North Wales, PA. Transcribed telephone conversations with Linda Carlson, ICF Incorporated, Washington, D.C.

Union Carbide Corporation. P. Petrunich. 1987 (March 4). Cleveland, OH. Letter with enclosures addressed to Tony Bansal, ICF Incorporated, Washington, D.C.

VI. HIGH-GRADE ELECTRICAL PAPER

A. Product Description

Classification of asbestos paper products into specific categories is difficult. Similar products may be classified differently by two manufacturers due to their differing end applications. Also, manufacturers may place all of their products into the category for which most of the material is used, or they may divide the products into each end application. Our division of paper products into different categories is based on the information obtained from both the manufacturers and users of these products.

Asbestos is used in electrical paper insulation because of its high thermal and electrical resistance that permit the paper to act effectively as an insulator and to protect the conductor from fire at the same time. Asbestos electrical insulation is composed of 80 to 85 percent asbestos fiber encapsulated in high temperature organic binders. It is formed on conventional papermaking machines and may be obtained in rolls, sheets, and semi-rigid boards (ICF 1986).

The major use of asbestos electrical paper is insulation for high temperature, low voltage applications such as in motors, generators, transformers, switch gears, and other heavy electrical apparatuses. Typically, operating temperatures are 250°F to 450°F (ICF 1986).

B. Producers of High-Grade Electrical Paper

At present, asbestos paper for electrical insulation is manufactured by only one firm, the Quin-T Corporation in Tilton, New Hampshire. A previous survey failed to identify any 1981 importers of asbestos electrical insulating paper, and the asbestos processor surveyed in 1986 was not aware of any such imports (ICF 1984, ICF 1986).

C. Trends

The production volumes and fiber consumption for electrical paper for

1985 are presented in Table 1. Production decreased by 20 percent between 1981 and 1985, from 841 short tons to 698 short tons (ICF 1986) (TSCA 1982a). Domestic fiber consumption declined between 1981 and 1985 by 11.5 percent, from 841 short tons to 744 short tons[1] (ICF 1986).

The only two secondary processors of high-grade electrical paper for insulation purposes have ceased manufacturing asbestos containing materials. In 1981, the Square D company, having plants in Clearwater, Florida and Milwaukee, Wisconsin, stopped processing. In 1985, Power Magnetics ceased all production of asbestos containing products (ICF 1986).

The sole manufacturer of asbestos electrical insulation estimates that asbestos products hold 10 percent of the total market. Their share of the market in high temperature applications may be as high as 75 to 80 percent (ICF 1986). The use of asbestos electrical paper in typical applications appears to be declining, as asbestos is being phased out in various applications. One manufacturer of transformers believes that the use of asbestos has been completely eliminated for this product (Square D 1986).

D. Substitutes

Asbestos is unique among raw minerals because it is a chemically inert and nearly indestructible mineral that can be processed into fiber. Asbestos

[1]Although the consumption value for electrical paper from the ICF 1986 survey indicates that the finished product is more than 100 percent asbestos, it is likely that some of the fiber consumption was in fact, inventory. The submitter could not be reached, however, for corroboration.

Table 1. Production of High-Grade Electrical Paper and Asbestos Fiber Consumption

	1985 Fiber Consumption (short tons)	1985 Production (short tons)	Reference
Total	744	698	ICF (1986a)

fibers partially adsorb the binder with which they are mixed during processing; they are then intertwined, and become the strengthening matrix of the product. By formulating the product with 85 percent asbestos fibers, manufacturers are also employing it as a filler. The remaining 15 percent of the product is the binder which holds the asbestos in the matrix. Industry leaders indicate that they have been unable to find a single substitute for asbestos that can reproduce the numerous qualities of the mineral. Hence, manufacturers have been forced to replace the asbestos fiber with a combination of substitute materials, including aramid and ceramic. The formulations of the substitute products most often include a combination of more than one type of substitute fiber and more than one filler in order to reproduce the properties of asbestos necessary for that application. Formulation of substitute products is done on an application-by-application basis by each manufacturer (ICF 1986).

The substitute products can be grouped into two major categories according to the type of asbestos substitute fiber used: aramid or ceramic (ICF 1986). Table 2 shows a comparison of these substitutes. The current market share of the different substitute formulations is presently unknown and our attempt to project the market shares in the event of an asbestos ban relies more on the informed judgement of industry rather than on specific data. It is evident from the survey that the market share of asbestos free electrical paper is increasing rapidly, as more companies replace asbestos (ICF 1986).

1. Aramid Paper

A typical aramid-based paper product, Nomex (R), the tradename for a substitute paper manufactured by Dupont, is made with an aromatic polyamide. It is thermally stable to 400°F and flame resistant. Quin-T Corporation in Tilton, NH, cites this substitute as performing better than asbestos paper in

Table 2. Substitutes for Asbestos High-Grade Electrical Paper

Paper Product	Manufacturer	Advantages	Disadvantages	Remarks	Reference
Aramid	Dupont	Performance is better. Thermal stability. Flame resistant.	Premium price. Low temperature range.	Aromatic polyamide paper.	ICF (1986a) ICF (1984a)
Ceramic	Carborundum Corp.	Good dielectric properties temperature resistance up to 2000°F. Easily handled. Easily cut.	Stiff. Expensive.	Ceramic paper.	ICF (1986a) ICF (1984a)

some situations. It is very expensive, however, and has a price of $10.48 per pound (five times that of the asbestos product). Quin-T indicated that this material would capture 80 percent of the asbestos market in the event of an asbestos ban (ICF 1986). The disadvantages of Nomex (R) are that it does not have the high temperature limits of asbestos and may not have the same range of applicability that asbestos has (DuPont 1980).

2. Ceramic Paper

Fiberfrax (R) is the name of a ceramic paper made by the Carborundum Corporation and is representative of other ceramic papers available. It has good dielectric properties as well as a temperature resistance up to 2000°F. Two advantages of this paper relative to asbestos are that it is easier to handle and easier to cut. Quin-T Corporation has indicated that this material will take 20 percent of the asbestos electrical paper market in the event of a ban of asbestos. The product is three times as expensive as the asbestos paper, and costs $7.04 per pound (ICF 1986).

Some of the drawbacks of ceramic paper products include the loss of tensile strength after exposure over extended periods, stiffness during use, and slightly more permeability than asbestos at low temperatures (Carborundum 1986).

E. Summary

It appears that substitutes for asbestos electrical paper currently exist. However, these products cost more to produce and may not perform as well. Asbestos is unique among known raw minerals because of its combination of strength, heat resistance, and low price. Since no across the board substitute fiber exists for the mineral, the manufacturer has been forced to replace asbestos with a combination of substitute materials, including aramid- and ceramic-based papers. The substitute materials are a combination of fibers and fillers designed with proprietary formulations.

The estimation of market shares and prices of the substitute formulations in the event of an asbestos ban relies to a large extent upon educated judgments of industry experts. Table 3 summarizes the findings of this analysis, and presents the data inputs for the Asbestos Regulatory Cost Model.

Table 3. Data Inputs for Asbestos Regulatory Cost Model
(006) High-Grade Electrical Paper

Product	Output	Product Asbestos Coefficient	Consumption Production Ratio	Price	Useful Life	Equivalent Price	Market Share	Reference
Asbestos Electrical Paper	698 tons	1.07 tons/ton	1	$2.53/lb.	3 years	$2.53/lb.	N/A	ICF (1986a)
Aramid Electrical Paper	N/A	N/A	N/A	$10.48/lb.	3 years	$10.48/lb.	80%	ICF (1986a), ICF (1984a)
Ceramic Electrical Paper	N/A	N/A	N/A	$7.04/lb.	3 years	$7.04/lb.	20%	ICF (1986a), ICF (1984a)

N/A: Not Applicable.

REFERENCES

Carborundum. 1980. Product Literature on Fiberfrax(R) Heat-Resistant Papers.

DuPont. 1980. Product Literature on Kevlar(R) Heat-Resistant Textiles.

ICF Incorporated. 1984. Imports of Asbestos Mixtures and Products. Washington DC: Office of Pesticides and Toxic Substances, U.S. Environmental Protection Agency. EPA CBI Document Control No. 20-8600681.

ICF Incorporated. 1986 (July-December). Survey of Primary and Secondary Processors of Asbestos Electrical Paper. Washington, D.C.

Krusell N, Cogley D. 1982. GCA Corp. Asbestos Substitute Performance Analysis. Revised Final Report. Washington DC: Office of Pesticides and Toxic Substances, U.S. Environmental Protection Agency. Contract 68-02-3168.

Quin-T Company. N. Hughes. 1986 (July-December). Erie, PA. Transcribed telephone conversation with Linda Carlson, ICF Incorporated, Washington, DC.

Square D Company. R. Burke. 1986 (July-December). Clearwater, FL. Transcribed telephone conversation with Jeremy Obaditch, ICF Incorporated, Washington, DC.

TSCA Section 8(a) Submission. 1982a Production Data for Primary Asbestos Processors, 1981. Washington, DC: Office of Toxic Substances, U.S. Environmental Protection Agency. EPA Document Control No. 20-8601012.

TSCA Section 8(a) Submission. 1982b Production Data for Secondary Asbestos Processors, 1981. Washington, DC: Office of Toxic Substances, U.S. Environmental Protection Agency. EPA Document Control No. 20-8670644.

VII. ROOFING FELT

A. Product Description

Asbestos roofing felt is made in two separate stages. In the first stage, asbestos fiber, cellulose fiber, and various fillers are combined to produce unsaturated roofing felt. The second stage involves saturating this felt by coating it with either coal tar or asphalt to produce the final product -- saturated roofing felt.

Unsaturated roofing felt is a paper product composed of 85 to 87 percent asbestos fiber (usually grades 6 or 7 chrysotile fiber), 8 to 12 percent cellulosic fibers, 3.5 percent starch fibers, and small amounts of fillers such as wet and dry strength polymers, kraft fibers,[1] fibrous glass, and mineral wool. The product is manufactured on conventional paper machines. The ingredients are combined and mixed with water and then fed through a series of machines that apply heat and rollers to produce a felt with uniform thickness. The felt can be either single- or multi-layered grade. For the multi-layered grade fiberglass filaments or wire strands may be embedded between the paper layers for reinforcement (Krusell and Cogley 1982).

These steps comprise the primary processing stage of production; the product is now considered an unsaturated felt and is ready to be coated. It can be coated at either the main plant, or it can be coated at geographical locations nearer to demand if lower transportation costs justify it.[2] The felt is coated by pulling it through a bath of hot asphalt or coal tar until it is thoroughly saturated. The paper then passes over a series of hot rollers so that the asphalt or coal tar is properly set. It may be coated with extra surface layers of asphalt or coal tar depending on the intended

[1]Kraft fibers consist of a blend of cellulose and wood pulp fibers.

[2]It is less expensive to ship unsaturated felt because it weighs much less.

application. After saturation and coating, the roofing felt passes over a series of cooling rollers that reduce its temperature and provide a smooth surface finish. The felt is then air-dried, rolled, and packaged for marketing as saturated roofing felt (Krusell and Cogley 1982).

Asbestos roofing felt is used for built-up roofing. There are two types of built-up roofing systems -- hot roof systems and cold roof systems. The hot roof system is the more common; it involves the application of several plys or layers of roofing felt alternating with hot asphalt or tar, often with a top layer of gravel imbedded in the asphalt. The layers used may be fiberglass felts, organic felts, or asbestos felts.

The other system is a cold roof system. It does not require the application of hot tar or asphalt, instead, adhesive tars or roof coatings are used to bond the layers together. The layers used may be single-ply membrane, fiberglass felts, organic felts, or asbestos felts.

Asbestos is used in roofing felts because of its dimensional stability and resistance to rot, fire, and heat. Dimensional stability, which refers to the product's ability to expand and contract with changes in temperature, is important because roofs are exposed to wide temperature fluctuations that may cause the roof to actually crack, allowing water to penetrate and settle. Because this water may remain trapped for long periods of time, rot resistance becomes crucial. In addition, rot resistance is important because flat roofs (on which built-up roofing is typically used) tend to have poor drainage and do not allow water to run off (ICF 1985).

B. Producers and Importers of Asbestos Roofing Felt

There were three primary processors and three secondary processors of asbestos roofing felt in 1981. The primary processors were Nicolet, Inc., Celotex Corporation, and Johns-Manville Corporation[3] (TSCA 1982a). However, no primary processors produced any asbestos felt in 1985 and none are currently producing asbestos roofing felt (ICF 1986).

The secondary processors in 1981 were B.F. Goodrich Corporation, Mineral Fiber Manufacturing Corporation, and Southern Roofing & Metal Company (TSCA 1982b). Southern Roofing & Metal Company stopped processing asbestos roofing felt in 1982. B.F. Goodrich Corporation processed imported asbestos roofing felt in part of 1985, but has now stopped. Mineral Fiber Manufacturing Corporation is the only domestic company which still processes asbestos roofing felt (ICF 1986).

Mineral Fiber Manufacturing Corporation does not purchase[4] asbestos roofing felt. They simply receive unsaturated roofing felt, coat and saturate it with asphalt, and return the saturated roofing felt to their supplier, a Canadian firm called Cascades, Inc. Cascades, Inc. then sells this product in the U.S. through Power Marketing Group, a distributor that does not process any asbestos itself. Power Marketing Group believes they are the only company selling this product in the U.S., and no other processors or importers of asbestos roofing felt were identified (Power 1987b, ICF 1984, ICF 1986).

C. Trends

The three primary processors produced approximately 3,107,538 squares of asbestos roofing felt in 1981 (TSCA 1982a), and they had all ceased production of this product in 1985. Information on imports by Power Marketing Groups and other companies in 1981 is not available, but Power Marketing Group believes it is the only importer of this product in 1985. Thus, we see that both

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[3]Johns-Manville Corporation has changed its name to Manville Sales Corporation.

[4]The company insists that it does not purchase or process any roofing felt. They provide the service of coating the felt and charge a fee for their service.

production and consumption of asbestos roofing felt have declined significantly in the U.S.

D. Substitutes

There are currently four products which have served or may serve as substitutes for asbestos roofing felt -- fiberglass felt, organic felt, modified bitumen, and single-ply membrane. A discussion of each one will be presented separately.

1. Organic Felt

Organic felt is the oldest roofing felt, and it had dominated the market until recently because it was very economical. It is composed primarily of wood pulp or cellulosic fiber, and this makes it susceptible to rotting. Although asbestos felt could not compete with organic felt on price, it was able to outperform it because of its heat, fire, and rot resistance. These resistance properties were particularly important because they allowed commercial users to save on their insurance premiums (Manville 1986). The recent substitution away from asbestos roofing felt has resulted in some increased market share for organic felt, but the primary beneficiary has been fiberglass felt. The current producers of organic felt include: Manville Sales, Celotex, Koppers, and Certainteed (Washington Roofing 1986).

2. Fiberglass Felt

Fiberglass roofing felt is made of glass or refractory silicate mixed with a binder. The exact composition is not available. Owens-Corning Corporation invented the continuous filament manufacturing process in 1964. The introduction of fiberglass felt drastically changed the market because it took virtually the entire market share of asbestos roofing felt and now has a major share of the roofing felt market. Fiberglass felt was able to do this because it possesses the same heat, fire, and rot resistant qualities of asbestos felt, but it is much less expensive and may require fewer layers.

Most of the recent substitution away from asbestos roofing felt was achieved through the use of fiberglass felt. The current producers of fiberglass felt include: Owens-Corning, Manville Sales, Tamco, and GAF (Washington Roofing 1986).

3. Modified Bitumen

Power Marketing Group states that the asbestos felt they sell is used almost exclusively in flashing applications. This refers to the process of waterproofing roof valleys or the area around any object which protrudes from the roof. Asbestos felt is used in these applications because fiberglass felt has a tendency to pull away when it is applied vertically as is often the case in flashing applications (Power 1986). Organic felt is not suitable for such applications because it is susceptible to rotting.[5] Power Marketing Group believes the only effective substitute is modified bitumen. However, it costs 10-15 percent more than asbestos roofing felt, and it also presents a fire risk because it must be applied with a torch (Power 1986).

4. Single-Ply Membrane

Single-ply membrane is a cold roof system. The product itself is a laminate (roll of bonded or impregnated layers) of modified bitumen and polymeric materials. For example, Koppers KMM(R) system is a 160 mil, five layer laminate composed of a thick plastic core protected on each surface by a layer of modified bitumen and an outer film of polyethylene.

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[5]The view expressed by Power Marketing Group concerning the usefulness of asbestos are not shared by members of the industry. The National Roofing Contractors Association does not recommend the use of asbestos felt, and most roof suppliers do not carry the product (National Roofing Contractors 1986; Washington Roofing 1986). One roofing contractor claimed that using fiberglass felt for virtually an entire job and then using asbestos felt for only the flashing applications would not be practical because it would cause unnecessary delay and confusion while conferring limited benefits (Johnny B. Quick 1986).

A single-ply membrane is typically loosely laid (i.e. without layers of tar) with a covering of loose gravel. If more than one sheet of membrane is required to cover an area, the edges of the sheets are sealed together by ironing them together or through the application of a coal adhesive (Krusell and Cogley 1982).

The fact that single-ply membrane roofing can be applied cold to the roof deck is an important advantage when city ordinances or other considerations prohibit hot tar because of the dangers associated with tar kettles. At temperatures ranging between 650°F and 750°F, the tar or asphalt mixture will burn and has, in some instances, exploded and caused damage to property and pedestrians. As a result, some communities do not allow the use of hot tar or asphalt (Krusell and Cogley 1982). Manufacturers of single-ply membrane roofing systems include: Carlisle Syntex, Plymouth Rubber, Gates Engineering, and Koppers (Washington Roofing 1986).

Table 1 presents the advantages and the disadvantages of asbestos roofing felt and its substitutes, and Table 2 presents the inputs for the Regulatory Cost Model. Because asbestos felt is now used primarily in flashing applications, the projected market shares of the substitutes are based on their ability to substitute for asbestos felt in this particular application.

E. <u>Summary</u>

Asbestos roofing felt is no longer produced in the U.S. It is only distributed by Power Marketing Group, a company that imports the asbestos product from Canada. Total U.S. consumption of this product was 283,200 squares in 1985.

There appears to be some disagreement between representatives of Power Marketing Group and other industry sources on the likely substitutes of asbestos roofing felt in the case of an asbestos ban. Our estimated market shares are an attempt to reconcile these two views. Modified bitumen is

Table 1. Substitutes for Asbestos High-Grade Electrical Paper

Product	Manufacturer	Advantages	Disadvantages	References
Asbestos Felt	Cascades, Inc. Kingsley Falls, Quebec	Dimensional stability. Rot, fire, and heat resistance. Effective in flashing applications.	Potential environmental and occupational health problems.	ICF (1986) Krusell and Cogley (1982)
Organic Felt	Manville Sales Corp. Celotex Corp. Koppers Co. Certainteed Corp.	Low cost.	Low durability. Low strength. Low rot resistance.	ICF (1986)
Fiberglass Felt	Owens-Corning Corp. GAF Corp. Tamco, Inc. Manville Sales Corp.	Rot, fire, and heat resistance. Dimensional stability Requires less asphalt saturation.	Less effective in flashing applications.	ICF (1986)
Modified Bitumen	Many	Effective in flashing applications.	Can only be applied with a torch.	Power (1986)
Single-Ply Membrane	Carlisle Syntex, Inc. Plymouth Rubber Corp. Koppers Co. Gates Engineering Co. Firestone Corp. Goodyear, Inc. Manville Sales Corp.	Can be applied cold. Rot, fire, and heat resistant. Dimensional stability. Effective in flashing applications.	High cost.	ICF (1986)

Table 2. Data Inputs for Asbestos Regulatory Cost Model

Product	Imports[a]	Product Asbestos Coefficient	Consumption/ Production Ratio	Price	Useful Life	Equivalent Price	Market Share	References
Asbestos Felt	283,200 squares[b]	0.0045 tons/square[b]	N/A	$6.65/square[b]	18 years	$6.65/square	N/A	ICF (1984) Power (1987a)
Fiberglass Felt	N/A	N/A	N/A	$3.85/square	18 years	$3.85/square	40%[b]	Washington Roofing (1986)
Modified Bitumen	N/A	N/A	N/A	$7.48/square[b]	18 years	$7.48 square	50%[b]	Power (1986)
Single-Ply Membrane	N/A	N/A	N/A	$29.26/square	18 years	$29.26/square	10%[b]	Washington Roofing (1986)

N/A: Not Applicable.

[a]This table is slightly different from the other data input tables. The heading for the second column is usually output and this refers only to domestic production. This number is then multiplied by the consumption production ratio to compute total domestic consumption. Because domestic production for this production is zero, we have provided the amount of roofing felt imported. The consumption production ratio is not computed because it is infinite.

[b]See Attachment for explanations.

projected to capture 50 percent of the market at a price of $7.48/square, fiberglass felt is projected to capture 40 percent of the market at a price of $3.85/square, and single-ply membrane is projected to capture 10 percent of the market at $29.26/square (see Attachment).

REFERENCES

ICF Incorporated. 1984. Importers of Asbestos Mixtures and Products. Washington, D.C.: Office of Pesticides and Toxic Substances, U.S. Environmental Protection Agency. EPA CBI Document Control No. 20-8600681.

ICF Incorporated. 1985. Appendix H: Asbestos Products and Their Substitutes, in Regulatory Impact Analysis of Controls on Asbestos and Asbestos Products. Washington, D.C.: Office of Pesticides and Toxic Substances, U.S. Environmental Protection Agency.

ICF Incorporated. 1986 (July-December). Survey of Primary and Secondary Processors of Asbestos Roofing Felt. Washington, D.C.

Johnny B. Quick Co. S. Feldman. 1986 (November 6). Washington, D.C. Transcribed telephone conversation with Peter Tzanetos, ICF Incorporated, Washington, D.C.

Krusell N, Cogley D. 1982. GCA Corp. Asbestos Substitute Performance Analysis. Revised Final Report. Washington, D.C.: Office of Pesticides and Toxic Substances, U.S. Environmental Protection Agency.

National Roofing Contractors Association. J. Lowinski. 1986 (October 6). Transcribed telephone conversation with Peter Tzanetos, ICF Incorporated, Washington, D.C.

Power Marketing Group. 1986. Public comment brief on asbestos roofing felt submitted to U.S. Environmental Protection Agency, Washington, D.C.

Power Marketing Group. G. Pytko. 1987a (January 30). Denver, CO, 80231. Letter to Peter Tzanetos, ICF Incorporated, Washington, D.C. 20006.

Power Marketing Group. G. Pytko. 1987b (January). Denver, CO, 80231. Transcribed telephone conversations with Peter Tzanetos, ICF Incorporated, Washington, D.C.

TSCA Section 8(a) Submission. 1982a. Production Data for Primary Asbestos Processors, 1981. Washington, DC: Office of Toxic Substances, U.S. Environmental Protection Agency. EPA Document Control No. 20-8601012.

TSCA Section 8(a) Submission. 1982b. Production Data for Secondary Asbestos Processors, 1981. Washington, DC: Office of Toxic Substances, U.S. Environmental Protection Agency. EPA Document Control No. 20-8670644.

Washington Roofing Products Co. Sales Representatives. 1986 (October 15 and November 7). Transcribed telephone conversations with Peter Tzanetos, ICF Incorporated, Washington, D.C.

ATTACHMENT

Because the information about substitutes obtained from various sources is somewhat contradictory, the projected market shares are based on a synthesis of the various opinions expressed. Thus, they are not attributable to any specific source, but they are the results of conversations with various industry members. It has been assumed that organic felt cannot be used in flashing applications due to its susceptibility to rotting.

Power Marketing Group believes that modified bitumen is the only effective substitute for asbestos felt and that its share should be 100 percent. Several industry sources (Washington Roofing 1986, Johnny B. Quick 1986) and the National Roofing Contractors Association (National Roofing Contractors Association 1986) believe that asbestos felt would be replaced with more conventional roofing materials. They estimate that fiberglass felt will take 80 percent of the market and single-ply membrane will take the remaining 20 percent. We have computed our market shares by weighting both of these opinions equally. Therefore, we estimate the following market shares: modified bitumen -- 50 percent, fiberglass felt -- 40 percent, and single-ply membrane -- 10 percent.

VIII. FILLER FOR ACETYLENE CYLINDERS

A. Product Description

Asbestos is used to produce a sponge-like filler that is placed in acetylene cylinders. The filler holds the liquified acetylene gas (acetone) in suspension in the steel cylinder and pulls the acetone up through the tank as the gas is released through the oxyacetylene torch. The torch is used to weld or cut metal and is sometimes used as an illuminant gas. The filler also acts as an insulator that offers fire protection in case the oxidation of the acetylene becomes uncontrollable. The desirable properties of asbestos in this function include its porosity, heat resistance, anti-corrosiveness and its strength as a binding agent (ICF 1986).

B. Producers and Importers of Filler for Acetylene Cylinders

Currently, there are three primary processors of asbestos filler for acetylene cylinders in the United States. The amount of fiber consumed and the number of cylinders produced in 1985 are listed in Table 1. There were no secondary processors of the filler in 1985 (ICF 1986). There were no acetylene cylinders imported to the U.S. in 1985. (NI Industries 1986).

C. Trends

Since 1981, domestic production of acetylene cylinders has decreased. The decrease is attributed to the severity of the last recession that contributed to the closing of the Los Angeles plant of NI Industries (NI Industries 1986). Recently, the market for acetylene cylinders has been stable and is expected to remain so for the foreseeable future (ICF 1986). Table 2 lists the fiber consumed and the cylinders produced in 1981 and 1985.

Table 1. Fiber Use and Production of Asbestos Filler -- 1985

	Asbestos Fiber Consumed (short tons)	Asbestos-Containing Acetylene Cylinders Produced	Reference
Total	584.1	392,121	ICF (1986)

Table 2. Acetylene Cylinder Market 1981-1985

Year	Asbestos Fiber Consumed (short tons)	Asbestos-Containing Acetylene Cylinders Produced	Reference
1981	863.0	528,432	ICF (1986)
1985	584.1	392,121	ICF (1986)

D. Substitutes

Currently, only one of the filler processors is producing a substitute filler. NI Industries processes a filler that contains glass fiber and the company reports that the glass filler performs as well as the asbestos filler. The only disadvantage that NI Industries cites is that the non-asbestos cylinder costs about 3 percent more than the asbestos cylinder. NI Industries also reports that it is attempting to gain the right to use a Union Carbide developed graphite filler. In addition, NI Industries plans to stop processing asbestos within the next year (NI Industries 1986). The other processors gave no indication about their plans for substituting asbestos in the manufacture of acetylene cylinder filler (ICF 1986). Table 3 summarizes the findings of this analysis, and presents the data inputs for the Asbestos Regulatory Cost Model.

E. Summary

Asbestos is used to produce a sponge-like filler that is placed in acetylene cylinders. Currently, there are three primary processors or importers. The market for acetylene cylinders is relatively stable and is expected to remain so for the foreseeable future. One of the processors, NI Industries, is producing a substitute glass filler that performs as well as the asbestos filler and costs about 3 percent more that the asbestos filler.

Table 3. Data Inputs for Asbestos Regulatory Cost Model
(008) Acetylene Cylinders

Product	Output	Product Asbestos Coefficient	Consumption Production Ratio	Price	Useful Life	Equivalent Price	Market Share	Reference
Acetylene Cylinders w/ asbestos filler	392,121 pieces	0.0014896 tons/piece	1.0	$90.00/piece	1 use	$90.00/piece	N/A	ICF (1986)
Acetylene Cylinders w/ glass filler	N/A	N/A	N/A	$93.00/piece	1 use	$93.00/piece	100%	ICF (1986)

N/A: Not Applicable.

REFERENCES

Coyne Cylinder Co. Mr. Jim Kirsch. 1986 (July-December). Huntsville, AL 35803. Transcribed telephone conversations with Rick Hollander and Eric Crabtree, ICF Incorporated, Washington, D.C.

ICF Incorporated. 1986 (July-December). Survey of Primary and Secondary Processors of Asbestos-Reinforced Plastic. Washington, D.C.

NI Industries Incorporated. A.J. Mankos and Don Hedges. 1986 (July-December). Indianapolis, IN 46224. Transcribed telephone conversations with Jeremy Obaditch and Eric Crabtree, ICF Incorporated, Washington, D.C.

U.S. Cylinders Division of Werco. Michael Rabren. 1986 (July-December). Citronelle, AL 36522. Transcribed telephone conversations with Jeremy Obaditch and Eric Crabtree, ICF Incorporated, Washington, D.C.

IX. FLOORING FELT

A. Product Description

Asbestos flooring felt is a paper product which is used as a backing for vinyl sheet floor products. It consists of approximately 85 percent asbestos and 15 percent latex binder by weight. Short fiber chrysotile asbestos (usually grades 5 through 7) is used and is generally obtained from Canada (Krusell and Cogley 1982). The latex binder is usually a styrene-butadiene type, although acrylic latexes can be used.

Asbestos flooring felt is manufactured on conventional papermaking machines. The ingredients are mixed together and combined with water. This mixture is then placed on a belt and forced through a series of machines which remove some of the water by applying heat and by suction. The next step is to force the mixture through rollers in order to produce a flat and uniform paper product. The felt is then allowed to cool before being rolled and wrapped.

These felt rolls are then used in producing vinyl sheet flooring. They are fed into coating machines where they are coated with vinyl and possibly decorated through various printing techniques. At this point, the product is considered a vinyl plastisol, and it may be colored by various additives or techniques. This printed sheet then goes through a fusion step where it is coated with a final layer of material called the "wear layer." The wear layer is a homogeneous polymer application that provides an impervious surface for the finished floor product.

Asbestos flooring felt has a number of desirable qualities. These include dimensional stability as well as high moisture, rot, and heat resistance.[1] The flooring is able to withstand these conditions without cracking, warping, or otherwise deteriorating. Asbestos flooring felt is also particularly

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[1] Dimensional stability refers to the product's ability to stretch and contract with temperature changes and "settling" of the floor deck.

useful in prolonging floor life when moisture from below the surface is a problem (Krusell and Cogley 1982).

B. Producers and Importers of Asbestos Flooring Felt

There were four domestic primary processors of this product in 1981: Armstrong World Industries, Congoleum Corporation, Nicolet, Inc., and Tarkett, Inc. (TSCA 1982a). There were no secondary processors of asbestos flooring felt in 1981 (TSCA 1982b). In addition, two importers of asbestos flooring felt were identified in 1981 -- Biscayne Decorative Products Division of National Gypsum Company and Armstrong World Industries (ICF 1984). Since that time, all four primary processors have ceased production of asbestos flooring felt, and both importers have stopped importing asbestos flooring felt (ICF 1986). Because none of the other respondents to our survey indicated that they had begun production of asbestos flooring since the 1981 survey or were aware of any other producers or importers of asbestos flooring felt, we have concluded that there are currently no domestic producers or consumers of this product (ICF 1986).

C. Trends

1981 production of asbestos flooring felt was 127,403 tons (TSCA 1982a). Because all four producers have since stopped processing asbestos, production declined to 0 tons in 1985. There is no information on 1981 or 1985 imports of asbestos flooring felt.

D. Substitutes

As previously discussed, the key advantages of asbestos flooring felt were its dimensional stability and high heat, moisture, and rot resistance. Substitutes fall into two categories -- raw materials which can be used to produce a non-asbestos flooring felt and products which replace flooring felt itself. The substitutes for asbestos in the production of flooring felt include fiberglass, Pulpex(R), ceramic fiber, clay, and Bontex 148(R). The substitutes for flooring felt include foam cushioned backings and backless sheet vinyl. Tables 1 and 2 list the various substitutes and their advantages and disadvantages.

All of the substitutes are purchased as raw materials to be used in the production of flooring felt which is then used to produce vinyl sheet flooring. As a result, there is no observable flooring felt market. Furthermore, flooring felt producers would not reveal how much of the substitute is required or what other ingredients are required to produce their particular non-asbestos felt. Fortunately, cost estimates are not needed since asbestos flooring felt is no longer produced or sold in the U.S. and is therefore not being modeled.

Fiberglass flooring felt is a product which shares all of the advantages of asbestos flooring felt. It possesses dimensional stability, and is resistant to heat, rot, and moisture. Furthermore, it we look at roofing felt, a very similar product, we see that the fiberglass felt is much less expensive than the asbestos felt. Although the roofing application is somewhat different, the result in the flooring felt market is probably analogous.

Hercules, Inc. has developed the product Pulpex(R) to replace asbestos in flooring felt. Pulpex(R) is a fibrillated polyolefin pulp and comes in two forms -- Pulpex E (composed of polyethylene) and Pulpex P (composed of polypropylene). Pulpex(R) is sold to four North American producers of flooring felt and to six flooring felt producers worldwide. It has been commercially available since 1981. Pulpex(R) shares many of the advantages of asbestos, but it has a lower tensile strength and is less heat resistent (Hercules 1986).

Tarkett, Inc. produces a flooring felt in-house which uses a clay product to substitute for asbestos. The company claims that there are no advantages

Table 1. Substitutes for Asbestos in Flooring Felt

Product	Manufacturer	Advantages	Disadvantages	References
Asbestos Felt	None	Dimensional stability. Moisture, rot, and heat resistance.	Potential environmental and occupational health hazards.	Krusell and Cogley (1982) ICF (1986)
Fiberglass	Many	Dimensional stability. Moisture, rot, and heat resistance.	None.	Krusell and Cogley (1982)
Pulpex(R)	Hercules Corp. Wilmington, DE	Dimensional stability. Moisture and rot resistance.	Low tensile strength.	Hercules (1986)
Bontex 148(R)	Georgia Bonded Fibers, Inc. Newark, NJ	Heat resistance.	High cost.	Georgia Bonded Fibers (1986)
Clay	Many	Dimensional stability. Moisture, rot, and heat resistance.	None.	Tarkett (1986)

Table 2. Substitutes for Asbestos Flooring Felt

Product	Manufacturer	Advantages	Disadvantages	References
Foam-Cushioned Backing	Many	Dimensional stability. Moisture resistance.	High cost.	Krusell and Cogley (1982)
"Backless" Vinyl	Many	Easy to install. Excellent elastic properties. Moisture resistance.	High cost.	Krusell and Cogley (1982)

or disadvantages relative to asbestos in making this change (Tarkett 1986). it is not known if any other producers are using clay to substitute for asbestos in flooring felt.

Georgia Bonded Fibers has developed the product Bontex 148(R) which can be used in producing a flooring underlay. Bontex 148(R) is composed of synthetic fibers and cellulose. Product samples have been sent to all major producers of flooring felt, but its use is still limited to experimental applications in this country. It has been used in flooring felt in Europe, but the major drawback in the U.S. appears to be price. The main advantage of this substitute is that it has high heat resistance (Georgia Bonded Fibers 1986).

In addition to substitutes for asbestos <u>in</u> flooring felt, it is also possible to substitute other products directly for the flooring felt. "Backless" sheet vinyl is a sheet flooring material with a special vinyl backing. This backing has excellent elastic properties which allow the flooring to stretch and contract under the most severe applications. In addition, this backless vinyl is easier and faster to install than asbestos felt-backed vinyl. It requires a minimum of adhesive deck bonding, usually only around the edges, and can be stapled into place (Krusell and Cogley 1982).

Another substitute for flooring felt is foam-cushioned backing. Foam-cushioned backing is formed by attaching a cellulosic foam layer to vinyl sheet. This product has very good dimensional stability and moisture resistance. Backless vinyl and foam-cushioned backings appear to be good, commercially available alternatives to felt-backed vinyl flooring (Krusell and Cogley 1982).

The durability of felt backing is not a factor in the service life of the vinyl sheet product. The service life is primarily a function of wear layer thickness, traffic, and maintenance. In addition, the cost of the felt backing is a very small percentage of the total cost of the vinyl sheet product. Because the costs of most substitute backings were likely to have been comparable to the cost of asbestos felt backing, user cost was probably not a significant obstacle to eliminating asbestos in flooring felt.

E. Summary

In 1981 there were four primary processors of asbestos flooring felt in the U.S. By 1985 they had all stopped using asbestos in the production of flooring felt. There are a number of different substitutes for asbestos in flooring felts such as fiberglass, Pulpex(R), ceramic fiber, clay, and Bontex 148(R). Because the cost of the felt backing is only a small portion of the total cost of the vinyl floor product, the removal of asbestos has had very little impact on this industry.

REFERENCES

Georgia Bonded Fibers, Inc. S. Grubin. 1986 (October 20). Newark, NJ. Transcribed telephone conversation with Peter Tzanetos, ICF Incorporated, Washington, D.C.

Hercules Corp. B. Rufe. 1986 (October 15). Wilmington, DE. Transcribed telephone conversation with Peter Tzanetos, ICF Incorporated, Washington, D.C.

ICF Incorporated. 1984. Imports of Asbestos Mixtures and Products. Washington, D.C.: Office of Pesticides and Toxic Substances, U.S. Environmental Protection Agency. EPA CBI Document Control No. 20-8600681.

ICF Incorporated. 1986 (July-December). Survey of Primary and Secondary Processors of Asbestos-Reinforced Plastic. Washington, D.C.

Krusell N, Cogley D. 1982. GCA Corp. Asbestos Substitute Performance Analysis. Revised Final Report. Washington, D.C.: Office of Pesticides and Toxic Substances, U.S. Environmental Protection Agency. Contract Number 68-02-3168.

Tarkett, Inc. R. Depree. 1986 (July-August). Whitehall, PA. Transcribed telephone conversation with Jeremy Obaditch, ICF Incorporated, Washington, D.C.

TSCA Section 8(a) Submission. 1982a. Production Data for Primary Asbestos Processors. 1981. Washington, D.C.: Office of Toxic Substances, U.S. Environmental Protection Agency. EPA Document Control No. 20-8601012.

TSCA Section 8(a) Submission. 1982b. Production Data for Secondary Asbestos Processors. 1981. Washington, D.C.: Office of Toxic Substances, U.S. Environmental Protection Agency. EPA Document Control No. 20-8670644.

X. CORRUGATED PAPER

A. Product Description

Corrugated paper is a type of commercial paper that is corrugated and cemented to a flat paper backing and is sometimes laminated with aluminum foil. It is manufactured with a high asbestos content (95 to 98 percent by weight) and a starch binder (2 to 5 percent) (Krusell and Cogley 1982).

The manufacturing of corrugated paper uses conventional paper making equipment in addition to a corrugation machine that produces the corrugated molding on the surface of the paper.

Corrugated asbestos paper is used as thermal insulation for pipe coverings and as block insulation. The paper can be used as an insulator in appliance, hot-water and low-pressure steam pipes, and process lines.

B. Producers of Corrugated Paper

At present, asbestos corrugated paper is no longer manufactured in the United States (ICF 1986a). In 1981 there were three producers of asbestos corrugated paper: Celotex Corporation, Johns-Manville Corporation, and Nicolet Industries (TSCA 1982). All three companies had ceased production by 1982 (ICF 1986a).

C. Trends

Production of asbestos corrugated paper fell from 46 tons in 1981 to 0 tons in 1985 (ICF 1985, ICF 1986a). A recent survey failed to identify any 1981 importers of asbestos corrugated paper (ICF 1984). In addition, none of the firms surveyed in 1986 are aware of any importers of asbestos corrugated paper (ICF 1986a).

D. Substitutes

Asbestos was used in corrugated paper primarily because it had heat and corrosion resistance, high tensile strength, and durability. It has been replaced by non-corrugated, asbestos-free commercial paper. The three main types of paper currently used for pipe and block insulation are ceramic fiber paper, calcium silicate, and fiberglass paper (ICF 1985).

Table 1 presents a summary of substitutes for asbestos corrugated paper. Ceramic fiber paper is used for both pipe and block insulation. It is heat resistant, resilient, has high tensile strength, low thermal conductivity, and low heat storage. Babcock & Wilcox produces a ceramic fiber pipe insulation blanket and a block insulation material. The raw material used is kaolin, a high purity alumina-silica fireclay. It has a melting point of 3200°F and a normal use limit of 2300°F, but it can be used at higher temperatures in specific applications.

Certain-Teed, Owens-Corning, and Knauf Corporation produce a fiberglass product that can be used up to 850°F. Fiberglass pipe insulation is also used at very low temperatures, (it can operate at temperatures as low as -50°F).

Calcium silicate pipe covering is produced by Owens-Corning under two brand names Kaylo(R), and Papco(R). These products are heat resistant and can be used in temperature applications from 1200°F to 1500°F. Calcium silicate is less efficient at low temperatures than fiberglass. Asbestos fiber previously was used in calcium silicate pipe covering for its strength, but it has been replaced with organic fiber.

No comparison of costs has been made between the asbestos and non-asbestos products because the asbestos product is no longer produced domestically and will not be a separate category in the cost model (ICF 1985).

E. Summary

Asbestos corrugated paper is no longer produced in the United States. In 1981, there had been a small amount left in inventory, but it has since been sold. Asbestos had been used in corrugated paper because of its high temperature resistance and its durability. Substitutes include ceramic fibers, fibrous glass, and calcium silicate fibers in conjunction with various

Table 1. Substitutes for Asbestos Corrugated Paper

Product	Manufacturer	Advantages	Disadvantages
Ceramic Block and Pipe Insulation Material	Babcock & Wilcox	Heat resistant, can operate up to 2300°F. High tensile strength. Low thermal conductivity.	Expensive. Not as strong as asbestos.
Calcium Silicate Pipe Insulation Material	Owens-Corning (Kaylo)	Heat resistant, can operate up to 1500°F. Easy application. Low thermal conductivity.	Expensive.
Fiberglass Block and Pipe Insulation Paper	Owens-Corning Certain-Teed	Used for both hot and cold temperatures. High insulating. Easy application.	Not as heat resistant as other substitutes. Not as strong as asbestos.

fillers. The entire market has already been substituted therefore market shares and price comparisons are not available.

REFERENCES

ICF Incorporated. 1986a (July-December). Survey of Primary and Secondary Processors of Asbestos Corrugated Paper. Washington, DC.

Krusell N, Cogley D. 1982. GCA Corp. Asbestos Substitute Performance Analysis. Revised Final Report. Washington DC: Office of Pesticides and Toxic Substances, U.S. Environmental Protection Agency. Contract 68-02-3168.

ICF Incorporated. 1984. Imports of Asbestos Mixtures and Products. Washington DC: Office of Pesticides and Toxic Substances, U.S. Environmental Protection Agency. EPA CBI Document Control No. 20-8600681.

ICF Incorporated. 1985. Appendix H: Asbestos Products and Their Substitutes, in Regulatory Impact Analysis of Controls on Asbestos and Asbestos Products. Washington DC: Office of Pesticides and Toxic Substances, U.S. Environmental Protection Agency.

TSCA Section 8(a) Submission. 1982. Production Data for Primary Asbestos Processors, 1981. Washington, DC: Office of Toxic Substances, U.S. Environmental Protection Agency. EPA Document Control No. 20-8601012.

XI. SPECIALTY PAPERS

Asbestos is used in papers primarily due to its chemical and heat resistant properties. Two types of asbestos specialty papers that are covered in this section include beverage and pharmaceutical filters and cooling tower fill. However, since the asbestos fill product is no longer processed in the United States, cooling tower fill is only briefly discussed below. Asbestos diaphragms for electrolytic cells, which were previously treated as specialty papers, are presented separately in Section XIII.

A. Cooling Tower Fill

Cooling towers are used to air-cool liquids from industrial processes or air conditioning systems. The hot liquid is passed over sheets of material (the cooling tower fill) in order to provide maximum exposure to air. Sheets of asbestos paper impregnated with melamine and neoprene may be used as fill for applications requiring high temperatures or where a fire hazard may exist. Cooling tower sheets are manufactured in various sizes, with typical sheets being 18 inches by 6 feet and 0.015 to 0.020 inches thick (ICF 1985). The composition of cooling tower fill includes a blend of two grades of chrysotile asbestos bound with neoprene latex. The asbestos content is 90 to 91 percent, the remaining 9 to 10 percent consisting of a binder material (Krusell and Cogley 1982).

The major use of asbestos fill has been cooling tower applications where high heat resistance was necessary. Due to the availability of good and inexpensive substitute products, however, asbestos fill has been forced out of the market. As a result, the 1981 producers of asbestos fill, Marley Cooling Tower Co. and Munters Corp., are no longer manufacturing asbestos fill in the United States (Krusell and Cogley 1982, Marley Cooling Tower 1986).

A wide variety of substitute materials are currently available for cooling tower fill including polyvinyl chloride (PVC), wood, stainless steel mesh, and polypropylene. Each of these substitutes is manufactured by Munters Corporation (ICF 1986). The PVC plastic is the primary asbestos fill substitute because it is, by far, the most cost-effective product, with high durability and modest cost. One industry source stated that PVC has actually increased the market for cooling tower fill (Munters 1986). Other products available as asbestos fill substitutes have limited application due to specific disadvantages. For example, it is not economically feasible to manufacture wood into the forms (e.g., sheet materials) required for cooling tower fill; and stainless steel, although more durable than PVC, is too expensive for extensive use (Marley Cooling Tower 1986). Portland cement reinforced with such fibers as mineral and cellulose is presently under development as a substitute for asbestos fill. Although not presently marketed, this substitute's use is restricted due to its availability only in limited shapes and at a high cost (Marley Cooling Tower 1986).

B. Beverage and Pharmaceutical Filters

1. Product Description

Asbestos has been used in filters for the purification and clarification of liquids because it offers an exceptionally large surface area per unit of weight and has a natural positive electrical charge which is very useful for removing negatively charged particles found in beverages (Krusell and Cogley 1982). Asbestos filter paper is made on a conventional cylinder or Fourdrinier papermaking machine but, due to the very low demand for the asbestos filters, these machines are primarily used to produce more popular paper products, such as the non-asbestos filter substitutes (i.e., diatomaceous earth and cellulose fiber product and loose cellulose fiber products) (Krusell and Cogley 1982). Asbestos filters may contain, in addition to asbestos, cellulose fibers, various types of latex resins, and occasionally, diatomaceous earth (Krusell and Cogley 1982). The asbestos content of beverage filters ranges from 5 percent, for rough filtering applications, to 50 percent, for very fine filtering. In general, as the asbestos content of the filter increases, the filtering qualities improve (Krusell and Cogley 1982).

Applications of asbestos filter paper are found primarily in the beer, wine, and liquor distilling industries where they are used to remove yeast cells and other microorganisms from liquids. Asbestos filters are also used for filtration of some fruit juices (e.g., apple juice) and for special applications in the cosmetics and pharmaceuticals industries (Krusell and Cogley 1982).

2. Producers of Beverage and Pharmaceutical Filters

In 1981 there were four companies manufacturing asbestos filters:

- Alsop Engineering, NY;
- Beaver Industries, NY;
- Cellulo Company, CA; and
- Ertel Engineering, NY.

In 1985, two companies, Cellulo and Ertel, discontinued the use of asbestos in the production of filters (Ertel Engineering 1986). The primary substitute materials used consisted of either diatomaceous earth and cellulose fibers, or loose cellulose fibers (ICF 1986). The other two companies, Alsop Engineering and Beaver Industries, refused to respond to the ICF survey. As a result, production estimates for these companies were estimated based on the methodology presented in Appendix A.

3. Trends

For many years the use of asbestos in filters has been declining. Nearly 1000 short tons of asbestos fiber were consumed per year for the production of filters in the late 1960s and early 1970s. In 1985, however, only about 300 short tons of asbestos fiber were used for the production of asbestos filters (ICF 1986).

4. Substitutes

The primary reason for the use of asbestos filters is their ability to remove haze from liquids. Asbestos filters absorb less liquid than non-asbestos filters due to the low porosity of asbestos fiber. Filters containing asbestos are also more compressible than non-asbestos filters, making it easier to fit them into filter equipment thereby reducing the chances of developing leaks (Krusell and Cogley 1982).

Filter papers manufactured with cellulose fibers and diatomaceous earth and those made with loose cellulose fibers are available as substitutes for asbestos beverage filters. Both substitute products are comparable in performance to the asbestos product, although they are more difficult to handle and more expensive (Cellulo 1986). In addition, the all cellulose filter product cannot be made in grades high enough for very fine filtration and, therefore, "filter aids", consisting of chemically treated cellulose fibers or diatomaceous earth, may be added to all cellulose filters to improve their performance. Table 1 presents the advantages and disadvantages of each substitutes compared to the asbestos filter product, while Table 2 presents the data inputs for the Asbestos Regulatory Cost Model. Non-asbestos substitute filters can be used almost interchangeably with asbestos filters in most applications because, like asbestos filters, they have high wet strength and can clarify, polish, and sterilize a wide variety of liquids (e.g., acids, alkalis, antiseptics, beer, wine, fruit juices) (Krusell and Cogley 1982). The non-asbestos substitutes were reported to have comparable service life when used in similar applications. These two substitutes are expected to each take over about half of the filter market.

5. <u>Summary</u>

Asbestos filter papers are used for the purification and clarification of liquids in the beer, wine and liquor distilling industries. The trends

Table 1. Advantages/Disadvantages of Non-Asbestos Filter Substitute Products

Substitute Products for Asbestos Beverage and Pharmaceutical Filters	Price ($/lb.)	Advantages	Disadvantages	References
Diatomaceous Earth and Cellulose Fiber	2.00	Generally same performance as asbestos product	More difficult to handle for end-user vs. asbestos product.	Cellulo Co. (1986)
			More costly than asbestos product.	Cellulo Co. (1986)
Loose Cellulose Fiber	1.00	Generally same performance as asbestos product.	More difficult to handle for end-user.	Cellulo Co. (1986)
			More costly than asbestos product.	Cellulo Co. (1986)
			Not made with grades high enough for very fine filtering.	ICF (1984)
			Many need "filter aid"- chemically treated cellulose fiber for a positive charge -- to improve performance.	ICF (1984)

Table 2. Data Inputs for Asbestos Regulatory Cost Model

Product	Output[a]	Product Asbestos Coefficient[b]	Consumption Production Ratio	Price[c]	Useful Life[d]	Equivalent Price	Market Share	Reference
Asbestos Filter Paper	434 tons	0.212	1.0	$4,300/ton[e]	1 use	$4,300/ton	N/A	TSCA (1982a), ICF (1984a), Cellulo (1986)
Diatomaceous Earth and Cellulose Filter Paper	N/A	N/A	N/A	$4,000/ton	1 use	$4,000/ton	50%	Cellulo (1986)
Loose Cellulose Fiber Filter Paper	N/A	N/A	N/A	$2,000/ton	1 use	$2,000/ton	50%	Cellulo (1986)

[a] The two producers of this asbestos product both refused to respond to our survey. We have assumed that their 1985 output is equal to their 1981 output.

[b] The two producers of this product both refused to respond to our survey. We have assumed the product asbestos coefficient is the same as the value used by RTI in the Regulatory Impact Analysis (RTI 1985).

[c] Prices in the text are given on a per pound basis, they have been converted into prices per ton for use in the ARCM.

[d] The product's useful life is typically 1 use, but some filters may have a longer life.

[e] The two producers of this product both refused to respond to our survey. We have assumed that the ratio between the price of asbestos filter paper and diatomaceous earth and cellulose filter paper is still the same as that reported in 1981 (ICF 1985).

show a definite decline in the use of asbestos fiber in filter production. Of the four companies producing asbestos filters in 1981, two (Alsop Engineering and Beaver Industries) have been assumed to still be producing in 1985 because they refused to respond to the ICF survey. The 1985 asbestos filter production was assumed to be 434 tons; 92 tons of asbestos fiber were consumed in this production. One reason for this decline is that the non-asbestos substitute products, which include diatomaceous earth and loose cellulose fibers, have been found to be comparable in performance to the asbestos product for most applications. These non-asbestos products are, however, more expensive.

REFERENCES

Cellulo Co. D. Eskes. 1986 (July-December). Fresno, CA, 93721. Transcribed telephone conversations with Rick Hollander, ICF Incorporated, Washington, D.C.

Ertel Engineering. W. Kearney. 1986 (November 1). Kingston, NY, 12401. Transcribed telephone conversation with Meg Wimmer, ICF Incorporated, Washington, D.C.

ICF Incorporated. 1985. Appendix H: Asbestos Products and Their Substitutes, in Regulatory Impact Analysis of Controls on Asbestos and Asbestos Products. Washington, D.C.: Office of Pesticides and Toxic Substances, U.S. Environmental Protection Agency.

ICF Incorporated. 1986 (July-December). Survey of Primary and Secondary Processors of Asbestos Beverages and Pharmaceuticals Filters. Washington, D.C.

Krusell N, and Cogley D. 1982. GCA Corp. Asbestos Substitute Performance Analysis. Revised Final Report. Washington, D.C.: Office of Pesticides and Toxic Substances, U.S. Environmental Protection Agency. Contract No. 68-02-3168.

Marley Cooling Tower Co. J. Nelson. 1986 (October 28). Louisville, KY, 40214. Transcribed telephone conversation with Meg Wimmer. ICF Incorporated, Washington, D.C.

Munters Corp. R. Miller. 1986 (July-December). Fort Meyers, FL. 33901. Transcribed telephone conversations with Mike Geschwind, ICF Incorporated, Washington, D.C.

RTI. 1985. CBI Addendum to Regulatory Impact Analysis of Controls on Asbestos and Asbestos Products. Research Triangle Park, N.C.: Office of Pesticides and Toxic Substances, U.S. Environmental Protection Agency. EPA CBI Document Control No. 208510620.

XII. VINYL-ASBESTOS FLOOR TILE

A. Product Description

Vinyl-asbestos floor tiles are manufactured from polyvinyl chloride polymers or copolymers and are usually produced in squares 12 inches by 12 inches. They are commonly sold in thicknesses of 1/16, 3/32, and 1/8 of an inch.

The exact composition of vinyl-asbestos floor tile varies by manufacturer. Typical ranges for the percentage of each constituent are:

- asbestos : 5-25 percent,
- binder : 15-20 percent,
- limestone : 53-73 percent,
- plasticizer: 5 percent,
- stabilizer : 1-2 percent, and
- pigment : 0.5-5 percent.

Although each company has its own specific process for manufacturing vinyl-asbestos floor tile, the basic steps are very similar. Raw asbestos fiber, pigment, and filler are mixed dry to form a cohesive mass to which liquid constituents are added if required. Although the mixture is exothermic (it generates heat during mixing), it may need to be heated further in order to reach a temperature of at least 300°F at which point it is fed into a two-roll mil where it is pressed into a slab or desired thickness. The slab is then passed through calenders, machines with rollers, where it acquires a uniform finished thickness (Krusell and Cogley 1982). Embossing, pigmenting, and other surface decoration is done while the material is still soft. The tile is then cooled using one of three processes: immersion in water, spraying with water, or placing in a refrigeration unit. In order to minimize shrinkage after cutting, the tile is allowed to air cool before it is cut into squares and waxed (Krusell and Cogley 1982).

Vinyl-asbestos floor tile can be used in commercial, residential, and institutional buildings. It is often used in heavy traffic areas such as supermarkets, department stores, commercial plants, kitchens, and "pivot points" -- entry ways and areas around elevators. The tile is also suitable for radiant-heated floors as long as temperatures do not exceed 100°F. The tile may be installed on concrete, prepared wood floors, or old tile floors (Floor Covering Weekly 1980).

B. Producers and Importers of Vinyl-Asbestos Floor Tile

There were six primary processors of this asbestos product in 1981: Amtico Division of American Biltrite, Armstrong World Industries, Azrock Industries, Congoleum Corp., Kentile Floors, Inc., and Tarkett, Inc. (TSCA 1982a). There were no secondary processors of vinyl-asbestos floor tile, and a survey of importers failed to identify any importers of vinyl-asbestos floor tile (TSCA 1982b, ICF 1984). All six primary processors have stopped using asbestos since that time. Tarkett, Inc. and Azrock Industries were the first companies to eliminate the use of asbestos in vinyl floor tiles. Armstrong World Industries had eliminated asbestos by the end of 1983, and Congoleum Corp. had eliminated it in 1984. Amtico Division of American Biltrite phased out asbestos in 1985, and Kentile Floors, Inc. phased out the use of asbestos in 1986. Because none of the other respondents to our survey indicated that they had begun production of vinyl-asbestos floor tile or were aware of any other producers or importers of vinyl-asbestos floor tile, we have concluded that there are currently no domestic producers or consumers of this product (ICF 1986).

C. Trends

1981 production of vinyl-asbestos floor tile was 58,352,864 square yards. In 1985, only one company was still processing asbestos in order to make floor tile and its production was 18,300,000 square yards. This represents a decline of almost 70 percent. In addition, Kentile Floors phased out asbestos use in 1986 and current production of vinyl-asbestos floor tiles is 0.

D. Substitutes

The use of asbestos in the production of vinyl composition floor tile conferred a number of advantages to consumers in its end use as well as to producers in its manufacturing process. Asbestos fiber imparted the following properties in its use in floor tile: abrasion and indentation resistance, dimensional stability, durability, flexibility, and resistance to moisture, heat, oil, grease, acids, and alkalis. The heat resistance and dimensional stability of asbestos are important in the manufacturing process. The ability to withstand high temperature prevents possible cracking. Dimensional stability prevents shrinkage or expansion during production and helps manufacturers meet their tolerance limits.

The major substitute for vinyl-asbestos floor tile is asbestos-free vinyl composition tile. Manufacturers have reformulated their mixtures using a combination of synthetic fibers, fillers, binders, resins, and glass. The binders and fillers include limestone, clay, and talc. The fiber substitutes include fiberglass, polyester, Pulpex(R), Santoweb WB(R), and Microfibers(R). The substitutes for asbestos in vinyl floor tiles and their characteristics are summarized in Table 1.

Fiberglass floor tile is produced by many manufacturers and has many of the same properties as asbestos fiber. It is used in floor tile primarily for its dimensional stability under wet conditions. Since fiberglass does not absorb moisture, the tile is prevented from shrinking. In addition, fiberglass is heat resistant and can withstand temperatures as high as 800°F without softening (Krusell and Cogley 1982).

Polyester fiber is produced by many manufacturers. When it is used in combination with other binders and fillers, it is able to achieve many of the

Table 1. Substitutes for Asbestos in Vinyl Floor Tile

Product	Manufacturer	Advantages	Disadvantages	References
Asbestos	None	Heat resistance during manufacture. Indentation resistance. Flexibility. Abrasion resistance. Moisture resistance. Chemical resistance. Fungal resistance. Dimensional stability.	Environmental and occupational health problems.	Krusell and Cogley (1982) ICF (1986)
Pulpex(R) (Polyolefin Pulp)	Hercules, Inc. Wilmington, DE	Dimensional stability. Moisture resistance. Rot resistance.	Low tensile strength. Low heat resistance.	Hercules (1986)
Santoweb WB(R) (Hardwood Fiber)	Monsanto Corp. St. Louis, MO	Impact resistance. Heat resistance.	Absorbs water when large amounts are used.	Monsanto (1986)
Microfibers(R) (Polyester and Cellulose Fibers)	Microfibers, Inc. Pawtucket, RI	Dimensional stability. Thickening properties.		Microfibers (1986)
Fiberglass	Many	Dimensional stability Moisture resistance. Rot resistance.	Lower strength. More brittle.	Krusell and Cogley (1982)
Polyester	Many	Dimensional stability. Moisture resistance.	Less flexible. Subject to bacterial attack.	Krusell and Cogley (1982)

characteristics of asbestos. The major drawbacks are that the tiles are less flexible and that the tiles are subject to bacterial attack (Krusell and Cogley 1982).

Pulpex(R) is a fibrillated polyolefin pulp made by Hercules, Inc. It also has many of the same characteristics as asbestos when used in combination with other fillers and binders, but it cannot be used at extremely high temperatures. Pulpex(R) has been commercially available in the U.S. since 1981. Although its primary use in the U.S. has been in flooring felt, it has been used in vinyl tile as an asbestos substitute in Europe (Hercules 1986).

Santoweb WB(R) is a hardwood fiber and has been on the market for 10 years. It is produced by Monsanto Corporation. Its major strengths are its high impact resistance and its high heat resistance. It can withstand temperatures of at least 300°F during calendaring. In addition, it is less brittle than fiberglass and more cost-effective than chopped polyester. The Santoweb WB(R) composition of floor tile is ideally 1.5 percent and the upper limit is 2.5 percent beyond which the floor tile will absorb too much water (Monsanto 1986).

Microfibers(R) are reinforcing fibers which consist of a combination of polyester, cotton, nylon, and cellulose fibers. Microfibers(R) are made by the Microfibers Corporation. Their primary advantages are their dimensional stability as well as their ability to serve as a thickener (Microfibers 1986).

Several non-asbestos blends use larger amounts of resins, binders, and fillers in place of asbestos. One producer of asbestos-free vinyl composition tile uses increased amounts of limestone and resin. These new vinyl composition tiles appear to share many of the qualities of vinyl-asbestos floor tile, but they have three drawbacks. They do not wear as well, they have reduced dimensional stability, and they are more expensive to produce (ICF 1986).

In addition to the new vinyl composition tiles being produced, substitutes for vinyl-asbestos floor tile include solid vinyl tile, rubber tile, ceramic tile, linoleum, wood, and carpet. However, these floor coverings lack many of the qualities of vinyl-asbestos floor tile. For example, solid vinyl is not as abrasion resistant as vinyl-asbestos tile and has a low resistance to solvent-based cleaning materials. Rubber tile is also susceptible to deterioration from certain cleaning compounds, is not grease resistant, and is more difficult to maintain. Carpet is less durable in most uses, and it is more difficult to keep clean. In addition to these drawbacks, all these substitutes are more expensive than vinyl-asbestos floor tile.

On the whole, vinyl composition tiles are the best substitute for vinyl-asbestos tiles in terms of prices and performance. Distributors claim that consumers of vinyl composition tile are almost never concerned about whether or not asbestos fibers are used. They believe that the most important considerations in choosing vinyl tile are color, style, and price and that there have been no difficulties in switching from vinyl-asbestos floor tile to vinyl composition tile (John Ligon, Inc. 1986, H&M Tile & Linoleum Co. 1986).

E. Summary

Asbestos fiber was used in the production of vinyl floor tiles because it imparted the following characteristics to the tile: abrasion and indentation resistance, dimensional stability, flexibility, and resistance to moisture, heat, oil, grease, acids, and alkalis. However, producers have been able to generate these characteristics by reformulating their mixtures using a combination of synthetic fibers, fillers, binders, resin, and glass. (A more complete description is not possible because floor tile producers consider these formulations to be proprietary.) This reformulation appears to have been successful because there are currently no domestic processors of vinyl-asbestos floor tile.

REFERENCES

Floor Covering Weekly. 1980. Handbook of Contract Floor Covering. New York, NY: Bart.

Hercules Corp. B. Rufe. 1986 (October 22). Wilmington, DE. Transcribed telephone conversation with Peter Tzanetos, ICF Incorporated, Washington, D.C.

H&M Tile & Linoleum Co., Inc. Sales Representative. 1986 (September 23). Washington, D.C. Transcribed telephone conversation with Peter Tzanetos, ICF Incorporated, Washington, D.C.

ICF Incorporated. 1984. Imports of Asbestos Mixtures and Products. Washington, D.C.: Office of Toxic Substances, U.S. Environmental Protection Agency. EPA Document Control Number 20-8600681.

ICF Incorporated. 1986 (July-December). Survey of Primary and Secondary Processors of Vinyl-Asbestos Floor Tile. Washington, D.C.

John Ligon, Inc. Sales Representative. 1986 (September 23). Bethesda, MD. Transcribed telephone conversation with Peter Tzanetos, ICF Incorporated, Washington, D.C.

Krusell N, and Cogley D. 1982. GCA Corp. Asbestos Substitute Performance Analysis. Revised Final Report. Washington, D.C.: Office of Pesticides and Toxic Substances, U.S. Environmental Protection Agency. Contract No. 68-02-3168.

Microfibers, Inc. A. Leach. 1986 (October 22). Pawtucket, RI. Transcribed telephone conversation with Peter Tzanetos, ICF Incorporated, Washington, D.C.

Monsanto Corp. J. Renshaw. 1986 (October 22). St. Louis, MO. Transcribed telephone conversation with Peter Tzanetos, ICF Incorporated, Washington, D.C.

TSCA Section 8(a) Submission. 1982a. Production Data for Primary Asbestos Processors, 1981. Washington, D.C.: Office of Toxic Substances, U.S. Environmental Protection Agency. EPA Document Control No. 20-8601012.

TSCA Section 8(a) Submission. 1982b. Production Data for Secondary Asbestos Processors, 1981. Washington, D.C.: Office of Toxic Substances, U.S. Environmental Protection Agency. EPA Document Control No. 20-8670644.

XIII. ASBESTOS DIAPHRAGMS

Asbestos Diaphragms are employed in the chlor-alkali industry for the production of chlorine and other primary products such as caustic soda. There are presently three types of electrolytic cells in commercial use: asbestos diaphragm cells, mercury cells, and membrane cells (Kirk-Othmer 1985). All electrolytic cells operate on the same principle -- an electric current decomposes a solution of brine into (1) chlorine, liberated at the anode (positive electrode) and (2) caustic soda and hydrogen, liberated at the cathode (negative electrode). The ratio of chlorine to caustic soda produced during the process is 1:1.1 by weight (Chemical Week 1982). Most of the chlorine produced in the United States is made using electrolytic cells (Kirk-Othmer 1985).

Asbestos diaphragm and mercury cells account for over 90 percent of domestic chlorine production; electrolytic cells using asbestos diaphragms accounted for 76.7 percent of the chlorine production capacity as of January 1, 1986, while mercury cell technology accounted for 16.5 percent (Chlorine Institute 1986b). In the past few years, a new technology, known as membrane cell technology, has been developed to replace diaphragm cells in the chlorine production process. As reported by the Chlorine Institute, membrane cell technology accounted for 2.4 percent of the total chlorine production capacity as of January 1, 1986 (Chlorine Institute 1986b).

In Sections A, B, and C of this paper, each of the cell technologies is discussed individually; Section D compares some salient characteristics of the three technologies, while Section E discusses market trends for the chorine production industry.

A. Asbestos Diaphragm Technology

In this chlor-alkali production process, an asbestos diaphragm is used to physically separate chlorine produced at the anode from caustic soda and hydrogen produced at the cathode; the diaphragm thus, acts as a mechanical barrier between the two chambers (Kirk-Othmer 1985).

Diaphragm cells are especially appropriate where salt (the raw material for chlorine production) is present at the plant site in underground formation. The salt can be solution-mined[1] with water, treated, and sent to the chlorine cells for decomposition into chlorine and caustic soda (Chlorine Institute 1986a). The diaphragm material is critical to the proper operation of a diaphragm cell and some of the properties that are necessary for proper cell operation are as follows (Chlorine Institute 1986a):

- sufficient mechanical strength;
- high chemical resistance to acids and alkalies;
- optimum electrical energy efficiency;
- easy to deposit on the cathode with uniform thickness and without voids;
- appropriate physical structure to permit percolation of depleted brine with minimum back-migration; and
- acceptable service life.

Asbestos is uniquely qualified as a diaphragm material, exhibiting the most favorable combination of these properties (Chlorine Institute 1986a). This has resulted in widespread use of asbestos made diaphragms throughout the chlorine production industry.

Asbestos diaphragms are prepared at the chlorine plant site itself and are not available as pre-manufactured products ready for use. In the diaphragm forming process, a slurry of asbestos in water is drawn through a screen or perforated plate by vacuum techniques. Asbestos fibers are deposited on the screen, or plate, forming a paper-like mat approximately an eighth of an inch

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[1] Water is pumped into the salt mine, a salt solution is then pumped out.

thick (Coats 1983). This asbestos-coated screen is used as the cathode in electrolytic cells. In the past twenty years, many advances have been made in the design of asbestos diaphragms and in the design of the cell itself. These have included the introduction of dimensionally stable metal anodes[2] as a replacement for graphite anodes and the development of the modified asbestos (resin bound) diaphragms which consist of chrysotile and polymeric powders of fibers stabilized at high temperatures before use (Chlorine Institute 1986a). Today, the majority of U.S. diaphragm cells utilize modified asbestos diaphragms and have metal anodes; they consume 2,300 KWH of power per ton of chlorine produced (Chlorine Institute 1986a, Chemical Week 1982).

The surface area of the diaphragm is quite large, ranging from approximately 200 to 1,000 square feet for a cell with a volume of 64 to 275 cu ft (Coats 1983). Each diaphragm may use 60 to 200 pounds of asbestos fiber and have a service life of three months to over one year (three months for plants where graphite anodes are still in use; 6 to 15 months for plants using resin bound asbestos diaphragms) (Chlorine Institute 1986b). Using modified asbestos diaphragm technology, production of 1000 tons of chlorine and co-products requires about 250 pounds or 0.125 ton of asbestos (Chlorine Institute 1986b). The only major disadvantage of using asbestos diaphragm cells is the weak concentration of the caustic soda produced by the cell (usually about 10 percent by weight) because of the permeability of the cell to both brine and water (Chemical Week 1981). This necessitates further processing for concentrating the caustic to the industry standard, typically 50 percent, using multiple-effect evaporators and large amounts of steam. Removing the excess salt involves crystallization and, possibly, ammonia extraction, both of which add to the cost of production (Chemical Week 1982).

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[2] Dimensionally stable anodes consist of a coating of ruthenium dioxide and titanium applied to an expanded titanium metal base (Kirk-Othmer 1983).

1. Producers of Asbestos Diaphragms

Asbestos diaphragms are not marketed; the chlorine producers purchase asbestos fiber and manufacture and install the diaphragm themselves. Table 1 provides a list of chlorine manufacturers (SRI 1984, Verbanic 1985). In 1985, 28 manufacturers were operating 57 chlorine plants in 26 states throughout the U.S. with an estimated total annual capacity of 13.2 million tons (Chlorine Institute 1986b), a reduction from previous years when annual capacity had reached almost 15 million tons (Verbanic 1985). The largest of these chlorine producers was Dow Chemical, with a combined annual capacity of 3,750,000 tons, approximately 28.5 percent of the total U.S. chlor-alkali capacity followed by PPG Industries and Diamond Shamrock, each accounting for about 10 percent of the chlorine production capacity (Verbanic 1985). Chlorine production and asbestos fiber consumption information for the period 1983-1985 is presented in Table 2. Based on this information, about 975 metric tons of asbestos fibers were estimated to have been consumed by the chlorine industry in the production of approximately 10 million tons of chlorine during 1985. According to a separate estimate given by the Chlorine Institute, 900 metric tons of asbestos had been consumed during this period.

2. Substitutes for Asbestos Diaphragms

No other substance has been found to be suitable for replacing asbestos diaphragms in electrolytic cells. This has resulted in the development of alternative cell technologies that require either the building of new chlorine plants or the retrofitting of existing plants. Among the new technologies, the most significant one that is steadily gaining acceptance in the U.S. is the membrane cell technology (Chemical Business 1985).

Table 1. Producers of Chlorine

Company[a]	Plant	Remarks
AMAX Inc.		
AMAX Specialty Metals Corp, Subsidiary		
Magnesium Division	Rowley, Utah	
Brunswick Pulp and Paper Company		
Brunswick Chemical Company, Division	Brunswick, GA	
Champion International Corporation		
Wood Chemicals and Associated Products Division	Caston, NC	
Diamond Shamrock Corporation		
Diamond Shamrock Chemicals Company	Battleground, TX	
Chlor-Alkali Division	Deer Park, TX	
	Delaware City, DE	
	La Porte, TX	
	Mobile, AL	
	Muscle Shoals, AL	146,000 tons/annum mercury-cell plant switching to membrane cells of the company's own design.[c]
Dow Chemical U.S.A.	Oyster Creek, TX	Combined capacity is 4,100,000. 2,000 tons/day on standby.[b]
	Pittsburg, CA	
	Plaquemine, LA	
	Freeport, TX	456,250 tons/annum of chlorine capacity has been shutdown -- about 10% of Dow's chlorine capacity on the Gulf Coast.[e]
E.I. duPont de Nemours & Co., Inc.	Niagara Falls, NY	
Chemicals and Pigment Department		
Petrochemicals Department	Corpus Christi, TX	
Freon Products Division		
FMC Corp., Industrial Chemical Group	South Charleston, WV	To close end of 1985.[b]
Formosa Plastics Corporation, U.S.A.	Baton Rouge, LA	
Fort Howard Paper Company	Green Bay, WI	
	Muskogee, OK	Membrane cell technology.
General Electric Company	Mount Vernon, IN	
Plastics Business Operations		
Georgia-Pacific Company	Bellingham, WA	
Chemical Division		
Georgia-Gulf Corporation	Plaquemine, LA	

Table 1 (Continued)

Company[a]	Plant	Remarks
The B.F. Goodrich Company	Clavert City, KY	Plant for sale.[b]
Convent Chemical Corporation, Subsidiary	Convent, LA	
Kaiser Aluminum and Chemical Corporation Kaiser Industrial Chemicals Division	Gramercy, LA	
LCP Chemicals and Plastics, Inc. LCP Chemicals Divisions	Acme, NC Ashtabula, OH Brunswick, GA Linden, NJ Syracuse, NY Orrington, ME Moundsville, WV	
Mobay Chemical Corporation Inorganic Chemicals Division	Baytown, Texas	
Monsanto Company Monsanto Industrial Chemicals Company	Sauget, IL	
Niacor	Niagara Falls, NY	Due to begin production in 1987. 50/50 joint venture between Olin and DuPont; will use membrane cell technology.[b]
Occidental Petroleum Corporation Occidental Chemical Corporation, Subsidiary Hooker Industrial and Specialty Chemicals	Niagara Falls, NY	
	Taft, LA	Membrane cell unit of 146,000 tons on stream in 1986.[b]
	Tacoma, WA	Includes membrane cell units.[c]
Olin Corporation Olins Chemicals Group	August, GA Charleston, TN Niagara Falls, NY	
Oregon Metallurgical Corporation	Albany, OR	
Pennwalt Corporation Chemicals Group Inorganic Chemicals Division	Portland, OR	
	Tacoma, WA	Membrane cell technology.[b]
	Wyandotte, MI	
PPG Industries	Lake Charles, LA Natrium, WV	

Table 1 (Continued)

Company[a]	Plant	Remarks
RMI Company	Ashtabula, OH	
Stauffer Chemical Company		
Chlor-Alkali Products Division	Henderson, NV	
	Le Moyne, AL	
	St. Gabriel, LA	
Titanium Metals Corporation of America		
TIMET Division	Henderson, NV	
Vertac Chemical Corporation	Vicksburg, MS	
Vulcan Materials Company		
Vulcan Chemicals, Division	Port Edward, WI	Approximately 75% of caustic/chlorine is produced via the asbestos diaphragm cell process.[d]
	Geismar, LA	
	Wichita, KS	
	Denver City, TX	Includes 73,000 tons of membrane technology.[b]
Weyerhaeuser	Longview, WA	

Sources:

[a] SRI 1984.

[b] Verbanic C. 1985.

[c] Chemical Engineering 1976. Cell employs modified Nafion perfluorosulfonic-acid membranes which separate the anode and cathode halves in the same manner as conventional asbestos diaphragms.

[d] Vulcan Chemicals 1986.

[e] Chemical Week 1986c.

Table 2. Chlorine Production/Asbestos Fiber Consumption

(1)	(2)	(3)	(4)	(5)	(6)
Year	Annual Capacity (millions of tons)[b]	Utilization Rate (on average)[b]	Production (millions of tons)[b] (2 x 3)	Percentage of Production Using Asbestos A Diaphragms	Consumption of Asbestos Fiber (tons)
1981	14.8	72%	10.7	75.0	1,004
1985	13.2	77%	10.2	76.7	977

Sources:

[a] Chlorine Institute 1986b.

[b] Chemical Week 1985 (February 1).

[c] Coats V. 1983.

B. Membrane Cells

Although diaphragms and membranes each serve a similar function of physically separating the two electrodes in an electrolytic cell, the mechanisms by which they operate are entirely different. In the diaphragm cell, brine flows through the asbestos diaphragm at a carefully controlled rate such that no back flow of hydroxyl ions occurs. In the membrane cell, a cation exchange membrane is used instead of a diaphragm, utilizing solid salt as opposed to brine. The cation exchange membrane permits the passage of sodium ions into the cathode compartment, but rejects the passage of chloride ions. Chlorine is formed on the anode side; hydrogen and caustic soda are formed on the cathode side. Because the membrane is very thin, some chloride or hydroxyl ion transfer occurs; however, pure water may be added to the cathode compartment to maintain a constant sodium hydroxide concentration (Kirk-Othmer 1985). As a result, membrane cells can produce caustic soda of high concentration (30-35 percent) with a low salt content (0.02-0.2 percent).

The most prominent advantages offered by the membrane cell technology are the reduced energy consumption, improved product quality, less frequent cell maintenance, and increased flexibility in plant operation (Chemical Marketing Reporter 1983). Worldwide, there are 70 plants that have opted for membrane technology, more than half of them being in Japan (Chemical Week 1986a). Outside Japan, the membrane process has been installed in 5 plants in the United States, 7 in Europe, 4 in Latin America, and 20 in other parts of the world (Chemical Week 1986a). Membrane cell technology is offered by firms such as Diamond Shamrock and Hooker Chemical, Japan's Asahi Chemical, Asahi Glass, and Tokuyama Soda, and Italy's Oronzio de Nora (Chemical Week 1981). Dow Chemical may now be added to this list. In July, 1986, Dow joined Italy's Oronzio de Nora in a new 50-50 joint venture to license technology and equipment. They will operate globally under the name, Oronzio de Nora

Technologies (Chemical Week 1986a).

The first large-scale membrane cell installation in the U.S. came on stream in late 1983 at a 73,000 ton/year facility of Vulcan Chemicals Division at Wichita, Kansas (Verbanic 1985). Other membrane facilities are presently being created either through retrofits of existing asbestos diaphragm cells to accept an ion-exchange membrane or through conversions (cell replacement) which require replacement of the diaphragm cells with membrane electrolyzers. Both retrofits and conversions require additions and modifications to existing ancillary equipment. Conversions have been occurring in the U.S. for several years but no commercial retrofits have been attempted in the U.S. to date.

It has been found that retrofits are not only costly but do not achieve the energy savings that total cell replacement (conversion) provides. Moreover, in some cases retrofitting is not even an option due to either the incompatibility of the available salt source and the available membrane materials, or the complexity of the diaphragm cell geometry. The cost of conversion varies widely, depending on cell size and type. An April 1986 Chlorine Institute survey of diaphragm cell producer members projected the membrane replacement cost of the current total chlorine production capacity of the industry to be $2.1 billion (1986 dollars) -- or about $75,600 per daily ton (Chlorine Institute 1986b).

Table 3 provides a list of manufacturers employing the membrane cell technology. Those facilities presently on stream have chlorine production capability from 12 to 400 tons/day each, for a combined capacity of less than 900 tons/day or approximately 328,000 tons per annum -- less than 2.5 percent of the total industry capacity (Chlorine Institute 1986b). By 1987 another 366,000 tons are expected to be added (i.e. Occidental, Niacor), creating a

Table 3. Chlorine Producers Using Membrane Cell Technology

Company	Plant Location	Annual Capacity (metric tons/ year)	Year Due on Stream
Fort Howard Paper Company[a]	Muskogee, OK	N/A[c]	N/A
P&G Paper Products Co.[a]	Green Bay, WI	N/A	N/A
Vulcan Chemicals Division[a]	Wichita, KS	73,000	1983
Pennwalt Corporation[a]	Tacoma, WA	91,000	1985
Occidental Chemical Corp.[a]	Taft, LA	146,000	1986
Niacor[b]	Niagara Falls, NY	220,000	1987

Source: [a] Chemical Week 1986a.
[b] Verbanic 1985.
[c] N.A. -- Not Available.

projected total annual capacity of approximately 542,000 tons/year employing membrane technology.

The cost of the high performance membrane materials which are being used in the newer cell installations are estimated to be in the order of 60 to 75 dollars per square foot of surface area (Coats 1983). Some cells may use membranes with an area of less than 10 square feet, while others may use membranes of over 50 square feet. Associated costs, such as installation and regasketing, are not well known due to the limited number of plants presently operating with the membrane cell technology (Chlorine Institute 1986b). However, the labor required to make a membrane for retrofit purposes is substantially greater than that required to prepare an asbestos diaphragm. In addition, the cost of making shaped membranes, necessary for optimal power efficiency for retrofit purposes, adds significantly to the cost (PPG Industries 1986).

Although the service life of a membrane cell is generally estimated at about 2 years (Chlorine Institute 1986b), it is possible to routinely achieve a three-year membrane life (Chemical Week 1986a). At typical operating conditions, about 85 tons of chlorine would be produced per square meter of membrane during a 2 year membrane life (Chlorine Institute 1986b).

C. <u>Mercury Cells</u>

Mercury cell technology involves a chemical process to separate the chlorine from the caustic soda and hydrogen as opposed to the physical processes of the diaphragm and membrane cells. The mercury cell process involves two subcells: (1) the brine (electrolyzer) subcell, and (2) the denuder or soda (decomposer) subcell.

The cathode in the mercury cell is a thin layer of mercury which is in contact with the brine. Closely spaced above the cathode is the anode. The anode is a suspended, horizontal assembly of blocks of graphite or dimensionally stable (titanium-base) anodes (Kirk-Othmer 1983). Purified, saturated brine containing approximately 25.5 percent by weight sodium chloride is decomposed as it passes between the cathode and anode in the primary brine cell. Chlorine gas is liberated at the anode and is then discharged to the purification process while sodium metal is liberated at the cathode. A low concentration amalgam, containing 0.25-0.5 percent by weight of sodium, is formed in the mercury cell (Kirk-Othmer 1985).

A second reaction is carried out in a separate device, the denuder subcell, where the dilute amalgam is fed and then reacted with water. The dilute amalgam is converted directly into 50 or 73 percent caustic that contains very little salt. A significant amount of electricity is involved in this reaction (Kirk-Othmer 1985).

Mercury cells must operate with solid salt in order to maintain a water balance. Unique to the operation of mercury cells is the total salt resaturation which occurs after the brine has passed through the primary brine subcell. At this point, a portion (or in some cases, all) of the depleted brine is dechlorinated, resaturated with solid salt, and returned to the cell-brine feed (Kirk-Othmer 1983).

Many of the mercury cells presently in operation have been in service for at least 20 years. During that period, some cell modifications have been made including the substitution of metal anodes for graphite anodes. Due to the wide difference in cell design, chlorine produced per mercury cell could vary from 1 ton/day to 7 or 8 tons/day. In addition, energy consumption varies. Total energy consumption using the mercury cell process could be less than that for using the diaphragm cell production process; while, in many cases, the disparity between technologies could be little or none (Chlorine Institute 1986b).

Mercury cells once accounted for a major part of the world's chlor-alkali capacity. However, in recent years, this technology has been steadily replaced by the asbestos diaphragm cell due primarily to the environmental and industrial hygiene concerns associated with mercury. The first major industrialized country to complete the process switchover was Japan, having eliminated the use of mercury cells in chlor-alkali production in 1986 (Chemical Week 1986b). In the United States, only 16.5 percent of chlorine is produced using mercury cell technology. No new mercury cell construction has occurred in the United States since 1970, and none is likely to in the future (Chlorine Institute 1986b).

D. Comparison of the Three Cells' Characteristics

The three cell technologies (asbestos diaphragm, membrane and mercury) each have distinct price, performance, and market characteristics as indicated in Table 4.

1. Cost of Cell Technology

Diaphragm cell technology is the most used technology for chlorine production in the United States, accounting for 76.7 percent of U.S.installed chlorine production capacity (Chlorine Institute 1986b). There are many different sizes and designs of asbestos diaphragm cells presently used in the industry. Hence, the costs of an asbestos diaphragm varies considerably, ranging from $250 to $2,000. Actual asbestos cost may represent only 10 to 20 percent of the total diaphragm replacement cost (Chlorine Institute 1986b). Other costs associated with the diaphragm include the cost of resin binders and the labor involved for removal and reinstallation of the cell (Chlorine Institute 1986b).

The membrane cell, which accounts for 2.4 percent of the present U.S. chlorine capacity, have estimated costs in the area of $60 to $75 per square foot (Chlorine Institute 1986b). Cells may use membranes with an area of less than 10 square feet, while others may use membranes of over 50 square feet.

Table 4. Comparison of Electrolytic Cell Technologies

	Asbestos Diaphragm	Membrane Cell	Mercury Cell
Price			
o Purchase Cost[j]	$250-$2,000[e]	$600-$3,750[b]	Not Available
o Other[j]	Other costs include cost of resin binders; labor removal and reinstallation of cell[a]	Associated costs of installation, regasketing, etc. not well known	Not Available
Performance			
o Service Life[j]	3 months to 15 months	2 years	20 years or more[d]
o Energy consumption[k] (KWH/metric ton of chlorinated produced)	2,800-3,000 (average) 2,300 (Best Available Technology)[c]	2,100-2,300[c]	2,900 (average)
o Purity of caustic soda[g] produced (alkali)	10-15% caustic, 1.0-1.2% salt content	30-35% caustic, 0.02-0.2% salt content	50% caustic with low salt content
Market Share[j]	76.7%	2.4%	16.5%

[a] The cost of asbestos for a diaphragm could range from $50-$250; actual asbestos cost may account for only 10-20 percent of the total diaphragm replacement cost (Chlorine Institute 1986b). The surface area of the diaphragm ranges from approximately 200 to 1,000 sq ft for a cell with a volume of 64 to 275 cu ft (Coats 1983).

[b] Some cells use membranes with an area of less than 10 square feet, while others use membranes of over 50 square feet.

[c] 20-30 percent less energy than mercury cell or asbestos diaphragm technology.

[d] During this 20 year period some cell modifications have been made (i.e., substitution of metal anodes for graphite anodes).

[e] N/A = Not Available.

[f] Rizzo 1983 (August).

[g] Chemical Week 1981 (May 27).

[h] Chemical Week 1982 (November 17).

[i] Chemical Week 1984 (February 1).

[j] Chlorine Institute 1986b.

[k] Verbanic 1985.

Hence, the purchase cost of materials for membrane cells may range from $600 to $3,750. Since only a few U.S. plants are operating with membrane cells, the associated costs of installation, regasketing, etc. are not well known (Chlorine Institute 1986b). However, the labor costs involved in making a membrane for retrofitting purposes is significantly more expensive than that required for preparing an asbestos diaphragm.

The mercury cell accounts for 16.5 percent of the U.S. chlorine production capacity; however, it is steadily being replaced by both the membrane cell and the asbestos diaphragm cell technologies. Price information for the mercury cell is not available.

2. Useful Service Life

The life of a membrane cell is about two years, while an asbestos diaphragm is expected to

last from three to 15 months. The modified (resin bound) asbestos diaphragm, which is most often employed in chlorine plants, lasts 6 to 15 months (Chlorine Institute 1986b).

Most of the mercury cells in operation today have been in service for 20 years or more, although during this period some cell modifications have been made such as the replacement of metal anodes for graphite anodes (Chlorine Institute 1986b).

3. Energy Consumption

In comparing the three cell technologies in terms of energy consumption, the membrane cell is generally the lowest consumer at 2,100 to 2,300 KWH per metric ton of chlorine produced (Verbanic 1985). In some instances total energy consumption via the mercury cell route may be less than that for the diaphragm cell, but typically, the disparity is marginal. On average, both technologies consume 2,800 to 3,000 KWH per metric ton of chlorine (Verbanic 1985).

4. Purity of Product

Lastly, a primary advantage the membrane cell has over the asbestos diaphragm is the quality of caustic soda produced. Membrane cells produce a stronger caustic solution, 30 to 35 percent, compared to the diaphragm's 10 to 15 percent (Chemical Week 1981). The caustic soda product produced via the mercury cell is more pure than that produced via the asbestos diaphragm cell.

E. Market Trends for the Chlorine Industry

Slow growth and overcapacity have characterized the industry since the early 1970s (Verbanic 1985). During these years of increasing environmental awareness, chlorine growth slowed to only 2 to 3 percent per year (Verbanic 1985). With the imposition of new regulations on several end-use markets (e.g., chlorinated pesticides and solvents, chlorofluorocarbons as aerosol propellants, etc.), demand for chlorine was reduced by several million tons by mid-1970 (Verbanic 1985). However, this drastic reduction in demand was not immediately recognized by producers, and installation of additional capacity continued throughout the 1970s. Consequently, operating rates in the chlor-alkali industry have been low since 1974, remaining below the 80 percent level except for 1979, when the high of 84 percent was achieved (Verbanic 1985). Operating rates have been improving for the industry as the economy has recovered from the 1982 recession (Verbanic 1985). Estimates for 1985 capacity utilization rates have been as high as 84 percent, while most estimates have remained in the area of 75-80 percent (Verbanic 1985). One source forecasts the 1986 average operating rate to be 87 percent, a definite gain over the 1985 average (Chemical Week 1985). The recent improvement stems from both a reduction in annual production capacity of more than 1 million tons and the departure by several well-known producers from the chlor-alkali industry (Verbanic 1985). Since 1980, some 23 chlor-alkali production facilities have been completely or partially closed, involving about 2,740,000 tons of annual production capacity (Chlorine Institute 1986a).

The chlor-alkali business is now a slow-growing, mature business with a long-term growth trend of 1.5 percent (Verbanic 1985). However, general gains may be expected in the 1986 chlor-alkali market, stemming from a 2 to 3 percent boost in industrial and chemical demand and a relative 8 percent decline in the trade-weighted value of the dollar, increasing the demand for chlorine products overseas (Chemical Week 1985).

As a result of slow-growth in demand, few, if any, new chlor-alkali plants are expected to open in the U.S. Rather than building new plants, existing firms are switching over from asbestos diaphragm and mercury cells to membrane cell technology because of the many advantages the membrane technology offers. The future of membrane cell technology in the chlor-alkali industry seems certain; it's not a question of whether U.S. producers will switch to membranes, but when and where (Chemical Week 1984).

REFERENCES

American Metal Market. 1983 (September 19). Vulcan opens plant in Wichita. p. 17.

Chemical Engineering. 1976 (March 29). New signs point to wider use of synthetic- membrane chlor-alkali cells. p. 61.

Chemical Marketing Reporter. 1983 (August 15). Vulcan chemicals starts running chloralkali plant. p. 15.

Chemical Week. 1981 (May 27). Polymeric membranes for chlor-alkali cells. pp. 13-14.

Chemical Week. 1982 (November 17). A revolution in chlor-alkali membranes. pp. 35-36.

Chemical Week. 1984 (February 1). Chlor-alkali: squeezing earnings from a low-growth business. pp. 26-29.

Chemical Week. 1985 (November 6). Better times for chlor-alkali in 1986. p. 28.

Chemical Week. 1986a (August 13). New entries vie in chlorine technology. pp. 22-23.

Chemical Week. 1986b (July 23). Japan abandons mercury cells. p. 10.

Chemical Week. 1986c (July 23). Dow shuts some chlorine capacity. p. 24.

Chlorine Institute. 1986a (June 30). Comments of the Chlorine Institute, Inc. The Chlorine Institute, Inc. 70 West 40th Street, New York, N.Y.

Chlorine Institute. 1986b. Questionnaire to the Chlorine Institute. The Chlorine Institute, Inc., 70 West 40th Street, New York, NY. Docket OPS 62036.

Coats V. 1983 (July 1). Vulcan Materials. Conversation with Maravene Edelstein, ICF Incorporated.

Kirk-Othmer. 1983. Alkali and chlorine products. Encyclopedia of Chemical Technology, Third edition: 799-865.

Kirk-Othmer. 1985. Alkali and chlorine products. Concise Encyclopedia of Chemical Technology: 59-63.

PPG Industries. 1986. Comments of PPG Industries, Inc. PPG Industries, Inc. One PPG Place, Pittsburgh, Pennsylvania. Docket Control No. OPTS-62036.

SRI International. 1984. Chlorine. In: 1984 Directory of Chemical Producers, United States: 490-491.

Rizzo P. 1986 (January). Chloralkali industry nears end of painful realignment period. Chemical Marketing Reporter: 27, 35.

Verbanic C. 1985 (September). Chlorine/caustic: anatomy of a struggle. Chemical Business: 50, 52, 57-59.

Vulcan Chemicals. 1986. Comments of the Vulcan Materials Company. Vulcan Chemicals, P.O. Box 7609, Birmingham, AL 35253.

XIV. ASBESTOS-CEMENT PIPE AND FITTINGS

A. Product Description

This 1988 report on asbestos-cement pipe has been updated from the 1986 report to account for the increased acceptance of polyvinyl chloride (PVC) pipe over the past two years. Sussex Plastics Engineering was hired to conduct a survey of the present status of standards for plastic pipe products suitable to replacing asbestos-cement pipe in potable water and sewer applications. This survey was intended to update the information of the Malcolm Pirnie (1983) report because plastic pipe standards have been extended to larger diameters and new products have been developed since 1986 (Sussex Plastics Engineering 1988a).

Asbestos-cement pipe is made of a mixture of Portland cement (42 to 53 percent by weight), asbestos fibers (15 to 25 percent by weight), and silica (34 to 40 percent by weight). These materials are combined with water and processed into a pliable mass that is wound around a steel cylinder and then compressed and cut into 10 or 13-foot lengths. The product then goes through a curing process, known as autoclaving, that involves immersion in water or pressurized steam to enhance corrosion resistance to high sulfate soils and waters. Cured pipes then undergo a finishing process that includes machining the ends and, optionally, lining the pipe with gilsonite coatings, asphalt-based coatings, or other coatings to protect the pipe from acidic or corrosive fluids (ICF 1985).

According to the Bureau of Mines, approximately 18 percent of the total asbestos fiber consumed in the U.S., or 30,871, tons was used in the production of asbestos-cement pipe in 1985 (Bureau of Mines 1986a, Bureau of Mines 1986b). Applications for asbestos-cement pipe may be divided into pressure pipe (water mains) and non-pressure pipe (sewer line) applications. The pressure pipe applications include conveyance of potable water, force main sewers, industrial process lines, and industrial fire protection systems (Association of Asbestos Cement Pipe Producers 1986b). Non-pressure pipe applications include use in storm drain pipes and sewer pipes, although these uses constitute only a small portion of present asbestos-cement pipe production. Asbestos-cement pipe is especially widespread throughout the Southeast, Mountain, and Pacific regions (Association of Asbestos Cement Pipe Producers 1986b).

Approximately 22 million linear feet, or 4,167 miles, of asbestos-cement pipe are installed annually in the U.S. (Association of Asbestos Cement Pipe Producers 1986a). As of 1986 it is roughly estimated that 400,000 miles of asbestos-cement pipe have been installed in the U.S., over 325,000 miles of which is asbestos-cement water pipe (Association of Asbestos Cement Pipe Producers 1986b; American Waterworks Association 1986). A small but unknown amount of asbestos-cement pipe is also used as conduits for electrical and telephone cables and for laterals from street mains to consumers (Krusell and Cogley 1982).

Asbestos-cement pipe comes in a variety of diameters, formulations, and weights designed for different applications. In the past, diameters ranged from 4 inches through 42 inches, however, current production of asbestos-cement pipe larger than 24 inches in diameter was not reported by any domestic manufacturer (Certain-Teed 1986c, JM Manufacturing 1986a, Capco 1986a, Capco 1986b). Standard lengths are 10 and 13 feet. Among the many factors that are important in selecting pipe for pressure (water mains) and non-pressure applications (sewer mains) the major ones are:

- Fluid conveyed;
- Flow capacity;
- Depth of cover/external loads;
- Soil characteristics;
- Flexibility;
- Bedding requirements; and
- Connections.

Other factors used in selecting pipe include cost, availability, useful life, and the experience of the engineer, contractor, or utility director (Malcolm Pirnie 1983).[1]

For the purpose of this discussion, the enormously complex asbestos-cement pipe market has been divided into 10 submarkets which are shown in Table 1. (These asbestos-cement submarkets were originally derived by Malcolm Pirnie (1983). Table 1 also shows, in addition to the 10 submarkets, the 1981 relative market share of each asbestos-cement pipe submarket by linear foot of asbestos-cement pipe (see Attachment, Item 1).[2]

In 1981, according to Table 1, by linear feet, approximately 83 percent of the asbestos-cement pipe produced was used in pressure applications and 17 percent was used in non-pressure applications. The relative market shares by weight of pressure and non-pressure asbestos-cement pipe shipments from 1980 to 1985 are presented in Table 2. Pressure pipe has taken a larger share of the asbestos-cement pipe shipments since 1980, comprising 89 percent of all asbestos-cement pipe shipments by 1985.

B. Producers and Importers of Asbestos-Cement Pipe

The number of plants producing asbestos-cement pipe was reduced from 9 to 5 between 1981 and 1983. All of those five are still operating today (ICF 1985, ICF 1986). Plants were closed or dismantled in response to several

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[1] For a more detailed description of the significance of each factor and how asbestos-cement pipe's performance relates to it, refer to Malcolm Pirnie (1983).

[2] 1981 data is used because this is the most recent year for which production of asbestos-cement pipe in each of the 10 submarkets chosen by Malcolm Pirnie (1983) are available. Note that in 1981 there were 5 additional submarkets of pipe >24" in diameter, one for each of the two operating pressure classes and one for each of the three depth of cover classes. Since asbestos-cement pipe is no longer produced over 24" in diameter these 5 submarkets have been deleted. Thus, the markets shares shown in Table 1 are derived only for asbestos-cement pipe 24" in diameter based upon 1981 production in each of the 10 submarkets (see Attachment, Item 1 and Malcolm Pirnie 1983).

Table 1. Asbestos-Cement Pipe Submarkets in the United States

Asbestos-Cement Pipe Application	Specifications	Share of Asbestos-Cement Pipe Market (by linear feet) Consumed in 1981
Pressure Flow Water Pipe	0-150 psi, 4"-12" diameter	59.52
Pressure Flow Water Pipe	>150 psi, 4"-12" diameter	5.33
Pressure Flow Water Pipe	0-150 psi, 12"-24" diameter	16.39
Pressure Flow Water Pipe	>150 psi, 12"-24" diameter	1.72
Total Pressure	82.96	
Non-Pressure Gravity Sewers	0'-8' deep, 4"-12" diameter	7.04
Non-Pressure Gravity Sewers	0'-8' deep, 12"-24" diameter	6.86
Non-Pressure Gravity Sewers	8'-16' deep, 4"-12" diameter	1.35
Non-Pressure Gravity Sewers	8'-16' deep, 12"-24" diameter	1.47
Non-Pressure Gravity Sewers	>16' deep, 4"-12" diameter	0.15
Non-Pressure Gravity Sewers	>16' deep, 12"-24" diameter	0.17
Total Non-Pressure	17.04	
Total Pressure and Non-Pressure		100.00

See Attachment, Item 1 for sources and calculations.

Table 2. Market Share of Domestic Asbestos-Cement Shipments by Weight

Year	Pressure Flow Water Pipe (percent)	Non-Pressure Flow Gravity Sewers (percent)
1980	73	27
1981	76	24
1982	85	15
1983	86	14
1984	89	11
1985	89	11

Source: Association of Asbestos Cement Pipe Producers 1986a.

factors. Among these were competition from substitute pipe (especially polyvinyl chloride), the drop in sewer system construction since EPA grant cutbacks in 1978, and the drop in housing starts in prior years (U.S. Industrial Outlook 1983). Table 3 lists these remaining domestic producers of asbestos-cement pipe. The locations of the remaining producers confirm the fact that the asbestos-cement pipe market is primarily in the southwestern part of the nation.

All companies which produce asbestos-cement pipe also produce PVC pipe (Association of Asbestos Cement Pipe Producers 1986a). There appears to be a greater demand for pressure pipe as is shown by Certain-Teed's Riverside, CA plant which produces only pressure pipe and is currently operating at 95 percent of capacity, while Certain-Teed's Hillsboro, TX plant, which produces both pressure and non-pressure asbestos-cement pipe, is operating at only 60 percent of capacity (Industrial Minerals 1986). No importers of asbestos-cement pipe were identified, although according to the U.S. Bureau of the Census a very small amount (relative to domestic production) of pipe was imported in 1985 (see Trends) (U.S. Dep. Com. 1986).

C. Trends

Domestic asbestos-cement pipe shipments from 1980 through 1985 are presented in Table 4. As Table 4 indicates domestic asbestos-cement pipe shipments have decreased by about 42 percent since 1980, with a 78 percent decline in non-pressure pipe shipments and a smaller decline (28 percent) in pressure pipe shipments (see Attachment, Item 2). Table 5 presents 1985 production of asbestos-cement pipe and asbestos consumption. There were 216,903 tons (15,062,708 feet) of asbestos-cement pipe, valued at about $110 million, produced in 1985 (ICF 1986, Association of Asbestos Cement Pipe Producers 1986b, see Attachment, Item 10).

Table 3. Producers of Asbestos-Cement Pipe

Company	Plant	Product Lines: Asbestos-Cement	Product Lines: PVC
Capco Inc.	Van Buren, AR	X	X
Certain-Teed Corp.	Riverside, CA Hillsboro, TX	X	X
JM Manufacturing Corp.	Stockton, CA	X	X
	Denison, TX	X	X

Table 4. Domestic asbestos-cement Pipe Shipments[a]

Year	Total Shipments (tons)	Pressure Pipe Shipments (tons)	Non-Pressure Pipe Shipments (tons)
1980	417,816	302,928	114,888
1981	346,678	265,147	81,531
1982	286,555	242,453	44,102
1983	288,671	248,863	39,808
1984	296,450	262,527	33,923
1985	243,873	218,191	25,682
Totals	1,880,043	1,540,109	339,934

[a]Association of Asbestos Cement Pipe Producers 1986a.

Table 5. 1985 Production of Asbestos-Cement Pipe

	Tons of Asbestos Consumed	Production (tons)
Total[a]	32,690.8	216,903

[a]One company refused to provide production and fiber consumption data for their asbestos-cement pipe plant (ICF 1986). Their production and fiber consumption have been estimated using a method described in Appendix A of this RIA.

Source: ICF 1986.

Imports of asbestos-cement pipe are insignificant. In 1984 they were about 4,191 tons, or equal to 1.4 percent, by weight, of domestic shipments and in 1985 they dropped to about 2,790 tons, or 1.1 percent, by weight, of domestic shipments (U.S. Dep. Comm. 1986).

The growth of the pipe industry, including asbestos-cement pipe, will be largely determined by trends in the sewer and waterworks construction industry. The value of sewer system construction, which accounts for 11 percent of the asbestos-cement pipe market in 1985, increased by about 5 percent in 1985 and is expected to increase further in 1986. In the longer term, sewer system construction may decline slightly due to less federal spending and the projected eventual leveling of housing starts at a relatively high level (U.S. Industrial Outlook 1986). Waterworks construction, accounting for about 89 percent of asbestos-cement pipe use, increased sharply in 1984 and 1985, recovering from a slump in the early 1980's. The increased level of housing starts and the record amounts of municipal bonds issued for waterworks systems were two important factors responsible for this change (U.S. Industrial Outlook 1986). For the longer term outlook, waterworks construction is predicted to be one of the fastest growing segments of public construction. Growth will come from two sources: the high level of housing starts, and the need to replace old waterworks in cities (engineers recommend that this should be done every 50 years) (U.S. Industrial Outlook 1986). The new demand in asbestos-cement pipe's largest market could have a positive impact on the demand for asbestos-cement pipe, although detailed forecasts are not available.

Potential growth in asbestos-cement pipe demand will be limited by the availability of satisfactory substitutes (discussed below). In some instances, notably PVC pipe, costs are approaching those of asbestos-cement pipe, especially large diameter pipes (ICF 1985).

D. Substitutes

As Table 1 indicates, there are many submarkets within the asbestos-cement pipe market. In reality, this exhibit provides only a broad aggregate of pipe submarkets because every site has unique characteristics in which price and performance tradeoffs among different types of pipe must be made.

For all 10 submarkets of asbestos-cement pipe, Malcolm Pirnie (1983) found two main substitutes: polyvinyl chloride (PVC) and ductile iron pipe. The major factors Malcolm Pirnie (1983) considered in determining substitutes in the non-pressure submarkets were pipe diameter, depth of cover, and soil characteristics and for pressure submarkets the major factors were pipe diameter, operating pressure, fluid characteristics and soil characteristics (Malcolm Pirnie 1983). (For a more in-depth discussion of how these substitutes were determined see Malcolm Pirnie 1983.)

The following paragraphs describe the two substitutes and discuss two other products that have already replaced asbestos-cement in the over 24 inch diameter submarkets. It should be noted that the substitutes discussed here are the ones most likely to replace asbestos-cement pipe because of their price and performance characteristics, but are not the only ones available (Malcom Pirnie 1983).

1. Polyvinyl Chloride Pipe (PVC)

PVC pipe is produced by more than 13 U.S. companies including the three producers of asbestos-cement pipe (ICF 1985). The advantages of PVC pipe include the following:

- Lightweight;
- Long laying lengths; and
- Ease of installation (Malcolm Pirnie 1983).

Industry representatives report that PVC can be joined to existing asbestos-cement pipe when repairs in water or sewer mains are required (ICF 1985). Disadvantages of PVC include:

- Subject to attack by certain organic chemicals.
- Subject to excessive deflection when improperly installed.
- Limited range of diameters are available.
- Subject to surface changes caused by long term ultra-violet exposure (Malcolm Pirnie 1983).

In addition it cannot withstand high temperatures as well as asbestos-cement pipe or some other substitutes (ICF 1985).

PVC is the most important substitute for asbestos-cement pipe because it could fill much of the asbestos-cement pipe market if asbestos were banned (American Concrete Pressure Pipe Association 1986, Industrial Minerals 1986), especially in the following applications (Malcolm Pirnie 1983):[3]

- pressure pipe, 0-150 psi, 4"-12" diameter
- pressure pipe, 0-150 psi, 12"-24" diameter
- non-pressure, 0'-16' deep, 4"-24" diameter

Thus PVC is the most probable substitute for the "small" end of the asbestos-cement pressure pipe market (small diameter pipe under low pressure), and for all diameter pipes (at relative shallow depths) in the non-pressure market. PVC has largely taken over the sewer market (Industrial Minerals 1986, Sussex Plastics Engineering 1988a and b, JM Manufacturing 1988).

2. Ductile Iron (DI) Pipe

Ductile iron pipe is manufactured by at least six companies, including the Jim Walter Corporation (the parent company of U.S. Pipe and Foundry), American Cast Iron Pipe Company, McWane Cast Iron Pipe Company, Pacific Cast

[3] In the 1986 report, ductile iron was the pipe chosen to replace asbestos-cement in the pressure pipe, 0-150 psi, 12"-24" diameter category. Based on the updated Sussex Plastics Engineering (1988) survey of PVC pipe standards and availability, PVC is the most likely substitute for asbestos is this submarket (Sussex Plastics Engineering 1988a and b and ICF estimate).

In 1988, PVC has also taken over the 4"-12" non-pressure (sewer/gravity) pipe market and might therefore also take away the >16' deep, 4"-12" diameter market from the other major substitute, ductile iron (JM Manufacturing 1988). However, because this submarket represents only 0.15 percent of the entire asbestos-cement pipe market, it was considered insignificant and has been left as a ductile iron submarket in this analysis.

Iron Company, the Clow Company, and Atlantic States Cast Iron Company. Clow, Atlantic States, and Pacific States are all owned by McWane Cast Iron Pipe Company. U.S. Pipe and Foundry and American Cast Iron Pipe Company are the largest producers (Ductile Iron Pipe Research Association 1986b).

Ductile iron is produced by adding magnesium to molten iron and then casting the materials centrifugally to control pipe thickness. The pipe is lined with cement mortar and often encased in plastic to prevent internal and external corrosion. The pipe is usually cut into 18 or 20 foot lengths.

The major advantages of ductile iron pipe include:

- Long laying lengths;
- Not brittle;
- High internal pressure and load bearing capacity; and
- High beam and impact strength (Malcolm Pirnie 1983).

Ductile iron is very strong, can handle stress from water hammer and highway traffic, and is more flexible and less brittle than cement-based pipes. Major disadvantages of ductile iron are:

- Subject to corrosion where acids are present;
- Subject to chemical attack in corrosive soils; and
- High weight (Malcolm Pirnie 1983).

However, DI is usually lined and sometimes encased to prevent corrosion and rusting.

Ductile iron pipe is a direct competitor with asbestos-cement pipe in several submarkets, most importantly in parts of the pressure pipe (water main) submarket. In this study, DI has been chosen as the probable substitute for asbestos-cement pipe in the following submarkets (Malcolm Pirnie 1983):

- pressure pipe, >150 psi, 4"-24" diameter
- non-pressure pipe, >16' deep, 4"-24" diameter

Table 6 shows the costs of asbestos-cement pipe and its two major substitutes, PVC and ductile iron.[4] F.O.B. plant prices are based on weighted averages of several companies' prices (see Attachment, Items 4-7). Installation costs were derived from Means Guide to Building Construction Costs (1986) (see Attachment, Item 8). In 1986, industry representatives reported that the price of PVC had come down as the market for it had grown and possibly because of falling oil and natural gas prices (Industrial Minerals 1986). Since 1986, the price of PVC pipe has increased approximately 50 percent due to a temporary shortage of resin, which is one of the primary ingredients in the manufacture of PVC pipe. When the supply of resin increases, the price of PVC pipe should decline (see Attachment, Items 5a-b) (JM Manufacturing 1988, Sussex Plastics Engineering 1988a). DI is overall the most expensive substitute.

The following concrete substitutes have already replaced asbestos-cement pipe in the over 24 inch diameter submarkets; asbestos-cement pipe is no longer made in diameters greater than 24 inches.

a. Prestressed Concrete Pipe (PCP)

Prestressed concrete pipe is the most probable substitute for asbestos-cement pipe in large water mains (greater than 24" diameter). PCP is all pressure pipe. It ranges from 16 to 252 inches in diameter. It is less expensive, less brittle, and comes in longer lengths, 20 feet or longer, than asbestos-cement pipe (American Concrete Pressure Pipe Association 1986).

[4] There is some uncertainty about the comparative installation costs of asbestos-cement and DI pipes. Estimates given by industry representatives indicated that ductile iron is sometimes more expensive to install than asbestos-cement pipe because its flexibility demands some compacting of the soil around the pipe. Yet engineers also say that DI is easier to install because it is less brittle and comes in longer lengths, normally 18 feet sections as opposed to asbestos-cement which is 10 and 13 feet (Ductile Iron Pipe Research Association 1986a).

Table 6. Cost of Asbestos-Cement Pipe and Substitutes

	Asbestos-Cement Pipe	PVC Pipe	Ductile Iron Pipe	References
FOB Plant Cost[a] ($/foot)	6.74	6.84	10.01	Certain-Teed 1986, JM Manufacturing 1986b, McWane 1986, U.S. Pipe 1986, Atlantic Cast Iron Pipe 1986.
Installation Cost[b] ($/foot)	2.20	4.24	5.86	Means 1985.
Total Cost ($/foot)	8.94	11.08	15.87	
Operating Life[c] (years)	50	50	50	ICF 1985.
Present Value[d] ($/foot)	8.94	11.08	15.87	

[a]See Attachment, Items 4-7 for calculations.

[b]Derived from Means 1985. See Attachment, Item 8 for calculations.

[c]Operating life estimates for pipe vary from 35 to 1,000,000 years. Operating life depends on many factors, including the appropriateness of the pipe for a specific site and application. The 50 years estimated here is a reasonable estimate for the useful life of pipe (ICF 1985).

[d]Present values equal total cost because operating life is the same for asbestos-cement pipe and its substitutes.

PCP is made of sand, gravel, and cement cast into various thicknesses and lengths. Steel wire under tension is wound around the outside of the pipe core before a mortar coating is applied. The wire adds to the pipe's ability to withstand the forces of water flowing through it under pressure. Another type of concrete pipe which is very similar to PCP is pretensioned concrete pipe. It is made the same way as PCP except that a rod, as opposed to a wire, is wrapped around the pipe before the last mortar coat. This rod enables one to use less steel for the interior cylinder than for PCP (U.S. Concrete Pipe 1986). PCP and other types of concrete pipe are produced by many manufacturers who can use readily-available local materials and produce customized shapes and lengths to meet local specifications.

b. Reinforced Concrete Pipe (RCP)

Reinforced concrete pipe and other pipes have already substituted for asbestos-cement pipe in storm drains and sewer lines which require diameters greater than 24 inches.

RCP is made of sand, gravel, and cement reinforced with steel bars and/or welded wire mesh (ICF 1985). It differs from PCP and pretensioned concrete pipe in that RCP has steel bars or a wire cage for a core instead of a steel cylinder and it does not have a wire or rod wrapped around it before the final mortar coat. The lack of a steel cylinder core makes it more permeable than the previously mentioned concrete pipes. Therefore it is used for nuisance runoff, sewer and storm drain pipe (U.S. Concrete Pipe 1986). At large diameters, it was less expensive than asbestos-cement pipe. The price factor explains why over 60 percent of U.S. sewer lines of greater than 24" diameter are made of reinforced concrete. The second most important material used in this submarket (greater than 24" diameter) is vitrified clay pipe, which accounts for 15 percent of the in-place pipe. In 1981, asbestos-cement pipe occupied fifth place in this market, accounting for 0.5 percent of it (Krusell and Cogley 1982).

Reinforced concrete pipe is produced by many manufacturers in the United States, in contrast to asbestos-cement pipe, which is produced at only a few plants. The disappearance of asbestos-cement pipe from the market has had no noticeable impact on the submarkets in which reinforced concrete pipe already dominated.

If asbestos-cement pipe were not available, based on the 1981 submarket shares, it is estimated that by weight of asbestos-cement pipe, 91.16 percent would shift to PVC and 8.84 percent to ductile iron (see Attachment, Item 9). By linear foot, 92.63 of the previous purchasers of asbestos-cement pipe would purchase PVC and 7.37 percent would use ductile iron (see Attachment, Item 1). Table 7 presents the data for the asbestos regulatory cost model and summarizes the findings of this analysis. Data inputs for the Asbestos Regulatory Cost Model are presented in units of linear feet because prices of asbestos-cement pipe and its substitutes are only available in cost per linear foot.

E. Summary

There are two types of asbestos-cement pipe; pressure pipe which comprises 89 percent of the asbestos-cement pipe market and non-pressure pipe which comprises about 11 percent of the market (Association of Asbestos Cement Pipe Producers 1986a). Pressure pipe applications include conveyance of potable water, force main sewers, industrial process lines, and industrial fire-protection systems. Non-pressure pipe applications include use in storm drains and sewers (Association of Asbestos Cement Pipe Producers 1986b).

Three companies, with a total of five plants, are still producing asbestos-cement pipe. In 1981, there had been nine plants operating (ICF 1985, ICF 1986). From 1980 through 1985 domestic pipe shipments have declined

Table 7. Data Inputs for Asbestos Regulatory Cost Model[a]

Product	Output (ft.)	Product Asbestos Coefficient	Consumption Production Ratio	Price ($/ft.)	Useful Life	Equivalent Price ($/ft.)	Market Share	Reference
Asbestos-Cement Pipe	15,062,708	0.0022	1.0128	8.94	50 years	8.94	N/A	See Attachment
PVC Pipe	N/A	N/A	N/A	11.08	50 years	11.08	92.63%	See Attachment
Ductile Iron Pipe	N/A	N/A	N/A	15.87	50 years	15.87	7.37%	See Attachment

N/A: Not Applicable.

[a]See Attachment, Items 1, 3-8, and 10-12 for explanation.

42 percent, with a 78 percent decline in non-pressure pipe shipments and a 28 percent decline in pressure pipe shipments (Association of Asbestos Cement Pipe Producers 1986a). Imports in 1985, about 1 percent of domestic shipments, were insignificant (U.S. Dep. Com. 1986). The two major substitutes are PVC and ductile iron pipe. If asbestos were no longer available it is estimated (by linear foot) that PVC would take 92.63 and ductile iron 7.37 of the asbestos-cement pipe market. PVC costs slightly more than asbestos-cement pipe and ductile iron costs almost twice as much as asbestos-cement pipe.

ATTACHMENT

(1) Calculations to derive each submarket's share, by linear feet, of the entire asbestos-cement pipe market.

In order to determine the market share by linear feet of each of the ten asbestos-cement pipe submarkets shown in Table 1, it is necessary to convert the amount of tons of asbestos-cement pipe produced in each submarket into linear feet of asbestos-cement pipe. First the average weight per foot of asbestos-cement pipe is calculated for each submarket. This weight per foot for each submarket is then multiplied by the tons of asbestos-cement pipe produced in 1981 in each submarket, giving linear feet produced in each submarket (As stated in the text, 1981 production data is the most recent available that is broken down into the ten submarkets). The calculations are shown in the following subsections a and b.

(a) Calculation of the weight per foot of asbestos-cement pipe in each submarket.

For the 0-150 pressure pipe submarkets an average was taken of Class 100 and 150 pipe. For the 0-8 feet depth non-pressure pipe submarkets Class 2400 pipe was used. For the 8-16 feet depth an average of Class 2400 and 3300 were used. For the >150 psi pressure pipe submarkets, an average was taken of Class 150 and 200 pipe and for >16 feet depth submarkets Class 3300 was used.

Submarkets taken by PVC as determined by Malcolm Pirnie (1983), Sussex Plastics Engineering (1988a), and ICF estimate.

0-150 psi, 4"-12" diameter

	Class 100 (lb/ft)	Class 150 (lb/ft)	
4"	7.2	7.9	
6"	10.6	11.9	
8"	16.0	18.3	Average for this submarket is 19.51 lb/ft.
10"	23.5	30.0	
12"	30.6	39.1	

0-150 psi, 12"-24" diameter

	Class 100 (lb/ft)	Class 150 (lb/ft)	
12"	30.6	39.1	
14"	36.3	51.8	
16"	46.6	65.9	
18"	63.8	91.3	Average for this submarket is 73.53 lb/ft.
20"	77.0	111.0	
24"	109.0	160.0	

0-8' deep, 4"-12" diameter

	Class 2400 (lb/ft)	
4"	5.3	
6"	9.1	
8"	12.8	Average for this submarket is 13.61 lb/ft.
10"	17.5	
12"	23.3	

0-8' deep, 12"-24" diameter

	Class 2400 (lb/ft)	
12"	23.3	
14"	27.1	
15"	30.0	
16"	33.2	Average for this submarket is 40.74 lb/ft.
18"	43.2	
20"	48.9	
21"	54.1	
24"	66.1	

8-16' deep, 4"-12" diameter

	Class 2400 (lb/ft)	Class 3300 (lb/ft)	
4"	5.3	6.6	
6"	9.1	10.7	
8"	12.8	14.9	Average for this submarket is 14.75 lb/ft.
10"	17.5	20.2	
12"	23.3	27.1	

8-16' deep, 12"-24" diameter

	Class 2400 (lb/ft)	Class 3300 (lb/ft)	
12"	23.3	27.1	
14"	27.1	31.2	
15"	30.0	34.8	
16"	33.2	37.7	Average for this submarket is 43.50 lb/ft.
18"	43.2	48.2	
20"	48.9	54.9	
21"	54.1	62.3	
24"	66.1	73.9	

Submarkets taken by Ductile Iron (DI) as determined by Malcolm Pirnie (1983), Sussex Plastics Engineering (1988a) and ICF estimate.

>150 psi, 4"-12" diameter

	Class 100 (lb/ft)	Class 150 (lb/ft)	
4"	7.9	9.2	
6"	11.9	15.6	
8"	18.3	23.1	Average for this submarket is 23.94 lb/ft.
10"	30.0	35.4	
12"	39.1	48.9	

>150 psi, 12"-24"

	Class 150 (lb/ft)	Class 200 (lb/ft)	
12"	39.1	48.9	
14"	51.8	61.8	
16"	65.9	79.9	
18"	91.3	--	Average for this submarket is 78.86 lb/ft.[5]
20"	111.0	--	
24"	160.0	--	

>16' deep, 4"-12" diameter

	Class 3300 (lb/ft)	
4"	6.6	
6"	10.7	
8"	14.9	Average for this submarket is 15.90 lb/ft.
10"	20.2	
12"	27.1	

[5] Weights were not found for all sizes, so this is an average of only the weights shown. The reader may note that later, for calculating ductile iron prices, averages were taken across rows for pipe of the same class, however, because the pipes in the above case are of different classes we did not feel this method was appropriate.

>16' deep, 12"-24" diameter.

	Class 3300 (lb/ft)
12"	27.1
14"	31.2
15"	34.8
16"	37.7
18"	48.2
20"	54.9
21"	62.3
24"	73.9

Average for this submarket is 46.26 lb/ft.

Source: Certain-Teed 1986c.

(b) Calculations to convert ton production for each submarket into each submarket's share by linear feet of the entire asbestos-cement pipe market.

	Tons Produced in 1981 for 24" Diameter	Multiplication Factors to Convert to Linear Feet	Linear Feet of Pipe Per Submarket	Submarket Share
		PVC Submarkets		
0-150 psi, 4"-12"[a]	108,843	x 2,000 lb/ton x 1 ft/19.51 =	11,157,662.737	59.52%
0-150 psi, 12"-24"[a]	112,957	x 2,000 lb/ton x 1 ft/73.53 =	3,072,405.821	16.39%
0-8' deep, 4"-12"	8,977	x 2,000 lb/ton x 1 ft/13.61 =	1,319,177.076	7.04%
0-8' deep, 12-24"	26,182	x 2,000 lb/ton x 1 ft/40.74 =	1,285,321.551	6.86%
8-16' deep, 4"-12"	1,870	x 2,000 lb/ton x 1 ft/14.75 =	253,559.322	1.35%
8-16' deep, 12"-24"	5,984	x 2,000 lb/ton x 1 ft/43.50 =	275,126.437	1.47%
				92.63%

	Tons Produced in 1981 for 24" Diameter	Multiplication Factors to Convert to Linear Feet	Linear Feet of Pipe Per Submarket	Submarket Share
		DI Submarkets		
>150 psi, 4"-12"[a]	11,969	x 2,000 lb/ton x 1 ft/23.94 =	999,916.458	5.33%
>150 psi, 12"-24"[a]	12,717	x 2,000 lb/ton x 1 ft/78.86 =	322,520.923	1.72%
>16' deep, 4"-12"	224	x 2,000 lb/ton x 1 ft/15.90 =	28,176.101	0.15%
>16' deep, 12-24"	748	x 2,000 lb/ton x 1 ft/46.26 =	32,338.954	0.17%
				7.37%
		Total	18,746,205.379	100.00%

Total market shares held by pressure and non-pressure pipe.

Pressure Pipe : 82.96%
Non-Pressure Pipe: 17.04%

Total market shares of the asbestos-cement replacement market that will be taken by PVC and Ductile Iron Pipe.

PVC Pipe : 92.63%
Ductile Iron Pipe: 7.37%

[a]These are pressure pipe submarkets.

The source for the 1981 tonnage is ICF 1985. The weight per ton came from Attachment, Item 1a.

(2) Calculation of the decline of asbestos-cement shipments, in tons, since 1980, based on Table 4.

All Pipe

(1980-1985)/1980 x 100 = (417,816-243,873)/417,816 x 100 = 42%

Pressure Pipe

(1980-1985)/1980 x 100 = (302,928-218,191)/302,928 x 100 = 28%

Non-pressure Pipe

(1980-1985)/1980 x 100 = (114,888-25,682)/114,888 x 100 = 78%

Source: Association of Asbestos Cement Pipe Producers 1986a.

(3) Prices for asbestos-cement pressure and non-pressure pipe in each submarket

For the 0-150 pressure pipe submarkets an average was taken of Class 100 and 150 pipe.

For the 0-8 feet depth non-pressure pipe submarkets Class 2400 pipe was used.

For the 8-16 feet depth non-pressure pipe submarkets an average of Class 2400 and 3300 were used.

For the >150 psi pressure pipe submarkets an average was taken of Class 150 and 200 pipe (when prices for Class 200 are not available on average of Class 150 is taken), and for >16 feet depth submarkets Class 3300 was used.

Submarkets taken by PVC as determined by Malcolm Pirnie (1983), Sussex Plastics Engineering (1988a) and ICF estimate.

0-150 psi, 4"-12" diameter

	Class 100 ($/ft)	Class 150 ($/ft)	
4"	2.05	2.16	
6"	2.66	3.01	
8"	3.95	4.46	Average for this submarket is $4.46/ft.
10"	4.96	6.51	
12"	6.53	8.30	

0-150 psi, 12"-24" diameter

	Class 100 ($/ft)	Class 150 ($/ft)	
12"	6.53	8.30	
14"	7.92	10.11	
16"	10.14	12.49	
18"	15.31	18.31	Average for this submarket is $15.43/ft.
20"	17.53	22.27	
24"	25.15	31.05	

0-8' deep, 4"-12" diameter

	Class 2400 ($/ft)	
4"	1.15	
6"	1.65	
8"	2.40	Average for this submarket is $2.87/ft.
10"	4.00	
12"	5.15	

0-8' deep, 12"-24" diameter

	Class 2400 ($/ft)	
12"	5.15	
14"	6.21	
15"	8.40	
16"	8.83	Average for this submarket is $11.14/ft.
18"	11.38	
20"	14.11	
21"	14.36	
24"	20.67	

8-16' deep, 4"-12" diameter

	Class 2400 ($/ft)	Class 3300 ($/ft)	
4"	1.15	1.31	
6"	1.65	1.88	
8"	2.40	2.57	Average for this submarket is $3.02/ft.
10"	4.00	4.39	
12"	5.15	5.73	

8-16' deep, 12"-24" diameter

	Class 2400 ($/ft)	Class 3300 ($/ft)	
12"	5.15	5.73	
14"	6.21	7.85	
15"	8.40	9.07	
16"	8.83	9.61	Average for this submarket is $11.62/ft.
18"	11.38	12.38	
20"	14.11	15.39	
21"	14.36	15.80	
24"	20.67	20.96	

Submarkets taken by Ductile Iron (DI) as determined by Malcolm Pirnie (1983), Sussex Plastics Engineering (1988a) and ICF estimate.

≥150 psi, 4"-12" diameter

	Class 150 ($/ft)	Class 200 ($/ft)	
4"	2.16	2.36	
6"	3.01	3.41	
8"	4.46	4.78	Average for this submarket is $5.23/ft.
10"	6.51	7.50	
12"	8.30	9.77	

≥150 psi, 12"-24" diameter

	Class 150 ($/ft)	
12"	8.30	
14"	10.11	
16"	12.49	
18"	18.31	Average for this submarket is $17.09/ft
20"	22.27	
24"	31.05	

≥16' deep, 4"-12" diameter

	Class 3300 ($/ft)	
4"	1.31	
6"	1.88	
8"	2.57	Average for this submarket is $3.18/ft.
10"	4.39	
12"	5.73	

>16' deep, 12"-24" diameter.

	Class 3300 ($/ft)	
12"	5.73	
14"	7.85	
15"	9.07	
16"	9.61	Average for this submarket is $12.10/ft.
18"	12.38	
20"	15.39	
21"	15.80	
24"	20.96	

Source: Certain-Teed 1986c.

(4) Weighted average calculation of F.O.B. plant price for A/C pipe

Submarket	Submarket's Share of Overall PVC Market (by Linear Foot)	x	Price/Foot	=	Submarket's Weighted Price Per Foot
0-150 psi, 4"-12" diameter	0.5952	x	$ 4.46	=	$2.65
0-150 psi, 12"-24" diameter	0.1639	x	$15.43	=	$2.53
0-8' deep, 4"-12" diameter	0.0704	x	$ 2.87	=	$0.20
0-8' deep, 12"-24" diameter	0.0686	x	$11.14	=	$0.76
8-16' deep, 4"-12" diameter	0.0135	x	$ 3.02	=	$0.04
8-16' deep, 12"-24" diameter	0.0147	x	$11.62	=	$0.17
>=50 psi, 4"-12" diameter	0.0533	x	$ 5.23	=	$0.28
>=150 psi, 12"-14" diameter	0.0172	x	$17.09	=	$0.29
>+16' deep, 4"-12" diameter	0.0015	x	$ 3.18	=	$0.00
>+16' deep, 12"-14" diameter	0.0017	x	$12.10	=	$0.02
			Total Weighted Price		$6.94

However, according to Certain-Teed (1986), these prices are 3 percent above plant F.O.B. cost.

Therefore, the actual price is: $6.94/1.03 = $6.74

Source: Certain-Teed 1986, ICF 1985.

(5a) <u>Calculations of PVC Pipe prices for PVC Submarkets</u>
(Source: JM Manufacturing 1986b)

<u>0-150 psi, 4"-12" diameter</u>

	Class 150 ($/ft)	
4"	1.20	
6"	2.20	
8"	3.80	Average for this submarket is $4.19/ft.
10"	5.75	
12"	8.00	

<u>0-150 psi, 4"-12" diameter</u>

See Items 5b and c. Average for this submarket is $17.19.

	Sewer Pipe ($/ft)	
4"	0.45	
6"	1.00	
8"	1.85	Average for this submarket is $2.06/ft.
10"	2.90	
12"	4.10	

<u>0-8' deep, 12"-24" diameter</u>

	Sewer Pipe ($/ft)	
12"	4.10	
15"	5.90	
18"	9.85	Average for this submarket is $10.29/ft.
21"	13.72	
24"	17.87	

<u>8-16' deep, 4"-12" diameter</u>

	Sewer Pipe ($/ft)	
4"	0.45	
6"	1.00	
8"	1.85	Average for this submarket is $2.06/ft.
10"	2.90	
12"	4.10	

8-16' deep, 12"-24" diameter

	Sewer Pipe ($/ft)	
12"	4.10	
15"	5.90	
18"	9.85	Average for this submarket is $10.29/ft.
21"	13.72	
24"	17.87	

(5b) Calculation of 1988 PVC Pipe Prices for Updated PVC Submarkets

0-150 psi, 4"-12" diameter, Water or Pressure Pipe

	Extrusion (DR 18)	JM Manufacturing (DR 18)	Row Average	
4"	$ 1.85	$ 2.00	$ 1.93	
6"	$ 3.50	$ 3.60	$ 3.55	Average price for this
8"	$ 5.90	$ 6.20	$ 6.05	submarket is: $6.68
10"	$ 8.90	$ 9.20	$ 9.05	
12"	$12.60	$13.00	$12.80	

0-150 psi, 12"-24" diameter, Water or Pressure Pipe
(New PVC submarket, formerly a Ductile Iron submarket)

	Extrusion* (DR 18, 25)	JM Manufacturing* (DR 18, 25)	Row Average	
12"	$12.60	$13.00	$12.80	
14"	$12.50	$12.50	$12.50	Average price for this
16"	$16.00	$15.80	$15.90	submarket is: $26.04
18"	$22.10	$19.80	$20.95	
20"	$27.50	$24.40	$25.95	
24"	$39.50	$33.75	$36.63	

* In diameters of 14"-24", DR 25 is the type of pressure pipe usually used. DR 18, which is more expensive and stronger than DR 25, is the type of PVC pipe usually used for diameters of ≤12" (JM Manufacturing 1988).

0-8' deep, 4"-12" diameter, Sewer or Gravity Pipe

	Extrusion	JM Manufacturing	Certain-Teed	Row Average	
4"	$ 0.75	$ 0.75	$ 0.75	$ 0.75	
6"	$ 1.60	$ 1.60	$ 1.50	$ 1.57	Average price for
8"	$ 2.80	$ 2.90	$ 2.75	$ 2.82	this submarket
10"	$ 4.50	$ 4.50	$ 4.30	$ 4.43	is: $3.16
12"	$ 6.20	$ 6.40	$ 6.05	$ 6.22	

0-8' deep, 12"-24" diameter, Sewer or Gravity Pipe

	Extrusion	JM Manufacturing	Certain-Teed	Row Average	
12"	$ 6.20	$ 6.40	$ 6.05	$ 6.22	
15"	$ 9.20	$ 9.50	$ 9.25	$ 9.32	Average price for
18"	$14.50	$15.10	$14.50	$14.70	this submarket
21"	$21.00	$21.00	$19.75	$20.58	is: $15.01
24"	$27.00	$27.45	$25.50	$26.65	

8-16' deep, 4"-12" diameter, Sewer or Gravity Pipe

	Extrusion	JM Manufacturing	Certain-Teed	Row Average	
4"	$ 0.75	$ 0.75	$ 0.75	$ 0.75	
6"	$ 1.60	$ 1.60	$ 1.50	$ 1.57	Average price for
8"	$ 2.80	$ 2.90	$ 2.75	$ 2.82	this submarket
10"	$ 4.50	$ 4.50	$ 4.30	$ 4.43	is: $3.16
12"	$ 6.20	$ 6.40	$ 6.05	$ 6.22	

8-16' deep, 12"-24" diameter, Sewer or Gravity Pipe

	Extrusion	JM Manufacturing	Certain-Teed	Row Average	
12"	$ 6.20	$ 6.40	$ 6.05	$ 6.22	
15"	$ 9.20	$ 9.50	$ 9.25	$ 9.32	Average price for
18"	$14.50	$15.10	$14.50	$14.70	this submarket
21"	$21.00	$21.00	$19.75	$20.58	is: $15.01
24"	$27.00	$27.45	$25.50	$26.65	

(Sources: Extrusion 1988, JM Manufacturing 1988, and Certain-Teed 1988.)

(5c) Calculation of 1986 price of the new PVC submarket (0-150 psi, 12"-24")

The 1988 price of PVC is approximately 51 percent higher than the 1986 price due to a temporary nationwide shortage of resin, one of the primary ingredients in the manufacture of PVC pipe. Because of this temporary increase in price, the 1986 prices of PVC probably are more reflective of the long range price of PVC than are the 1988 prices. In order to determine what the 1986 price of the new PVC submarket (0-150 psi, 12"-24" diameter) would be, an average percent increase in price for all the 1986 submarkets of PVC pipe was calculated and this percent was then subtracted from the 1988 price of the new PVC submarket. These calculations are shown below.

Average Increase from 1986 PVC Prices to 1988 Prices
Taken from 5a and 5b Above

	1986 Price	1988 Price	Percent Increase
0-150 psi, 4"-12" diameter	$ 4.19	$ 6.68	59.31
0-8' deep, 4"-12" diameter	$ 2.06	$ 3.16	53.24
0-8' deep, 12"-24" diameter	$10.29	$15.01	45.87
8-16' deep, 4"-12" diameter	$ 2.06	$ 3.16	53.24
8-16' deep, 12"-24" diameter	$10.29	$15.01	45.87
Average Percent Price Increase			51.50

The price for the new PVC category is a 1988 price and thus reflects the temporary increase due to the resin shortage in the U.S. Deducting this percent increase of 51.50 percent from the 1988 price, we can derive a 1986 price for this new category.

$$\$26.04/1.5150 = \$17.19$$

(6) Calculations of Ductile Iron Pipe Prices ($/ft) for Ductile Iron Submarkets

All prices are for Class 50 pipe, except for the last Ductile Iron submarket. Each average submarket price is derived from the average price for each diameter within the submarket.

≥ 150 psi, 4"-12" diameter

	McWane	U.S. Pipe	Atlantic	Class 50 Average
4"	-	-	4.33	4.33
6"	-	-	4.78	4.78
8"	6.03	6.28	6.58	6.30
10"	-	-	8.70	8.70
12"	10.70	10.61	11.13	10.81

Average for this submarket is $6.98/ft.

≥150 psi, 12"-24" diameter

12"	10.70	10.61	11.13	10.81
14"	-	-	14.45	14.45
16"	15.68	16.28	16.93	16.30
18"	-	-	19.58	19.58
20"	-	-	22.39	22.39
24"	26.06	27.06	28.25	27.12

Average for this submarket is $18.44/ft.

$\geq$ 16' deep, 4"-12" diameter

4"	-	-	4.33	4.33	
6"	-	-	4.78	4.78	Average for this submarket is
8"	6.03	6.28	6.58	6.30	$6.98/ft.
10"	-	-	8.70	8.70	
12"	10.70	10.61	11.13	10.81	

	Class	U.S. Pipe	Atlantic	Class 50 Average	
12"	50	10.61	11.13	10.87	
14"	52	-	16.67	16.67	
16"	52	18.70	19.46	19.08	Average for this submarket is
18"	54	-	25.19	25.19	$22.55/ft.
20"	54	-	28.56	28.56	
24"	54	34.21	35.62	34.92	

Sources: McWane 1986; U.S. Pipe 1986; Atlantic Cast Iron Pipe 1986.

(7) Determination of average prices for PVC and Ductile Iron

Since PVC is 92.63 percent of the substitute market, we must determine a weighted market price.

PVC

Submarket	Submarket's Share of Overall PVC Market (by linear foot)	x	Price/Foot	=	Submarket's Weighted Price ($/ft.)
0-150 psi, 4"-12" diameter	59.52/92.63	x	$ 4.19	=	$2.69
0-150 psi, 12"-24" diameter	16.39/92.63	x	$17.19	=	$3.04
0-8' deep, 4"-12" diameter	7.04/92.63	x	$ 2.06	=	$0.16
0-8' deep, 12"-24" diameter	6.86/92.63	x	$10.29	=	$0.76
8'-16' deep, 4"-12" diameter	1.35/92.63	x	$ 2.06	=	$0.03
8'-16' deep, 12"-24" diameter	1.47/92.63	x	$10.29	=	$0.16
			Total Weighted PVC Price:		$6.84

Since Ductile Iron is 7.37 percent of the substitute market, we must determine a weighted market price.

Ductile Iron (DI)

Submarket	Submarket's Share of Overall DI Market (by linear foot)	x	Price/Foot	=	Submarket's Weighted Price ($/ft.)
>=150 psi, 4"-12" diameter	5.33/7.37	x	$ 6.98	=	$ 5.05
>=150 psi, 12"-24" diameter	1.72/7.37	x	$18.44	=	$ 4.30
>=16' deep, 4"-12" diameter	0.15/7.37	x	$ 6.98	=	$ 0.14
>=16' deep, 12"-24" diameter	0.17/7.37	x	$22.55	=	$ 0.52
			Total Weighted DI Price:		$10.01

(8) Calculations for Installation Costs ($/foot)

Costs are derived using an average of Means 1985 prices for 4"-12" diameter water distribution pipe. Piping excavation and backfill are excluded.

	A/C Pressure (150 psi)	PVC Pressure (Class 150, SDR 18)	DI, Class 250 Water Pipe		
			Mechanical Joint		
				4"	$3.50
				6"	$4.00
				8"	$6.30
4"	$1.68	$2.52		10"	$7.55
6"	$1.74	$2.80		12"	$9.40
8"	$2.34	$4.24			
10"	$2.51	$4.85	Tyson Joint		
12"	$2.71	$6.80		4"	$3.19
				6"	$3.65
				8"	$5.75
				10"	$6.80
				12"	$8.50
Average Total:	$2.20	$4.24	Average Total for Tyson and Mechanical:		$5.86

Source: Means 1985.

(9) Determination of Submarket Share by Weight Based on 1981 Production[a]

Submarket	1981 Tons Produced <=24" Diameter	1981 Market Share by Weight (percent)
PVC		
0-150 psi, 4"-12" diameter	108,843	37.47
0-150 psi, 12"-24" diameter	112,957	38.89
0-8' deep, 4"-12" diameter	8,977	3.09
0-8' deep, 12"-24" diameter	26,182	9.01
8-16' deep, 4"-12" diameter	1,870	0.64
8-16' deep, 12"-24" diameter	5,894	2.06
	264,813	91.16
Ductile Iron (DI)		
>=150 psi, 4"-12" diameter	11,969	4.12
>=150 psi, 12"-24" diameter	12,717	4.38
>=16' deep, 4"-12" diameter	224	0.08
>=16' deep, 12"-24" diameter	748	0.26
	25,658	8.84
Total 1981 Production	290,471	100.00

[a]See text for explanation of why 1981 production data is used.

Source: ICF 1985.

(10) Calculations for conversion of 1985 asbestos-cement pipe production from tons to feet.

216,903 tons of asbestos-cement pipe were produced in 1985 (ICF 1986). According to the Association of Asbestos Cement Pipe Producers (1986a), approximately 16,899,000 feet, or 243,873 tons, of asbestos-cement pressure pipe were shipped in the U.S. in 1985. Dividing tons by feet gives 0.0144 tons/feet of asbestos-cement pressure pipe.[6]

216,903 tons/(0.0144 tons/feet) = 15,062,708 feet of asbestos-cement pipe produced in 1985.

[6] Even though this ratio is derived for pressure pipe, because pressure pipe is about 90 percent of all asbestos-cement pipe shipments, we apply it to our ton figure above, which includes both pressure and non-pressure asbestos-cement pipe. Comparable figures of the length of non-pressure pipe tonnage were not available.

(11) Calculations for product asbestos coefficient for asbestos regulatory cost model.

In 1985, 32,690.7 tons of asbestos were consumed in the production of asbestos-cement pipe (ICF 1986).

32,690.7 tons of asbestos/15,062,708 feet of asbestos-cement pipe
= 0.0022 tons/feet.

(12) Calculations for consumption production ratio for asbestos regulatory cost model.

In 1985, 2790.4065 tons of asbestos-cement pipe were imported into the U.S. (U.S. Dep. Comm 1986). This ton figure is converted to linear feet using the 0.0144 tons/linear foot figure derived previously.

2790.4065 tons/(0.0144 tons/feet)
= 193,778 feet of asbestos-cement pipe were imported in 1985.

The consumption production ratio is:

(domestic production + imports)/(domestic production)
= (15,062,708 + 193,778)/15,062,708
= 1.0129.

REFERENCES

American Concrete Pressure Pipe Association. J. Willet. 1986 (October 15). Vienna, VA. Transcribed telephone conversation with Michael Geschwind, ICF Incorporated, Washington, DC.

American Water Works Association. J. Sullivan. 1986 (July 15). Comments of Jack Sullivan, Deputy Director of AWWA at the Environmental Protection Agency legislative hearing on its asbestos ban and phaseout proposal.

Association of Asbestos Cement Pipe Producers. 1986a (June 29). Written statement of Joseph Jackson, President. In Opening Written Comments of the Asbestos Information Agency/North America and Asbestos Institute. U.S. Environmental Protection Agency. OPTS 62036.

Association of Asbestos Cement Pipe Producers. 1986b (July 15). Testimony of Joseph Jackson, President. Environmental Protection Agency Legislative hearing on its asbestos ban and phaseout proposal.

Atlantic Cast Iron Pipe. F. Tone. 1986 (December 24). Phillipsburg, NJ. Transcribed telephone conversations with Michael Geschwind, ICF Incorporated, Washington, DC.

Bureau of Mines. 1986a. Washington, DC. U.S. Department of the Interior. Mineral Commodity Summaries 1986.

Bureau of Mines. 1986b. Washington, DC. U.S. Department of the Interior. Asbestos, In: 1985 Minerals Yearbook. Volume 1 by Robert Virta. U.S. Government Printing Office. Washington, D.C.

Capco Inc. H. Gunin. 1986a (November 5). Birmingham, AL. Transcribed telephone conversation with Michael Geschwind, ICF Incorporated, Washington, DC.

Capco Inc. Perrell. 1986b (December 23). Birmingham, AL. Transcribed telephone conversation with Michael Geschwind, ICF Incorporated, Washington, DC.

Certain-Teed. A. Baruer. 1986 (December 22). Houston, TX. Transcribed telephone conversation with Michael Geschwind, ICF Incorporated, Washington, DC.

Certain-Teed. J. Junta. 1988 (May 19). Valley Forge, PA. Transcribed telephone conversation with Michael Geschwind, ICF Incorporated, Fairfax, VA.

Ductile Iron Pipe Research Association. M. Wooten. 1986a (October 15). Birmingham, Al. Transcribed telephone conversation with Michael Geschwind, ICF Incorporated, Washington, DC.

Ductile Iron Pipe Research Association. M. Tucker. 1986b (October 20). California, Regional Engineer. Transcribed telephone conversation with Michael Geschwind, ICF Incorporated, Washington, DC.

Extrusion Technologies. J. Edmondson. 1988 (May 19). Warrentown, VA. Transcribed telephone conversation with Michael Geschwind, ICF Incorporated, Fairfax, VA.

ICF Incorporated. 1985. Appendix H. Asbestos Products and Their Substitutes, in Regulatory Impact Analysis of Controls on Asbestos and Asbestos Products. Washington, DC: Office of Pesticides and Toxic Substances, U.S. Environmental Protection Agency.

ICF Incorporated. 1986 (July-December). Survey of Primary and Secondary Processors of Asbestos-Cement Pipe. Washington, DC.

Industrial Minerals. 1986 (April). Certain-Teed in profile: Tackling the asbestos cement dilemma. G. Clarke, editor. London. pp. 68-74.

JM Manufacturing Corporation. A. Gorski. 1986a (December 22). Stockton, CA. Transcribed telephone conversation with Michael Geschwind, ICF Incorporated, Washington, DC.

JM Manufacturing Corporation. Sales Representative. 1986b (November 21). Stockton, CA. Transcribed telephone conversation with Michael Geschwind, ICF Incorporated, Washington, DC.

JM Manufacturing Corporation. F. Marchant. 1988 (May 19). Virginia. Transcribed telephone conversation with Michael Geschwind, ICF Incorporated, Fairfax, Va.

Krusell N.,Cogley D. 1982. GCA Corp. Asbestos Substitute Performance Analysis. Revised Final Report. Washington, DC: Office of Pesticides and Toxic Substances, U.S. Environmental Protection Agency. Contract 68-02-3168.

Malcolm Pirnie, Inc. 1983 (September). Investigation of asbestos-cement pipe in the water and wastewater industry. Paramus, New Jersey: Malcolm Pirnie, Inc.

McWane Pipe Company. S. Simoneaux. 1986 (November 21). Birmingham, AL. Transcribed telephone conversation with Michael Geschwind, ICF Incorporated, Washington, DC.

Means. 1985. Means Building Construction Cost Data 1986. R.S. Means and Company. Kingston, MA. 1985.

Sussex Plastics Engineering, Inc. 1988a (May 13). Survey of Plastic Pipe Products Suitable for Replacement of Asbestos Cement, Pipe. Andover, NJ. Prepared for: ICF Incorporated, Fairfax, Va. 22031.

Sussex Plastics Engineering, Inc. L. Sansone. 1988b (May 19). Andover, NJ. Transcribed telephone conversation with Michael Geschwind, ICF Incorporated, Fairfax, VA.

U.S. Concrete Pipe. K. Tarpinian. 1986 (November 24). Baldwin Park, CA. Transcribed telephone conversation with Michael Geschwind, ICF Incorporated, Washington, DC.

U.S. Dep. Comm. 1986. U.S. Department of Commerce. Consumption of Imports FY 246/1985 Annual. Suitland, MD. Bureau of the Census. U.S. Department of Commerce.

U.S. Industrial Outlook. 1983 (January). Chapter 2, Construction. U.S. Department of Commerce. Washington, DC.

U.S. Industrial Outlook. 1986 (January). Chapter 1, Construction. U.S. Department of Commerce. Washington, DC.

U.S. Pipe and Foundry. C. Kieselhorst. 1986 (November 21). Birmingham, AL. Transcribed telephone conversation with Michael Geschwind, ICF Incorporated, Washington, DC.

U.S. Dep. Comm. 1986. U.S. Department of Commerce. Consumption of Imports FY 246/1985 Annual. Suitland, MD. Bureau of the Census. U.S. Department of Commerce.

U.S. Industrial Outlook. 1983 (January). Chapter 2, Construction. U.S. Department of Commerce. Washington, DC.

U.S. Industrial Outlook. 1986 (January). Chapter 1, Construction. U.S. Department of Commerce. Washington, DC.

U.S. Pipe and Foundry. C. Kieselhorst. 1986 (November 21). Birmingham, AL. Transcribed telephone conversation with Michael Geschwind, ICF Incorporated, Washington, DC.

XV. Asbestos-Cement Flat Sheet

A. Product Description

Asbestos is used as a reinforcing material because of its high tensile strength, flexibility, thermal resistance, chemical inertness, and large aspect ratio (ratio of length to diameter).

Flat asbestos-cement sheet is made from a mixture of Portland cement, asbestos fiber, and silica. Sometimes, an additional fraction of finely ground inert filler and pigment may be included. Asbestos fiber is used to improve the strength, stiffness, and toughness of the material, resulting in a product that is rigid, durable, noncombustible, and resistant to heat, weather, and corrosive chemicals (Krusell and Cogley 1982). In the past, sheets usually contained between 15 and 40 percent asbestos fiber with Portland cement and silica accounting for the rest (ICF 1985). However, Nicolet, the only remaining U.S. producer of asbestos-cement flat sheet has a formulation containing 45.6 percent asbestos (ICF 1986). A significant feature of the asbestos-cement sheet is its wet strength, which enables it to be molded into complex shapes at the end of the production process (Krusell and Cogley 1982).

Asbestos-cement sheets, both flat and corrugated, are manufactured by using a dry, a wet, or a wet-mechanical process. In the dry process, asbestos, cement, and filler are mixed together; the mixture is placed on a flat conveyor belt, sprayed with water, and compressed by steel rolls; the sheet is then cut and autoclaved. The wet process is similar, except water is added to the mixture in the initial stages, forming a slurry. The slurry is then placed on a flat conveyor belt and the excess water is squeezed out by a press. The wet-mechanical process is similar in principal to some papermaking processes: a thin layer of slurry is pumped onto a fine screen from which water is removed; this layer is then transferred onto a conveyor, from which more water is removed by vacuum; more layers are then added, their water removed, and the process continues until the desired thickness is achieved (Krusell and Cogley 1982).

Flat asbestos-cement sheet is used where fire and moisture resistance are required. It is used primarily in the construction industry as wall lining in factories and agricultural buildings, fire-resistant walls, curtain walls, partitions, soffit material (covering the underside of structural components), and decorative paneling in both exterior and interior applications. It is also used in utility applications, such as electrical barrier boards, bus bar run separators, reactance coil partitions, and as a component of vaults, ovens, safes, heaters, and boilers. A second type of flat asbestos-cement sheet being produced domestically is used for laboratory work surfaces, such as table tops and fume hoods liners (Nicolet 1986a and b, Krusell and Cogley 1982). In 1985, approximately 20 percent of flat asbestos-cement sheet production was for laboratory surfaces and 80 percent for construction/utility applications[1] (Nicolet 1986b).

B. Producers and Importers of Flat Asbestos-Cement Sheet

In 1981 there were four producers of flat asbestos-cement sheet: International Building Products, Johns-Manville, Nicolet, and National Gypsum (TSCA 1982). Manville Sales Corporation (formerly Johns-Manville) stopped flat asbestos-cement sheet production in 1985. In 1986, Nicolet is the only remaining U.S. producer although they have temporarily stopped flat asbestos-cement sheet production due to a shortage of orders (ICF 1986).

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[1] Asbestos-cement flat sheet for construction/utility applications can be broken down into two categories: ebonized, or asphalt-impregnated flat asbestos-cement sheet (no longer being produced in the U.S.), once used as a mounting/insulating board for low to medium temperature, high voltage electrical apparatus; and non-ebonized (construction/utility) asbestos-cement sheet, used for low voltage applications with no moisture (Tailored Industries 1986).

There is only one known importer of flat asbestos-cement sheet into the U.S., Atlas International Building Products (AIBP) located in Montreal, Quebec, Canada (Atlas 1986a, b, and c). In 1981, there were four U.S. importers of flat asbestos-cement sheet: R.E. Hebert & Co., Rochester, NY; GII Corporation (now Eternit, Inc.), Reading, PA; Roofing Wholesale Co., Phoenix, AZ; and Tara Wholesale Co., Seattle, WA (ICF 1984). None of these companies currently import flat asbestos-cement sheet (R.E. Hebert & Co. 1986, Eternit 1986b, Roofing Wholesale Co. 1986).

C. Trends

Flat asbestos-cement sheet production volume for 1985 was converted to a 1/2" basis. Manville ceased flat asbestos-cement production in 1985.[2] However, a decline in flat asbestos-cement sheet manufacture during the past five years is very obvious from the figures for fiber consumption during this time. In 1981, 10,766 tons of asbestos fiber were consumed in the production of flat asbestos-cement sheet. This declined to 2,579 tons by 1985, a reduction of 76 percent (ICF 1985, ICF 1986). Even though the raw material mix may have changed a little, it is reasonable to conclude that production of output has decreased in a similar fashion. Nicolet claims that the market for flat asbestos-cement sheet is rapidly declining (Nicolet 1986b).

It is not known how much flat asbestos-cement sheet is imported into the U.S. According to the U.S. Bureau of the Census, imports of asbestos-cement products other than pipe, tubes, and fittings declined by 278 percent from 39,407.3630 tons in 1981 to 10,416.3785 tons in 1985. In 1985, 8,489 tons of this category, or 81.5 percent, came from Canada (U.S. Dep. Comm. 1986a and b). This number most likely includes flat and corrugated asbestos-cement

[2] 1981 production is not directly comparable with 1985 data because a majority of 1981 data was reported in 100 square feet and the remainder (Nicolet's) in tons. In addition, the thickness used as a base for the square footage data was not given in 1981.

sheet and asbestos-cement shingles (Atlas 1986a, Atlas 1986c, Eternit 1986b). It is not known precisely what part is asbestos-cement sheet, however it is believed to be very small (Eternit 1986b). AIBP, which is the only known importer of asbestos-cement flat and corrugated sheet and asbestos-cement shingles into the U.S., estimated that roughly 10 percent of their shipments to the U.S. are flat asbestos-cement sheet (Atlas 1986a). Ten percent of their shipments, or 848.9 tons, converts to about 3,396 squares[3] of 1/2" thick flat asbestos-cement sheet imported into the U.S. in 1985 (see Attachment, Item 2). This estimate is probably low because it does not include some flat asbestos-cement sheet from countries other than Canada, although that quantity is expected to be very small.

D. Substitutes

The following section presents separate discussions of substitutes for flat asbestos-cement construction/utility sheets and laboratory work surface sheets. Table 1 summarizes the product substitutes for flat asbestos-cement construction/utility sheet.

1. Construction/Utility Substitutes

a. Calcium Silicates

Manville Sales Corporation, once the largest producer of flat asbestos-cement sheet, makes a variety of calcium silicate substitutes for flat asbestos-cement sheet. These include: Transite(R) II, Marinite(R), Flexboard(R) II, Colorlith(R) II, Ebony(R) II, and six architectural panels: Stonehenge(R) II, Agean(R) II, Splitwood(R) II, Sandstone(R) II,

[3] Square = 100 square feet.

Table 1. Product Substitutes for Flat Asbestos-Cement Sheet in Construction/Utility Applications

Product/Substitute	Manufacturer	Advantages	Disadvantages	Availability	Source
Flat asbestos-cement sheet	Nicolet Ambler, PA	Can be molded. High thermal resistance. Weather resistance. Chemical resistance. Flexibility.	May crack or bend when impacted.	National	ICF 1984a, ICF 1986
<u>Calcium Silicate Product Substitutes</u>					
Transite(R) II (calcium silicate)	Manville Sales Denver, CO	Colorfastness. Integral color. Freeze/thaw resistance. Accepts paint. Fire retardant. Rust, rot, and corrosion resistant.	Less strength than A/C sheet. Maximum operating temperature, 450°F, is less than A/C sheets. Very brittle.	National	Manville 1986c and 1985a, Coastal GFRC 1986, Western Slate 1986
Flexboard(R) II (calcium silicate)	Manville Sales Denver, CO	Colorfastness. Integral color. Freeze/thaw resistant. Water resistant Resists dents/scratches.	Much less strength than A/C sheet. Maximum operating temperature, 250°F, much less than A/C sheets. Difficult to drill without breakage. Brittle.	National	Manville 1986a, c; Western Slate 1986
Marinite(R) (calcium silicate)	Manville Sales Denver, CO	Greater heat resistance than A/C sheets, 1200-1500°F.	Higher moisture absorbance. Less dense than A/C sheet. Lower strength.	National	Manville 1987, Zircar 1986a.
Efkex(R) and Eterboard(R) (calcium silicate)	Eternit, Inc. Reading, PA	Noncombustible. Water resistant. Higher impact resistance than A/C sheet. High strength/weight ratio. Insect and rot resistant. No painting required for exterior for use.	500°F continuous maximum temperature lower than A/C sheets. Not thicker than 1/4".	National	Eternit 1986a. Eternit 1986b.
Latricrete(R) EP (epoxy primed cement board -- calcium silicate)	Laticrete Int'l Bethany, CT	Fire, weather, and impact resistant. Low moisture absorption. Durable.	Less water resistant than A/C sheet. Less strength than A/C sheet.	National	Laticrete 1986.

Table 1 (Continued)

Product/Substitute	Manufacturer	Advantages	Disadvantages	Availability	Source
<u>Non-Calcium Silicate Product Substitutes</u>					
Ultra-Board(TM) (cement, mica and fibrous glass)	Weyerhaeuser Tacoma, WA (U.S. distributor) TAC Construction Materials, UK (manufacturer, owned by Eternit)	Noncombustible. Frost resistant. Insect/vermin resistant. Flexible. Durable.	Less strength than A/C sheet. Eflex, or Eterboard. Continuous maximum temperature, generally 500°F, lower than A/C sheets.	National	Weyerhaeuser 1985, Eternit 1986a, b
Minerit(R) (cement, cellulose and	Oy Partek Ab Scandanvia (manufacturer) Sanspray Santa Clara, CA (distributor)	Less brittle than A/C sheet. Moisture, rot and corrosion resistant noncombustible.	Less strength than A/C sheet. Less fire resistant than A/C sheet. Loses strength in prolonged soaking. 300°F maximum continuous temperature, lower A/C sheet's.	National	Sanspray 1986a, b
Durock(R) Tile Backer Board (cement and fiberglass mesh)	USG Corp. Chicago, IL	Water resistant. Fire resistant.	Conductive rather than insulative. Less fire resistant than A/C sheet. Interior use only. 3'x5' not standard 4'x8' A/C sheet size.	National	U.S.G. Corporation 1986, Laticrete 1986
Wonderboard(R) (cement and fiberglass mesh)	Modulars, Inc. Hamilton, OH	Water resistant. Fire resistant.	Less fire resistant than A/C sheets. 3'x5' not standard 4'x8' A/C sheet size.	National	U.S.G. Corporation 1986, Laticrete 1986
Glass-Reinforced Cement (GRC) Sheet or Sterling Board	Tailored Industries Pittsburgh, PA and 3-4 other U.S. distributors. Tunnel Building Products Norwich, England (manufacturer)	Superior overall strength. Higher impact resistance. Higher strength/weight ratio. Water impermeable. Rot proof. Accepts paint.	Expensive. Lower service temperature than A/C sheet. If cut, edges may chip. Cement may break down in high corrosion environment.	National	Tunnel Building Products 1986, Cem-Fil Corporation 1986, Krusell and Cogley 1982
Benelex(R) (laminated wood composite)	Masonite Corp. Laurel, MS	Lightweight. Strong. Abrasion resistant surface.	Low maximum service temperature, 195°F. Low weather resistance.	National	Masonite 1986a, b, and n.d.

Table 1 (Continued)

Product/Substitute	Manufacturer	Advantages	Disadvantages	Availability	Source
Glass Polyester (GPO) Sheet	Glastic Co. Cleveland, OH Haxite Co. Erie, PA; and several others	Low moisture absorbance. Better electrical insulator. Less brittle. Continuous operating temperature, 350-550°F, higher than the old ebonized A/C's.	Very expensive.	National	Glastic 1986
Zircar(R) Refractory Sheet (75% alumina, 16% silica, 9% other metal oxides)	Zircar Products Florida, NY	Over twice maximum service temperature of A/C. Greater flexural strength. Shock resistant. Low moisture absorbance. Not brittle. Moldable or rigid form.	Very expensive. Sheets are only 2'x4' in size.	National	Zircar 1986a, b, c
Monolux(R)	Cape Boards and panels UK (producer) WB Arnold & Co. West Caldwell, NJ (U.S. distributor)	Noncombustible. Rigid and inert. Chemical resistant. Water resistant. Greater heat resistance than A/C.	Not Known.	National	ICF 1986a

Klefstone(R)II, and Rentone(R) II (Manville 1985a and b, Manville 1986a and c).[4] Transite(R) II primarily is used in high temperature areas, such as ovens, kilns, induction heaters, and furnaces, insulators, electronic high-temperature resistant plates, as well as in the metallurgy, glassforming and thermosetting industries (Manville 1986c). Other uses include fume hoods, benches, and counter tops (Manville 1985a).

Marinite(R) I, D, C, Metal Mover(R), and Metalform(R) are Manville's higher temperature calcium silicate sheets. They have various architectural uses including fireproofing and structural support protection, as well as uses in press platen insulation applications and metal processing industries (Zircar 1986b and 1986c). Their maximum temperature use ranges from 1200 to 1500°F. They are not used for electrical applications primarily because of their high moisture absorption. Marinite(R) sheets are also not used as a structural support replacements for asbestos-cement sheet because they do not have the strength of either asbestos-cement or Transite(R) II sheets (Zircar 1986b and 1986c).

Flexboard(R) II is used primarily as a building and utility board for exterior and interior walls, partitions, ceilings, and soffits in homes, warehouses, schools and commercial buildings (Manville 1986a). Colorlith(R) II is used in laboratories for table tops, fume hood bases and liners, shelves, and window sills (Manville 1985b and 1986c). Ebony(R) II is recommended for base and mounting panels for electrical equipment (Manville 1985a).

For most of the Manville products mentioned above there have been serious problems. All of Manville's new products, except Marinite(R), have much lower heat resistance than asbestos-cement. While asbestos-cement sheet is rated at

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[4] The II refers to a non-asbestos product, replacing Manville's old asbestos products.

600°F, it has been used successfully temperatures close to 1000°F. Transite II was initially rated at 600°F, but this was reduced to 450°F after customer complaints. Flexboard(R) II can not be used over 250°F (Manville 1986c, Tailored Industries 1986). The second major disadvantage of these Manville products is their brittleness. Transite(R) II and Flexboard(R) II often break during shipping (Western Slate 1986, Tailored Industries 1986).

Eflex(R) and Eterboard(R), made by Eternit, Inc., are, respectively, high and medium-high density, calcium silicate cement boards with several interior and exterior applications. They are used in construction as soffits, fire resistant paneling, ceilings, walls, partitions, and substrates for tile and stone. In industry and laboratories, they are used for fumigation chambers, welding booths, electrical arc barriers, wet areas such as cooling towers, and occasionally for laboratory table tops and fume hoods. They have also been used in agriculture as walls, partitions, and feed bins (Eternit 1986a and 1986b).

Laticrete(R) EP Cement Board is an interior/exterior calcium silicate epoxy primed cement and mineral fiber board which, like the previous two products, is used primarily for tile backing (Laticrete 1986). It is also used for partitions, soffits, balconies, decks, hearth and stove guards, and in agricultural buildings, pens and animal feeders. Though fire, impact, and weather resistant, it does not match asbestos-cement sheet's performance.

b. Non-Calcium Silicates

Ultra-Board(TM) is another direct competitor with Eflex(R) and Eterboard(R) and has similar uses. It comes in four varieties, each with different densities and fire resistances. In construction it is used for interior and exterior partitions, curtain walls, soffits, fascias, tile backer board, laminated paneling, doors and ventilation ducts. Other uses include laboratory furniture, fume hoods, oven linings, welding booths, foundry and molten metal applications, electrical bus bar barriers and swimming pool panels. One variety, Ultra-Board(TM) VC, is a special fire resistant board with a high maximum operating temperature of 1,650°F and is used for lining steel, concrete, and timber beams and columns (Weyerhaueser 1985, Eternit 1986b).

Minerit(R), made from Portland cement, cellulose fibers and marble fillers, was designed as a replacement for flat asbestos-cement sheet and is a competitor with products such as Eflex(R), Eterboard(R), and Ultra-Board(TM). It is used for architectural panels, decorative panels, waste plants, partitions, soffits, fume hood liners, and in agricultural areas for its rot warp and corrosion resistance (Sanspray 1986a and b).

Durock(R) Tile Backer Board and Wonderboard(R) are the primary substitute tile backer boards for use in moist areas such as in bathrooms and kitchens. Both boards are made from cement and vinyl coated fiberglass mesh, while Wonderboard also contains ceramic aggregate. In addition to moisture resistance, both boards have good fire resistance and can be used as stove and oven guards. They do not, however, have the fire or heat resistance of asbestos-cement sheet. Wonderboard(R) can be used for interior or exterior applications, while Durock(R) Tile Backer Board is for interior use only. A new product for exterior use, Durock(R) Exterior Cement Board, was released in October 1986 (U.S.G. Corporation 1986).

While Sterling Board(R) or glass-reinforced cement (GRC) sheet, imported from England, is a substitute that has many properties which are most similar to those of flat asbestos-cement sheet it has not taken the share of the market that was predicted when the board was introduced in the U.S. in the late 1970's (Cem-Fil 1986). Its primary uses are for soffit and fascia panels, fireproof partitions, storage sheds, garages, wall panels, permanent form boards, drywall finishing for steel, masonry and concrete, and even as road signs (ICF 1985). While flat GRC sheet has a very small market in the U.S. due to so many competing products, in Europe, Australia, and Scandanavia flat GRC sheet is very popular (Cem-Fil 1986). For flat GRC sheet to match asbestos-cement's properties requires very expensive alkalai-resistant glass; this cost in addition to large shipping costs (overseas from England) make the product 30 to 40 percent more expensive than flat asbestos-cement sheet (Chem-Fil 1986). Sterling Board currently has a very small share of the flat asbestos-cement sheet replacement market (Cem-Fil 1986, Tunnel Building Products 1986, National Tile Roofing Manufacturers' Association 1986).

Benelex(R), a 100 percent wood composite, is readily available and is used in a range of electrical apparatus,including bus bar barrier boards, switching plates, as well as in non-electrical applications, such as locomotive floors, high performance industrial conveyers, and laboratory surfaces. Approximately 70 percent of its uses are electrical (Masonite 1986a). It competes with GPO and flat asbestos-cement sheet, and has substituted for ebonized asbestos-cement sheet in less critical electrical applications -- those with low voltage, heat, and moisture (Masonite 1986a, Glastic 1986).

Glass polyester (GPO) sheet is used primarily in electrical applications such as switchgear mounting panels and boxes. GPO has already taken most of the replacement market in applications where ebonized asbestos was once used -- critical areas with high voltage and/or low moisture. GPO still competes with non-ebonized asbestos-cement sheet and other substitutes in non-critical areas with lower voltage and without moisture. GPO also replaces flat asbestos-cement sheet and Transite(R) II in press platen applications which require insulators to reduce heat loss from the thermosetting resin mold. According to one manufacturer, GPO is replacing Manville's Transite(R) II and Ebony(R) II because these products are too brittle. One significant disadvantage of GPO is that it is two to three times as costly as other substitutes with similar uses (Glastic 1986).

Zircar(R) Refractory Sheet 100, a ceramic alumina sheet, is abrasion resistant and exceeds asbestos-cement sheet's resistance to heat. It is used in high temperature applications to replace asbestos-cement sheet in oven construction and shelving, induction heating and coil fixtures, electrical terminal blocks, fireproof structural insulation, and molten metal transport. Zircar(R) Refractory sheets are very expensive (Zircar 1986a and b).

Monolux(R) is a noncombustible industrial insulating board used in small ovens and dryers, high temperature ducts, and as insulation in furnaces and kilns (ICF 1985). It is rigid, durable, inert, and resistant to attack by insects and vermin. The board is unaffected by dilute acids and alkalis, brine, chlorine, or volatile solvents. It will not disintegrate, warp, or swell under prolonged immersion in water. Monolux(R) is more resistant to heat than asbestos-cement sheet (Krusell and Cogley 1982).

Other materials such as brick, masonry, wood, stucco, galvanized steel, and aluminum sheet can be used in exterior architectural/building applications. However, they are not major substitutes for flat asbestos-cement sheet (ICF 1985).

In discussions with substitute producers, it appears that there is one flat asbestos-cement construction/utility sheet application for which satisfactory substitutes are not available when one considers cost and/or performance; this application is pizza oven hearths. Some substitute producers claim that the best potential substitutes, Transite(R) II and Zircar(R) Refractory Sheet, are not adequate; Transite(R) II is too brittle and does not have the high temperature capability of asbestos-cement (Western Slate 1986, Tailored Industries 1986), while Zircar(R) Refractory Sheet is very expensive (see Attachment, Item 4). In addition, one substitute sheet manufacturer claims that its largest size, 24 by 48 inches, is too small for an oven hearth (Tailored Industries 1986). According to Zircar(R) Products, however, three pizza oven manufacturers are using Zircar(R) Refractory Sheets in pizza ovens (Zircar 1986b).

i. Cost and Market Shares for Construction/Utility Sheets

The cost for 1/2" thick flat asbestos-cement construction/ utility sheet is $1.81/square foot (see Attachment, Item 3). The average price for substitute flat calcium silicate construction/utility sheet is $1.82/square foot and for flat non-calcium silicate construction/utility sheet is $4.17/square foot (see Attachment, Item 4).

No substitute producers were able to estimate how the current flat asbestos-cement construction/utility sheet market is broken down among its end uses: construction, high temperature, and electrical applications. However, one industry contact estimated that 95 percent of the flat asbestos-cement construction/utility market would be taken over by calcium silicate sheets, with non-calcium silicate sheets taking over the remaining 5 percent (Eternit 1986b).

2. Laboratory Work Surface Substitutes

Substitutes for asbestos-cement laboratory work surfaces, which as previously mentioned represent 20 percent of the flat asbestos-cement sheet market (Nicolet 1986b), are compared in Table 2.

Epoxy resin is the best material for making laboratory table tops. Its market has grown partially because five companies currently produce it whereas in the past there had been only one producer (General Equipment Manufacturers 1986b). Epoxy impregnated sandstone's properties (e.g., chemical resistance and strength) make for a excellent laboratory top, however it is very heavy and must be handled carefully during installation (S. Blickman Inc. 1986). Epoxy impregnated sandstone is made by two companies, Waller Brothers Stone

Table 2. Characteristics of Laboratory Work Tops Made from Asbestos-Cement Sheet and Substitute Products

Property	Asbestos-Cement Sheet	Epoxy Resin	Epoxy Resin Impregnated Sandstone	Colorlith(R) II	Laminated Plastic (Formica)
Chemical Resistance	Very Good	Excellent	Very Good	Excellent	Fair
Heat Resistance	Excellent	Excellent	Very Good	Fair	Fair
Stain Resistance	Good	Excellent	Very Good	Excellent	Good
Moisture Resistance	Good	Excellent	Very Good	Good	Very Good

Sources: Manville 1985b, Manville 1986c, ICF 1984a.

Company and Taylor Stone Company, both in Ohio (Waller Brothers 1986). Fabrication of Colorlith(R) II, a Manville product, into a table top requires much more time and more difficult processing than is required to make flat asbestos-cement sheet into table tops (Western Slate 1986). For example, because of its moisture absorption, one must either bake Colorlith(R) II for a very long time to remove moisture and prevent the later paint coats from blistering, or if one does not bake before painting, it is necessary to resand and repaint if blistering of initial paint coats occurs. In addition, Colorlith(R) II is very brittle and may crack during shipping (Western Slate 1986, General Equipment Manufacturers 1986a). Other laboratory surface products, such as industrial grade formica, plastic laminates, Dupont's Corian(R), and Celotex's Fibertop(R) can substitute for asbestos-cement sheet in biology and general science laboratories, but not in chemistry or industrial laboratories. Furthermore, these products last half as long as other asbestos-cement laboratory table top substitutes (Waller Brothers 1986, General Equipment Manufacturers 1986a and b).

a. Cost and Market Shares for Laboratory Work Surface Sheet

Fabricated asbestos-cement laboratory work surface sheets are approximately $10.50/square foot. Fabricated epoxy resin sheets are the most expensive substitute at $13.50/square foot. Epoxy impregnated sandstone and Colorlith(R) II are both $12.00/square foot. Plastic laminates are about half the price of sandstone, or $6.00/square foot; however, as previously mentioned, plastic laminates cannot be used in corrosive environments and do not last as long as the other substitutes.[5]

[5] Because the prices for laboratory work tops are for fabricated tops and include the extra costs necessary to turn a bare laboratory work sheet into a laboratory table top, they are generally much higher than those for asbestos-cement and substitute construction/utility sheets which require no additional fabrication. For the asbestos regulatory cost model it is necessary to derive a price for laboratory worksheets that is comparable to

Asbestos-cement flat sheet, which held about half of the laboratory work surface market a few years ago (S. Blickman Inc. 1986), now holds about 10 percent of this market. The remainder of this market is currently divided among epoxy resin, 50 percent; sandstone, 25 percent and Colorlith(R) II, 15 percent. It is projected that if asbestos were banned the laboratory work surface market would be broken down as follows: epoxy resin, 60 percent; sandstone, 25 percent (or more); Colorlith(R) II, 10 percent; and plastic laminates and others, 5 percent (or less)[6] (see Attachment, Item 5).

Table 3 presents the data for the asbestos regulatory cost model and summarizes the findings of this analysis (see Attachment, Items 6-8 for calculations).

E. Summary

There are two types of asbestos-cement flat sheet produced domestically; the first type, comprising 80 percent of the market, is used for construction/ utility applications and the second type, used for laboratory work surfaces, accounts for the remaining 20 percent of flat asbestos-cement sheet (Nicolet 1986a, b). Currently, Nicolet is the only remaining domestic producer of flat asbestos-cement sheet and they temporarily stopped production in 1986 due to a shortage of orders (ICF 1985, Nicolet 1986b). Nicolet claims that market is rapidly declining for this product (Nicolet 1986b). Atlas International Building products of Montreal, Quebec, Canada is the only company known to import flat asbestos-cement sheet into the U.S. (Atlas 1986a, b, c).

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the price of asbestos-cement and substitute construction/utility sheets. This weighted average price for all substitute laboratory work sheets is $2.17/square foot (see Attachment, Items 5-6).

[6] The previous breakdown of the substitute market into 95 percent calcium silicates and 5 percent non-calcium silicates for construction/utility sheet applies only to the construction/utility sheet market and not to the laboratory table top market.

Table 3. Data Inputs for Asbestos Regulatory Cost Model[a]

Product	Output (100 sq. ft.)	Product Asbestos Coefficient (tons/100 sq. ft.)	Consumption Production Ratio	Price ($/100 sq. ft.)	Useful Life[b]	Equivalent Price ($/100 sq. ft.)	Market Share	Reference
Asbestos-Cement Flat Sheet	22,621	0.114	1.15	$181.00	25 years	$181.00	N/A	See Attachment
Calcium Silicate Construction/Utility Flat Sheet	N/A	N/A	N/A	$182.00	25 years	$182.00	76%	See Attachment
Non-Calcium Silicate Construction/Utility Flat Sheet	N/A	N/A	N/A	$417.00	25 years	$417.00	4%	See Attachment
Substitute Laboratory Work Sheet	N/A	N/A	N/A	$217.00	25 years	$217.00	20%	See Attachment

N/A: Not Applicable.

[a] See Attachment, Items 1-8 for sources and calculations.

[b] ICF 1985. The useful life of substitutes varies depending on the application, but for the same application flat asbestos-cement sheet and its substitutes will have approximately the same useful life.

Although there is no single substitute that can replace flat asbestos-cement sheet in all of its applications, there are substitutes available for each specific application. One industry contact estimated that the flat asbestos-cement construction/utility market would be 95 percent calcium silicates costing just slightly more than the asbestos product and 5 percent non-calcium silicates which are more than twice the price of flat asbestos-cement sheets. The three major substitutes for laboratory work surface flat asbestos-cement sheet -- epoxy resin, sandstone, and Colorlith(R) II -- are 15-30 percent more expensive than the asbestos product.

ATTACHMENT

(1) Methodology for determining Nicolet's and Manville's production of flat asbestos-cement sheet and converting it to a 1/2" basis.

This calculation is based on confidential business information.

(2) Calculation of imports of flat asbestos-cement sheet.

10,416.3785 tons of asbestos-cement flat and corrugated sheet and asbestos-cement shingles were imported into the U.S. in 1985. 81.5 percent, or 8,489 tons, of this figure is from Canada. Atlas International Building Products (AIBP), the only importer of these products from Canada estimates that 10 percent of their imports is asbestos-cement flat sheet (Atlas 1986a). Ten percent equals 848.93 tons of 1,697,869.70 lb. of flat asbestos-cement sheet.

Using Nicolet's weight for 1/2" thick sheet of 5 lb./square foot:

> 1,697,869.70 lb. of flat asbestos-cement sheet/(170 lb./34.03 square feet or 5 lb./square foot) = 339,573.94 square feet or 3,395.74 squares of asbestos-cement flat sheet imported into the U.S. in 1985.

This estimate may be low because it does not include the 18.5 percent of asbestos-cement products other than pipe, tubes, and fittings imported from countries other than Canada. Imports from these other countries may possibly include some flat asbestos-cement sheet (U.S. Dep. Comm. 1986a and b).

(3) Calculation of cost of asbestos-cement construction/utility sheet.

This calculation is based on confidential business information.

(4) Calculation of cost of substitutes for flat asbestos-cement construction/utility sheet.

Flat Sheet Product	Thickness	F.O.B. Plant Price/ Thickness	Comments	Source
Asbestos-Cement Sheet	1/2"	$1.81		Nicolet 1986a
Calcium Silicates				
Transite(R) II	1/2"	$2.08	15% more expensive than asbestos-cement sheet	Manville 1986c
Flexboard(R) II	1/2"	$2.08	15% more expensive than asbestos-cement sheet	Manville 1986c
Marinite(R) I	1/2"	$3.00		Manville 1987
Eflex(R)	1/4"	$1.25	Thickest is 1/4"	Eternit 1986c
Eterboard(R)	1/4"	$0.90	Thickest is 1/4"	Eternit 1986c
Laticrete(R) EP	1/2"	$1.60		Laticrete 1986

Flat Sheet Product	Thickness	F.O.B. Plant Price/ Thickness	Comments	Source
Non-Calcium Silicates				
Ultra-board(TM)	1/2"	$0.90		Eternit 1986b, Weyerhaeuser 1986
Miniret(R)	1/2"	$1.65		Wiley-Baley 1986
Durock(R)	1/2"	$0.65		U.S.G. Crop. 1986
Wonderboard(R)	1/2"	$0.65		Modulars 1986
GRC	1/2"	$2.44	35% more expensive than asbestos-cement sheet	Cem-Fil 1986
Benelex(R)	1/2"	$1.65		Masonite 1986b
GPO (fiberglass reinforced polyester)	1/2"	$5.43	3 times more expensive than asbestos-cement sheet	R.E. Hebert & Co. 1986
Zircar(R) Refractory	1/2"	$20.00		Zircar 1986a

It is estimated that 95 percent of the flat asbestos-cement construction/ utility market would be taken over by calcium silicates and the remaining 5 percent by non-calcium silicates (Eternit 1986). The average price for calcium silicates is $1.82/square foot while the average price for non-calcium silicates is $4.17/square foot.

(5) Sources used to determine market shares and prices for laboratory work surfaces.

	Share	Sources
	Current Market Shares	
Asbestos-Cement	10%	Waller Brothers 1986
Epoxy Resin	50%	General Equipment Manufacturers 1986b, Waller Brothers 1986, S. Blickman Inc. 1986, Laboratory Services 1986
Sandstone	25%	General Equipment Manufacturers 1986b, Waller Brothers 1986
Colorlith(R) II	15%	Waller Brothers 1986
Plastic	--	-
	Projected Market Shares	
Epoxy Resin	60%	S. Blickman Inc. 1986, General Equipment Manufacturers 1986b, Waller Brothers 1986, Laboratory Services 1986
Sandstone	25% or more	Waller Brothers
Colorlith(R) II	10%	General Equipment Manufacturers 1986b, Waller Brothers 1986
Plastic laminates and others	5% or less	Waller Brothers 1986, Laboratory Services 1986

Prices for fabricated laboratory tops are based on the following sources:

	Price (sq. ft.)	Sources
Asbestos-Cement	$10.50	Waller Brothers 1986, S. Blickman Inc. 1986
Epoxy Resin	$13.50	Waller Brothers 1986, S. Blickman Inc. 1986, General Equipment Manufacturers 1986b, Western Slate 1986
Sandstone	$12.00	Waller Brothers 1986, S. Blickman Inc. 1986, General Equipment Manufacturers 1986
Colorlith(R) II	$12.00	Waller Brothers 1986; S. Blickman Inc. 1986, Western Slate 1986
Plastic laminates and others	$ 6.00	General Equipment Manufacturers 1986b

(6) Calculating to determine weighted average cost of substitutes for flat asbestos-cement laboratory work sheets to be used in asbestos regulatory cost model.

Prices for asbestos-cement laboratory work sheets and its substitutes are end-product prices. Therefore, in order to determine a price for substitute work sheets that can be compared to the prices for asbestos-cement and substitute construction/utility sheets (raw product) for the asbestos regulatory cost model, the following methodology is used.

A weighted average price based on projected market share is determined by multiplying each substitute by its projected market share as shown on the previous page.

0.60 ($13.50) + 0.25 ($12.00) + 0.10 ($12.00) + 0.05 ($6.00) = $12.60. This is the average cost for substitute laboratory table tops.

Next we determine the ratio of weighted average substitute cost to the asbestos-cement laboratory table top cost.

$12.60/$10.50 = 1.2

This factor is multiplied by the cost for flat asbestos-cement construction/utility sheets ($1.81/square foot) to derive a price for fabricated laboratory top sheets that is comparable to the cost of construction/utility asbestos-cement substitute sheets, and can thus be used in the asbestos regulatory cost model.

1.2 x (cost of flat asbestos-cement construction/utility sheet)
= 1.2 x $1.81/square foot = $2.17/square foot
or $217 square.

(7) Calculations for consumption-production ratio for asbestos regulatory cost model.

Domestic production of flat asbestos-cement sheet = 22,621 squares
Imports of flat asbestos-cement sheet = 3,396 squares

As stated in the text and Attachment, Item 2, this import amount is probably low.

(Domestic production + imports)/domestic production
= 26,017 squares/22,621 squares
= 1.15.

(8) Calculation of product asbestos coefficient for flat asbestos-cement sheet.

Tons of asbestos used/squares of flat asbestos-cement sheet produced.

= 2,578.8 tons/22,621 squares
= 0.114 tons/square.

REFERENCES

Atlas International Building Products. R. Cadieux. 1986a (October 2 and December 17). Montreal, Quebec, Canada. Transcribed telephone conversations with Michael Geschwind, ICF Incorporated, Washington, DC.

Atlas International Building Products. T. Eames. 1986b (November 6). Port Newark, NJ. Transcribed telephone conversation with Michael Geschwind, ICF Incorporated, Washington, DC.

Atlas International Building Products. J. Payac. 1986c (November 25). Montreal, Quebec, Canada. Transcribed telephone conversation with Michael Geschwind, ICF Incorporated, Washington, DC.

Cem-Fil Corporation. R. Cook. 1986 (November 3 and 6). Atlanta, GA. Division of Pilkington Corporation. Transcribed telephone conversation with Michael Geschwind, ICF Incorporated, Washington, DC.

Coastal GFRC, Inc. B. Horsley. 1986 (November 3). Hooksett, NH. Transcribed telephone conversation with Michael Geschwind, ICF Incorporated, Washington, DC.

Eternit, Inc. 1986a (September). Reading, PA. Product literature on Eflex(R) and Eterboard(R) fiber reinforced cement panels.

Eternit, Inc. B. Morrissey. 1986b (October 27 and November 4). Reading, PA. Transcribed telephone conversations with Michael Geschwind, ICF Incorporated, Washington, DC.

General Equipment Manufacturers. D. Klein. 1986a (November 18). Crystal Springs, MT. Transcribed telephone conversation with Michael Geschwind, ICF Incorporated, Washington, DC.

General Equipment Manufacturers. B. Errington. 1986b (November 18). Crystal Springs, MT. Transcribed telephone conversation with Michael Geschwind, ICF Incorporated, Washington, DC.

Glastic Company. P. Leslie. 1986 (November 20). Cleveland, OH. Transcribed telephone conversation with Michael Geschwind, ICF Incorporated, Washington, DC.

ICF Incorporated. 1984. Imports of Asbestos Mixtures and Products. Washington, DC: Office of Pesticides and Toxic Substances, U.S. Environmental Protection Agency. EPA CBI Document Control No. 20-8600681.

ICF Incorporated. 1985. Appendix H: Asbestos products and their substitutes, in Regulatory Analysis of Controls on Asbestos and Asbestos Products. Washington, DC: Office of Pesticides and Toxic Substances, U.S. Environmental Protection Agency.

ICF Incorporated. 1986 (July-December). Survey of Primary and Secondary Processors of Asbestos-Cement Flat Sheet. Washington, DC.

Krusell N., Cogley D. 1982. GCA Corp. Asbestos substitute performance analysis: revised final report. Washington, DC: Office of Pesticides and Toxic substances. U.S. Environmental Protection Agency Contract 68-02-3168.

Laboratories Service, Inc. M. Kloosterman. 1986 (November 17) Plymouth, MI. Division of Durcon. Transcribed telephone conversation with Michael Geschwind, ICF Incorporated, Washington, DC.

Laticrete International, Inc. T. McKeon. 1986 (November 6) Bethany, CT. Transcribed telephone conversation with Michael Geschwind, ICF Incorporated, Washington, DC.

Manville Sales Corporation. 1985a (May). Denver, CO. Product literature on Transite(R) II non-asbestos industrial board, Ebony(R) II non-asbestos electrical panel board.

Manville Sales Corporation. 1985b (August). Denver, CO. Product literature on Colorlith(R) II laboratory work tops.

Manville Sales Corporation. 1986a (January and May). Denver, CO. Product literature on Flexboard(R) II non-asbestos fiber cement board and non-asbestos architectural boards.

Manville Sales Corporation. K. Hart. 1986b (October 28). Denver, CO. Transcribed telephone conversation with Michael Geschwind, ICF Incorporated, Washington, DC.

Manville Sales Corporation. T. Kroll. 1986c (October 28). Denver, CO. Transcribed telephone conversation with Michael Geschwind, ICF Incorporated, Washington, DC.

Manville Sales Corporation. D. Filarowicz. 1987 (January 5). Transcribed telephone conversation with Michael Geschwind, ICF Incorporated, Washington, DC.

Masonite Corporation. D. Pelligrini. 1986a (November 3). Chicago, IL. Transcribed telephone conversation with Michael Geschwind, ICF Incorporated, Washington, DC.

Masonite Corporation. F. Pickering. 1986b (December 2). Laurel, MS. Transcribed telephone conversation with Michael Geschwind, ICF Incorporated, Washington, DC.

Masonite Corporation. (n.d.). Chicago, IL. Product literature on Benelex(R) 402 Industrial Laminate Electrical Insulation.

Modulars, Inc. P. Dinkle. 1986 (November 24). Hamilton, OH. Transcribed telephone conversation with Michael Geschwind, ICF Incorporated, Washington, DC.

National Tile Roofing Manufacturer's Association. W. Pruter. 1986 (November 13). Los Angeles, CA. 90039. Transcribed telephone conversation with Michael Geschwind, ICF Incorporated, Washington, DC.

Nicolet, Inc. 1986a (April). Product literature MM30-1 and MM33-1 and Price Lists on Monobestos(R) Board and Kolormate(R). Nicolet, Inc. Ambler, PA.

Nicolet, Inc. B. McNamara. 1986b (November 26). Ambler, PA. Transcribed telephone conversation with Michael Geschwind, ICF Incorporated, Washington, DC.

R.E. Hebert & Co. D. Popeil. 1986 (November 6). Rochester, NY. Transcribed telephone conversation with Michael Geschwind, ICF Incorporated, Washington, DC.

Roofing Wholesale Co., Inc. J. Pierzchalski. 1986 (October 24). Phoenix, AZ. Transcribed telephone conversation with Michael Geschwind, ICF Incorporated, Washington, DC.

Sanspray Corporation. 1986a. Santa Clara, CA. Product literature on Minerit(R): asbestos-free non-combustible cement board.

Sanspray Corporation. B. McClenahan. 1986b (November 6). Santa Clara, CA. Transcribed telephone conversation with Michael Geschwind, ICF Incorporated, Washington, DC.

S. Blickman, Inc. B. Stanton. 1986 (November 17). Butler, NJ. Transcribed telephone conversation with Michael Geschwind, ICF Incorporated, Washington, DC.

Tailored Industries. H. Morse. 1986 (November 20). Pittsburgh, PA. Transcribed telephone conversation with Michael Geschwind, ICF Incorporated, Washington, DC.

TSCA Section 8(a) submission. 1982. Primary Data for Primary Asbestos Processors, 1981. Washington, DC: Office of Pesticides and Toxic Substances, U.S. Environmental Protection Agency. EPA Document Control No. 20-8601012.

Tunnel Building Products. G. Bridge. 1986 (November 6). Norwich, Cheshire, U.K. Division of Pilkington. Transcribed telephone conversation with Michael Geschwind, ICF Incorporated, Washington, DC.

U.S. Dep. Comm. 1986a. U.S. Department of Commerce. Consumption of Imports FY 246/1985 Annual. Suitland, MD. Bureau of the Census. U.S. Department of Commerce.

U.S. Dep. Comm. P. Confer. 1986b. Suitland, MD. U.S. Department of Commerce. Division of Minerals and Metals. Bureau of the Census. Transcribed telephone conversation with Michael Geschwind, ICF Incorporated, Washington, DC.

U.S.G. Corporation. D. Sardelli. 1986 (November 20). Stamford, CT. Transcribed telephone conversation with Michael Geschwind, ICF Incorporated, Washington, DC.

Waller Brothers Stone Company. F. Waller. 1986 (November 19). McDermoth, OH. Transcribed telephone conversation with Michael Geschwind, ICF Incorporated, Washington, DC.

Western Slate Company. B. Astrene. 1986 (September 22 and November 4). Elmhurst, IL. Transcribed telephone conversations with Michael Geschwind, ICF Incorporated, Washington, DC.

Weyerhaeuser. 1985 (August). Tacoma, WA. Product literature No. UB-A185 on Ultraboard(TM).

Wiley-Baley, Inc. D. Duff. 1986 (November 24). Seattle, WA. Transcribed telephone conversation with Michael Geschwind, ICF Incorporated, Washington, DC.

Zircar Products, Inc. 1986a (April). Florida, NY. Price list and product literature on high temperature thermal insulation refractory sheets and Refractory Sheet Competitive Product Comparison literature.

Zircar Products, Inc. J. Ritter. 1986b (November 3). Florida, NY. Transcribed telephone conversation with Michael Geschwind, ICF Incorporated, Washington, DC.

Zircar Products, Inc. D. Hamling. 1986c (December 2). Florida, NY. Transcribed telephone conversation with Michael Geschwind, ICF Incorporated, Washington, DC.

XVI. CORRUGATED ASBESTOS-CEMENT SHEET

A. Product Description

Asbestos-cement corrugated sheet is made from a mixture of Portland cement and asbestos fiber. An additional fraction of finely ground inert filler and pigments is sometimes included (Krusell and Cogley 1982). In general, sheets contain between 15 and 40 percent asbestos fiber, although, for curing in short time periods, a general formulation of 12 to 25 percent asbestos, 45 to 54 percent cement, and 30 to 40 percent silica is used (Cogley 1980).

Asbestos-cement corrugated sheet is manufactured by using a dry, wet, or wet-mechanical process. In the dry process, asbestos, cement, and filler are mixed together. This mixture is placed on a flat conveyer, sprayed with water, and compressed by steel rolls. The sheet is then cut and autoclaved. The wet process is similar, except water is added to the mixture in the initial stages forming a slurry. The slurry is then placed on a flat conveyer and the excess water is squeezed out by a press. The wet-mechanical process is similar in principal to some papermaking processes. This process begins similarly to the wet process, however, a thin layer of slurry is pumped onto a fine screen from which water is removed. This layer is then transferred onto a conveyor, from which more water is removed by vacuum. More layers are then added, water removed, and the process continues until the desired thickness is achieved (Krusell and Cogley 1982).

Asbestos is used as a reinforcing material in cement sheet products because of its high tensile strength, flexibility, thermal resistance, chemical inertness, and large aspect ratio (ratio of length to diameter). Cement sheet becomes strong, stiff, and tough when asbestos fiber is added, resulting in a product that is stable, rigid, durable, noncombustible, and resistant to heat, weather, and corrosive chemicals (Krusell and Cogley 1982).

Corrugated asbestos-cement sheet has been used historically in industrial and agricultural applications, serving as siding and roofing in factories, warehouses, and agricultural buildings (Krusell and Cogley 1982; Atlas 1986a). It has also been used as a lining for waterways, such as water slides in amusement parks and bulkheads in canals or to keep water away from coastal homes, and for special applications in cooling towers (Krusell and Cogley 1982; Atlas International Building Products 1986 a and b). The present applications of corrugated asbestos-cement sheet are limited to the replacement market in the U.S., primarily because of the availability of good substitutes. Approximately 85 percent of the replacement market is for general construction in chemical, potash, paper, ammunition, and other industries; about 10 percent is used for replacement in waterways, and 5 percent for replacement in cooling towers (Atlas 1986a and b).

B. Producers and Importers of Corrugated Asbestos-Cement Sheet

Corrugated asbestos-cement sheet is no longer being produced in the U.S. The last company to produce corrugated asbestos-cement sheet, International Building Products, Inc. in New Orleans, Louisiana, closed in March 1986 (ICF 1985 and 1986; Atlas 1986a).

Currently, the only company known to import corrugated asbestos-cement sheet into the U.S. is Atlas International Building Products, Inc. (AIBP) of Montreal, Canada (Coastal GFRC 1986). Atlas of Canada bought International Building Products' equipment when they went out of business and created Atlas International Building Products, the U.S. sales division of Atlas. International Building Products had been one of Atlas' main competitors. AIBP has no plants in the U.S. and ships directly to its U.S. customers (Atlas 1986a and b). Their only U.S. sales representative is in Port Newark, NJ and is believed to be affiliated with the Port Newark Refrigerated Warehouse (Eternit 1986, Atlas 1986b). It is not known precisely when International Buildings

Products stopped production of corrugated asbestos-cement sheet or if any was produced in 1985.

C. Trends

It is not known how much corrugated A/C sheet was imported into the U.S. in 1985. According to the U.S. Bureau of the Census 10,416.3785 tons of A/C products other than pipe, tubes, and fittings were imported in 1985, of which 8,489 tons, or 81.5 percent came from Canada (U.S. Dep. Comm. 1986a, 1986b). This number most likely includes flat and corrugated asbestos-cement sheet and asbestos-cement shingles (Atlas 1986a, 1986c, Eternit 1986). AIBP, which is the only known importer of A/C flat and corrugated sheet and A/C shingles into the U.S., estimated that roughly 10 percent of their shipments to the U.S. are corrugated asbestos-cement sheet (Atlas 1986a). Ten percent of their shipments, 848.9 tons, converts to about 38,59[1] squares of 3/8" thick corrugated asbestos-cement sheet imported into the U.S. in 1985 (see Attachment, Item 1). This estimate is probably low because it does not include some flat asbestos-cement sheet from other countries, although that quantity is expected to be very small.

D. Substitutes

Table 1 presents a list of product substitutes for corrugated asbestos-cement sheet, as well as their advantages and disadvantages. Fiberglass reinforced plastic (FRP) corrugated sheet is a lightweight, corrosion resistant, and strong product which comes in four basic varieties: fire resistant translucent, non-fire resistant translucent, fire resistant opaque, and non-fire resistant opaque. The fire resistant varieties are the best FRP substitutes for asbestos-cement corrugated sheet (Resolite 1986a and b, Sequentia 1986). FRP corrugated panels are used primarily for industrial and

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[1] Square = 100 square feet.

Table 1. Product Substitutes for Corrugated Asbestos-Cement Sheet

Product Substitute	Manufacturer	Advantages	Disadvantages	Availability	References
Corrugated A/C Sheet	Imported from Atlas International Building Products Montreal, Canada	Can be molded. High thermal resistance. Weather resistance. Chemical resistance. Flexibility.	Brittle. Cracks or bends when impacted. Heavy. Expensive to install.	National	Krusell and Cogley 1982, ICF 1984, H&F Manufacturing 1986a
Substitutes					
FRP Corrugated Sheet	Resolite Zelionople, PA Sequentia Cleveland, OH Lasco, Inc. Anahiem, CA Filon Division Hawthorne, CA and many others	Corrosion and chemical resistance. Not as noisy as aluminum. Lightweight. Can be colored easily. Translucent or opaque. Many colors. Durable. High strength/shatterproof. Easy to install. Can be cut easily.	Not as temperature resistant as A/C sheet. Combustible at 700-900°F. Not recommended for continuous use above 200°F. More flexible than A/C sheet and thus needs more support.	National	Resolite 1986a, b; Sequentia 1984, 1986; ICF 1984
PVC Corrugated Sheet	H&F Manufacturing Feasterville, PA and many others	Not brittle. More impact resistant. Doesn't absorb moisture. Water repellant and weather resistant. Easier to handle. Lighter. Broad chemical resistance. Corrosion resistance. Available in longer lengths than A/C sheet. Several colors available. Non-combustible.	More expensive than other substitutes. Thermoplastic -- loses strength at 165°F.	National	H&F Manufacturing 1986a, b
Aluminum Corrugated Sheet	Corrugated Metals, Inc. Jersey City, NJ Reynolds Eastman, GA and several others	Lighter than A/C sheet. Available in large sheets. Doesn't crack. Less expensive than other substitutes.	Weak in corrosive environment. Can be noisy. Conducts electricity.	National	Corrugated Metals, Inc. 1986a, ICF 1984
Steel Corrugated Panel	Corrugated Metals, Inc. Jersey City, NJ Reynolds Eastman, GA and several others	Can stand more force. Available in wide range of thicknesses. Lighter than A/C, but heavier than other substitutes.	May rust. Very weak in corrosive environment. Conducts electricity.	National	Corrugated Metals, Inc. 1986a, ICF 1984

wastewater purposes. They are used in factories, chemical plants, mining operations, cooling towers, or in any area where strong corrosion resistance and/or light transmission is desired (Resolite 1986a and b, Sequentia 1986). About 95 percent of all cooling towers were once clad with corrugated asbestos-cement sheet, however, today nearly 100 percent are clad with corrugated FRP sheet. Corrugated FRP sheet is not generally used for waterways (Resolite 1986b). The Resolite division of H.H. Robertson makes a high strength FRP product called Tred-Safe(R), which is strong and rigid enough to walk on (Resolite 1986a).

A second substitute for asbestos-cement corrugated sheet is corrugated polyvinyl chloride (PVC) sheet for roofing and siding. Corrugated PVC panels are used in chemical plants, pulp and paper manufacturing plants, oil refineries, steel mills, horticulture and industrial process buildings, warehouses, enclosures, compressor houses, as cooling tower siding and louvers, and in other areas (H&F Manufacturing 1986a and b). Both PVC and FRP are available in the same 4.2" pitch corrugation as asbestos-cement corrugated sheet.

Aluminum siding and roofing is a third substitute for corrugated asbestos-cement sheet, with a relatively wide range of applications. Aluminum corrugated sheet is used in pulp and paper mills, but not in environments with sulfuric acid or phosphates (Reynolds 1986). Aluminum and other metal-based products, such as steel paneling, are not appropriate in most highly corrosive environments. However, both steel and aluminum are used for waterways and bulkheads (Alpha Marine 1986; Reynolds 1986).

Corrugated Sterling Board(R) (corrugated glass-reinforced cement (GRC) sheet, made in England) is one of the substitutes with properties most similar to those of corrugated asbestos-cement sheet, but it has not taken the share of the market that was once predicted when it was introduced in the U.S. in the early 1980's. The major reason for this lack of popularity is its high cost (about 30-40 percent higher than other corrugated products). It continues to be popular in Europe and Scandanavia, primarily because of less competition (Cem-Fil 1986).

Table 2 compares the costs of various corrugated asbestos-cement sheet substitutes. Aluminum and galvanized steel are the least expensive substitutes and are about two-thirds the cost of PVC corrugated sheet. The service life for FRP and PVC is a minimum of 20 years. They may last longer, however, they only have been on the market for about 20 years (H&F Manufacturing 1986b). Galvanized steel sheet can last from 10 to 20 years, depending on the environment in which it is used (H&F Manufacturing 1986b, Corrugated Metals, Inc. 1986b). Maintenance costs are essentially zero for all products. FRP may not be appropriate for certain heavy duty uses because it is more flexible than other substitutes and may require extra support (Resolite 1986b). Aluminum siding is the least expensive of any substitute. Steel paneling, while less expensive than PVC or FRP corrugated sheet siding, is much heavier and less corrosion resistant and therefore has restricted applications.

As previously mentioned, corrugated asbestos-cement sheet is now primarily being used in the small replacement market. Estimating the possible market share for the substitutes if corrugated asbestos-cement sheet were unavailable is difficult because each substitute has many applications. In general, these products could substitute for corrugated asbestos-cement sheet in its three major kinds of applications: (1) roofing and siding on industrial and commercial structures; (2) specialty applications in cooling towers; and (3) waterway liners and bulkheads. In general construction, the replacement market for corrugated asbestos-cement sheet will be 45 percent FRP, 35 percent aluminum, 10 percent PVC, and 10 percent galvanized steel (Reynolds 1986;

Table 2. Costs for Corrugated Sheet Siding[a]

	Asbestos-Cement	FRP	PVC	Aluminum	Galvanized Steel
F.O.B. Cost ($/100 sq. ft.)	170[b]	173[c]	230[d]	105[e]	75[e]
Installation Cost[f] ($/100 sq. ft.)	107	73	71	83	82
Total Cost ($/100 sq. ft.)	277	246	301	188	157
Operating Life (years)	30[g]	20[g]	20[g]	20[h]	15[h]
Present Value ($/100 sq. ft.)	277	303	371	232	233

[a]See Attachment, Items 2-6 for calculations.

[b]Atlas 1986a.

[c]Sequentia 1984; Resolite 1986a.

[d]H&F Manufacturing 1986a.

[e]Corrugated Metals, Inc. 1986a; Reynolds 1986.

[f]Means 1986. Installation costs are for siding on a steel frame.

[g]ICF 1984.

[h]Corrugated Metals, Inc. 1986a.

Interstate Contractors 1986). About 95 percent of new cooling tower cladding is corrugated FRP sheet, with the remaining 5 percent of this market being taken by PVC (Sequentia 1986; H&F Manufacturing 1986b). The waterways and bulkhead market will probably be evenly divided between aluminum and coated steel (Alpha Marine 1986; Reynolds 1986). Because the asbestos-cement corrugated sheet market is 85 percent general construction, 10 percent cooling tower exteriors and 5 percent waterways and bulkheads (Atlas 1986a), the overall replacement market will probably breakdown as follows (see Attachment, Item 8):

Substitute Product	Projected Market Share (Percent)
FRP	48
Aluminum	32
Steel	11
PVC	9

Table 3 presents the data for the asbestos regulatory cost model and summarizes the findings of this analysis (see Attachment, Items 7-10).

E. Summary

Currently, the applications of asbestos-cement corrugated sheet in the U.S. are limited to the replacement market, primarily due to the availability of adequate substitutes. This replacement market is approximately 85 percent general construction, 10 percent waterways and 5 percent in cooling towers. Asbestos-cement corrugated sheet is no longer produced in the U.S. The only known importer is Atlas International Building Products in Montreal, Quebec, Canada (Atlas 1986a, Atlas 1986c).

The four substitutes and their projected market shares are Fiberglass-reinforced plastic, 48 percent, aluminum, 32 percent; steel, 11 percent; and

Table 3. Data Inputs for Asbestos Regulatory Cost Model

Product	Imports (3/8" thick, 100 sq. ft.)	Product Asbestos Coefficient	Consumption Production Ratio	Price ($/100 sq. ft.)	Useful Life	Equivalent Price ($/100 sq. ft.)	Market Share	Reference
Asbestos-Cement Corrugated Sheet	3,859[a]	0.0855[b]	Infinity[c]	277.00	30 years	277.00	N/A	See Attachment
FRP	N/A	N/A	N/A	246.00	20 years	288.15	48%	See Attachment
Aluminum	N/A	N/A	N/A	188.00	20 years	220.21	32%	See Attachment
Steel	N/A	N/A	N/A	157.00	15 years	213.90	11%	See Attachment
PVC	N/A	N/A	N/A	301.00	20 years	352.57	9%	See Attachment

N/A: Not Applicable.

[a]See Attachment, Item 1.

[b]See Attachment, Item 9.

[c]See Attachment, Item 10.

polyvinyl chloride, 9 percent. Aluminum and steel are 19 percent less expensive than imported asbestos-cement corrugated sheet, while FRP is 9 percent and PVC is 34 percent more expensive than imported asbestos-cement corrugated sheet.

ATTACHMENT

(1) Calculation of corrugated asbestos-cement sheet imported into the U.S.

10,416.7785 tons of flat and corrugated asbestos-cement sheet and asbestos-cement shingles were imported into the U.S. in 1985. Of this amount, 8,489 tons, or 81.5 percent, came from Canada. AIBP, the only importer of these products from Canada roughly estimated that 10 percent of their imports were corrugated sheet (Atlas 1986a). This equals 848.9 tons, or 1,697,800 lbs. of corrugated asbestos-cement sheet. AIBP's 3/8 inch thick sheet weighs 440 lbs./square (1,697,800 lbs.)/(440 lbs./square) = 3,858.65 = 3,859 squares of imported corrugated asbestos-cement sheet.

(2) Calculations for F.O.B. plant price of aluminum corrugated sheet.

The price is an average for two major producers for 4.0 ribbed, 0.32" thick when purchased in less than 10,000 square feet quantities.

$1.20/square foot (Corrugated Metals 1986a)
$0.90/square foot (Reynolds 1986)
Average price is $1.05 square foot

(4) Calculations for F.O.B. plant of RFP sheet.

Resolite's prices for translucent and opaque fire resistant FRP corrugated sheet with 4.2" pitch corrugation are:

Translucent $1.44/square foot (Resolite 1986a)
Opaque $1.47/square foot (Resolite 1986a)
Average cost is $1.455 or $1.46/square foot

Sequentia's prices for translucent and opaque fire resistant FRP corrugated sheet with 4.2" pitch corrugation are:

Translucent $1.80/square foot (Sequentia 1986a)
Opaque $2.19/square foot (Sequentia 1986a)
Average cost is $1.995 or $2.00/square foot

The average of these two prices is $1.73/square foot.

(4) Calculations for F.O.B. plant price of corrugated PVC sheet.

The price is derived by averaging H&F Manufacturing's prices for different purchase amounts of 1/8" thick corrugated PVC sheet.

When over 5,000 square feet purchased	$2.16/square foot
When over 2,500 square feet purchased	$2.27/square foot
When up to 2,500 square feet purchased	$2.46/square foot

This gives an average price of $2.30/square foot for PVC (H&F Manufacturing 1986a).

(5) Calculations for F.O.B. plant price of steel corrugated sheet.

The price is an average for two major producers for 4.0 ribbed sheet when purchased in less than 10,000 square feet quantities.

Corrugated Metals prices for steel corrugated steel are:

22 gauge thick \$0.86/square foot (Corrugated Metals 1986b)
24 gauge thick \$0.71/square foot (Corrugated Metals 1986b)
Average price is \$0.79/square foot

22 and 24 gauge are used because they are the most popular thicknesses.

Reynolds estimated that the average cost for 4.0 ribbed steel sheet is approximately \$0.70/square foot (Reynolds 1986).

Thus, the average cost for these is:

\$0.79/square foot
\$0.70/square foot
Average price is \$0.745 or \$0.75/square foot for steel sheet.

(6) Calculations for installation costs.

Installation costs are all taken from Means 1986.

Asbestos-cement corrugated sheet.

Mineral fiber cement panels, corrugated, 3/8" thick as siding on a one story steel frame cost \$1.07/square foot to install.

Steel Corrugated Sheet.

Steel Siding.

24 gauge \$0.82 square foot
22 gauge \$0.82/square foot
Average cost is \$0.82/square foot to install.

PVC Corrugated Sheet. Corrugated vinyl sheets used as siding, 0.120" thick, cost \$0.71/square foot to install.

Aluminum Corrugated Sheet. Aluminum industrial corrugated sheet used as siding, 0.024" thick, mounted on a steel frame costs \$0.83/square foot to install.

Corrugated FRP Sheet. Corrugated fiberglass siding, all weights, costs \$0.73/square foot to install.

(7) Present value calculations (discount rate is 5 percent).

$$PV = TC \times (a/b) \times (b-1)/(a-1)$$

where:

$a = (1.05)^{Ns}$
$b = (1.05)^{Na}$
Ns = Life of substitute product
Na = Life of asbestos product
TC = Total cost of substitute product

Na = 30 years.
Ns for FRP, PVC, and aluminum = 20 years
Ns for steel = 15 years

Thus, b = (1.05)**30 = 4.3219
and for FRP, PVC, and aluminum a = (1.05)**20 = 2.6533
and for steel a = (1.05)**15 = 2.0789

FRP

PV = \$246 x (2.6533/4.3219) x (4.3219-1)/(2.6533-1) = \$303

PVC

PV = \$301 x (2.6533/4.3219) x (4.3219-1)/(2.6533-1) = \$371.29 = \$371

Aluminum

PV = \$188 x (2.6533/4.3219) x (4.3219-1)/(2.6533-1) = \$232

Steel

PV = \$157 x (2.0789/4.3219) x (4.3219-1)/(2.0789-1) = \$233

(8) <u>Calculation of market shares in the replacement market</u>.

Because 85 percent of corrugated asbestos-cement sheet's uses in the replacement market are in general construction, 10 percent are for cooling towers, and 5 percent are for waterways overall (Atlas 1986a), substitute products market shares are derived as follows:

General construction replacement (85%)

FRP	45% x 0.85 = 38.25%
Aluminum	35% x 0.85 = 29.75%
PVC	10% x 0.85 = 8.50%
Steel	10% x 0.85 = 8.50%

Cooling tower replacement (10%)

FRP	95% x 0.10 = 9.50%
PVC	5% x 0.10 = 0.50%

Waterways and bulkhead replacement (5%)

Aluminum	50% x 0.05 = 2.50%
Steel	50% x 0.05 = 2.50%

Thus the total market share for each product is:

FRP	=	38.25% + 9.50%	=	47.75%	=	48%
Aluminum	=	29.75% + 2.50%	=	32.25%	=	32%
Steel	=	8.50% + 2.50%	=	11.00%	=	11%
PVC	=	8.50% + 0.50%	=	9.00%	=	9%

(9) Calculation of product asbestos coefficient for asbestos-cement sheet for asbestos regulatory cost model.

Because this product is not produced domestically and only imported information on the amount of asbestos used was not available and thus it was assumed to have the same product asbestos coefficient as flat asbestos-cement sheet -- 0.114 tons/square. However, this is for 1/2" thick flat sheet whereas imported corrugated sheet is 3/8" thick. Therefore, to find the coefficient for corrugated sheet: (0.114 tons/square)/(1/2 inches) = (X)/(3/8 inches).

Solving for X,

X = 0.75 (0.114 tons/square) = 0.0855 tons/square

(10) Calculation for consumption/production ratio for asbestos regulatory cost model.

Domestic production of corrugated asbestos-cement sheet = 0
Imports of corrugated asbestos-cement sheet = 3,859 squares

(Domestic production + imports)/(domestic production)

= (0 + 3,859)/0 = infinity.

REFERENCES

Alpha Marine, Inc. L. West. 1986 (December 17). Ft. Lauderdale, FL. Transcribed telephone conversation with Michael Geschwind, ICF Incorporated, Washington, DC.

Atlas International Building Products, Inc. R. Cadieux. 1986a (October 2 and December 17). Montreal, Quebec, Canada. Transcribed telephone conversations with Michael Geschwind, ICF Incorporated, Washington, DC.

Atlas International Building Products, Inc. T. Eames. 1986b (November 6). Port Newark, NJ. Transcribed telephone conversation with Michael Geschwind, ICF Incorporated, Washington, DC.

Atlas International Building Products, Inc. J. Payac. 1986c (December 16). Port Newark, NJ. Transcribed telephone conversation with Michael Geschwind, ICF Incorporated, Washington, DC.

Cem-Fil Corporation. R. Cook. 1986 (November 4). Lawrenceville, GA. Transcribed telephone conversation with Michael Geschwind, ICF Incorporated, Washington, DC.

Coastal GFRC, Inc. B. Horsley. 1986 (November 3). Hooksett, NH. Transcribed telephone conversation with Michael Geschwind, ICF Incorporated, Washington, DC.

Cogley D. 1980. GCA Corp. Other substitutes for asbestos-cement sheet. In: Proceedings of the National Workshop on Substitutes for Asbestos, July 14-16, 1980. Levin A. and Pillsbury H., eds. Washington, DC: U.S. Environmental Protection Agency, Office of Pesticides and Toxic Substances EPA-560/3-80-001.

Corrugated Metals, Inc. J. Webberly. 1986a (November 7). Jersey City, NJ. Transcribed telephone conversation with Michael Geschwind, ICF Incorporated, Washington, DC.

Corrugated Metals, Inc. R. Huskey. 1986b (December 18). Chicago, IL. Transcribed telephone conversation with Michael Geschwind, ICF Incorporated, Washington, DC.

Eternit, Inc. B. Morrissey. 1986 (November 4). Reading, PA. Transcribed telephone conversation with Michael Geschwind, ICF Incorporated, Washington, DC.

H&F Manufacturing Corp. 1986a (January 6). Feasterville, PA. Product literature and price list on phase 2 PVC panels.

H&F Manufacturing Corp. J. Huscher 1986b (November 3 and 6). Feasterville, PA. Transcribed telephone conversations with Michael Geschwind, ICF Incorporated, Washington, DC.

ICF Incorporated. 1985. Appendix H: Asbestos products and their substitutes, in Regulatory Impact Analysis of Controls on Asbestos and Asbestos Products. Washington, DC: Office of Pesticides and Toxic Substances, U.S. Environmental Protection Agency.

ICF Incorporated. 1986. (July - December). Survey of Primary and Secondary Processors of Asbestos-Cement Corrugated Sheet. Washington, DC.

Interstate Contractors. G. Burdette. 1986 (December 18). Mulberry, FL. Transcribed telephone conversation with Michael Geschwind, ICF Incorporated, Washington, DC.

Krusell N., Cogley D. 1982. GCA Corp. Asbestos substitute performance analysis. Revised final report. Washington, DC: Office of Pesticides and Toxic Substances, U.S. Environmental Protection Agency. Contract 68-02-3168.

Means 1986. Means Building Construction Costs. Roofing and Siding. R.S. Means and Company. Kingston, MA. 1985. pp. 140-147.

Resolite. 1986a. Resolite Division of H.H. Robertson Company. Zelienople, PA. 1986 Sweets Catalog (8/85); CR Catalog (11/84); Wastewater Treatment Facilities (8/85); Tred-Safe (R) Brochure (5/84); Resolite R42 Brochure; Fiberglass Reinforced Panel Council: Plastic Panel Systems.

Resolite. B. Reckard. 1986b (November 3). Resolite Division of H.H. Robertson Company. Zelienople, PA. Transcribed telephone conversation with Michael Geschwind, ICF Incorporated, Washington, DC.

Reynolds Aluminum. J. Green. 1986 (December 18). Construction Products Division. Eastman, GA. Transcribed telephone conversation with Michael Geschwind, ICF Incorporated, Washington, DC.

Sequentia. 1984 (November 1). Cleveland, OH. Reinforced Fiberglass Division. Product literature and price list on alsynite/structoglass fiberglass reinforced plastic sheet.

Sequentia. D. Schmidt. 1986 (November 3). Cleveland, OH. Transcribed telephone conversation with Michael Geschwind, ICF Incorporated, Washington, DC.

U.S. Dep. Comm. 1986a. U.S. Department of Commerce. Consumption of Imports FY246/1985 Annual. Suitland, MD. Bureau of the Census. U.S. Department of Commerce.

U.S. Dep. Comm. P. Confer. 1986b (October 3). Suitland, MD. U.S. Department of Commerce. Division of Minerals and Metals. Bureau of the Census. Transcribed telephone conversation with Michael Geschwind, ICF Incorporated, Washington, D.C.

XVII. ASBESTOS-CEMENT SHINGLES

A. Product Description

All asbestos-cement siding and roofing shingles are made from the same materials; a mixture of Portland cement, asbestos fiber, ground silica, and sometimes an additional fraction of finely ground inert filler and pigment (Supradur 1986a and b, Krusell and Cogley 1982). Domestically produced shingles now contain 18 percent asbestos, while imported shingles have 13 percent asbestos by weight (PEI 1986, ICF 1986, Atlas 1986c, see Attachment, Item 1).

In manufacturing asbestos-cement shingles, the raw materials are mixed either in a dry or wet state. The mixture is then placed on a moving conveyor belt, adding water if the mixture is dry. The mixture proceeds through a series of press rolls and is then textured with a high pressure grain roll. The shingles are then cured, cut to size, punched, or otherwise molded. Further processing may include autoclaving, coating, shaping or further compression (AIA/NA and AI 1986, Supradur 1986c).

Asbestos-cement siding shingles usually resemble shakes or machine-grooved shingles, and asbestos-cement roofing shingles generally resemble either shakes or slate (Supradur 1985). The slate style is the most popular asbestos-cement roofing shingle. Most of the siding products are thinner than asbestos-cement roofing shingles and have a painted finish (Supradur 1986b). It is estimated that 77 percent of the asbestos shingle market is siding shingles and 23 percent is roofing shingles (PEI 1986, see Attachment, Item 1).

Asbestos-cement roofing and siding shingles have been used primarily on residential properties, although some applications have also been found in schools, churches, and historical restoration projects (Supradur 1986a, Raleigh 1986). In rural areas they are often found in agricultural buildings and farm houses and are used to prevent fire or water damage because of their resistance to both (National Tile Roofing Manufacturer's Association 1986, Raleigh 1986). Currently, asbestos-cement roofing shingles have relatively no use in new construction (Atlas 1986b) and are principally being used for replacement and maintenance in luxury homes, schools, churches, and historical restorations (Atlas 1986b, Supradur 1986a). For historical restoration they could be used either to preserve the historical integrity of a landmark that originally had asbestos-cement shingles, or to replace real slate with a variety of asbestos-cement shingles that resemble slate (Atlas 1986b; National Roofing Contractor's Association 1986). Asbestos-cement shingles are used mostly in the Northeast and the Midwest and are generally not found in the West or South (National Tile Roofing Manufacturer's Association 1986).

B. Producers and Importers of Asbestos-Cement Shingles

In 1981, there were three producers of asbestos-cement shingles: International Building Products, National Gypsum, and Supradur Manufacturing. National Gypsum stopped production prior to 1982 (TSCA 1982, ICF 1984). International Building Products closed their asbestos operations completely in March 1986, however it is not known when they last produced asbestos-cement shingles (Atlas 1986a). Table 1 presents production data for the only remaining domestic producer of asbestos-cement roofing and siding shingles.

The only known importer of asbestos-cement shingles is Atlas International Building Products (AIBP) in Montreal, Quebec, Canada (Atlas 1986a and 1986b, Eternit 1986).

C. Trends

Domestic production of asbestos-cement shingles for 1981 and 1985 are presented in Table 2. While total domestic production of asbestos-cement

Table 1. Production of Asbestos-Cement Shingles

	1985 Asbestos Consumption (tons)	1985 Asbestos-Cement Shingle Production (squares)
Total	3,893	176,643

Source: ICF 1986.

Table 2. Production of Asbestos-Cement Shingles

Year	Number of Producers	Output (squares)
1981	3	266,670
1985	1	176,643

Sources: ICF 1986, TSCA 1982.

shingles has declined 34 percent since 1981, Supradur's production has increased 15 percent during this period (see Attachment, Item 3).

It is not know how many asbestos-cement shingles are imported in the U.S. According to the Bureau of the Census, 10,416.3785 tons of asbestos-cement products other than pipe, tubes, and fittings were imported in 1985, of which 8,489 tons, or 81.5 percent came from Canada (U.S. Dept. Comm. 1986a, 1986b). This number most likely includes flat and corrugated asbestos-cement sheet and asbestos-cement shingles. AIBP, the only importer of these products from Canada roughly estimated that 80 percent of their U.S. shipments are asbestos-cement shingles (Atlas 1986a, Atlas 1987). Eighty percent of Canadian shipments, or 6,791 tons, converts to 64,654 squares of asbestos-cement shingles imported in 1985.

D. Substitutes

Table 3 summarizes the primary substitutes for asbestos-cement siding and roofing shingles. There are no substitutes for asbestos-cement shingles in the maintenance and repair market because there are no substitute products that resemble the asbestos-cement product closely enough to be able to replace it in parts (National Roofing Contractor's Association 1986, Supradur 1986b). Slate is the only shingle that would be close in appearance to some asbestos-cement shingles, but it is much thicker and far more expensive (Supradur 1986b). For our study, we will consider substitutes that can be used instead of asbestos-cement shingles for complete remodeling or new construction. The following section presents separate discussions of substitutes for asbestos-cement siding shingles and asbestos-cement roofing shingles.

1. Asbestos-Cement Siding Shingle Substitutes

The three primary substitutes for asbestos-cement siding shingles are wood, aluminum, and vinyl siding. Wood siding includes hardboard siding and

Table 3. Product Substitutes for Asbestos-Cement Shingles

Product Substitute	Manufacturer	Advantages	Disadvantages	Availability	References
Siding Substitutes					
Red Cedar Shingles and Handsplit Shakes	Over 450 in U.S. and Canada.	Relatively high strength/weight ratio. Effective insulator. Rigid. Wind resistant. Attractive.	Non fire-resistant. Usually requires stain or protective coating.	National	Red Cedar Shingles and Handsplit Shake Bureau 1986b, Chemco 1986b
Hardboard Siding	U.S. Plywood, Stamford, CT; Weyerhaueser, Tacoma, WA; and more than 10 others	More insulative than vinyl and aluminum. Doesn't dent easily as aluminum. Not as noisy as aluminum. Doesn't expand and contract like vinyl. Doesn't have knots like cedar wood.	Absorbs moisture. Requires protective paint. Doesn't have longevity of vinyl and aluminum. More expensive to install.	National	Weyerhaeuser 1986, American Home Improvement 1986
Vinyl Siding	Certain-Teed, Valley Forge, PA; Vipco, Columbus, OH; and several others	Easy to cut and handle. Won't peel, flake, blister or corrode. Inexpensive. No maintenance required.	Can be dented, but not as easily as aluminum. Can't be painted. Color may fade over time. Expands and contracts with temperature change. Can be brittle in cold weather. Available only in light colors. Flexible.	National	Certain-Teed 1986, Commonwealth Aluminum 1986, Alcoa 1986a, b
Aluminum Siding	Alcan Aluminum, Warren, OH; Alcoa Building Products, Sidney, OH; and several others	Several colors. Lightweight. Corrosion resistant. Holds color well. No maintenance required. Stiffer than vinyl.	Can be dented. Cannot be painted. More expensive than vinyl.	National	Alcoa 1986a, b, Commonwealth Aluminum 1986

Table 3 (Continued)

Product Substitute	Manufacturer	Advantages	Disadvantages	Availability	References
Roofing Substitutes					
Asphalt Fiberglass and Organic	Manville Sales, Denver,CO; Owens-Corning, Toledo, OH; GAF, NY, NY; Georgia Pacific, Atlanta, GA; and several others	Fire resistant. Weather resistant. Wind resistant. Low cost. Easy application. Lightweight	Fiberglass shingles. May be brittle. Shorter life. Tendency to conform.	National	Asphalt Roofing Manufacturer's Association 1981, National Roofing Contractor's Association 1986, ICF 1984
Cedar Wood Shingles and Shakes	American Wood Treating, Mission, B.C., Canada and over 450 other mills in B.C., WA, OR and ID	Relatively high strength/weight ratio. Effective insulator. Rigid. Wind resistant. Attractive.	Not as fire resistant as other products.	National	Red Cedar Shingle and Handsplit Shake Bureau 1985
Tire, Concrete and Clay	Monier, Orange, CA; Ludowici-Celadon, New Lexington, OH; U.S. Tile, Corona, CA; and several others	Durable. Wind and weather resistant. Incombustible. Insulative.	Heavy. Expensive to install.	National	National Tile Roofing Manufacturer's Association (n.d.), Means 1986

red cedar shakes and shingles[1] with a small amount of redwood or cedar paneling. Hardboard is the most common wood siding product, comprising 69 percent of the wood siding category (American Hardboard Association 1986a, Red Cedar Shingle & Handsplit Shake Bureau 1986b, see Attachment, Item 4). Hardboard is made by mixing wood fiber (90 percent) with phenolic resin (10 percent) and compressing them under high pressure. Usually a wood grain is embossed onto the board to make it resemble redwood or cedar; it can also have a stucco or shake appearance. Hardboard comes in two main sizes: lap panels which are 1 foot by 16 feet and boards which are 4 by 8 feet. Both come in thicknesses varying from 7/16 to 1/4 inch. Hardboard has a national market, although in the South and the Southwest brick and stucco, respectively, are preferred (Weyerhaeuser 1986). There are about 10 major manufacturers of hardboard siding including U.S. Plywood, Stamford, CT; Weyerhaueser, Kalamath Falls, OR; Masonite, Laurel, MS; and Georgia-Pacific, Atlanta, GA (Weyerhaueser 1986).

Red cedar siding shakes and shingles comprise the remaining 31 percent of the wood siding category (American Hardboard Association 1986a, Red Cedar Shingle & Handsplit Shake Bureau 1986b, see Attachment, Item 4). Over 90 percent of cedar siding is used in the Northeast, particularly New England. Red cedar is an effective insulator because its cellular structure retards the passage of heat and cold through the wood (Red Cedar Shingle & Handsplit Shake Bureau 1986b). Cedar siding is usually stained by users although the stains are usually flammable and make the product much less flame resistant.

Vinyl siding has been one of the largest growing siding products and can especially substitute for asbestos-cement shingles in residential areas. It

[1] Shingles are sawed on both surfaces, whereas shakes have at least one split surface and thus present a rugged, irregular texture (Red Cedar Shingle and Handsplit Shake Bureau 1986a).

competes mostly with aluminum siding. Vinyl has taken a larger share of the siding market in the past few years, thereby reducing aluminum's share. Both aluminum and vinyl siding often have a simulated wood-grain finish and are available in several colors. One major problem with vinyl is its tendency to expand and contract with changes in temperature. In hot weather vinyl siding may expand and come loose from the exterior wall. In order to minimize this expansion problem, vinyl siding is only available in light colors that do not absorb as much heat (Alcoa 1986b, Commonwealth Aluminum 1986). Major producers of vinyl siding include Certain-Teed, Valley Forge, PA; Vipco Inc., Columbus, OH; Mastic Corp., South Bend, IN; Wolverine, Lincoln Park, MI; Bird Inc., Bardstown, KY; Alcoa Building Products, Sidney, OH; and Alside, a division of USX Corporation (Certain-Teed 1986).

Aluminum is a proven product and has been available for over 30 years, longer than vinyl siding. While aluminum is more temperature resistant than vinyl, it dents much more easily than other siding products (Commonwealth Aluminum 1986, Certain-Teed 1986). Though metal, aluminum siding resists rusting by forming a protective oxide coating (Commonwealth Aluminum 1986). Three major producers of aluminum siding are Alcan Aluminum in Warren, OH, Alcoa Building Products in Sidney, OH, and Reynolds in Richmond, VA. Both Reynolds and Alcoa also produce vinyl siding.

Painted steel, stucco, masonry, brick, and concrete blocks may also be used as siding, but they will not be significant substitutes for asbestos-cement siding shingles (Commonwealth Aluminum 1986, Krusell and Cogley 1982, American Hardboard Association 1986b).

2. <u>Asbestos-Cement Roofing Shingle Substitutes</u>

The primary substitutes for asbestos-cement roofing shingles are asphalt shingles (fiberglass or organic), cedar wood shingles, and tile (concrete or clay). Asphalt shingles are the most competitive asbestos-cement roofing shingles substitute, even though they have a shorter service life than other substitutes (National Roofing Contractor's Association 1986). Before 1960, most asphalt shingles had an organic or wood-pulp base. Today, however, 83 percent of standard strip asphalt shingles have a fiberglass base. All asphalt shingles are fire resistant (fiberglass-asphalt shingles have a Class A fire rating, the highest fire rating available; organic-asphalt shingles have a Class C fire rating, which is a lower rating than Class A, but still somewhat fire resistant). Fiberglass-asphalt have slightly less bulk and are lighter weight than the organic-asphalt shingles (Asphalt Roofing Manufacturer's Association 1984). Some contractor's prefer the organic- asphalt because they have a longer proven track record than fiberglass-asphalt shingles and some of the very light weight and cheaper fiberglass-based shingles are very brittle; however, many feel that this problem has been resolved by the manufacturers (Qualified Remodeler Magazine 1986, RSI 1986a). There are over 20 domestic manufacturers of asphalt shingles including Owens-Corning Fiberglas, GAF, Georgia Pacific, and Lunday-Thagard (Owens-Corning Fiberglas 1986, Asphalt Roofing Manufacturer's Association 1981).

Although not as fire resistant, red cedar wood shingles and shakes are popular roofing substitutes. Cedar shingles are made in the Northwest and in British Columbia, Canada by over 450 mills; however, some of these are virtually one man operations (Red Cedar Shingle & Handsplit Shake Bureau 1985). Ninety-five percent of Canadian production is shipped to the U.S. and accounts for 70 percent of U.S. domestic consumption (Red Cedar Shingle & Handsplit Shake Bureau 1986a). Red cedar shingles and shakes are distributed across the U.S., the highest concentration being in California, Washington, Oregon, and Texas (Red Cedar Shingle & Handsplit Shake Bureau 1986b). Only 15 to 30 percent of cedar roofing shingles and shakes are fire resistant, with a fire rating of either Class B or Class C. Because of the fire hazard posed by non-fire resistant cedar roofing shingles, some California towns have outlawed their use (RSI 1986b, American Wood Treating 1986, Chemco 1986a and b). Approximately 72,000,000 squares of asphalt fiberglass and organic strip shingles were produced in 1985 (Asphalt Roofing Manufacturer's Association 1986, see Attachment, Item 6).

The tile roofing market is about the same size as the cedar roofing market, each of which are less than one-tenth the size of the asphalt roofing shingle market (National Tile Roofing Manufacturers Association 1986, Red Cedar Shingle and Handsplit Shake bureau 1986a, Asphalt Roofing Manufacturers Association 1986). Concrete comprises 90 percent of the tile market and clay holds the remaining 10 percent (National Tile Roofing Manufacturer's Association 1986). Tile is used primarily in the Sunbelt -- Florida, California, and the South (Raleigh 1986, National Tile Roofing Manufacturer's Association 1986). It is very insulative because the air space between the tile and the underlayment creates a heat flow barrier (National Tile Roofing Manufacturer's Association (n.d.)). Tile is available in three main styles: s-tile, mission, and flat (shakes or slate-like). There are more than 13 U.S. concrete tile manufacturers; the largest in the U.S. and the world is Monier Roof Tile in Orange, CA (Monier 1986a, National Tile Roofing Manufacturer's Association (n.d.)). The four clay roof tile manufacturer's, all located near clay deposits, are Ludowici-Celadon, New Lexington, OH,; U.S. Tile, San Valle, and MCA in Corona, CA (National Tile Roofing Manufacturer's Association 1986). Slate is very expensive and has a very small share of the roofing market. It is primarily used in the Vermont and New York area, the two states where it is quarried.

The cost of asbestos-cement shingles and substitute roofing and siding products are compared in Table 4.

Table 4. Cost of A/C Shingles and Substitutes[a]

	A/C Shingles	Vinyl Siding	Aluminum Siding	Asphalt Roofing Shingles	Tile Roofing	Wood Siding and Roofing[b,c]
FOB Plant Cost ($/square)	65	50	65	19	63	53
Installation Cost ($/square)	48	63	63	30	110	109
Total Cost ($/square)	113	113	128	49	173	162
Operating Life (years)	40	50	50	20	50	30
Present Value ($/square)	113	106	120	67	163	181

[a]See Attachment, Items 8-13 for equations used to determine costs.

[b]Wood siding includes hardboard and cedar shingles and shakes (see text). Wood roofing includes only cedar shingles and shakes (see text).

[c]In order to simplify the number of inputs for the asbestos regulatory cost model, wood siding and wood roofing are combined into one wood roofing/siding category for which price and market share are determined (see Attachment, Item 11 for calculations).

Siding. Wood siding is the most expensive asbestos-cement siding substitute overall.[2] Asbestos-cement shingles, vinyl siding, and aluminum siding are close in overall price.

The substitute market for asbestos-cement siding shingles is divided among wood (hardboard and cedar shakes and shingles), 40 percent; vinyl, 35 percent; and aluminum, 25 percent (see Attachment, Items 4-5).

Roofing. Table 4 shows that asphalt roofing shingles, the most popular substitute for asbestos-cement roofing shingles, are also the least expensive overall, even though they have half the service life. Both tile and cedar shingles and shake roofing are more than double the cost of asphalt roofing (see Attachment, Items 11-14).

The current market share for substitute roofing shingles, based on 1985 production, is asphalt shingles (primarily asphalt-fiberglass), 86 percent, with tile (primarily concrete) and cedar wood shingles each taking 7 percent (see Attachment, Item 6). Asphalt-fiberglass shingles has been and continues to be the fastest growing segment of the roofing market, while cedar roofing shingle and shake production has declined since 1983 (Red Cedar Shingle & Handsplit Shake Bureau 1986b).

Because the domestic asbestos-cement shingle market is 77 percent siding and 23 percent roofing (PEI 1986), the combined roofing and siding replacement market for asbestos-cement shingles would probably breakdown as follows (see Attachment, Items 4-7):

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[2] For the asbestos regulatory cost model, in order to simplify the number of inputs, wood siding and wood roofing are combined into one wood roofing/ siding category for which price and market share are determined (see Attachment, Item 4-7, 11).

	Projected Market Share (percent)
Wood	32
Vinyl	27
Asphalt	20
Aluminum	19
Tile	2
Total	100

Table 5 presents the data for the asbestos regulatory cost model and summarizes the findings of this analysis.

E. Summary

Asbestos-cement siding shingles resemble shakes or machine-grooved shingles and asbestos-cement roofing shingles generally resemble either shakes or slate (Supradur 1985). They are primarily being used for replacement and maintenance in luxury homes, schools, churches, and historical restoration projects (Atlas 1986b, Supradur 1986a). Of three domestic producers in 1981, only one, Supradur, remains in 1986. Production has declined 34 percent from 266,670 squares in 1981 to 176,643 squares in 1985 (ICF 1986, TSCA 1982). Only one company, Atlas International Building Products (AIBP) of Montreal, Quebec, Canada is known to import asbestos-cement shingles into the U.S. (Atlas 1986a, Atlas 1986c).

There are no substitutes for asbestos-cement shingles for maintenance and repair applications because no substitute products resemble the asbestos product closely enough to replace it in part (National Roofing Contractor's Association 1986, Supradur 1986b). However, there are many adequate substitutes that can be used for complete replacement, remodeling or in new construction. The replacement market is as follows: wood siding and roofing,

Table 5. Data Inputs for Asbestos Regulatory Cost Model[a]

Product	Output (squares)	Product Asbestos Coefficient	Consumption Production Ratio	Price ($/square)	Useful Life	Equivalent Price ($/square)	Market Share	Reference
Asbestos-Cement Shingles	176,643	0.022	1.37	$113.00	40 years	$113.00	N/A	See Attachment
Wood Siding and Roofing	N/A	N/A	N/A	$162.00	30 years	$174.05	32%	See Attachment
Vinyl Siding	N/A	N/A	N/A	$113.00	50 years	$109.16	27%	See Attachment
Asphalt Roofing Shingles	N/A	N/A	N/A	$ 49.00	20 years	$ 61.66	20%	See Attachment
Aluminum Siding	N/A	N/A	N/A	$128.00	50 years	$123.65	19%	See Attachment
Tile Roofing	N/A	N/A	N/A	$173.00	50 years	$167.12	2%	See Attachment

N/A: Not Applicable.

[a]See Attachment, Items 4-16 for explanation and calculations.

32 percent; vinyl siding, 27 percent; asphalt-based roofing, 20 percent; aluminum siding, 19 percent; and tile roofing, 2 percent. Vinyl and aluminum siding cost about the same as the asbestos product. Asphalt-based roofing shingles are about half the cost, and tile roofing and wood siding and roofing are 45-60 percent more expensive than asbestos-cement shingles.

<u>ATTACHMENT</u>

(1) <u>Calculation of percent of asbestos in domestic asbestos-cement shingles</u>.

One domestic producer has a production capacity of 134,800 squares or 12,000 tons for siding shingles and 40,000 squares or 9,500 tons for roofing shingles (PEI 1986). This gives an average weight of 178 lbs./square ((12,000 tons x 2,000 lbs./ton)/(134,800 squares)) for siding shingles and 475 lbs./square ((9,500 tons x 2,000 lbs./ton)/(40,000 squares)) for roofing shingles. This yields a roofing and siding shingle weighted average weight of 246 lbs./square ((134,800 squares x 178 lbs./square + 40,000 squares x 475 lbs./ square)/174,800 squares). The domestic producer's shingles have an average of 44 lbs. of asbestos per square. Therefore, ((44 lbs. of asbestos/square)/246 lbs./square) x 100 = 17.89 percent or 18 percent asbestos by weight in asbestos-cement domestic shingles.

From the production capacities in squares shown above, it is estimated that 77 percent of the asbestos-cement shingle market is siding and 23 percent is roofing.

(2) <u>Calculation for imports of asbestos-cement shingles</u>.

10,416.3785 tons of asbestos-cement flat and corrugated sheet and asbestos-cement shingles were imported into the U.S. in 1985. 81.5 percent, or 8,489 tons, of this figure was from Canada. Atlas International Building Products (AIBP), the only importer of these products from Canada estimates that 80 percent of their imports is asbestos-cement shingles (Atlas 1986a). Ten percent equals 6,791 tons or 13,582,000 lbs. of asbestos-cement shingles.

AIBP estimates that 60 percent of the asbestos-cement shingles imports are siding and 40 percent are roofing shingles:

Siding = 0.6 x (6,791 tons) = 4,075 tons = 8,150,000 lbs.
Roofing = 0.4 x (6,791 tons) = 2,716 tons = 5,432,960 lbs.

AIBP's siding and roofing shingles weigh 155 lbs./square and 450 lbs./square, respectively.

Siding Shingles = (8,150,000 lbs.)/(455 lbs./square)
= 52,581 squares

Roofing Shingles = (5,432,960 lbs.)/(450 lbs./square)
= 12,073 squares

Total Imports = 64,654 squares

This estimate may be low because it does not include the 18.5 percent of asbestos-cement products other than pipe, tubes, and fittings imported from countries other than Canada. These imports from other countries may possibly include some flat asbestos-cement shingles (U.S. Dep. Comm. 1986a, 1986b).

(3) Calculations for changes in production of asbestos-cement shingles between 1981 and 1985 (TSCA 1982, ICF 1986).

(1985 production - 1981 production/1981 production) * 100
= (176,643 squares - 266,670 squares/266,670 squares) * 100
= -33.8% = -34%.

Domestic production has changed as follows:

(1985 production - 1981 production/1981 production) * 100
= (176,643 squares - 153,603 squares/153,603 squares) * 100
= 15%.

(4) Calculations for the share of cedar shingle and hardboard in the wood siding market.

Members of the Red Cedar Shingle and Handsplit Shake bureau produced 355,825 squares in 1985. Since this association accounts for only 70 percent of the cedar shingle and shake market, 355,825/0.70, or 508,321 red cedar shingles and shakes were produced in 1985 (Red Cedar Shingle and Handsplit Shake Bureau 1986a and b). This combined with 1,128,992 squares of hardboard siding produced in 1985 makes for a total of 1,637,313 squares (American Hardboard Association 1986a and 1986b).

(508,321/1,637,313) * 100 = 31% red cedar siding
(1,128,992/1,637,313) * 100 = 69% hardboard siding

(5) Estimates of the projected market share for wood, vinyl, and aluminum in the siding market were based on estimates from the following references: Qualified Remodeler Magazine 1986; Alcoa 1986a and b; Contractor's Guide 1986.

(6) Calculations of projected market shares in the asbestos-cement shingles replacement roofing market.

Asphalt fiberglass and organic standard strip shingles produced in 1985 = 71,766,672 (Asphalt Roofing Manufacturer's Association 1986b).

Members of the Red Cedar Shingle and Handsplit Shake Bureau produced 3,885,174 squares of roofing shingles and shakes in 1985. Since this association accounts for only 70 percent of the cedar shingle and shake market, 3,885,174/0.70, or 5,550,249 squares of red cedar shingles and shakes for roofing were produced in 1985 (Red Cedar Shingle and Handsplit Shake Bureau 1986a and b).

About 6,000,000 squares of tile roofing were produced in 1985 (National Tile Roofing Manufacturer's Association 1986).

This makes a total of 83,316,921 squares consisting of 86.1 percent asphalt shingles, 6.7 percent wood, and 7.2 percent tile.

(7) Calculation of total replacement market shares.

The following calculations are based on the fact that 77 percent of the asbestos-cement shingle market is siding, and 23 percent is roofing (PEI 1986).

Wood roofing	6.7% (0.23) +			
and siding	40.0% (0.77)	= 32.34%	=	32%
Vinyl	35.0% (0.77)	= 26.95%	=	27%
Asphalt	86.1% (0.23)	= 19.80%	=	20%
Aluminum	25.0% (0.77)	= 19.25%	=	19%
Tile	7.2% (0.23)	= 1.66%	=	2%

(8) Calculation of costs for asbestos-cement roofing and siding shingles.

The asbestos-cement shingle F.O.B. plant cost is based on Supradur's average price according to an ICF survey (ICF 1986). The asbestos-cement shingle installation cost is a weighted average for 325 lb./square and 500 lb./square roofing shingles and 167 lb./square siding shingles (Means 1986a).

Roofing asbestos-cement shingle cost

325 lb. $40/square
500 lb. $73/square
Average $56.50

Siding asbestos-cement shingle cost $46/square for 167 lb./square (Means 1986).

Because 77 percent of asbestos-cement shingle market is siding and 23 percent roofing,

(56.50/square * 0.23) + ($46/square * 0.77) = $48.42
= $48 for installation of asbestos-cement shingles.

(9) Cost of vinyl siding.

The F.O.B. plant cost for vinyl siding is based on the following references: Alcoa 1986a and b; Certain-Teed 1986.

The installation cost is for solid PVC panels 8"-10" wide, plain or insulated (Means 1986).

(10) Cost of aluminum siding.

The F.O.B. plant cost for aluminum siding is based on the following references: Alcoa 1986a and b; Certain-Teed 1986.

The installation cost for aluminum siding is the same as for PVC siding (American Home Improvement 1986; Wages and Evans 1986; Johnny B. Quick 1986).

(11) Cost of wood siding and roofing.

To determine the cost of wood siding and roofing, costs are first derived separately for wood siding alone and wood roofing alone. These costs are then multiplied by their share of the asbestos-cement shingle replacement market to give a weighted average cost for wood roofing and siding.

(a) Cost of wood siding.

The F.O.B. plant price of cedar siding shingles and shakes is $80/square (American Wood Treating 1986). The F.O.B. plant price for hardboard wood siding is $40/square (Weyerhaeuser 1986, U.S. Plywood 1986).

Since the 69 percent of the wood siding replacement market for asbestos-cement shingles is hardboard and 31 percent is cedar shakes and shingles (see previous calculations), the average cost for all wood siding will be

($80/square x 0.31) + ($40/square x 0.69) =
$52.40/square for wood siding

The installation costs for cedar wood siding shingles and shakes are averaged from Means 1986.

16" long with 7-1/2" exposure = $78/square
18" long with 7-1/2" exposure = $71/square
18" long with 8-1/2" exposure = $80/square
Average of these three = $76.33 or $76/square

The installation costs for hardboard siding was estimated to be double that for aluminum and PVC, or $126/square. Even if this estimate is a bit high, it will include the cost for painting that hardboard siding requires (American Home Improvement 1986, Moon Sidings 1986, National Home Improvement Co. 1986).

The weighted average cost for all wood siding is based on 69 percent of the replacement market being hardboard and 31 percent cedar siding (see previous calculations).

($126/square x 0.69) + ($76/square x 0.31) = $110.50 or $111/square is the average installation cost for wood siding.

The operational life for wood siding is determined by taking a weighted average of that for hardboard and for cedar wood.

Hardboard life = 25 years (American Hardboard Association 1985, Weyerhaeuser 1986).

Cedar life = 40 years (ICF 1985).

(40 years x 0.31) + (25 years x 0.69) = 29.65 years = 30 years

(b) <u>Cost of wood roofing</u>.

The average estimated F.O.B. plant cost for non-fire treated cedar roofing shingles is \$68/square (American Wood Treating 1986, RSI 1986, Chemco 1986a).

The installation cost is an average of 16" and 18" roofing shingles.

16" = \$64/square
<u>18" = \$58/square</u>
Average = \$61/square

(c) <u>Cost of wood siding and roofing</u>

The wood roofing market represents 1.54 percent of the entire asbestos-cement shingle replacement market. The wood siding market represents 30.80 percent of the entire asbestos-cement shingle replacement market for a total market share of 32.34 percent for wood (see previous market share calculations). Therefore, roofing is ((1.54/32.34) x 100), or 4.8 percent of the wood replacement market and siding is ((30.80/32.34) x 100), or 95.2 percent of the wood replacement market.

Thus the weighted average F.O.B. plant cost for wood is:

(\$52/square x 0.952) + (\$68 x 0.048) = \$52.77/square = \$53/square

The weighted average cost for installation of wood roofing and siding is:

(\$111/square x 0.952) + (\$61/square + 0.048) = \$108.60 = \$109/square

The total cost for wood is:

\$52.77 + \$108.60 = \$161.37/square or
(\$163/square x 0.952) + (\$129/square x 0.048) = \$167.37/square

The average weighted operating life for wood roofing and siding is:

(30 years x 0.952) + (40 years x 0.048) = 30.48 years = 30 years

(12) <u>Cost for asphalt standard strip shingles</u>.

The F.O.B. plant cost for asphalt shingles is a weighted average of asphalt fiberglass, 83 percent, and asphalt organic, 17 percent, shingles (Asphalt Roofing Manufacturer's Association 1986).

Average price for fiberglass shingles = \$18.50/square (Owens-Corning 1986).

Average for organic shingles = \$20/square (Owens-Corning 1986).

(\$18.50/square x 0.83) = (\$20/square x 0.17) = \$18.75
= \$19/square is the cost for asphalt shingles.

Installation cost is also a weighted average of standard strip organic, 235-240 lb./square, and fiberglass, 210-235 lb./square shingles.

Installation cost for fiberglass = \$30/square (Means 1986)
Installation cost for organic = \$27/square (Means 1986)

(\$30/square x 0.83) + (\$27/square x 0.17) = \$29.50
= \$30/square is the average cost for installation of asphalt shingles.

(13) <u>Cost of roofing tile</u>.

The tile market is about 10 percent clay tile and 90 percent concrete tile (National Tile Roofing Manufacturer's Association 1986).

The F.O.B. plant cost for clay tile is an average of four companies, San Valle, U.S. Tile, MCA, and Ludowici-Celadon's prices for Mission, S, and Flat tile. S-tile was weighted 65 percent while the Mission and Flat were each weighted 17.5 percent. Ludowici's average price was weighted 30 percent, while the other three companies were each weighted 23.33 percent (U.S. Tile 1986, MCA 1986, San Valle 1986, Ludowici-Celadon 1986). This gave a clay tile price of \$134/square.

((0.30 (0.65 * 250.00 + 0.175 * 310.00 + 0.175 * 310.00)) +
(0.233 (0.65 * 70.40 + 0.175 * 97.20 + 0.175 * 114.75)) +
(0.233 (0.65 * 55.00 + 0.175 * 106.00 + 0.175 * 106.00)) +
(0.233 (0.65 * 58.50 + 0.175 * 90.40 + 0.175 * 100.57))).

The national average F.O.B. plant cost for concrete tile is \$55/square (Monier Roofing Tile Company 1986a and b).

Using the above tile market shares an average weighted price was derived: (\$55/square x 0.90) + (\$134/square x 0.10) = \$62.90 = \$63/square for tile roofing, F.O.B. plant.

Installation cost for clay was based on an average of S and Mission tile:

Mission = \$84/square (Means 1986)
<u>S-Tile = \$130/square (Means 1986)</u>
Average cost = \$107 for clay tile installation

Installation for concrete tile is based on the S-tile and corrugated tile = \$110/square (Means 1986).

Total installation cost for tile, concrete (90 percent) and clay (10 percent), is: (\$110/square x 0.90) + (\$107/square x 0.10) = \$109.7 = \$110/square.

(14) <u>Present value calculations for substitutes</u>.

N_a = life of asbestos product
N_b = life of substitute product

TC = total cost of product

$PV = TC \times (a/b) \times (b-1)/(a-1)$

$a = (1.05)^{N_a}$
$b = (1.05)^{N_b}$

$N_a = 40$ years
$a = (1.05)^{40} = 7.0400$

(a) <u>Vinyl siding</u>

$TC = \$113$/square
$N_b = 50$ years
$b = (1.05)^{50} = 11.4674$

$PV = \$113 \text{ square} \times (11.4674/7.0400) \times (7.0400 - 1)/(11.4674 - 1)$
$= \$106.21 = \$106$/square

(b) <u>Aluminum siding</u>

$TC = \$128$/square
$N_b = 50$ years
$b = (1.05)^{50} = 11.4674$

$PV = \$128 \text{ square} \times (11.4674/7.0400) \times (7.0400 - 1)/(11.6674 - 1)$
$= \$120.31 = \$120$/square

(c) <u>Wood siding</u>

$TC = \$163$/square
$N_b = 30$ years
$b = (1.05)^{30} = 4.3219$

$PV = \$163 \text{ square} \times (4.3219/7.0400) \times (7.0400 - 1)/(4.3219 - 1)$
$= \$181.95 = \$182$/square

(d) <u>Wood roofing</u>

$N_a = N_b = 40$ years

Therefore $PV = TC$

(e) <u>Wood siding and roofing</u>

$TC = \$162$/square
$N_b = 30$ years
$b = (1.05)^{30} = 4.3219$

$PV = \$162 \text{ square} \times (4.3219/7.0400) \times (7.0400 - 1)/(4.3219 - 1)$
$= \$180.83 = \$181$/square

(f) <u>Asphalt roofing</u>

$TC = \$49$/square
$N_b = 20$ years
$b = (1.05)^{20} = 2.6533$

$$PV = \$49 \text{ square} \times (2.6533/7.0400) \times (7.0400 - 1)/(2.6533 - 1)$$
$$= \$67.47 = \$67/\text{square}$$

(g) Tile roofing

$TC = \$173/\text{square}$
$N_b = 50 \text{ years}$
$B = (1.05)^{50} = 11.4674$

$$PV = \$173 \text{ square} \times (11.4674/7.0400) \times (7.0400 - 1)/(11.4674 - 1)$$
$$= \$162.61 = \$162/\text{square}$$

(15) Calculations for product asbestos coefficient for Asbestos Regulatory Cost Model.

Tons of asbestos used per unit of output

= 3,893 tons/176,643 squares
= 0.0220 tons/square

(16) Calculations for consumption-production ratio for Asbestos Regulatory Cost Model.

(Domestic production + Imports)/Domestic production

(176,643 squares + 64,654 squares)/(176,643 squares) = 1.37

REFERENCES

AIA/NA and AI. 1986 (June 29). Opening written comments of the Asbestos Information Association/North America and Asbestos Institute on EPA's proposed mining and import restrictions and proposed manufacturing, importation and processing prohibitions. Testimony of Alfred E. Netter, President of Supradur Manufacturing Corporation.

Alcoa. R. Egbert. 1986a (November 25). Alcoa Building Products. Rockville, Maryland. Transcribed telephone conversation with Michael Geschwind, ICF Incorporated, Washington, D.C.

Alcoa. J. Kelemen. 1986b (December 5). Alcoa Building Products. Rockville, Maryland. Transcribed telephone conversation with Michael Geschwind, ICF Incorporated, Washington, D.C.

American Hardboard Association. 1985 (June). Association Literature: "Questions, Answers: Hardboard Siding." Palatine, IL.

American Hardboard Association. 1986a (October). Association Literature: Exterior walls product shipments 1977-1985." Palatine, IL.

American Hardboard Association. 1986b (November 25). Palatine, IL. Transcribed telephone conversation with Michael Geschwind, ICF Incorporated, Washington, DC.

American Home Improvement Co. M. Duncan. 1986 (December 11). Brentwood, Maryland. Transcribed telephone conversation with Michael Geschwind, ICF Incorporated, Washington, D.C.

American Wood Treating. J. Feaver. 1986 (November 21). Mission, B.C., Canada. Transcribed telephone conversation with Michael Geschwind, ICF Incorporated, Washington, D.C.

Asphalt Roofing Manufacturer's Association. 1981. Rockville, Maryland. Association literature: "What you should know about fiberglass shingles."

Asphalt Roofing Manufacturer's Association. 1984. Rockville, Maryland. Association literature: "The Asphalt Roofing Industry."

Asphalt Roofing Manufacturer's Association. 1986 (February 2). Rockville, Maryland. Association Literature: "Production of strip shingles."

Atlas International Building Products. R. Cadieux. 1986a (October 2 and December 17). Montreal, Quebec, Canada. Transcribed telephone conversation with Michael Geschwind, ICF Incorporated, Washington, D.C.

Atlas International Building Products. T. Eames. 1986b (November 6). Port Newark, NJ. Transcribed telephone conversation with Michael Geschwind, ICF Incorporated, Washington, D.C.

Atlas International Building Products. J. Payac. 1986c (November 25). Montreal, Quebec, Canada. Transcribed telephone conversation with Michael Geschwind, ICF Incorporated, Washington, D.C.

Atlas International Building Products. R. Cadieux. 1987 (July 7). Montreal, Quebec, Canada. Transcribed telephone conversation with Michael Geschwind, ICF Incorporated, Washington, D.C.

Certain-Teed. S. Howe. 1986 (December 4). Valley Forge, PA. Transcribed telephone conversation with Michael Geschwind, ICF Incorporated, Washington, D.C.

Chemco. D. Fandrem. 1986a (November 21). Ferndale, WA. Transcribed telephone conversation with Michael Geschwind, ICF Incorporated, Washington, DC.

Chemco. F. Trosino. 1986b (November 21. Ferndale, WA. Transcribed telephone conversation with Michael Geschwind, ICF Incorporated, Washington, DC.

Commonwealth Aluminum. B. Sullenberger. 1986 (December 4). Bethesda, Maryland. Transcribed telephone conversation with Michael Geschwind, ICF Incorporated, Washington, DC.

Contractors Guide Magazine. 1986 (February). Skokie, IL. 60077. Siding/Sheathing Survey. Market Report #9. pp. 1-10.

Eternit, Inc. B. Morrissey. 1986 (November 4). Reading, PA. Transcribed telephone conversation with Michael Geschwind, ICF Incorporated, Washington, DC.

ICF Incorporated. 1985. Appendix H: Asbestos Products and Their Substitutes, in Regulatory Impact Analysis of Controls on Asbestos and Asbestos Products. Washington, D.C.: Office of Pesticides and Toxic Substances, U.S. Environmental Protection Agency.

ICF Incorporated. 1986 (July-December). Survey of Primary and Secondary Processors of Asbestos-Cement Shingles. Washington, DC.

Krusell N., Cogley D. 1982. GCA Corp. Asbestos substitute performance analysis: Revised final report. Washington, DC: Office of Pesticides and Toxic Substances. U.S. Environmental Protection Agency Contract 68-02-3168.

Johnny B. Quick. M. Ryan. 1986 (December 11). Washington, DC. Transcribed telephone conversation with Michael Geschwind, ICF Incorporated, Washington, DC.

Ludowici-Celadon. D. Mohler. 1986 (November 25). New Lexington, OH. Transcribed telephone conversation with Michael Geschwind, ICF Incorporated, Washington, DC.

MCA. Sales Representative. 1986 (December 3). Maharuchi Ceramics Company. Corona, CA. Transcribed telephone conversation with Michael Geschwind, ICF Incorporated, Washington, DC.

Means. 1986. Kingston, MA. 02364. Means Building Construction Cost Data. Shingles, Roofing and Siding. R.S. Means Company Inc. pp. 141-150.

Monier Roof Tile Company. B. Mittenmeyer. 1986a (November 25). Lakeland, FL. Transcribed telephone conversation with Michael Geschwind, ICF Incorporated, Washington, DC.

Monier Roof Tile Company. T. Lua. 1986b (November 25). Corona, CA. Transcribed telephone conversation with Michael Geschwind, ICF Incorporated, Washington, DC.

Moon Sidings. S. Cho. 1986 (December 11). Fairfax, VA. Transcribed telephone conversation with Michael Geschwind, ICF Incorporated, Washington, DC.

National Home Improvement Co., Inc. H. Richard. 1986 (December 11). Washington, DC. Transcribed telephone conversation with Michael Geschwind, ICF Incorporated, Washington, DC.

National Roofing Contractor's Association. J. Wolenski. 1986 (November 13). Chicago, IL. Transcribed telephone conversation with Michael Geschwind, ICF Incorporated, Washington, DC.

National Tile Roofing Manufacturer's Association. W. Pruter. 1986 (November 13). Los Angeles, CA 90039. Transcribed telephone conversation with Michael Geschwind, ICF Incorporated, Washington, DC.

National Tile Roofing Manufacturer's Association. (n.d.) Los Angeles, CA 90039. Association literature: Roofing tile; List of Members, 1986-1987.

Owens-Corning Fiberglas. S. Persinger. 1986 (November 21). Toledo, OH. Transcribed telephone conversation with Michael Geschwind, ICF Incorporated, Washington, DC.

PEI. 1986 (September 26). OTS survey of Supradur Manufacturing Corporation, Rye, NY. Completed by Alfred E. Netter, President of Supradur.

Qualified Remodeler Magazine. B. Sour. 1986 (November 25). Division of Harcourt, Brace, Jovanich. Chicago, IL. Transcribed telephone conversation with Michael Geschwind, ICF Incorporated, Washington, DC.

Raleigh Incorporated. B. Raleigh. 1986 (November 17). Belvedere, IL. Transcribed telephone conversation with Michael Geschwind, ICF Incorporated, Washington, DC.

Red Cedar Shingle & Handsplit Shake Bureau. 1985 Bellevue, WA. Association literature: "Of shakes and shingles..."; "Timeless beauty: red cedar shingles & handsplit shakes."

Red Cedar Shingle & Handsplit Shake Bureau. P. Wood. 1986a (November 21). Bellevue, WA. Transcribed telephone conversation with Michael Geschwind, ICF Incorporated, Washington, DC.

Red Cedar Shingle & Handsplit Shake Bureau. 1986b. Bellevue, WA. Association literature: Production and distribution of red cedar shingles and handsplit shakes, 1983-1985.

RSI. 1986a (August). Chicago, IL. Roofing, Siding, and Insulation Magazine.

"The fiberglass shingles flap." p. 10.

RSI. 1986b (October). Chicago, IL. Roofing, Siding, and Insulation Magazine. "Ban-aid for wood shakes?" p. 32.

San Valle Tile Company. J. Danner. 1986 (December 3). Corona, CA. Transcribed telephone conversation with Michael Geschwind, ICF Incorporated, Washington, DC.

Supradur Manufacturing Corporation. 1985 (September). Wind Gap, PA. Product literature on pre-shrunk mineral fiber siding and roofing specifications.

Supradur Manufacturing Corporation. 1986a (July 15). Testimony of Alfred Netter, President, at the Environmental Protection Agency legislative hearing on its asbestos ban and phase out proposal.

Supradur Manufacturing Corporation. M. Mueller. 1986b (November 4). Wind Gap, PA. Transcribed telephone conversation with Michael Geschwind, ICF Incorporated, Washington, DC.

Supradur Manufacturing Corporation. A. Netter. 1986c (November 4). Letter to Michael Geschwind, ICF Incorporated, Washington, D.C.

TSCA Section 8(a) Submission. 1982. Production Data for Primary Asbestos Processors, 1981. Washington, DC: Office of Toxic Substances, U.S. Environmental Protection Agency. EPA Document Control No. 20-8601012.

U.S. Department of Commerce. 1986a. U.S. Department of Commerce. Consumption of Imports FY 246/1985 Annual. Suitland, MD. Bureau of the Census. U.S. Department of Commerce.

U.S. Department of Commerce P. Confer. 1986b (October 3). Suitland, MD. U.S. Department of Commerce, Division of Minerals and Metals. Bureau of the Census. Transcribed telephone conversation with Michael Geschwind, ICF Incorporated, Washington, DC.

U.S. Plywood. G. Landin. 1986 (November 25). Stamford CT. Transcribed telephone conversation with Michael Geschwind, ICF Incorporated, Washington, DC.

U.S. Tile Company. L. Linville. 1986 (December 3). Corona, CA. Transcribed telephone conversation with Michael Geschwind, ICF Incorporated, Washington, DC.

Wages and Evans. G. Evans. 1986 (December 11). Transcribed telephone conversation with Michael Geschwind, ICF Incorporated, Washington, DC.

Weyerhaeuser Corporation. G. Downey. 1986 (December 4). Transcribed telephone conversation with Michael Geschwind, ICF Incorporated, Washington, DC.

XVIII. DRUM BRAKE LININGS

A. Product Description

Most new light and medium vehicles, i.e., passenger cars and light trucks, are equipped with drum brakes on the rear wheels (and disc brakes on the front). A drum brake consists of a metal drum within which there are two curved metal "shoes," lined on the outside with molded friction material, called drum brake linings. When the brakes are applied, the curved shoes are pressed out against a metal drum that is connected to the wheels of the vehicle. The pressure of the shoes against the drum stops the turning of the wheels. There are two drum linings (one for each brake shoe) for each wheel (GM 1986a, ICF 1985).

In light and medium vehicles, the lining segments are usually a third of an inch thick or less. In heavy vehicles (i.e., heavy trucks and off-road vehicles), the segments are at least three-quarters of an inch thick and are called brake blocks, instead of drum brake linings (Allied Automotive 1986).

Asbestos-based drum brake linings contain approximately 0.38 lbs.[1] of asbestos fiber per lining on average (ICF 1986a). Asbestos is used because of its thermal stability, reinforcing properties, flexibility, resistance to wear, and relatively low cost (Krusell and Cogley 1982).

The primary production process for drum brake linings is a wet-mix process in which asbestos is combined with resins, fillers, and other product modifiers and the mixture is then extruded into flat, pliable sheets. The sheets are cut, formed into a curved shape, and then molded for 4 to 8 hours under moderate heat and pressure. After grinding, the linings are bonded (glued) or riveted to the brake shoe (ICF 1985). While bonded brake linings

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[1] See Attachment, Item 1.

have greater frictional surface area, riveted linings are quieter (Allied Automotive 1986).

Secondary processing of drum linings may be of several types. Some processors install new brake linings into brake assemblies for vehicles. Others repackage linings for sale as replacement parts in the aftermarket. Neither of these secondary processes involve grinding, drilling, or any other treatment of the brake linings that is performed by the primary processors. Another distinct type of secondary processing is automotive rebuilding. Rebuilders receive used, worn brake linings attached to the shoes. The old linings are removed from the shoes, the shoes are cleaned by abrasion, and new linings are attached. The rebuilt shoes with linings are then packaged and sold for the aftermarket (ICF 1985, Krusell and Cogley 1982).

B. Producers and Importers of Drum Brake Linings

Table 1 lists the thirteen primary processors of drum brake linings in 1985. All produced an asbestos-based product. Nine of the processors also produced substitutes (ICF 1986a).

Changes in primary processors from 1981 to 1985 include Friction Division Product's purchase of Thiokol's Trenton, NJ, plant and Brake System Inc.'s purchase of one of Raymark's Stratford, CT, plants (Friction Division Products 1986; Brake Systems 1986). Brassbestos of Paterson, NJ, went out of business in August, 1985 (ICF 1986a) and H.K. Porter of Huntington, IN, discontinued production of drum brake linings in 1986 (PEI Associates 1986). Thus, eleven companies continue to produce asbestos drum brake linings.

Table 2 lists the five current secondary processors of drum brake linings. The Standard Motor Products plant was formerly owned by the EIS division of Parker-Hannifan (ICF 1986a). At Echlin's Dallas, TX, plant, which was formerly owned by Raymark, linings are attached to brake shoes without any

Table 1. 1985 Primary Processors of Drum Brake Linings

Company	Plant Location(s)	Product: Asbestos	Product: Non-Asbestos	References
Allied Automotive	Cleveland, TN Green Island, NY	X X	X X	ICF 1986a, Allied Automotive 1986, TSCA 1982a
General Motors, Inland Division	Dayton, OH	X	X	ICF 1986a, TSCA 1982a
LSI-Certified Brakes (Division of Lear-Siegler)	Danville, KY	X		ICF 1986a, TSCA 1982a
Abex	Winchester, VA	X	X	Abex 1986, TSCA 1982a
Nuturn	Smithville, TN	X	X	ICF 1986a, TSCA 1982a
Virginia Friction Products	Walkerton, VA	X	X	ICF 1986a, TSCA 1982a
Chrysler	Wayne, MI	X	X	ICF 1986a, TSCA 1982a
U.S. Automotive Manufacturing	Tappahannock, VA	X		ICF 1986a, TSCA 1982a
Friction Division Products (plant formerly owned by Thiokol)	Trenton, NJ	X		ICF 1986a, TSCA 1982a
Carlisle, Motion Control Industries Div.	Ridgway, PA	X	X	ICF 1986a, TSCA 1982a
H.K. Porter[a]	Huntington, IN	X	X	ICF 1986a, TSCA 1982a
Brassbestos[b]	Paterson, NJ	X		ICF 1986a, TSCA 1982a
Brake Systems Inc. (Division of Echlin) (plant formerly owned by Raymark)	Stratford, CT	X	X	Brake Systems 1986, TSCA 1982a

[a] H.K. Porter stopped production of asbestos and semi-metallic drum brake linings in 1986 (PEI Associates 1986).

[b] Brassbestos went out of business in August 1985 (ICF 1986a). It is assumed that they produced asbestos-based on drum brake linings in 1985.

Table 2. 1985 Secondary Processors of Drum Brake Linings

Company	Plant Location	Product		References
		Asbestos	Non-Asbestos	
Cali-Blok, EIS Div. of Parker-Hannifan	Gardena, CA	X	X	ICF 1986b, TSCA 1982b
Standard Motor Products	West Bend, WI	X		ICF 1986b, TSCA 1982b
Wagner	Parsippany, NJ	X	N/A	ICF 1986b, ICF 1985
Allied Automotive*	South Bend, IN	N/A	N/A	TSCA 1982b
Echlin	Dallas, TX	X	N/A	Brake Systems 1986, TSCA 1982b

NA: Information not available.

* Did not participate in 1986 ICF Survey.

Table 3 (Continued)

Company	Location	References
American Isuzu Motor Inc.	Whittier, CA	Automobile Importers of America 1986
Nissan Motor Corp.	Gardena, CA	Automobile Importers of America 1986
Porsche Cars North America	Reno, NV	Automobile Importers of America 1986
Renault USA, Inc.	New York, New York	Automobile Importers of America 1986
Rolls-Royce Motors, Inc.	Lyndhurst, NJ	Automobile Importers of America 1986
Subaru of America Inc.	Pennsauken, NJ	Automobile Importers of America 1986
Volvo Cars of North America	Rockleigh, NJ	Automobile Importers of America 1986
Hyundai Motor America	Garden Grove, CA	Automobile Importers of America 1986
Original Quality, Inc.	Jacksonville, FA	Automobile Importers of America 1986

Table 3. Importers of Asbestos-Based Drum Brake Linings

Company	Location	References
Guardian Corp. (Division of Wagner)	Parsippany, NJ	Wagner 1986a, ICF 1984
LSI-Certified Brakes (Division of Lear-Siegler)	Danville, KY	ICF 1986a, ICF 1984
Abex	Winchester, VA	ICF 1984
Toyota Motor Sales, U.S.A	Torrence, CA	ICF 1986a, ICF 1984
Mercedes-Benz of North America	Montvale, NJ	ICF 1984
Saab-Scania of America	Orange, CT	ICF 1986a, ICF 1984
Volkswagen of America	Troy, MI	ICF 1986a, ICF 1984
BMW of North America	Montvale, NJ	ICF 1984
Western Automotive Warehouse Distributors	Los Angeles, CA	ICF 1984
U.S. Suzuki Motor Corporation	Brea, CA	ICF 1986a, ICF 1984
Hawthorne Bonded Brake Co.	Los Angeles, CA	ICF 1986a, ICF 1984
Peugeot Motors of America	Lyndhurst, NJ	ICF 1984
General Motors	Dayton, OH	ICF 1984
J.I. Case Company	Racine, WI	ICF 1984
Alfa Romeo	Englewood Cliffs, NJ	Automobile Importers of America 1986
Fiat	Dearborn, MI	Automobile Importers of America 1986
Jaguar	Leonia, NJ	Automobile Importers of America 1986
Lotus Performance Cars	Norwood, NJ	Automobile Importers of America 1986
Mazda (North America) Inc.	Irvine, CA	Automobile Importers of America 1986
Mitsubishi Motors Corp. Services, Inc.	Southfield, MA	Automobile Importers of America 1986
American Honda Motor Co.	Gardena, CA	Automobile Importers of America 1986

Table 3. Importers of Asbestos-Based Drum Brake Linings

Company	Location	References
Wagner	Parsippany, NJ	Wagner 1986a, Wagner 1986b
Toyota Motor Sales, U.S.A	Torrence, CA	ICF 1986a, ICF 1984
U.S. Suzuki Motor Corp.	Brea, CA	ICF 1986a, ICF 1984
Mercedes-Benz of North America	Montvale, NJ	ICF 1984
Abex	Winchester, VA	ICF 1984
Kawasaki Motors Corp. U.S.A	Santa Ana, CA	ICF 1986a, ICF 1984
General Motors	Dayton, OH	ICF 1984
Volkswagen of America, Inc.	Troy, MI	ICF 1986a, 1986b
Western Automotive Warehouse Distributors	Los Angeles, CA	ICF 1984
J.I. Case Co.	Racine, WI	ICF 1984
Peugeot Motors of America, Inc.	Lyndhust, NJ	ICF 1984
Climax Molybdenum	Golden, Co.	ICF 1984
Original Quality Inc.	Jacksonville, FL	Original Quality 1986
Fiat	Dearborn, MI	Automobile Importers of America 1986
American Honda Motor Co.	Gardena, CA	Automobile Importers of America 1986
American Isuzu Motor Inc.	Whittier, CA	Automobile Importers of America 1986
Mazda (North America) Inc.	Irvine, CA	Automobile Importers of America 1986
Mitsubishi Motors Corp. Services	Southfield, MI	Automobile Importers of America 1986
Nissan Motor Corp.	Gardena, CA	Automobile Importers of America 1986
Renault USA, Inc.	New York, NY	Automobile Importers of America 1986
Subaru of America, Inc.	Pennsauken, NJ	Automobile Importers of America 1986
Hyundai Motor America	Garden Grove, CA	Automobile Importers of America 1986

[a] Volkswagen stated that in the 1987 model year, all vehicles will be fitted with only non-asbestos brake linings (ICF 1986a).

additional processing (Brake Systems 1986). Similarly, Wagner installs brake linings with no additional processing (Wagner 1986a).

Table 3 lists the twenty-one importers of asbestos-based drum brake linings.

C. Trends

Table 4 gives the production of asbestos-based drum brake linings and the corresponding consumption of asbestos fiber. From 1981 to 1985 there was a 19.6 percent decline in production of asbestos drum brake linings. This is probably due to substitution of asbestos in the OEM, and the fact that certain luxury and high-performance cars, that currently account for roughly 5 percent of OEM light/medium vehicles, are now equipped with four disc brakes (e.g., Cadillac Seville and El Dorado, Corvette, Pontiac STE and Fiero, and high-performance Camaros and Firebirds) (GM 1986a).[2]

In addition, it should be noted that some luxury imports, e.g., Mercedes, BMW, and Saab, use disc brakes on all four wheels (GM 1986a, Saab-Scania of America 1986). New Saab cars, in fact, use non-asbestos semi-metallic disc brake pads on all four wheels (Saab-Scania of America 1986). Information was not available on whether all four disc brakes in Mercedes and BMW cars were also non-asbestos-based. Nonetheless, the great majority of imported vehicles are still equipped with asbestos-based rear drum brakes (Ford 1986a, Abex 1986, MIT 1986).

Producers and purchasers of drum brake linings indicated that as of the 1986 model year, asbestos linings still account for 90-95 percent of the original equipment market (OEM) and virtually 100 percent of the aftermarket (GM 1986a, GM 1986c, Chrysler 1986, Allied Automotive 1986, Wagner 1986b, Ford 1986a). However, producers and users agreed that adequate substitutes have

[2] Disc brakes are a higher-performance brake. Applications of drum and disc brakes are discussed in further detail later in this section.

(ICF 1986a). Wagner installs asbestos and non-asbestos brake pads with no additional processing (Wagner 1986a).

Table 3 lists the 1981 and 1985 importers of asbestos-based disc brake pads.

C. Trends

Table 4 gives the production of asbestos-based disc brake pads (light/medium vehicles) and the corresponding consumption of asbestos fiber. The percent change in production and fiber consumption from 1981 to 1985 are -30.2 percent and -25.3 percent, respectively.

It should be noted that some luxury import cars are now equipped with four semi-metallic disc brakes (Allied Automotive 1986). Saab is one such example (Saab-Scania of America 1986). However, the great majority of imported cars still have asbestos-based rear drum brakes (Ford 1986a, Abex 1986, MIT 1986).

A survey of producers, purchasers, and other sources revealed that currently asbestos probably holds no more than 15 percent of the OEM for disc brake pads (light/medium vehicles) (ICF 1986a, GM 1986a, Ford 1986b, Chrysler 1986, Chilton's Motor Age 1986, Allied Automotive 1986, DuPont 1986).[4] The share, however, is significantly higher for the aftermarket, though probably not a majority (GM 1986a).[5]

Allied Automotive stated that by 1990 asbestos would be replaced by nearly 100 percent in the OEM (Allied Automotive 1986). One source stated that by 1990, 90 percent of OEM light/medium vehicles are projected to be front-wheel drive, requiring semi-metallic disc brakes in the front (Chilton's Motor Age 1986). Given the above two projections and the current trends of GM, Ford, and Chrysler, it is clear that by 1990 asbestos-based pads will be almost

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[4] See Attachment, Item 2.

[5] See Attachment, Item 2.

Table 4. Production and Fiber Consumption for Asbestos-Based Drum Brake Linings

	1981	1985	References
Production (pieces)	160,470,368	129,042,578[a]	ICF 1986a, TSCA 1982a
Asbestos Fiber Consumption (tons)	23,878.0	24,691.8[b]	ICF 1986a, TSCA 1982a

[a] Abex, Allied Automotive (both plants), Brake Systems, and Brassbestos did not provide production information. Brassbestos went out of business in August, 1985; it is assumed that they produced asbestos-based drum brake linings in 1985 (ICF 1986a). Production was estimated for these four companies using a method described in the Appendix A of this RIA.

[b] Abex, Allied Automotive (both plants), Brake Systems, and Brassbestos did not provide fiber consumption information. Brassbestos went out of business in August, 1985; however, it is assumed that they consumed asbestos fiber for the production of asbestos-based drum brake linings in 1985 (ICF 1986a). Fiber consumption for these four companies was estimated using a method described in Appendix A of this RIA.

been developed for many, if not most, OEM drum brake lining applications (Abex 1986, GM 1986c, Ford 1986a).[3] A report by the American Society of Mechanical Engineers concluded that automobile and most trucks could have completely non-asbestos friction systems by 1992 (ASME 1987). Producers and users stated that time is required to gear up commercial production of the substitute linings, redesign brake systems to accommodate the particular coefficient of friction of the substitute material (where required), and to conduct field tests in order to gain the acceptance of lining producers, vehicle and brake system manufacturers, and consumers (GM 1986c, Ford 1986a, Abex 1986).

With the exception of Allied Automotive and Abex, producers are apparently not yet producing substitute drum brake linings in sizeable quantities (ICF 1986a).[4] Estimates for the time required to develop adequate production capacity for substitutes were not available; however, this time period is likely to be linked to vehicle manufacturers' approval of new substitutes.

Unlike disc brakes pads, in which a superior substitute has been available for the last fifteen years (i.e., semi-metallic pads), non-asbestos drum brake linings are relatively new (Abex 1986, Ford 1986a). Both producers and users of brake linings are highly averse to the risk that could be associated with the use of new materials. The risk is magnified, furthermore, when a major brake system redesign is required for a substitute lining (Abex 1986, Ford

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[3] Representatives from Ford and GM agreed there were adequate substitutes for many light/medium vehicle applications (cars and light trucks), but there were problems with finding good substitutes for large cars and medium-sized trucks (e.g., 2 1/2-ton delivery trucks) (Ford 1986a, GM 1986c). A representative from Abex, however, firmly believed that adequate substitutes have been developed for all drum brake lining applications (Abex 1986).

[4] As indicated earlier, Allied Automotive estimates that 18 percent of its 1986 drum brake lining production will be non-asbestos (Allied Automotive 1986). Abex did not provide an estimate of the current share of its OEM drum brake linings that are non-asbestos, but did indicate that a significant percentage was non-asbestos (Abex 1986).

1986a, GM 1986c, Allied Automotive 1986, Wagner 1986b).[5] This risk translates into stringent and lengthy testing processes required by both government and automobile and brake lining manufacturers before acceptance of new friction materials and brake systems.

Sufficient laboratory and vehicle testing has been conducted for the substitute drum brake linings in order to certify that they comply with federal performance and safety regulations (Abex 1986, Ford 1986a, GM 1986c).[6] However, vehicle manufacturers also require, on average, a total of one million miles of field testing in a variety of geographic locations, and under a variety of road conditions, before a new brake lining material or brake system design will be incorporated into OEM vehicles. Brake lining producers and vehicle manufacturers agreed that this field testing has only begun (Abex 1986, Ford 1986a, GM 1986c).

According to Ford, a potential alternative for asbestos in drum brake linings would be to make light/medium vehicles with four non-asbestos (semi-metallic) disc brakes (Ford 1986a).[7] However, brake lining producers

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[5] Producers and users stated that there are two general types of substitute linings -- those that require only minor modifications of brake systems and those that require major modifications or total brake system redesigns (Ford 1986a, Abex 1986).

[6] Compliance with federal performance and safety regulations -- Federal Motor Vehicle Safety Standards (FMVSS) 105, 121, and the proposed 135 -- can be certified at the testing facilities of OEM brake lining producers. At these facilities, producers always employ, at a minimum, dynamometer testing (recognized in the industry to be the most reliable and accurate laboratory testing method) and vehicle testing in a controlled environment (i.e., race track) (Abex 1986, Ford 1986a, GM 1986c).

[7] Semi-metallic disc brakes are already used on the front wheels of 85 percent of all new light/medium vehicles (Allied Automotive 1986), and certain domestic luxury and high-performance cars are now equipped with four non-asbestos disc brakes (GM 1986a). Disc brakes, particularly semi-metallic disc brakes, have higher performance than drum brakes because they have longer service life and are generally better at removing heat quickly (GM 1986a). Perhaps even more important for automakers, disc brakes have a very strong marketing advantage: disc brakes make cars sell. They are an important selling point with consumers (Ford 1986a, GM 1986a, Abex 1986).

and vehicle manufacturers agreed that there currently is not a significant trend towards four disc brakes in light/medium vehicles, nor is there likely to be in the near future, because of important performance and economic factors (Abex 1986, GM 1986a, GM 1986c, GMI 1986, Ford 1986a). First drum brakes make superior parking brakes (GM 1986a, Ford 1986a, Abex 1986).[8] Disc brakes, furthermore, reduce fuel economy because of "parasitic drag" and are much higher in cost than drum brakes because of the mechanical system required for disc brakes (Ford 1986a, GM 1986a). Because drum brakes are significantly cheaper and are a lower performance brake, they are used for the rear wheels, with disc brakes in the front, in the vast majority of the light/medium vehicle OEM (95 percent) (GM 1986a).[9] In most light/medium vehicles, particularly those with front-wheel drive, there is significantly less brake load or brake force in the rear than in the front.[10] Therefore, the cheaper lower-performance drum brakes are used in the rear since the rear brakes do not have to do much work (GM 1986a).[11] A final key factor that would stall a significant switch-over to four-disc-brake cars is the enormous equipment redesign that would be required (GMI 1986). Therefore, for the above-mentioned reasons, drum brake linings, at least in the near future, will continue to be produced for the light/medium vehicle OEM at roughly a 1:1 ratio with disc brakes.

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[8] The parking brake either utilizes the existing rear drum brakes (service brakes), is a separate rear drum brake, or is a separate front disc brake (front parking brake) (GM 1986a).

[9] The remaining 5 percent are the luxury and high performance cars equipped with four disc brakes (GM 1986a).

[10] In front-wheel drive cars, the brake load is 85 percent in the front and in rear-wheel drive cars, about 70 percent of the load is in the front (Ford 1986a, Design News 1984).

[11] In most cars, in fact, rear drum brakes would have the same service life as rear disc brakes because of the light brake load (GM 1986a).

D. Substitutes

As indicated earlier, primary processors and vehicle manufacturers agree that acceptable drum brake lining formulations have been developed for many, if not most, drum brake lining applications. Although these substitutes do not have the same performance characteristics as asbestos-based linings (no substitute currently provides all the advantages that asbestos linings do), they are "acceptable" from the standpoint of vehicle drivers: drivers will accept changes in performance, as long as there are no "surprises" while driving that reduce safety (Abex 1986, Ford 1986a, GM 1986c, MIT 1986). Non-asbestos organics (NAOs) are acceptable substitutes that have been developed for the OEM. Lining producers and vehicle manufacturers agree that NAOs would take the majority of the asbestos-based OEM in the event of a ban (GM 1986c, Abex 1986, Ford 1986a, Carlisle 1986).

NAO drum brake lining formulations, in general, include the following: fiberglass and/or Kevlar(R), mineral fibers,[12] occasionally some steel wool, and fillers and resins (Ford 1986a). Fiberglass and Kevlar(R), however, usually account for only a small percentage of the total formulation. For example, a representative from Ford stated that the optimal level of Kevlar(R) in drum brake lining formulations is usually about 3 percent by weight (Ford 1986a). Thus, labelling substitute drum brake linings as Kevlar(R)-based or fiberglass-based (producers tend to do this for marketing reasons) is misleading (Abex 1986, Ford 1986a, GM 1986c).

Of the thirteen primary processors of drum brake linings in 1985, at least eight currently produce NAO linings. These firms are: Allied Automotive, General Motors Inland Division, Abex, Nuturn, Virginia Friction Products,

[12] Mineral fibers commonly used by producers include: wollastonite, phosphate fiber, aluminum silicate fiber, Franklin fiber, mineral wool, and PMF (processed mineral fiber) (ICF 1986a).

Chrysler, Carlisle, and Brake Systems Inc. (ICF 1986a). Although, the producers did not reveal the exact formulations of their NAO linings, they provided partial lists of the ingredients in their mixtures (ICF 1986a).

Five of the primary processors also produce a semi-metallic drum brake lining. These firms are: Abex, Allied Automotive, Carlisle, General Motors Inland Division, and H.K. Porter (Abex 1986, Allied Automotive 1986, ICF 1986a). Lining producers and vehicle manufacturers generally agree, however, that there are serious production and performance problems with semi-metallic drum brake linings (Abex 1986, GM 1986c, Ford 1986a, Carlisle 1986). H.K. Porter, in fact, discontinued its semi-metallic (and asbestos) drum brake lining operations in 1986; the firm stated that it was unable to find adequate substitute linings (PEI Associates 1986). Representatives from Abex and Ford stated that semi-metallics are very difficult to process into the required thin arc-shaped lining segments and are, thus, very prone to crack (Abex 1986, Ford 1986a).[13] These representatives also stated there were unacceptable performance problems, including "morning sickness," which involves moisture getting into the lining overnight, rendering the product useless until it heats up and dries out (Abex 1986, Ford 1986a). For the above reasons, lining producers and vehicle manufacturers agreed that semi-metallics would not take much of a share of the asbestos-based OEM in the event of a ban (Abex 1986, GM 1986c, Ford 1986a, Carlisle 1986).

Primary processors and vehicle manufacturers agree that there is adequate dynamometer and vehicle-testing capacity among the OEM producers to develop substitutes for the remaining OEM drum brake lining applications, i.e. medium-sized trucks with four-drum-brake systems. The difficulty in

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[13] Semi-metallics can, however, be successfully manufactured for very heavy brake block applications, where the arc of the segments is much wider than in drum brake linings (because of the larger drum) and the segments are considerably thicker (Abex 1986).

developing acceptable substitute linings for medium-sized trucks results from the more severe braking requirements for the rear drum brakes of these vehicles than for the majority of light/medium vehicles and the fact that the drum brake linings for medium-sized trucks must be riveted, not bonded, to the brake shoe. Thus, an acceptable substitute lining must have structural strength around the rivet area (Batelle 1987). Nevertheless, given enough time substitute linings for medium-sized trucks will be developed, particularly since brake systems can always be redesigned by including servo mechanical systems to amplify or modify the braking ability of a particular substitute lining in order to achieve the desired performance (Ford 1986a, Abex 1986, GM 1986c, MIT 1986).

Replacement of asbestos-based drum brake linings in the aftermarket, however, may be much more difficult. Most asbestos-based drum brake linings producers and auto manufacturers agree that brake systems designed for asbestos linings should continue to use asbestos linings. The parties maintain a position that substitute lining formulations that were designed for the OEM, when used to replace worn asbestos linings, do not perform as well as asbestos, and could jeopardize brake safety (Allied Automotive 1986, GM 1986b, GM 1986c, Wagner 1986b, Ford 1986a, Ford 1986b). Abex, however, indicated that it is selling its OEM non-asbestos organic drum brake linings for the aftermarket and reports that they are performing well (Abex 1986).

In general there are three important reasons for little or no development of substitute formulations engineered for aftermarket brake systems designed for asbestos:

- Considerable technical difficulties with developing adequate substitutes for a system designed specifically for asbestos;

- No federal safety and performance standards for brakes for the aftermarket;[14] and,
- High cost of producing and testing substitute formulations (Ford 1986a, Wagner 1986b, Abex 1986).

Aftermarket producers, except for those who also produce for the OEM, are generally small and almost totally lacking in testing equipment (Ford 1986a). Two firms stated that if some of these firms devoted substantial resources to testing and research and development, they would be out of business (Ford 1986a, Abex 1986). As long as there are asbestos drum brakes sold in the aftermarket, there will be little, if any, economic incentive to develop retrofit substitutes (LBJ Space Center 1986). However, even with a ban on asbestos linings for the aftermarket, the cost of substitutes designed for the aftermarket are likely to be prohibitive, given the technical difficulties (LBJ Space Center 1986).

Table 5 provides the data for the regulatory cost model. The substitute linings in the table are an NAO lining produced by Abex and a semi-metallic lining made by General Motors Inland Division. It is assumed that semi-metallic drum brake linings will account for a negligible share of the market. Note that the equivalent price of the NAO lining given in Table 5 is close to the asbestos lining price because of the longer service life.

E. Summary

Asbestos drum brakes are found on the rear wheels of most new light and medium vehicles, i.e., passenger cars and light trucks (GM 1986a). Thirteen companies produced asbestos drum brake linings in 1985 and by the end of 1986 only eleven continued to produce the asbestos product (ICF 1986a, PEI Associates 1986). In 1985, these producers consumed 24,691.8 tons of asbestos to produce 129,042,578 asbestos drum brake linings. Between 1981 and 1985,

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[14] By contrast, OEM brakes must meet federal regulatory standards -- FMVSS 105 and 121 (and, in the future, the proposed 135).

Table 5. Data Inputs on Drum Brake Linings for Asbestos Regulatory Cost Model[a]

Product	Output	Product Asbestos Coefficient	Consumption Production Ratio	Price	Useful Life	Equivalent Price	Market Share	Reference
Asbestos Mixture	129,042,578 pieces[b]	0.00019 tons/piece	1.15	$0.63/piece	4 years	$0.63/piece	N/A	ICF 1986a, ICF 1985
NAO	N/A	N/A	N/A	$0.79/piece	5 years	$0.65/piece	99%	Abex 1986, Ford 1986a, Carlisle 1986
Semi-Metallic	N/A	N/A	N/A	$1.09/piece	4 years	$1.09/piece	1%	ICF 1986a, Abex 1986, Ford 1986a, Carlisle 1986

N/A: Not Applicable.

[a] See Attachment, Items 3-5.

[b] The output for drum brake linings is split into OEM brakes (34,713,675 pieces) and aftermarket brakes (94,328,903 pieces) based on the ratio of OEM and replacement sales shown in Appendix A.

production of the asbestos linings declined 19.6 percent (ICF 1986a). However, asbestos linings still accounted for 90-95 percent of the OEM and virtually 100 percent of the aftermarket (GM 1986a, GM 1986c, Chrysler 1986, Allied Automotive 1986, Wagner 1986b, Ford 1986a). Acceptable substitutes have been developed for many, if not most, drum brake lining applications. For the OEM, NAOs are expected to take 99 percent and semi-metallics 1 percent of the asbestos drum brake lining market if asbestos were not available. NAOs cost the same as asbestos linings, while semi-metallics cost 73 percent more than the asbestos-based product. Developing adequate substitutes for the aftermarket will be difficult due to technical difficulties and economic factors.

ATTACHMENT

1. The asbestos fiber content per lining was calculated by dividing the 1985 asbestos fiber consumption for drum brake linings by the 1985 production of drum brake linings for producers for which both fiber consumption and production data were available: 24,691.8 tons (49,383,600 lbs.) divided by 129,042,578 pieces, or 0.38 lbs per piece.

2. A large producer of asbestos-based drum brake linings in 1981, stated that the share held by asbestos in its OEM linings was 97 percent in 1983, 96 percent in 1984, 91 percent in 1985, and is estimated to be 82 percent in 1986. One automobile manufacturer stated that currently 95 percent of its OEM drum brake linings were asbestos-based (GM 1986a). A second automobile manufacturer stated that currently 98.5 percent of its OEM linings were asbestos-based (Chrysler 1986). On the basis of these figures, it is assumed that asbestos holds roughly 90-95 percent of the OEM for drum brake linings. Two major producers of brake systems for the automobile and truck aftermarkets stated that 100 percent of the aftermarket was still asbestos-based.

3. The product asbestos coefficient is the same value calculated in Item 1 above, converted into tons per piece.

4. The consumption production ratio was calculated using 19,580,493 pieces as the value for the 1985 U.S. imports. (Total 1985 production is 129,042,078 pieces.) This value, however, only includes imports for the firms who provided information (see Table 4).

5. The asbestos product price is a weighted average (by production) of prices for producers who provided information. The useful life of the asbestos product was assumed to be the same as that reported in 1984 in Appendix A (ICF 1985). The two substitute lining prices were calculated by increasing the weighted average asbestos product price by what Abex and GM, respectively, reported as the percentage price increase for their substitute product over their asbestos product. One company indicated that its NAO lining cost 25 percent more than its asbestos-based lining; another company stated its semi-metallic lining was approximately 73 percent higher than its asbestos lining. While the first company did not indicate the service life of its NAO lining compared to its asbestos product, another manufacturer of NAO drum brake linings, reported that NAO linings had the same or up to 50 percent longer service life. Thus, a service life increase of 25 percent over the life of the asbestos product (that was given in Appendix H) is used in Table 5. It was not clear whether semi-metallic linings had longer or shorter service life than asbestos linings; therefore, the same service life as the asbestos product is used.

REFERENCES

Abex Corp. R. Nelson. 1986 (December 3). American Society of Mechanical Engineers Conference in Washington, D.C. Transcribed conversation with Richard Hollander, ICF Incorporated, Washington, D.C.

Allied Automotive. E. Rogers. 1986 (October 17). Troy, NY. Transcribed telephone conversation with Richard Hollander, ICF Incorporated, Washington, D.C.

ASME. 1987 (April 15). The American Society of Mechanical Engineers. Final Report on Analyses of the Feasibility of Replacing Asbestos in Automobile and Truck Brakes. Prepared for the Environmental Protection Agency.

Automobile Importers of America. 1986. Comments of Automobile Importers of America on Proposed Asbestos Ban Rule. EPA Document Control No. OPTS-62036.

Battelle Columbus Laboratories. S. Barber. 1987 (June 26). Columbus, OH. Transcribed telephone conversation with Michael Geschwind, ICF Incorporated, Washington, D.C.

Brake Systems Inc. S. Mayo. 1986 (November 18). Stratford, CT. Transcribed telephone conversation with Richard Hollander, ICF Incorporated, Washington, D.C.

Carlisle. R. Tami. 1986 (October 17). Ridgway, PA. Transcribed telephone conversation with Richard Hollander, ICF Incorporated, Washington, D.C.

Chrysler Corp. M. Heitkamp. 1986 (November 4). Detroit, MI. Transcribed telephone conversation with Richard Hollander, ICF Incorporated, Washington, D.C.

Design News. 1984 (March 26). Asbestos Substitutes in Friction Applications. S. Scott.

Ford Motor Co. A. Anderson. 1986a (December 3). American Society of Mechanical Engineers Conference in Washington, D.C. Transcribed conversation with Richard Hollander, ICF Incorporated, Washington, D.C.

Ford Motor Co. 1986b. Comments of Ford Motor Co. on Proposed Asbestos Ban Rule. EPA Document Control No. OPTS-62036.

Friction Division Products. R. Carney. 1986 (July-December). Trenton, NJ. Transcribed telephone conversation with Richard Hollander, ICF Incorporated, Washington, D.C.

General Motors Corp. F. Brookes. 1986a (November 19). Dayton, OH. Transcribed telephone conversation with Richard Hollander, ICF Incorporated, Washington, D.C.

General Motors Corp. 1986b. Comments of General Motors Corp. on Proposed Asbestos Ban Rule. EPA Document Control No. OPTS-62036.

General Motors Corp. P. Vernia. 1986c (December 3). American Society of Mechanical Engineers Conference in Washington, D.C. Transcribed conversation with Richard Hollander, ICF Incorporated, Washington, D.C.

General Motors Institute. S. Gratch. 1986 (December 3). American Society of Mechanical Engineers Conference in Washington, D.C. Transcribed conversation with Richard Hollander, ICF Incorporated, Washington, D.C.

ICF Incorporated. 1984. Imports of Asbestos Mixtures and Products. Washington, D.C.: Office of Pesticides and Toxic Substances, U.S. Environmental Protection Agency. EPA CBI Document Control No. 20-8600681.

ICF Incorporated. 1985. Appendix H: Asbestos Products and Their Substitutes, in Regulatory Impact Analysis of Controls on Asbestos and Asbestos Products. Washington, D.C.: Office of Pesticides and Toxic Substances, U.S. Environmental Protection Agency.

ICF Incorporated. 1986a (July-December). Survey of Primary Processors of Disc Brake Pads (Light and Medium Vehicles). Washington, D.C.

ICF Incorporated. 1986b (July-December). Survey of Secondary Processors of Disc Brake Pads (Light and Medium Vehicles). Washington, D.C.

Krusell N., Cogley D. 1982. GCA Corp. Asbestos Substitute Performance Analysis, Revised Final Report. Washington, D.C.: Office of Pesticides and Toxic Substances, U.S. Environmental Protection Agency. Contract 68-02-3168.

Lyndon B. Johnson Space Center. J. McCullough. 1986 (December 3). American Society of Mechanical Engineers Conference in Washington, D.C. Transcribed conversation with Richard Hollander, ICF Incorporated, Washington, D.C.

Massachusetts Institute of Technology. E. Rabinowicz. 1986 (December 3). American Society of Mechanical Engineers Conference in Washington, D.C. Transcribed conversation with Richard Hollander, ICF Incorporated, Washington, D.C.

Original Quality, Inc. 1986. Comments of Original Quality, Inc. on Proposed Asbestos Ban Rule. EPA Document Control No. OPTS-62036.

PEI Associates. 1986. OTS. Survey of Asbestos Product Manufacturers. Washington, D.C.: Office of Pesticides and Toxic Substances, U.S. Environmental Protection Agency.

Saab-Scania of America. D. Rainey. 1986 (November 21). Orange, CT. Transcribed conversation with Richard Hollander, ICF Incorporated, Washington, D.C.

TSCA Section 8(a) Submission. 1982a. Production Data for Primary Asbestos Processors, 1981. Washington, D.C.: Office of Toxic Substances, U.S. Environmental Protection Agency. EPA Document Control No. 20-8601012.

TSCA Section 8(a) Submission. 1982b. Production Data for Secondary Asbestos Processors, 1981. Washington, D.C.: Office of Toxic Substances, U.S. Environmental Protection Agency. EPA Document Control No. 20-8670644.

Wagner Corp. F. Hayes. 1986a (December 5). Parsippany, N.J. Transcribed telephone conversation with Richard Hollander, ICF Incorporated, Washington, D.C.

Wagner Corp. 1986b. Comments of Wagner Corp. on Proposed Asbestos Ban Rule. EPA Document Control No. OPTS-62036.

XIX. DISC BRAKE PADS (LIGHT/MEDIUM VEHICLES)

A. Product Description

Disc brakes are used on the front wheels of virtually all (95 percent) light and medium vehicles (cars and light trucks) (GM 1986a). Approximately 5 percent of light/medium vehicles, certain luxury and high-performance cars (e.g., Cadillac Seville and El Dorado, Corvette, Pontiac STE and Fiero, high-performance Camaro and Firebird), have disc brakes on all four wheels (GM 1986a). A disc brake consists of a caliper to which are attached two steel plates, each lined with a molded friction material called a disc brake pad. The two disc brake pads straddle the rotor, or disc, that is in the center of a vehicle's wheel. Friction between the disc and the brake pad stops the vehicle when the brakes are applied (ICF 1985, Krusell and Cogley 1982).

Asbestos-based disc brake pads, like drum brake linings, are molded products containing asbestos fiber, fillers, additives, and resins. A dry-mix process is usually used in their manufacture; the basic steps in this process are as follows:

- Mixing of fibers, dry resins, and property modifiers;
- Molding and curing using heat and pressure; and
- Finishing by grinding and drilling.

The degree of automation of these steps may vary considerably among manufacturers, but once the finishing is completed, the pads are either bonded (glued) or riveted to the steel plates (ICF 1985, Krusell and Cogley 1982, Allied Automotive 1986).[1] The approximate asbestos fiber content per pad is 0.22 lbs. (ICF 1986a).[2]

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[1] While bonded brake pads have greater frictional surface, riveted pads are quieter (Allied Automotive 1986).

[2] See Attachment, Item 1.

Secondary processing of disc brake pads includes installation of pads into new brake assemblies, repackaging for sale to the aftermarket, and retrofitting worn brake pads with new pads for resale (ICF 1985, Krusell and Cogley 1982).

In addition to asbestos-based disc brake pads, there are semi-metallics. Semi-metallics pads have been in the domestic market for the last 15 years (Abex 1986). These pads are molded products containing chopped steel wool, sponge iron, graphite powder, fillers, and resins (Allied Automotive 1986, Ford 1986a). Some semi-metallic pads contain a very thin asbestos-containing backing, or underlayer, between the plate and pad. Other semi-metallic pads have no underlayer or have one made of a non-asbestos material. The underlayer acts as a thermal barrier between the pad and plate, and helps to bond the pad to the plate (Allied Automotive 1986). Producers generally do not consider semi-metallic pads with the asbestos underlayer to be asbestos pads since the lining itself contains no asbestos and the underlayer is only a very small percentage of the total content of the pad (Allied Automotive 1986).

Disc brake pads are used in the front of light/medium vehicles, whether rear-wheel or front-wheel drive, because of the heavier brake load or brake force in the front of vehicles (GM 1986a).[3] Disc brakes have higher performance than drum brakes, which are usually used in the rear, because they have longer service life and are generally more efficient at dissipating (GM 1986a). Front-wheel drive vehicles, which have greater brake load in the front (and, thus, generate more brake heat in the front) than rear-wheel drive vehicles, use semi-metallic disc brakes in the front, exclusively (Allied

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[3] In front-wheel drive cars the brake load is 85 percent in the front and in rear-wheel drive cars, about 70 percent of the load is in the front (Ford 1986a, Design News 1984).

Automotive 1986, Chilton's Motor Age 1986). Semi-metallic disc brakes perform better at higher temperatures than asbestos-based disc brakes and have a longer service life (Allied Automotive 1986, GM 1986a). Rear-wheel drive vehicles generally use asbestos-based disc brake pads in the front, though some also use semi-metallic front disc brakes (e.g., Ford Mustang) (Ford 1986b, GM 1986a). In general, at lower temperatures, asbestos-based disc brakes perform better than semi-metallics, and are quieter (GM 1986a, Allied Automotive 1986).

B. Producers and Importers of Disc Brake Pads (Light/Medium Vehicles)

Table 1 lists the fourteen 1985 primary processors of disc brake pads (asbestos and non-asbestos) for light/medium vehicles. Thirteen of the processors produced asbestos-based pads in 1985 and, currently, twelve are still producing. Twelve of the producers also produced a non-asbestos pad (Brake Systems 1986, ICF 1986a). Friction Division Products only produces non-asbestos pads (ICF 1986a).

Changes in primary processors from 1981 to 1985 include Friction Division Product's purchase of Thiokol's Trenton, NJ, plant and Brake Systems Inc.'s purchase of one of Raymark's Stratford, CT, plants (ICF 1986a, Brake Systems 1986). Brassbestos of Paterson, NJ, went out of business in August, 1985 (ICF 1986a). H.K. Porter of Huntington, IN (not listed in Table 1), stopped producing disc brake pads altogether prior to 1985 (ICF 1986a).

Table 2 lists the 1985 secondary processors of disc brake pads. The Standard Motor Products plant, formerly owned by the EIS Division of Parker-Hannifin, no longer is involved in secondary processing of asbestos-based pads

Table 1. 1985 Primary Processors of Disc Brake Pads
(Light and Medium Vehicles)

Company	Plant Location(s)	Product		References
		Asbestos	Non-Asbestos	
Brake Systems Inc. (Division of Echlin) (plant formerly owned by Raymark)	Stratford, CT	X	X	Brake Systems 1986, TSCA 1982a
Delco Moraine Division, General Motors	Dayton, OH	X	X	GM 1986a, TSCA 1982a
Abex	Winchester, VA	X	X	Abex 1986, TSCA 1982a
Allied Automotive	Green Island, NY Cleveland, TN	X X	X X	Allied Automotive 1986, TSCA 1982a
Nuturn	Smithville, TN	X	X	ICF 1986a, TSCA 1982a
Auto Specialties Manufacturing Company	St. Joseph, MI	X	X	ICF 1986a, TSCA 1982a
LSI-Certified Brakes (Division of Lear-Siegler)	Danville, KY	X	X	ICF 1986a, TSCA 1982a
Brassbestos	Paterson, NJ	X[a]		ICF 1986a, TSCA 1982a
Friction Division Products (plant formerly owned by Thiokol)	Trenton, NJ		X	ICF 1986a, TSCA 1982a
U.S. Automotive Manufacturing	Tappahannock, VA	X		ICF 1986a, TSCA 1982a
Virginia Friction Products	Walkerton, VA	X	X	ICF 1986a, TSCA 1982a
H. Krasne Manufacturing	Los Angeles, CA	X	X	ICF 1986a, TSCA 1982a
Chrysler	Wayne, MI	X	X	ICF 1986a, TSCA 1982a
Auto Friction Corp.	Lawrence, MA	X	X	ICF 1986a, TSCA 1982a

[a]Brassbestos went out of business in August 1985. However, it is assumed that they produced asbestos-based disc brake pads in 1985.

Table 2. 1985 Secondary Processors of Disc Brakes Pads
(Light and Medium Vehicles)

Company	Plant Location	Product		References
		Asbestos	Non-Asbestos	
Standard Motor Products (plants formerly owned by EIS Division of Parker-Hannifin)	West Bend, WI		N/A	ICF 1986b, TSCA 1982b
Wagner	Parsippany, NJ	X	N/A	ICF 1986b, ICF 1985
Cali-Blok (EIS Division of Parker-Hannifin)	Gardena, CA	X	X	ICF 1986b, TSCA 1982b

N/A: Information not available.

Table 4. Production and Fiber Consumption for Asbestos-Based Disc Brake Pads (Light and Medium Vehicles)

	1981	1985	Percent Change (%)	References
Production (pieces)	94,409,007	65,869,172[a]	-30.2	ICF 1986a, TSCA 1982a
Asbestos Fiber Consumption (tons)	9,525.9	7,119.2[b]	-25.3	ICF 1986a, TSCA 1982a

[a]Allied Automotive, Abex, Brassbestos, and Brake Systems Inc. did not provide 1985 asbestos disc brake pad production data. Their production was estimated using a method described in the Appendix A of this RIA.

[b]Abex, Brassbestos, and Brake Systems Inc. did not provide 1985 fiber consumption data. Their fiber consumption was estimated using a method described in the Appendix A of this RIA.

completely replaced in the OEM.[6] Although asbestos is still contained in the underlayer of some semi-metallic pads, the trend is, also, towards complete replacement.[7]

D. Substitutes

Semi-metallics are the only major substitute for asbestos-based disc brake pads (light/medium vehicles). GM, Ford, and Chrysler indicated that essentially all of their non-asbestos disc brake pads were semi-metallic (GM 1986a, Ford 1986b, Chrysler 1986). Nine of the fourteen producers of disc brake pads make a semi-metallic product: Allied Automotive, Nuturn, Friction Division Products, GM, Virginia Friction Products, H. Krasne Manufacturing Co., Chrysler, Abex, and LSI-Certified Brakes (ICF 1986a, Allied Automotive 1986, Abex 1986). Nuturn and Virginia Friction Products stated that Kevlar was also contained in their semi-metallic pads (ICF 1986a). A representative from GM stated that non-semi-metallic non-asbestos pads had a very small share of the OEM (GM 1986a). The other class of non-semi-metallic substitute pads are the non-asbestos organic (NAO) pads. Two producers, Brake Systems Inc. and Auto Friction Corp., were found to make these pads, but neither indicated whether they produced them in sizeable quantities (ICF 1986a).

As indicated earlier, asbestos holds only 15 percent of OEM disc brake pads (light/medium vehicles). Thus, the balance of 85 percent is nearly all semi-metallics (Allied Automotive 1986). Given the trend towards 100 percent front-wheel drive light/medium vehicles, it is clear that semi-metallics will replace most if not all asbestos pads in the near future (Chilton's Motor Age 1986, Allied Automotive 1986).

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[6] See Attachment, Item 2, for the current trends of GM, Ford, and Chrysler.

[7] See Attachment, Item 3.

Substitutes for the thin asbestos underlayer in some semi-metallic pads include either no underlayer or a chopped fiberglass or Kevlar(R) underlayer, depending upon the application (Allied Automotive 1986). Allied Automotive stated that the substitutes for the asbestos underlayer performed just as well (Allied Automotive 1986).

Replacement of asbestos pads with substitutes in the aftermarket, however, is much more difficult. Most producers and users agreed that brake systems designed for asbestos pads should continue to use asbestos. Semi-metallic pads which were designed for the OEM, when used to replace worn asbestos pads, do not perform as well as asbestos, and could jeopardize brake safety (Allied Automotive 1986, GM 1986b, Wagner 1986b, Ford 1986c). A much higher percentage of vehicles in the aftermarket, furthermore, are rear-wheel drive, most of which were designed to have asbestos front disc brakes (Chilton's Motor Age 1986).

In general, there are three important reasons for little or no development of substitutes engineered for aftermarket brake systems that were designed for asbestos:

- Considerable technical difficulties with developing adequate substitutes for a system designed specifically for asbestos;
- No federal safety and performance standards for brakes for the aftermarket;[8] and,
- High cost of producing and testing substitute formulations (Allied Automotive 1986, GM 1986c, Ford 1986a, Ford 1986b, Wagner 1986b, Abex 1986).

Aftermarket producers, except for those who also produce for the OEM, are generally small and almost totally lacking in testing equipment (Ford 1986a). If any of these firms devoted substantial resources to testing

[8] By contrast, OEM brakes must meet certain regulatory standards, Federal Motor Vehicle Safety Standards (FMVSS) 105 and 121 (and, in the future, the proposed 135) (Ford 1986a, Abex 1986).

and research and development, they would be out of business (Ford 1986a, Abex 1986). As long as there are asbestos disc brakes sold in the aftermarket, there will be little, if any, economic incentive to develop retrofit substitutes (LBJ Space Center 1986). However, even with a ban on asbestos pads for the aftermarket, the cost of substitutes designed for the aftermarket are likely to be prohibitive, given the technical difficulties (LBJ Space Center 1986).

Table 5 provides the data for the regulatory cost model. The substitute is the semi-metallic disc brake pad. Price and performance data were not available for NAO pads either because companies would not provide information or production was in very limited quantities (ICF 1986a). It is assumed, however, that NAO pads would account for a negligible share of the market. Note that the equivalent price of the semi-metallic pad is slightly less than the asbestos pad price because of the significantly longer service life.

E. Summary

Disc brakes are used on the front wheels of virtually all (95 percent) light and medium vehicles (cars and light trucks). Approximately 5 percent of all light/medium vehicles have disc brakes on all four wheels (GM 1986a). Thirteen companies consumed 7,119.2 tons of asbestos to produce 65,869,172 asbestos disc brake pads in 1985. Twelve companies are still producing. Between 1981 and 1985, production of asbestos disc brake pads declined approximately 30 percent (ICF 1986a, TSCA 1982a). Currently, asbestos only comprises 15 percent of the OEM for disc brake pads; the balance of 85 percent is held by semi-metallics (Allied Automotive 1986). If asbestos were no longer available it is predicted that semi-metallics would take 100 percent of the asbestos market. The

Table 5. Data Inputs on Disc Brake Pads (LMV) for Asbestos Regulatory Cost Model[a]

Product	Output	Product Asbestos Coefficient	Consumption Production Ratio	Price	Useful Life	Equivalent Price	Market Share	Reference
Asbestos Mixture	65,869,172 pieces[b]	0.00011 tons/piece	1.19	$0.42/piece	4 years	$0.42/piece	N/A	ICF 1986a, ICF 1985
Semi-Metallic	N/A	N/A	N/A	$0.67/piece	7.4 years	$0.40/piece	100%	ICF 1986a, H. Krasne 1986, Cali-Blok 1986

N/A: Not Applicable.

[a] See Attachment, Items 4-6.

[b] The output for disc brake pads (light and medium motor vehicles) is split into OEM brakes (10,077,464 pieces) and aftermarket brakes (55,791,708 pieces) based on the ratio of OEM and replacement sales shown in Appendix A.

equivalent price of semi-metallic disc brake pads is slightly less than the price of asbestos disc brake pads (ICF 1986a).

ATTACHMENT

1. The asbestos fiber content per pad was calculated by dividing the 1985 asbestos fiber consumption for disc brake pads by the 1985 production for producers for which both fiber consumption and production were available: 7,119.2 tons (14,238,400 lbs.) divided by 65,869,172 pieces, or 0.22 lbs. per piece.

2. GM, Ford, and Chrysler, the three largest U.S. automakers, and thus, probably the three largest consumers of OEM disc brake pads for light/medium vehicles, were asked for the share asbestos held in their OEM pads. One company stated that currently only 5 percent of the OEM pads it consumes were asbestos-based. The second company stated in its 1986 model year the share was 6.9 percent, and projected it to be 3.9 percent in the 1987 model year. The third company stated asbestos held 40 percent of its OEM pads in the 1986 model year, but projected the share to be 10 percent in the 1987 model year (Ford 1986b). An editor from Chilton's Motor Age, an important trade publication, stated that currently 75 percent of domestic OEM light/medium vehicles were front-wheel drive (Chilton's Motor Age 1986). Because front-wheel drive vehicles use semi-metallic pads, the asbestos share of OEM pads could not be more than 25 percent, and probably somewhat less, given the fact that some rear-wheel drive cars use semi-metallic pads (e.g., Ford Mustang) (Chilton's Motor Age 1986). A large producer of asbestos-based pads in 1981 and a major supplier of materials for friction products both agree that the asbestos share of OEM pads for light/medium vehicles is 15 percent. Therefore, 15 percent would be a good estimate for the current share.

3. A large producer of semi-metallic pads, stated that in the 1986 vehicle model year, 50 percent of both its OEM and aftermarket semi-metallic pads contained an asbestos underlayer, but by January 1987, 90 percent of both its OEM and aftermarket pads would use either no underlayer or one made of a non-asbestos material. An automobile manufacturer stated that in its 1986 model year, 12.7 percent of its semi-metallic pads contained an asbestos underlayer, all of which were purchased from a single source. The rest of its pads contained no underlayer at all. The second automobile manufacturer estimated the OEM share that contained an asbestos underlayer to be currently 10 percent. The third automobile manufacturer stated that in the 1986 model year, 99.65 percent of its semi-metallic pads had an asbestos underlayer, and the share would be 91.75 percent in the 1987 model year. Nonetheless, the overall trend is towards complete replacement.

4. The product asbestos coefficient is the same value calculated in Item 1 above, converted into tons per piece.

5. The consumption production ratio was calculated using 12,589,555 pieces as the value for the 1985 U.S. imports. (Total 1985 production is 65,898,172 pieces.) This value, however, only includes imports for the firms who provided information (see Table 4).

6. The asbestos product price is a weighted average (by production) of prices for producers who provided information. The useful life of the asbestos product was assumed to be the same as that reported in 1984 in Appendix H (ICF 1985). The price of the semi-metallic pad was computed by increasing the weighted average asbestos product price by what GM stated was the percentage price increase of its semi-metallic product over its asbestos product (60.2 percent). The useful life of the semi-metallic pad was computed by taking the average of what two companies stated to be the percent increase in useful life of their semi-metallic pads over their asbestos pads (the straight average of 100 percent and 71 percent, or 85.5 percent), and then increasing the useful life of the asbestos product (given in Appendix H) by this value (85.5 percent) (ICF 1986a, 1986b). (Note: GM did not provide information on the useful life.)

REFERENCES

Abex Corp. R. Nelson. 1986b (December 3). American Society of Mechanical Engineers Conference in Washington, D.C. Transcribed conversation with Richard Hollander, ICF Incorporated, Washington, D.C.

Allied Automotive. E. Rogers. 1986 (October 17). Troy, NY. Transcribed telephone conversation with Richard Hollander, ICF Incorporated, Washington, D.C.

Automobile Importers of America. 1986. Comments of Automobile Importers of America on Proposed Asbestos Ban Rule. EPA Document Control No. OPTS-62036.

Brake Systems Inc. S. Mayo. 1986 (November 18). Stratford, CT. Transcribed telephone conversation with Richard Hollander, ICF Incorporated, Washington, D.C.

Cali-Blok. W. Favio. 1986 (July-December). Gardena, CA. Transcribed telephone conversation with Richard Hollander, ICF Incorporated, Washington, D.C.

Chilton's Motor Age. S. Davis. 1986 (October 17). Radnor, PA. Transcribed telephone conversation with Richard Hollander, ICF Incorporated, Washington, D.C.

Chrysler Corp. M. Heitkamp. 1986 (November 4). Detroit, MI. Transcribed telephone conversation with Richard Hollander, ICF Incorporated, Washington, D.C.

Design News. 1984. Asbestos Substitutes in Friction Applications. S. Scott. March 26, 1984.

DuPont. T. Merriman. 1986 (November 5). Wilmington, DE. Transcribed telephone conversation with Richard Hollander, ICF Incorporated, Washington, D.C.

Ford Motor Co. A. Anderson. 1986a (December 3). American Society of Mechanical Engineers Conference in Washington, D.C. Transcribed conversation with Richard Hollander, ICF Incorporated, Washington, D.C.

Ford Motor Co. A. Amburg. 1986b (November 5). Dearborn, MI. Transcribed telephone conversation with Richard Hollander, ICF Incorporated, Washington, D.C.

Ford Motor Co. 1986c. Comments of Ford Motor Co. on Proposed Asbestos Ban Rule. EPA Document Control No. OPTS-62036.

General Motors Corp. F. Brookes. 1986a (November 19). Dayton, OH. Transcribed telephone conversation with Richard Hollander, ICF Incorporated, Washington, D.C.

General Motors Corp. 1986b. Comments of General Motors Corp. on Proposed Asbestos Ban Rule. EPA Document Control No. OPTS-62036.

General Motors Corp. P. Vernia. 1986c (December 3). American Society of Mechanical Engineers Conference in Washington, D.C. Transcribed conversation with Richard Hollander, ICF Incorporated, Washington, D.C.

H.K. Porter Co. F. Donnell. 1986 (November 30). Huntington, IN. Transcribed telephone conversation with Richard Hollander, ICF Incorporated, Washington, D.C.

H. Krasne Manufacturing Co. G. Mosen. 1986 (July-December). Los Angeles, CA. Transcribed telephone conversation with Richard Hollander, ICF Incorporated, Washington, D.C.

ICF Incorporated. 1984. Imports of Asbestos Mixtures and Products. Washington, D.C.: Office of Pesticide and Toxic Substances, U.S. Environmental Protection Agency. EPA CBI Document Control No. 20-8600681.

ICF Incorporated. 1985. Appendix H: Asbestos Products and Their Substitutes, in Regulatory Impact Analysis of Controls on Asbestos and Asbestos Products. Washington, D.C.: Office of Pesticides and Toxic Substances, U.S. Environmental Protection Agency.

ICF Incorporated. 1986a (July-December). Survey of Primary Processors of Disc Brake Pads (Light and Medium Vehicles). Washington, D.C.

ICF Incorporated. 1986b (July-December). Survey of Secondary Processors of Disc Brake Pads (Light and Medium Vehicles). Washington, D.C.

Krusell N., Cogley D. 1982. GCA Corp. Asbestos Substitute Performance Analysis, Revised Final Report. Washington, D.C.: Office of Pesticides and Toxic Substances, U.S. Environmental Protection Agency. Contract No. 68-02-3168.

Lyndon B. Johnson Space Center. J. McCullough. 1986 (December 3). American Society of Mechanical Engineers Conference in Washington, D.C. Transcribed conversation with Richard Hollander, ICF Incorporated, Washington, D.C.

Massachusetts Institute of Technology. E. Rabinowicz. 1986 (December 3). American Society of Mechanical Engineers Conference in Washington, D.C. Transcribed conversation with Richard Hollander, ICF Incorporated, Washington, D.C.

Saab-Scania of America. D. Rainey. 1986 (November 21). Orange, CT. Transcribed conversation with Richard Hollander, ICF Incorporated, Washington, D.C.

TSCA Section 8(a) submission. 1982a. Production Data for Primary Asbestos Processors, 1981. Washington, D.C.: Office of Toxic Substances, U.S. Environmental Protection Agency. EPA Document Control No. 20-8601012.

TSCA Section 8(a) submission. 1982b. Production Data for Secondary Asbestos Processors, 1981. Washington, D.C.: Office of Toxic Substances, U.S. Environmental Protection Agency. EPA Document Control No. 20-8670644.

Wagner Corp. F. Hayes. 1986a (December 5). Parsippanny, NJ. Transcribed telephone conversation with Richard Hollander, ICF Incorporated, Washington, D.C.

Wagner Corp. 1986b. Comments of Wagner Corp. on Proposed Asbestos Ban Rule. EPA Document Control No. OPTS-62036.

XX. DISC BRAKE PADS (HEAVY VEHICLES)

A. Product Description

Disc brake pads (both asbestos and non-asbestos) for heavy vehicles are a small and relatively new market (Allied Automotive 1986, Carlisle 1986). Although disc brake pads were small percentage of heavy vehicle brakes in the past, these systems are increasingly common for these vehicles. Except for the larger size, the pads are similar to those described for light and medium vehicles (Allied Automotive 1986). Disc brake pads for heavy vehicles, to date, are only used on the front wheels of certain intermediate-sized trucks (12,000-22,000 lbs. per axle) (Allied Automotive 1986). One producer, Allied Automotive, stated that disc brakes could never be used for the heaviest trucks, while another producer, Carlisle, indicated that, in perhaps five years, disc brakes will be developed for large trucks such as tractor trailers (Allied Automotive 1986, Carlisle 1986).

Although non-asbestos semi-metallic pads have nearly always been used for disc brakes for heavy vehicles in small proportions (Allied Automotive 1986, Carlisle 1986), in the past, asbestos-based pads were used to a greater extent. Asbestos disc brakes for heavy vehicles are now apparently only used to replace worn asbestos pads in the aftermarket (ICF 1986a, ICF 1985, Allied Automotive 1986, Carlisle 1986). The switch to semi-metallic pads from asbestos pads is due to the high braking temperatures generated in this vehicle application; semi-metallic pads, in general, have superior performance and service life at high temperatures (Allied Automotive 1986).

Semi-metallic pads are molded products containing chopped steel wool, sponge iron, graphite powder, fillers, and resins (Allied Automotive 1986, Ford 1986). Some semi-metallic pads for heavy vehicles may contain a very thin asbestos-containing backing, or underlayer, between the pad and the steel plate to which it is attached.[1] Other semi-metallic pads have no underlayer or have one made of chopped Kevlar or fiberglass (Allied Automotive 1986). The underlayer acts as a thermal barrier between the pad and plate and helps to bond the pad to the plate (Allied Automotive 1986). Producers generally do not consider semi-metallic pads with asbestos underlayers to be asbestos pads since the lining itself contains no asbestos and the underlayer accounts for only a very small percentage of the total content of the pad (Allied Automotive 1986).

Primary and secondary processing of asbestos-based pads is the same as that described for light and medium vehicles. According to Carlisle, the approximate asbestos fiber content per pad is 1.5 lbs. (ICF 1986a).

B. Producers and Importers of Disc Brake Pads (Heavy Vehicles)

Table 1 lists the four producers of (asbestos and non-asbestos) disc brake pads for heavy vehicles in 1985. Carlisle, and possibly Allied Automotive, produced asbestos-based pads in 1985. However, an Allied Automotive representative stated that the firm currently manufactures only semi-metallic pads (Allied Automotive 1986). Brake Systems and Raymark, only manufacture semi-metallic pads (Brake Systems 1986, ICF 1986a, Design News 1984).

Table 2 lists the sole secondary processor of disc brake pads for heavy vehicles in 1985. The firm, Hall Brake Supply, was also the only secondary processor in 1981 (TSCA 1982b). The pads produced by the firm are all asbestos-based (ICF 1986b).

There were no importers of asbestos disc brake pads for heavy vehicles in 1985 (ICF 1986a).

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[1] Information is not available on the percentage of semi-metallic pads that possibly contain an asbestos underlayer. Brake Systems, Inc. makes semi-metallic disc brake pads for heavy vehicles with an asbestos underlayer (Brake Systems 1986). Information was not available for the other producers.

Table 1. 1985 Primary Processors of Disc Brake Pads
(Heavy Vehicles)

Company	Plant Location	Product		References
		Asbestos	Non-Asbestos	
Carlisle, Motion Control Industries Division	Ridgway, PA	X	X	ICF 1986a, TSCA 1982a
Allied Automotive	Green Island, NY	N/A[a]	X	Allied Automotive 1986, TSCA 1982a
Brake Systems	Stratford, CT		X[b]	Brake Systems 1986
Raymark	N/A[c]		X	Design News 1984

N/A = Information not available.

[a]Allied Automotive refused to respond to our survey. It was assumed that they produced asbestos-based disc brake pads in 1985, however they currently only produce semi-metallic pads (Allied Automotive 1986).

[b]Brake Systems produces semi-metallic pads with a very small asbestos underlayer; this is not considered an asbestos disc brake pad (Brake Systems 1986).

[c]Raymark, itself, did not provide information on its disc brake pad production. They only produce semi-metallic pads (ICF 1986a, Design News 1984).

Table 2. 1985 Secondary Processors of Disc Brake Pads
(Heavy Vehicles)

Company	Plant Location	Product		References
		Asbestos	Non-Asbestos	
Hall Brake Supply	Phoenix, AZ	X		ICF 1986b, TSCA 1982b

C. Trends

Table 3 gives the production of asbestos-based disc brake pads for heavy vehicles and the corresponding consumption of asbestos fiber.

As previously mentioned, there were no importers of asbestos-based disc brake pads for heavy vehicles in 1985 (ICF 1986a). Hall Brake Supply was the sole importer in 1981. (ICF 1984).

According to Carlisle, the market for heavy-vehicle disc brakes is growing. The firm predicts that the switch to front disc brakes that occurred in cars and light trucks will also happen in intermediate- and large-sized trucks (Carlisle 1986).

D. Substitutes

According to Allied Automotive and Carlisle, 100 percent of the original equipment market (OEM) and most of the aftermarket is held by the semi-metallic pads (Allied Automotive 1986, Carlisle 1986). It is assumed that the 100 percent of the aftermarket will also become semi-metallic as aftermarket vehicles are scrapped and/or switch over to semi-metallic pads.[2]

Table 4 provides data inputs for the regulatory cost model.

E. Summary

Asbestos disc brake pads for heavy vehicles are used only on the front wheels of certain intermediate-sized trucks (12,000-22,000 lbs. per axle) (Allied Automotive 1986). Two producers, in 1985, consumed 117.6 tons of asbestos to produce 156,280 disc brake pads (heavy vehicles). Only one, Carlisle-Motion Control Industries, currently produces the asbestos disc brake pad for heavy vehicles (Allied Automotive 1986, Carlisle 1986, ICF 1986a).

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[2] Allied Automotive also reports that non-asbestos underlayers, which are made of either chopped fiberglass or Kevlar(R), perform just as well as asbestos underlayers (Allied Automotive 1986).

Table 3. Production and Fiber Consumption for Asbestos-Based Disc Brake Pads (Heavy Vehicles)

	1981		1985		
	Production (pieces)	Asbestos Fiber Consumption (tons)	Production (pieces)	Asbestos Fiber Consumption (tons)	References
Total	385,496	44.6	156,820[a]	117.6[a]	ICF 1986a, TSCA 1982a

[a]One company refused to provide production and fiber consumption data for their asbestos-based disc pads (heavy vehicles). Its production and fiber consumption have been estimated using a method described in Appendix A of this RIA.

Table 4. Data Inputs on Disc Brake Pads (HV) for Asbestos Regulatory Cost Model[a]

Product	Output	Product Asbestos Coefficient	Consumption Production Ratio	Price	Useful Life	Equivalent Price	Market Share	References
Asbestos Mixture	156,820 pieces	0.00075 tons/piece	1.0	$10.00/piece	0.5 years	$10.00/piece	N/A	ICF 1986a, ICF 1985, Carlisle 1986
Semi-Metallic	N/A	N/A	N/A	$12.50/piece	0.75 years	$8.40/piece	100%	Allied Automotive 1986, Carlisle 1986

N/A: Not Applicable.

[a]See Attachment, Items 1-2.

Asbestos-based pads are now only used to replace worn asbestos pads in the aftermarket. For OEM, semi-metallic pads are used rather than asbestos pads because of the high braking temperatures generated in this application. If asbestos were no longer available, it is estimated that 100 percent of the aftermarket would become semi-metallic. Semi-metallic disc brake pads (heavy vehicles) cost approximately 20 percent less than asbestos disc brake pads for heavy vehicles.

ATTACHMENT

1. The product asbestos coefficient, as well as the asbestos and semi-metallic pad prices were provided by Carlisle.

2. The useful life of the asbestos pad was assumed to be the same as that reported in 1984 in Appendix H (ICF 1985). Carlisle stated that semi-metallic pads have 50 percent longer service life than asbestos pads; thus, the useful life of the semi-metallic pad given in the table is 1.5 times the asbestos pad life.

REFERENCES

Allied Automotive. E. Rogers. 1986 (October 17). Troy, NY. Transcribed telephone conversation with Richard Hollander, ICF Incorporated, Washington, D.C.

Brake Systems Inc. S. Mayo. 1986 (November 18). Stratford, CT. Transcribed telephone conversation with Richard Hollander, ICF Incorporated, Washington, D.C.

Carlisle. R. Tami. 1986 (October 17). Ridgway, PA. Transcribed telephone conversation with Richard Hollander, ICF Incorporated, Washington, D.C.

Design News. 1984 (March 26). Asbestos Substitutes in Friction Applications. S. Scott.

Ford Motor Co. A. Anderson. 1986 (December 3). American Society of Mechanical Engineers Conference in Washington, D.C. Transcribed conversation with Richard Hollander, ICF Incorporated, Washington, D.C.

ICF Incorporated. 1984. Imports of Asbestos Mixtures and Products. Washington, D.C.: Office of Pesticides and Toxic Substances, U.S. Environmental Protection Agency. EPA CBI Document Control No. 20-8600681.

ICF Incorporated, 1985. Appendix H: Asbestos Products and Their Substitutes, In Regulatory Impact Analysis of Controls on Asbestos and Asbestos Products. Washington, D.C.: Office of Pesticides and Toxic Substances, U.S. Environmental Protection Agency.

ICF Incorporated. 1986a (July-December). Survey of Primary Processors of Disc Brake Pads (Heavy Vehicles). Washington, D.C.

ICF Incorporated. 1986b (July-December). Survey of Secondary Processors of Disc Brake Pads (Heavy Vehicles). Washington, D.C.

TSCA Section 8(a) submission. 1982a. Production Data for Primary Asbestos Processors, 1981. Washington, D.C.: Office of Toxic Substances, U.S. Environmental Protection Agency. EPA Document Control No. 20-8601012.

TSCA Section 8(a) submission. 1982b. Production Data for Secondary Asbestos Processors, 1981. Washington, D.C.: Office of Toxic Substances, U.S. Environmental Protection Agency. EPA Document Control No. 20-8670644.

XXI. BRAKE BLOCKS

A. Product Description

Brake blocks are brake linings used on the drum brakes of heavy vehicles -- heavy trucks, buses, and heavy off-road vehicles.[1] The comparable components on light/medium vehicles (cars and light trucks) are drum brake linings, which are discussed in Section XVIII. The heavy-vehicle drum brake consists of two curved metal "shoes" to which brake blocks are attached. When the brakes are applied, the curved shoes are pressed out against a metal drum that is connected to the wheels of the vehicle.[2] The pressure of the shoes against the drum stops the turning of the wheels (ICF 1985).

Each shoe has two blocks, a longer one (the anchor) and a shorter one (the cam), resulting in a total of four blocks per wheel. Each block is at least three-quarters of an inch thick and covers 50° to 60° of the arc around the wheel (Allied Automotive 1986, ICF 1985).

Asbestos-based brake blocks contain approximately 1.16 lbs.[3] of asbestos fiber per block on average (ICF 1986a). Asbestos is used because of its thermal stability, reinforcing properties, flexibility, resistance to wear, and relatively low cost (Krusell and Cogley 1982).

Brake blocks are usually manufactured by a dry mix process in which asbestos fiber is combined with a powdered binder (usually an epoxy novolac resin) to form briquets under pressure of 1,500 to 2,500 psi and temperature

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[1] Heavy trucks range from moderately heavy, 12-22,000 lbs. per axle, to very heavy, i.e., tractor trailers and logging and mining trucks (Allied Automotive 1986). Examples of heavy off-road vehicles include agricultural tractors and earth-moving equipment.

[2] Drum brakes for heavy vehicles are either air- or hydraulic-activated, depending upon the application. Tractor trailers, for example, would always use air brakes, while medium-sized trucks would normally use hydraulic brakes (Allied Automotive 1986).

[3] See Attachment, Item 1.

of 1985°F.[4] The briquets are then formed into blocks at 265°F to 300°F under additional pressure (2,000 to 3,000 psi) for 10 to 30 minutes. The blocks are then cut and ground to shape. After curing, grinding, drilling, and chamfering (cutting grooves), the block is finished (ICF 1985). The finished block is then riveted to the brake shoe (Allied Automotive 1986).

Secondary processing of brake blocks is similar to that of drum brake linings. Some processors install new brake blocks into brake assemblies for new vehicles. Others may repackage blocks for sale as replacement parts in the aftermarket. None of these secondary processes involve any grinding, drilling, or other treatment of the brake block. Another distinct type of secondary processing is brake rebuilding. Rebuilders receive used, worn blocks attached to the shoes. The old blocks are removed from the shoes, the shoes are cleaned by abrasion, and new blocks are attached. The rebuilt shoes with blocks are then packaged and sold for the aftermarket (ICF 1985, Krusell and Cogley 1982).

B. Producers and Importers of Brake Blocks

Table 1 lists the twelve primary processors of brake blocks in 1985. At least eight of these firms produced an asbestos-based product; Raymark did not provide information. Allied Automotive is a relatively small manufacturer of brake blocks, producing only for the severe braking applications segment of the market (i.e., logging and mining trucks) (Allied Automotive 1986). At least eleven of the processors also currently produce substitute products (ICF 1986a, Design News 1984).

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[4] Brake blocks may also be woven from asbestos yarn; however, the woven block is an older and far less common technology (Carlisle 1986a). Raymark and Standco Industries are, apparently, the only two producers who still make woven brake blocks (ICF 1986a).

Table 1. 1985 Primary Processors of Brake Blocks

Company	Plant Location(s)	Product		References
		Asbestos	Non-Asbestos	
Carlisle, Motion Control Industries Division	Ridgway, PA	X	X	ICF 1986a, TSCA 1982a
Abex	Salisbury, NC Winchester, VA	X X	X X	Abex 1986, TSCA 1982a
Nuturn	New Castle, IN	X	X	ICF 1986a, TSCA 1982a
Allied Automotive	Cleveland, TN	X	X	Allied Automotive 1986, TSCA 1982a
Raymark	Crawfordsville, IN	N/A[a]	X	Design News 1984, TSCA 1982a
Standco Industries	Houston, TX	X		ICF 1986a, TSCA 1982a
H.K. Porter	Huntington, IN	X[b]	X	ICF 1986a, TSCA 1982a
Brake Systems Inc. (Division of Echlin) (plant formerly owned by Molded Industrial Friction Co.)	Prattville, AL		X	ICF 1986a, TSCA 1982a
Palmer Products Corp.	Louisville, KY	X	X	ICF 1986a, TSCA 1982a
Friction Products	Medina, OH		X	Friction Products 1986
Scan Pac	Menomonee Falls, WI		X	ICF 1986a, TSCA 1982a
Wheeling Brake Block	Bridgeport, CT	X[c]	X	ICF 1986a, ICF 1985

N/A = Information not available.

[a]Raymark refused to provide production information. However, it was assumed that they produced asbestos brake blocks in 1985.

[b]H.K. Porter stated that it would phase out its production of asbestos brake blocks by the end of 1986 (PEI Associates 1986).

[c]Wheeling Brake Block of Bridgeport, CT phased out its production of asbestos brake blocks in 1985 (Wheeling Brake Block 1986).

Changes in primary processors from 1981 to 1985 include Brake Systems Inc.'s purchase of Molded Industrial Friction Co.'s plant in Prattville, AL. The Brake Systems plant phased out asbestos-based blocks prior to 1985, and now produces only a non-asbestos product (ICF 1986a). Wheeling Brake Block of Bridgeport, CT, phased out its asbestos-based brake block operations in 1986. The firm currently manufactures a non-asbestos product (Wheeling Brake Block 1986). H.K. Porter stated it would phase out production of asbestos-based blocks by the end of 1986 (PEI Associates 1986).

Table 2 lists the three current secondary processors of brake blocks. Freightliner Corporation of Portland, OR, is essentially Mercedes-Benz's U.S. truck operations (Freightliner 1986). Information was not available on the type of secondary processing in which these firms were involved.

Table 3 lists the importers of asbestos-based brake blocks. There were four importers in 1981. Hall Brake Supply, one of the 1981 importers, did not import in 1985. Navistar International and Abex did not provide information on their imports, therefore the total 1985 imports could not be determined.

C. Trends

Table 4 gives the production of asbestos-based brake blocks and the corresponding consumption of asbestos fiber. Although, producers and purchasers of brake blocks did not provide current market shares, they indicated that the majority of the original equipment market (OEM) and aftermarket is probably still asbestos-based (Abex 1986, Ford 1986a, DuPont

Table 2. 1985 Secondary Processors of Brake Blocks

Company	Plant Location	Product		References
		Asbestos	Non-Asbestos	
Hall Brake Supply	Phoenix, AZ	X	N/A	ICF 1986b, TSCA 1982b
FMC Corporation	Cedar Rapids, IA	X		ICF 1986b, TSCA 1982b
Freightliner Corporation	Portland, OR	X	N/A	ICF 1986b, TSCA 1982b

N/A = Information not available.

Table 3. Imports of Asbestos-Based Brake Blocks

	1981 Quantity Imported (pieces)	1985 Quantity Imported (pieces)	References
Total	182,809	N/A	ICF 1984

N/A = Information not available.

Table 4. Production and Fiber Consumption for Asbestos-Based Brake Blocks

	1981	1985	References
Production (pieces)	18,457,840	4,570,266[a]	ICF 1986a, TSCA 1982a
Asbestos Fiber Consumption (tons)	12,992.5	2,643.6[b]	ICF 1986a, TSCA 1982a

[a]Allied Automotive, Abex, Raymark, and Wheeling Brake Block refused to provide production data for their asbestos-based brake blocks. Data on production for Allied Automotive, Abex and Raymark was estimated using a method described in the Appendix A to this RIA. Data for Wheeling Brake Block is not included. They did not make asbestos brake blocks in 1981 and they have stopped production of asbestos brake blocks in 1986. We, therefore, assume that their 1985 production is small.

[b]Abex, Raymark, and Wheeling Brake Block refused to provide fiber consumption data for their asbestos-based brake blocks. Data on fiber consumption for Abex and Raymark was estimated using a method described in the Appendix A to this RIA. Data for Wheeling Brake Block is not included. They did not make the asbestos product in 1981 and they have stopped production in 1986. Therefore, we assume their 1985 fiber consumption is small.

1986).[5] Representatives from Ford and Abex agreed that good substitutes have been developed for a range of brake block applications; however, some heavy truck and heavy vehicle applications (which they did not specify) do not yet have substitutes (Ford 1986a, Abex 1986). Ford also indicated that while substitutes have been developed, many may not be near the point of large-scale commercial production (Ford 1986a). DuPont, a major supplier of materials for friction products, e.g., Kevlar(R), estimated that currently 75 percent of OEM brake blocks are still asbestos-based (DuPont 1986). Thus, 75 percent is assumed to be the asbestos-based OEM share, as it is the only available figure and it is not out of line with the comments of Ford and Abex. All firms, however, agreed that substantial progress is being made towards the replacement of asbestos blocks in the OEM (Abex 1986, Ford 1986a, DuPont 1986).

D. Substitutes

For the vast majority of applications, i.e. heavy trucks and off-road vehicles, excluding the super-heavy applications (logging and mining trucks), the major group of substitutes are the non-asbestos organics (NAOs) (Carlisle 1986a, DuPont 1986, Allied Automotive 1986). In fact, 65 percent of Nuturn's brake block production is currently NAO blocks (ICF 1986a). The major substitute for the super-heavy braking applications (logging and mining trucks), which represent a very small share of the total market, is the full-metallic block (Carlisle 1986a, Allied Automotive 1986).

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[5] 100 percent of railroad car brake blocks are non-asbestos (Ford 1986a, Abex 1986); and probably 100 percent of aircraft brake blocks are also non-asbestos (Krusell and Cogley 1982). These types of brake blocks have been non-asbestos for the last several years, and it is likely that asbestos-based blocks were never used to any great extent (if at all) for these markets (Krusell and Cogley 1982). Therefore, for the purposes of defining the asbestos-based brake block market, railroad car and aircraft brake blocks will be excluded.

NAO formulations generally contain the following ingredients: Kevlar(R) and/or fiberglass and/or mineral fibers,[6] perhaps some steel wool and/or other fibers, and fillers and resins (ICF 1986a). Fiberglass and Kevlar(R) usually account for only a small percentage of the total formulation. For example, a representative from DuPont stated that the optimal level of Kevlar(R) in brake block formulations is usually only 5 percent by weight (DuPont 1986). Thus, labelling substitute brake blocks as Kevlar(R)-based or fiberglass-based (producers tend to do this for marketing reasons) is misleading (Carlisle 1986b, Abex 1986, Ford 1986a). Of the twelve primary processors of brake blocks in 1985, at least eight currently produce NAO blocks. These firms are: Carlisle, Abex, Nuturn, H.K. Porter, Brake Systems Inc., Palmer Products, Scan Pac, and Wheeling Brake Block (Abex 1986, Wheeling Brake Block 1986, ICF 1986a).[7]

Producers generally agree that NAO brake blocks have the same or better performance than asbestos-based blocks, as well as improved service life (ICF 1986a, Allied Automotive 1986, Carlisle 1986a). A representative from Carlisle, the largest producer of brake blocks in 1981 (with approximately 36.6 percent of the market), stated that, on average, NAO blocks had 30 percent greater service life than asbestos blocks. (Nuturn, another major producer, claimed its NAO blocks had 100 percent greater service life (ICF 1986a).) NAO blocks are priced 30-50 percent higher than asbestos blocks, according to Carlisle (Carlisle 1986a).

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[6] Mineral fibers commonly used by producers include: wollastonite, phosphate fiber, aluminum silicate fiber, Franklin fiber, mineral wool, and PMF (processed mineral fiber) (ICF 1986a).

[7] Raymark did not provide information; Allied Automotive is in the process of developing a non-asbestos, non-full-metallic block (Allied Automotive 1986).

Full-metallic blocks are molded from sintered steel wool and sponge iron, and contain no resin (Ford 1986a). Producers of full-metallic blocks include Allied Automotive and Wheeling Brake Block (Allied Automotive 1986, Wheeling Brake Block 1986).[8] Allied Automotive stated that these substitutes had improved performance over asbestos for extremely high temperature ranges (Allied Automotive 1986). By contrast, Wheeling Brake Block, which manufactures full-metallic blocks in only limited quantities, stated that in the past its product generally had poor performance compared to asbestos blocks, however they have been improving this product recently (Wheeling Brake Block 1986, 1987). Allied Automotive indicated that the full-metallic blocks have up to two times longer service life than asbestos blocks, while Wheeling Brake Block felt their product had the same life as asbestos blocks (Allied Automotive 1987, Wheeling Brake Block 1987). Carlisle, which used to make the full-metallic brake block, but no longer does so, also stated that full-metallics had about the same life as asbestos brake blocks (Carlisle 1987). For the purposes of the asbestos regulatory cost model the useful life of the full metallic brake block has been assumed to be the same as for the asbestos block.[9]

Full-metallic brake blocks on average are 20 percent more expensive per component than asbestos brake blocks, assuming the useful lives are the same. The computation for the price of the full metallic brake block price does include an adjustment for the longer life of Allied Automotive's product.[10]

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[8] S.K. Wellman of Toronto, Ontario, Canada also produces a full-metallic brake block. They are specialty items, however, and are not carried in stock (S.K. Wellman 1987).

[9] See Attachment, Item 4.

[10] See Attachment, Item 4.

A potential substitute for brake blocks in the future may be carbon fiber and carbon/carbon fiber composite brake blocks (Ashland Petroleum 1986). Up to the present time, carbon fiber and carbon/carbon fiber composite blocks have been so expensive that they have only been used in very demanding applications such as high-performance military aircraft and large commercial airline applications (Ashland Petroleum 1986). These carbon-based blocks are used because of their high thermal stability and low weight (Krusell and Cogley 1982). The Ashland Carbon Fibers Division of Ashland Petroleum, however, has recently developed a low cost carbon fiber and carbon pitch product (which is used in combination with the carbon fiber for the carbon/carbon fiber composite) for use in carbon-based brake blocks. The firm believes that carbon blocks will now be manufactured more widely for the commercial and industrial brake block markets (Ashland Petroleum 1986).

Given the current OEM market shares, however, it is clear that in the near-term NAO brake blocks will capture the majority of the asbestos-based OEM in the event of a ban (Carlisle 1986a, Allied Automotive 1986). A representative from Carlisle stated that 75-80 percent of the OEM would likely be NAO blocks, with only 0.5 percent being full-metallic; the balance being substitutes not yet developed (Carlisle 1986a).[11]

Choice of replacement of asbestos-based brake blocks in the aftermarket, however, is more difficult to estimate. Many producers and users agreed that brake systems designed for asbestos brake blocks should continue to use asbestos. Substitute linings which were designed for the OEM, when used to replace worn blocks, do not perform as well as asbestos, and could jeopardize brake safety (Allied Automotive 1986, Ford 1986b). Abex, however, indicated

[11] Until other replacements can be found for the remaining 19.5-24.5 percent of asbestos-based applications, it is assumed for the present that the NAO substitute will replace 99.5 percent of the asbestos market if asbestos were no longer available. See Attachment, Item 5.

that it is selling its OEM non-asbestos-organic blocks for the aftermarket, and reports that they are performing well (Abex 1986). Given this evidence, we have concluded that the aftermarket shares would be identical to the OEM shares.

Table 5 provides data for the regulatory cost model. The substitutes are the NAO and full-metallic blocks. Note that the equivalent price of the NAO block given in the table is close to the asbestos block price because of the longer service life.

E. Summary

Brake blocks are brake linings used in drum brakes of heavy vehicles such as heavy trucks, buses, and heavy off-road vehicles (ICF 1985). There were nine producers of asbestos-based brake blocks in 1985. These companies consumed 2,643.6 tons of asbestos and produced 4,570,266 pieces of brake blocks. Since 1985, H.K. Porter and Wheeling Brake Block have stopped processing asbestos. This leaves seven current producers of asbestos brake blocks (ICF 1986a).

A majority of the OEM (about 75 percent) and the aftermarket is still asbestos-based (Abex 1986, Ford 1986a, DuPont 1986). The major group of substitutes for most applications are the non-asbestos organics (NAOs). It is projected that they would capture 99.5 percent of the asbestos brake block market if asbestos were not available. Full metallic brakes are a major substitute in super-heavy braking applications and they are projected to capture the remaining 0.5 percent of the asbestos market.

Table 5. Data Inputs on Brake Blocks for Asbestos Regulatory Cost Model[a]

Product	Output	Product Asbestos Coefficient	Consumption Production Ratio	Price	Useful Life	Equivalent Price	Market Share	References
Asbestos Mixture	4,570,266 pieces	0.00058 tons/piece	1.01	$5.74/piece	0.5 years	$5.74/piece	N/A	ICF 1986a, ICF 1985,
NAO	N/A	N/A	N/A	$8.04/piece	0.65 years	$6.22/piece	99.5%	Carlisle 1986a
Full-Metallic	N/A	N/A	N/A	$6.89/piece	0.5 years	$6.89/piece	0.5%	Allied Automotive 1986, Wheeling Brake Block 1986, Carlisle 1986a

N/A: Not Applicable.

[a]See Attachment, Items 2-5.

ATTACHMENT

1. The asbestos fiber content per block was calculated by dividing the 1985 asbestos fiber consumption for brake blocks by the 1985 asbestos brake block production: 2,643.6 tons (5,287,200 lbs.) divided by 4,570,266 pieces, or 1.16 lbs. per piece.

2. The product asbestos coefficient is the same value calculated in Item 1 above, converted into tons per piece.

3. The consumption production ratio was calculated using 41,808 pieces as the value for 1985 U.S. imports. (Total 1985 production is 4,570,266 pieces.) This value, however, only includes imports for the firms who provided information (see Table 4).

4. The asbestos product price is a weighted average (by production) of prices for producers who provided both price and production information for 1985. The useful life of the asbestos product was assumed to be the same as that reported in 1984 in Appendix H (ICF 1985).

   The price and useful life of the NAO block was calculated by multiplying what Carlisle reported as the average percent increase in price and useful life, respectively, of an NAO block over an average asbestos block by the (weighted average) asbestos product price and useful life, respectively. As mentioned in the text, Carlisle stated that NAO blocks are 30-50 percent higher in price (thus, 40 percent is used as the price increase) and have 30 percent longer useful life.

   The price and useful life of full-metallic brake blocks was computed based on information from three firms. Wheeling Brake Block claims their full-metallic brake block has the same useful life as asbestos brake blocks, but is 10-15 percent (12.5 percent average) more expensive (Wheeling Brake Block 1987). Carlisle, which no longer makes the full-metallic product but is familiar with the market, stated that full-metallic brake blocks have the same life as asbestos brake blocks, but are approximately 25 percent more expensive (Carlisle 1987). A third firm, Allied Automotive, claims their full metallic brake block have up to double the useful life (we assumed 50 percent on average), but is 83 percent more expensive than their premium asbestos product (Allied Automotive 1987). In order to average the estimates for these three firms, an equivalent price for the Allied Product had to be computed. (The equivalent price is a present value calculation that determines the price a product would have if it had the same useful life as asbestos.) This calculation showed Allied Automotive's full-metallic product to be 22.65 percent more expensive than asbestos blocks. The average cost of the full-metallic brake block is therefore 20.05 percent more expensive than asbestos brake blocks.

5. The market shares for the substitutes are provided by Carlisle. Carlisle stated the super-heavy applications (logging and mining trucks), for which full-metallic blocks would be used, represent only 0.5 percent of the market. Seventy-five to 80 percent of the market, stated Carlisle, would be captured by NAO blocks and the rest of the market would be taken by substitutes not yet developed. However, until other replacements can be found for the remaining 19.5-24.5 percent of asbestos-based applications, it is assumed that for the present that NAO blocks will replace 99.5 percent of the asbestos market if asbestos were no longer available.

REFERENCES

Abex Corp. R. Nelson. 1986 (December 3). American Society of Mechanical Engineers Conference in Washington, D.C. Transcribed conversation with Richard Hollander, ICF Incorporated, Washington, D.C.

Allied Automotive. E. Rogers. 1986 (October 17). Troy, NY. Transcribed telephone conversation with Richard Hollander, ICF Incorporated, Washington, D.C.

Allied Automotive. B. Bush. 1987 (July 10). Troy, NY. Transcribed telephone conversation with Michael Geschwind, ICF Incorporated, Washington, D.C.

Ashland Petroleum Co. 1986. Product Literature. Carboflex and Aerocarb -- Ashland's New Low Cost Carbon Fiber and Carbonizing Products for Future Brake Applications. Ashland, KY.

Carlisle, Motion Control Industries Div. R. Tami. 1986a (October 17). Ridgway, PA. Transcribed telephone conversation with Richard Hollander, ICF Incorporated, Washington, D.C.

Carlisle, Motion Control Industries Div. 1986b. Product Literature. Tracking Enduramid . Ridgway, PA.

Carlisle, Motion Control Industries Div. R. Tami. 1987 (July 10). Ridgway, PA. Transcribed telephone conversation with Michael Geschwind, ICF Incorporated, Washington, D.C.

Design News. 1984 (March 26). Asbestos Substitutes in Friction Applications. S. Scott.

DuPont. T. Merriman. 1986 (November 5). Wilmington, DE. Transcribed telephone conversation with Richard Hollander, ICF Incorporated, Washington, D.C.

Ford Motor Co. A. Anderson. 1986a (December 3). American Society of Mechanical Engineers Conference in Washington, D.C. Transcribed conversation with Richard Hollander, ICF Incorporated, Washington, D.C.

Ford Motor Co. 1986b. Comments of Ford Motor Co. on Proposed Asbestos Ban Rule. EPA Document Control No. OPTS-62036.

Freightliner Corp. T. Robinson. 1986 (November 26). Portland, OR. Transcribed telephone conversation with Richard Hollander, ICF Incorporated, Washington, D.C.

Friction Products. D. Cramer. 1986 (October 9). Medina, OH. Transcribed telephone conversation with Michael Geschwind, ICF Incorporated, Washington, DC.

ICF Incorporated. 1984. Imports of Asbestos Mixtures and Products. Washington, D.C.: Office of Pesticides and Toxic Substances, U.S. Environmental Protection Agency. EPA CBI Document Control No. 20-8600681.

ICF Incorporated. 1985. Appendix H: Asbestos Products and Their Substitutes, in Regulatory Impact Analysis of Controls on Asbestos and Asbestos Products. Washington, D.C.: Office of Pesticides and Toxic Substances, U.S. Environmental Protection Agency.

ICF Incorporated. 1986a (July-December). Survey of Primary Processors of Brake Blocks. Washington, D.C.

ICF Incorporated. 1986b (July-December). Survey of Secondary Processors of Brake Blocks. Washington, D.C.

Krusell N., Cogley D. 1982. GCA Corp. Asbestos Substitute Performance Analysis, Revised Final Report. Washington, D.C.: Office of Pesticides and Toxic Substances, U.S. Environmental Protection Agency. Contract 68-02-3168.

PEI Associates, Inc. 1986. OTS Survey of Asbestos Products Manufacturers. Washington, D.C.: Office of Pesticides and Toxic Substances, U.S. Environmental Protection Agency.

S.K. Wellman. P. Douglass. 1987 (July 10). Toronto, Ontario, Canada. Transcribed telephone conversation with Michael Geschwind, ICF Incorporated, Washington, DC.

TSCA Section 8(a) submission. 1982a. Production Data for Primary Asbestos Processors, 1981. Washington, D.C.: Office of Toxic Substances, U.S. Environmental Protection Agency. EPA Document Control No. 20-8601012.

TSCA Section 8(a) submission. 1982b. Production Data for Secondary Asbestos Processors, 1981. Washington, D.C.: Office of Toxic Substances, U.S. Environmental Protection Agency. EPA Document Control No. 20-8670644.

Wheeling Brake Block. G. Beckett. 1986 (November 20). Bridgeport, CT. Transcribed telephone conversation with Richard Hollander, ICF Incorporated, Washington, D.C.

Wheeling Brake Block. G. Beckett. 1987 (July 10). Toronto, Ontario, Canada. Transcribed telephone conversation with Michael Geschwind, ICF Incorporated, Washington, D.C.

XXII. CLUTCH FACINGS

A. Product Description

Clutch facings are friction materials attached to both sides of the steel disc in the clutch mechanism of manual-transmission vehicles. Two metal pressure plates flanking the disc are pressed against the clutch facings by springs when the clutch is engaged. This pressure keeps the gears of the vehicle in position by means of a metal component that extends between the disc and the gears. When the driver steps on the clutch pedal to change gears, the springs pressing the plates against the clutch facings are pulled back, releasing the pressure that holds the gears in position (ICF 1985).

Clutch facings are made of molded or woven friction materials. Molded facings are used more widely than the woven (H.K. Porter 1986, ICF 1985). Woven clutch facings are a premium product. They have longer service life and engage gears better than molded facings; however, they cost substantially more (H.K. Porter 1986, ICF 1985). Woven clutch facings are, therefore, used in luxury automobiles (e.g., Mercedes-Benz) and high-performance vehicles. They may also be used in off-road vehicles, such as agricultural tractors and earth-moving equipment, where improved service life is important (H.K. Porter 1986, Deere and Co. 1986).[1]

Molded and woven clutch facings for the automotive markets are usually made of asbestos or fiberglass (ICF 1985).[2] The molded products are usually

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[1] The service life of these off-road vehicles ranges from 20 to 35 years, or roughly five times the life of an automobile. Clutch facings for these vehicles must last the lifetime of the vehicle, as the typical cost of opening up the transmission to replace a worn facing is on the order of $10,000 (Deere and Co. 1986).

[2] In heavy trucks and heavy earth-moving equipment, the clutch facings are replaced by buttons which can withstand greater pressure but are heavier, noisier, and cost more than materials used in automobiles. The buttons are made of sintered metal (bonded metal particles). Asbestos has almost never been used for these clutch applications (S.K. Wellman 1986). Thus, for the purpose of defining the asbestos-based clutch facing market, heavy vehicle clutch components will be excluded.

made by a dry mix process, as described for disc brake pads. Asbestos fiber or fiberglass is combined with binders in the molding process, during which wires are run through the component to give it shape. The final product is then pressed, cured, and ground to its final shape. Woven clutch facings are made by running asbestos or fiberglass yarn or cord through a wet mix to pick up the wet mixture. The yarn or cord is then woven after drying. The woven product is then hot-pressed, cured, and ground, as other wet-mix friction products (e.g., drum brake linings for light/medium vehicles) (ICF 1985, Krusell and Cogley 1982).

Secondary processing of clutch facings is similar to the secondary processing of automotive friction products previously discussed. Woven clutch facings may be rebuilt, as described for other automotive products (ICF 1985, Krusell and Cogley 1982). Repair of clutches is similar to repair of drum and disc brakes, as described earlier (ICF 1985, Krusell and Cogley 1982).

Asbestos-based molded clutch facings currently produced contain approximately 0.26 lbs. of asbestos fiber per piece (ICF 1986a).[3] (Data was not available on the asbestos fiber content per piece for woven facings.) Asbestos fiber is used to impart stability under friction, good wear up to 480°F, quietness, and very high tensile strength of 10,000 psi (ICF 1985).

B. Producers and Importers of Clutch Facings

Table 1 lists the three primary processors of clutch facings in 1985.[4] All three produce for the automobile, truck, and off-road vehicle markets; and, all firms make asbestos as well as non-asbestos facings (ICF 1986a). Raymark manufactures woven and, probably, molded facings (ICF 1986a, H.K. Porter 1986). H.K. Porter manufactures only woven facings; the firm stated

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[3] See Attachment, Item 1.

[4] Producers of clutch buttons (which are non-asbestos) for heavy trucks and off-road vehicles are not included.

Table 1. 1985 Primary Processors of Clutch Facings

Company	Plant Location(s)	Product: Asbestos	Product: Non-Asbestos	References
Raymark	Manheim, PA	X	X	ICF 1986a, TSCA 1982a
	Stratford, CT[a]	N/A	N/A	TSCA 1982a
	Crawfordsville, IN[a]	N/A	N/A	PEI Associates 1986
H.K. Porter	Huntington, IN	X	X	ICF 1986a, TSCA 1982a
Nuturn	Smithville, TN	X	X	ICF 1986a, TSCA 1982

N/A = Information not available.

[a]This plant refused to respond to our survey. It is assumed that they are still producing asbestos clutch facings.

that it and Raymark are probably the only two current producers of woven facings (H.K. Porter 1986). H.K. Porter stated, however, that it would completely replace production of asbestos-based clutch facings with non-asbestos substitutes by the end of 1986 (PEI Associates 1986). Standco Industries of Houston, TX, (not listed in Table 1) ceased production of asbestos clutch facings prior to 1985; information was not available on whether it produced a non-asbestos product (ICF 1986a).

Table 2 lists the six current secondary processors of clutch facings. Freightliner Corporation of Portland, OR, is essentially Mercedes-Benz's U.S. truck operations (Freightliner 1986). Information was not available on the type of secondary processing in which these firms were involved (ICF 1986b).

Table 3 lists the 27 current importers of asbestos-based clutch facings. According to DuPont, non-asbestos clutch facings are used extensively in European cars; most new German cars, in fact, are equipped with non-asbestos facings (DuPont 1986). Nuturn of Smithville, TN, (not listed in Table 3) stopped importing asbestos-based clutch facings prior to 1985 (Nuturn 1986). Saab-Scania of America (Orange, CT; not listed in Table 3) reported that Saab cars are equipped with non-asbestos clutch facings; the firm stopped importing asbestos facings prior to 1985 (Saab-Scania of America 1986). New Mercedes-Benz automobiles are also equipped with non-asbestos clutch facings (DuPont 1986b).

C. <u>Trends</u>

Table 4 gives the production of asbestos-based clutch facings and the corresponding consumption of asbestos fiber. The 1985 values for production and fiber consumption do not include Raymark's Crawfordsville, IN, plant. Information on the size of the clutch facings production at the Crawfordsville plant was not available (ICF 1986a).

Table 2. 1985 Secondary Processors of Clutch Facings

Company	Plant Location(s)	Product		References
		Asbestos	Non-Asbestos	
Stanhope	Brookville, OH	X	N/A	ICF 1986b, TSCA 1982b
Comdaco	Kansas City, MO	X	N/A	ICF 1986b, TSCA 1982b
Freightliner Corp.	Portland, OR	X	N/A	ICF 1986b, TSCA 1982b
Hall Brake Supply	Phoenix, AZ	X	N/A	ICF 1986b, TSCA 1982b
Borg and Beck Clutch	Chicago, IL	N/A	N/A	TSCA 1982b
Dana Corp.	Wichita Falls, TX	N/A	N/A	TSCA 1982b

N/A = Information not available.

Table 3. Importers of Asbestos-Based Clutch Facings

Company	Location	References
U.S. Suzuki Motor Corp.	Brea, CA	ICF 1986a, ICF 1984
Toyota Motor Sales, USA	Torrence, CA	ICF 1986a, ICF 1984
Western Automotive Warehouse Distributors	Los Angeles, CA	ICF 1984
Kawasaki Motors Corp.	Santa Ana, CA	ICF 1986a, ICF 1984
J.I. Case	Racine, WI	ICF 1984
General Motors	Dayton, OH	ICF 1984
BMW of North America	Montvale, NJ	ICF 1984
Mercedes-Benz of North America	Montvale, NJ	ICF 1984
Volkswagen of America	Troy, MI	ICF 1986a, ICF 1984
Peugeot Motors of America	Lyndhurst, NJ	ICF 1984
Freightliner Corp.	Portland, OR	ICF 1986a, ICF 1984
Original Quality Inc.	Jacksonville, FL	Original Quality 1986
Alfa Romeo	Englewood Cliffs, NJ	Automobile Importers of America 1986
Fiat	Dearborn, MI	Automobile Importers of America 1986
American Honda Motor Company	Gardena, CA	Automobile Importers of America 1986
American Isuzu Motor, Inc.	Whittier, CA	Automobile Importers of America 1986
Jaguar	Leonia, NJ	Automobile Importers of America 1986
Lotus Performance Cars	Norwood, NJ	Automobile Importers of America 1986
Mazda (North America) Inc.	Irvine, CA	Automobile Importers of America 1986
Mitsubishi Motors Corp. Services, Inc.	Southfield, MA	Automobile Importers of America 1986
Nissan Motor Corp.	Gardena, CA	Automobile Importers of America 1986
Porsche Cars North America	Reno, NV	Automobile Importers of America 1986
Renault USA, Inc.	New York, NY	Automobile Importers of America 1986

Table 3 (Continued)

Company	Location	References
Rolls-Royce Motors, Inc.	Lyndhurst, NJ	Automobile Importers of America 1986
Subaru of America, Inc.	Pennsauken, NJ	Automobile Importers of America 1986
Volvo Cars of North America	Rockleigh, NJ	Automobile Importers of America 1986
Hyundai Motor America	Garden Grove, CA	Automobile Importers of America 1986

Table 4. Production and Fiber Consumption for Asbestos-Based Clutch Facings

	1981	1985	References
Production (pieces)	7,478,934	7,237,112[a]	ICF 1986a, TSCA 1982a
Asbestos Fiber Consumption (tons)	1,120.5	993.5[b]	ICF 1986a, TSCA 1982a

[a]Raymark's Crawfordsville, IN and Stratford, CT plant refused to provide production data. Raymark's Stratford, CT production was estimated using a method described in the Appendix A of this RIA. The Crawfordsville, IN plant's production could not be estimated because they did respond to the 1981 TSCA Section 8(a) data request regarding this product and thus no previous production data were available to use for an estimate of 1985 production. Therefore, the number for total production does not include the production volume of Raymark's Crawfordsville, IN plant.

[b]Raymark's Crawfordsville, IN and Stratford, CT plant refused to provide fiber consumption data. Raymark's Stratford, CT plant fiber consumption was estimated using a method described in the Appendix A of this RIA. The Crawfordsville, IN plant's fiber consumption data could not be estimated because they did not respond to the 1981 TSCA Section 8(a) data request regarding this product and thus no previous fiber consumption data were available to use for an estimate of 1985 consumption. Therefore, the total fiber consumption number does not include asbestos fiber consumption of Raymark's Crawfordsville, IN plant.

The production of asbestos-based facings remained fairly level from 1981 to 1985. While the overall size of the clutch facings market (asbestos and non-asbestos substitutes) is not known, the asbestos-based share of the market may have declined somewhat. The vast majority of the clutch facings market is for light/medium vehicles, i.e., cars and light trucks (Ford 1986, Abex 1986). Currently, 15 percent of light/medium vehicles have manual transmissions (and, thus, use clutch facings), but this percentage has been steadily increasing (Ford 1986). Therefore, since the asbestos-based production remained fairly constant from 1981 to 1985, the non-asbestos-based share of the overall market may have increased.

D. Substitutes

All three primary processors of clutch facings produce a non-asbestos product; however, none of the producers would give estimates for the current shares the substitutes hold in the original equipment market (OEM) or aftermarket (ICF 1986a). U.S. automakers frequently import non-asbestos clutch facings from Europe, where they are used extensively. According to DuPont, the European woven clutch facings contain fiberglass, acrylic, and other fibers and are made primarily by Valeo, a French manufacturer (DuPont 1986 and 1987). Price and performance data for the European woven clutches were not available.

Raymark and H.K. Porter also produce non-asbestos fiberglass-based woven clutch facings (H.K. Porter 1986, DuPont 1987). While Raymark would not provide information, H.K. Porter stated that its fiberglass[5] woven facing has the same or improved performance and service life over asbestos-based woven facings, and that it is priced the same as its asbestos product. While the fiberglass product is more difficult to process, the same processing equipment can be used. Because woven clutch facings cost substantially more than molded

[5] The product also contains a smaller proportion of other fibers, which H.K. Porter did not specify (ICF 1986a).

products, however, H.K. Porter did not believe that woven fiberglass facings could capture the majority of the asbestos-based market in the event of a ban (ICF 1986a, H.K. Porter 1986).

Raymark and Nuturn manufacture non-asbestos molded clutch facings (ICF 1986a). Raymark's facing is fiberglass-based; the firm, however, would not provide price or performance information, nor would it estimate the expected market share in the event of a ban (ICF 1986a). Nuturn's facing contains aramid fiber, cellulose fiber, fiberglass, and ceramic fiber (ICF 1986a). Nuturn indicated that its non-asbestos product was priced 49 percent higher than its asbestos-based facing, but it had the same or up to 50 percent longer service life. This non-asbestos facing, however, would not be structurally stable in higher-temperature applications. Nuturn could not estimate the expected share of the market in the event of a ban (ICF 1986a).

Table 5 provides the data for the regulatory cost model. The substitute clutch facings included in the table are the European woven fiberglass facing, the molded fiberglass facing, Nuturn's molded product, and the woven fiberglass facing made by U.S. producers. Because price and useful life were not available for the European woven fiberglass clutch facing or Raymark's molded fiberglass facings, for the asbestos regulatory cost model it was assumed that the European product had the same price and longevity as the woven fiberglass facings produced by the U.S. firms Raymark and H.K. Porter, and that Raymark's molded fiberglass facing had the same life and price as Nuturn's aramid and fiberglass molded facing.

It should be noted that the asbestos substitute clutch facing market has been changing rapidly as substitutes improve. The market shares and prices shown in Table 5 are 1986 estimates; as of July, 1987 some of this information is already outdated and the market is still changing. This change is primarily due to U.S. firms improving their woven substitute facings (DuPont 1987).

Table 5. Data Inputs on Clutch Facings for Asbestos Regulatory Cost Model[a]

Product	Output	Product Asbestos Coefficient	Consumption Production Ratio	Price	Useful Life	Equivalent Price	Market Share	References
Asbestos mixture	7,237,112 pieces	0.00014 tons/piece	1.12	$1.71/piece	5 years	$1.71/piece	N/A	ICF 1986a, ICF 1985, b
Woven fiberglass (European product)	N/A	N/A	N/A	$2.92/piece	7.5 years	$2.11/piece	50%	DuPont 1986
Woven figerglass (U.S. Product)	N/A	N/A	N/A	$2.92/piece	7.5 years	$2.11/piece	30%	ICF 1986a
Molded aramid fiber, fiberglass, cellulose and ceramic fiber (Nuturn's product)	N/A	N/A	N/A	$2.55/piece	6.25 years	$2.12/piece	10%	ICF 1986a
Molded fiberglass	N/A	N/A	N/A	$2.55/piece	6.25 years	$2.12/piece	10%	ICF 1986a

N/A: Not Applicable.

[a]See Attachment, Items 2-7.

E. Summary

Clutch facings are friction materials attached to both sides of the steel disk in the clutch mechanism of manual transmission vehicles. Clutch facings are made of molded or woven friction materials; molded facings are used more widely than woven facings (ICF 1985, H.K. Porter 1986). In 1985, three producers consumed 993.5 tons of asbestos to produce 7,237,112 asbestos clutch facings. All three firms also make non-asbestos facings (ICF 1986a). The production of asbestos-based clutch facings remained fairly level from 1981 to 1985. The four major substitutes for the asbestos clutch facings are: European facings which contain fiberglass and other fibers; molded fiberglass-based facings produced by Raymark; a Nuturn molded facing containing aramid fiber, cellulose fiber, fiberglass and ceramic fiber; and fiberglass-based woven facing made by both Raymark and H.K. Porter (DuPont 1986 1987). Equivalents costs for the substitutes were 20-25 percent higher than for the asbestos product. If asbestos were not available it is estimated that the European substitute will take 50 percent, woven fiberglass 30 percent, molded fiberglass 10 percent and Nuturn's product 10 percent of the asbestos-based clutch facing market.

ATTACHMENT

1. The asbestos fiber content per piece was calculated by dividing the 1985 asbestos fiber consumption for molded asbestos clutch facings 993.5 tons or 1,987,000 lbs. by the 1985 production of molded asbestos clutch facings (7,237,112 pieces).

2. The product asbestos coefficient is the same value calculated in Item 1 above, converted into tons per piece.

3. The consumption production ratio was calculated using 885,947 pieces as the value for 1985 U.S. imports. (Total 1985 production of asbestos clutch facings is 7,237,112 pieces.) This value, however, only includes imports for the firms who provided information (see Table 4).

4. The asbestos mixture price is the price given by Nuturn for its molded asbestos product. The woven fiberglass mixture price is the price given by H.K. Porter for its woven fiberglass product.

5. The useful life of the asbestos mixture is assumed to be the same as that reported in 1984 in Appendix H (ICF 1985). The useful life of the woven fiberglass facing produced by U.S. firms is assumed to be 50 percent greater than the molded asbestos product, or 7.5 years. H.K. Porter stated the woven facing is a "premium" product with significantly longer service life than molded products (H.K. Porter 1986). Nuturn stated its substitute had the same or up to 50 percent increased service life (ICF 1986a). Thus, a 25 percent service life increase is assumed, which gives the Nuturn product a life of 6.25 years. Because price and useful life were not available for the European woven fiberglass clutch facing or Raymark's molded fiberglass facings, for the asbestos regulatory cost model it was assumed that the European product had the same price and longevity as the woven fiberglass facings produced by the U.S. firms Raymark and H.K. Porter, and that Raymark's molded fiberglass facing had the same life and price as Nuturn's aramid and fiberglass molded facing.

6. Based upon DuPont's statement that the European clutch facings are frequently used by U.S. automakers, a 50 percent share is assumed for the European facings. H.K. Porter stated that 30 percent of the market would be captured by the fiberglass woven facings. The remaining share is split equally between the molded fiberglass facings and Nuturn's product.

7. It should be noted that the asbestos substitute clutch facing market has been changing rapidly as substitutes improve. The market shares and prices shown in Table 5 are 1986 estimates; as of July, 1987 some of this information is already outdated and the market is still changing. This change is primarily due to U.S. firms improving their woven substitute facings (DuPont 1987).

REFERENCES

Abex Corp. R. Nelson. 1986b (December 3). American Society of Mechanical Engineers Conference in Washington, D.C. Transcribed conversation with Richard Hollander, ICF Incorporated, Washington, D.C.

Automobile Importers of America. 1986. Comments of Automobile Importers of America on Proposed Asbestos Ban Rule. EPA Document Control No. OPTS-62036.

Deere and Co. R. Grotelueschen. 1986 (October 30). Moline, IL. Transcribed telephone conversation with Richard Hollander, ICF Incorporated, Washington, D.C.

DuPont. T. Merriman. 1986 (November 5). Wilmington, DE. Transcribed telephone conversation with Richard Hollander, ICF Incorporated, Washington, D.C.

DuPont. R. Gould. 1987 (July 13). Wilmington, DE. Transcribed telephone conversation with Michael Geschwind, ICF Incorporated, Washington, D.C.

Ford Motor Co. A. Anderson. 1986 (December 3). American Society of Mechanical Engineers Conference in Washington, D.C. Transcribed conversation with Richard Hollander, ICF Incorporated, Washington, D.C.

Freightliner Corp. T. Robinson. 1986 (November 26). Portland, OR. Transcribed telephone conversation with Richard Hollander, ICF Incorporated, Washington, D.C.

H.K. Porter Co. F. Donnell. 1986 (November 20). Huntington, IN. Transcribed telephone conversation with Richard Hollander, ICF Incorporated, Washington, D.C.

ICF Incorporated. 1984. Imports of Asbestos Mixtures and Products. Washington, D.C.: Office of Pesticides and Toxic Substances, U.S. Environmental Protection Agency. EPA CBI Document Control No. 20-8600681.

ICF Incorporated. 1985. Appendix H: Asbestos Products and Their Substitutes, in Regulatory Impact Analysis of Controls on Asbestos and Asbestos Products. Washington, D.C.: Office of Pesticides and Toxic Substances, U.S. Environmental Protection Agency.

ICF Incorporated. 1986a (July-December). Survey of Primary Processors of Brake Blocks. Washington, D.C.

ICF Incorporated. 1986b (July-December). Survey of Secondary Processors of Brake Blocks. Washington, D.C.

Krusell N., Cogley D. 1982. GCA Corp. Asbestos Substitute Performance Analysis, Revised Final Report. Washington, D.C.: Office of Pesticides and Toxic Substances, U.S. Environmental Protection Agency. Contract 68-02-3168.

Nuturn. G. Swinfen. 1986 (July-December). Smithville, TN. Transcribed telephone conversation with Richard Hollander, ICF Incorporated, Washington, D.C.

Original Quality, Inc. 1986. Comments of Original Quality, Inc. on Proposed Asbestos Ban Rule. EPA Document Control No. OPTS-62036.

PEI Associates, Inc. 1986. OTS Survey of Asbestos Products Manufacturers. Washington, D.C.: Office of Pesticides and Toxic Substances, U.S. Environmental Protection Agency.

Saab-Scania of America. D. Rainey. 1986 (November 21). Orange, CT. Transcribed telephone conversation with Richard Hollander, ICF Incorporated, Washington, D.C.

S.K. Wellman. B. Laditka. 1986 (October 29). Bedford, OH. Transcribed telephone conversation with Richard Hollander, ICF Incorporated, Washington, DC.

TSCA Section 8(a) submission. 1982a. Production Data for Primary Asbestos Processors, 1981. Washington, D.C.: Office of Toxic Substances, U.S. Environmental Protection Agency. EPA Document Control No. 20-8601012.

TSCA Section 8(a) submission. 1982b. Production Data for Secondary Asbestos Processors, 1981. Washington, D.C.: Office of Toxic Substances, U.S. Environmental Protection Agency. EPA Document Control No. 20-8670644.

XXIII. AUTOMATIC TRANSMISSION FRICTION COMPONENTS

A. Product Description

An automatic transmission consists of 5 to 15 small metal rings called friction clutches, which are housed, along with gears, in a metal band called the transmission band. Each friction clutch is covered with a thin friction clutch plate which is made from a friction paper that contains asbestos or some other friction material. In addition, a lining, also made from this friction paper, is bonded to the inside of the transmission band (Mead 1986, Borg-Warner 1986). These automatic transmission friction components -- friction clutch plates and transmission band linings -- are immersed in a fluid environment which dissipates much of the heat generated when gears are changed. Asbestos-based automatic transmission friction components made by S.K. Wellman for medium trucks, for example, are 1/16 of an inch thick and may contain approximately 0.11 lbs. of asbestos per component (15 percent asbestos by weight) (S.K. Wellman 1986).[1]

Paper for automatic transmission components is manufactured by conventional paper-making processes; i.e., raw materials (the chosen friction material, fillers, and resins) are pulped and fed into a continuous papermaking machine. Finished paper is then removed from the machine (ICF 1985). Automatic transmission friction components are then cut from the paper, and after they are pressed and shaped, grooves (these can vary in design) are either cut or stamped into the components (ICF 1985).[2]

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[1] Raymark, another U.S. producer of asbestos-based automatic transmission friction components for automobiles, refused to provide information.

[2] Cut grooves are preferred over the stamped ones because they last longer (ICF 1985).

Two producers, Borg-Warner[3] and S.K. Wellman, purchase their friction paper. Information was not available on whether the other producer, Raymark, manufactures or purchases its friction paper. Armstrong World Industries (Fulton, NY) and Mead Corporation (South Lee, MA) produce friction paper for sale to the producers of automatic transmission components (ICF 1986a).[4]

Automobiles, light/medium trucks, and off-road vehicles use components made from friction paper (Borg-Warner 1986, S.K. Wellman 1986, Deere and Co. 1986). Friction components for the transmissions of heavy trucks, such as eighteen-wheel tractor trailers and logging and mining trucks, and certain off-road vehicles (heavy tractors and earth-moving equipment), however, are usually made from sintered metal that is molded into the desired shapes (S.K. Wellman 1986).

B. Producers and Importers of Automatic Transmission Friction Components

Table 1 lists the three current producers of (asbestos and non-asbestos) automatic transmission friction components. Borg-Warner produces only non-asbestos components (it did not produce asbestos-based components in 1981 either) (ICF 1986a). The other two manufacturers produced both asbestos and non-asbestos components in 1985 (S.K. Wellman 1986, Raymark 1986).[5] Borg-Warner produces transmission components for automobiles and trucks (ICF 1986a). S.K. Wellman produces components only for off-road vehicles and medium and heavy trucks (S.K. Wellman 1986). The third producer, Raymark,

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[3] Borg-Warner only uses non-asbestos-based friction paper (ICF 1986a).

[4] Armstrong World Industries makes both asbestos and non-asbestos friction paper; Mead Corporation only makes a non-asbestos variety. The latter company discontinued production of asbestos-based paper in December, 1983 (ICF 1986a).

[5] S.K. Wellman stopped producing asbestos-based automatic transmission friction components in March, 1987 (S.K. Wellman 1986).

Table 1. Producers of Automatic Transmission Friction Components

Company	Plant Location	Product: Asbestos	Product: Non-Asbestos	Market	References
S.K. Wellman	LaVergne, TN	X[a]	X	Medium and heavy trucks, off-road vehicles[a]	S.K. Wellman 1986, ICF 1984
Raymark	Stratford, CT Crawfordsville, IN	X N/A	X N/A	Autos, trucks, off-road vehicles[b]	ICF 1986a, ICF 1984, TSCA 1982a, Deere and Co. 1986
Borg-Warner	Frankfort, IL		X	Autos, trucks	ICF 1986a, TSCA 1982b

N/A = Information not available.

[a] S.K. Wellman stopped the production of asbestos-based automatic transmission friction components in March, 1987 (S.K. Wellman 1986).

[b] Off-road vehicles include tractors and earth-moving equipment.

makes components for automobiles, trucks, and off-road vehicles (Raymark 1986, S.K. Wellman 1986, Deere and Co. 1986).

There were no secondary processors of automatic transmission friction components in 1985 or in 1981 (ICF 1986b, 1985).

Table 2 lists the importers of asbestos-based components.

C. Trends

In 1981, the industry was slowly moving away from asbestos in automatic transmission components, and by 1985 substitution had increased rapidly (Borg-Warner 1986, ICF 1985). It is estimated that approximately 25 percent of the original equipment market (OEM) is still asbestos-based.[6] Data were not available for the percent share for the aftermarket, although it is likely to be higher than in the OEM.

Table 3 gives the production and fiber consumption of asbestos-based components. Because of the lack of available data, it is difficult to determine the actual decline in production from 1981 to 1985; however, sources generally agree that the substitution of asbestos in automatic transmission components will be complete, in at least new vehicles, in the near future (Borg-Warner 1986, S.K. Wellman 1986, DuPont 1986, Mead 1986).

D. Substitutes

Automatic transmission components made from cellulose-based friction paper are currently the main substitute for asbestos-based components (DuPont 1986, Mead 1986). Borg-Warner is the leading producer of cellulose-based components (Borg-Warner 1986). The chief cellulose material in its components is cotton fiber (Borg-Warner 1986). Cellulose-based components can also contain other fibers in smaller proportions. Mead Corporation produces friction paper containing greater than 50 percent cotton fibers with varying amounts of

[6] See Attachment, Item 1.

Table 2. Imports of Asbestos-Based Automatic Transmission Friction Components

Company	Location	References
Volkswagen of America	Troy, MI	ICF 1984
Toyota Motor Sales, USA	Torrence, CA	ICF 1984
Mercedes-Benz of North America	Montvale, NJ	ICF 1984
Western Automotive Warehouse Distributors	Los Angeles, CA	ICF 1984
Raymark, via their Japanese subsidiary, Daikin	Trumbull, CT[a]	ICF 1984
American Honda Motor Company	Gardena, CA	Automobile Importers of America 1986
American Isuzu Motor, Inc.	Whittier, CA	Automobile Importers of America 1986
Jaguar	Leonia, NJ	Automobile Importers of America 1986
Mazda (North America) Inc.	Irvine, CA	Automobile Importers of America 1986
Mitsubishi Motors Corp. Services, Inc.	Southfield, MA	Automobile Importers of America 1986
Nissan Motor Corp.	Gardena, CA	Automobile Importers of America 1986
Renault USA, Inc.	New York, NY	Automobile Importers of America 1986
Rolls-Royce Motors, Inc.	Lyndhurst, NJ	Automobile Importers of America 1986
Subaru of America, Inc.	Pennsauken, NJ	Automobile Importers of America 1986
Alfa Romeo	Englewood Cliffs, NJ	Automobile Importers of America 1986
Fiat	Dearborn, MI	Automobile Importers of America 1986
Lotus Performance Cars	Norwood, NJ	Automobile Importers of America 1986
Porsche Cars North America	Reno, NV	Automobile Importers of America 1986
Hyundai Motor America	Garden Grove, CA	Automobile Importers of America 1986
Volvo Cars of North America	Rockleigh, NJ	Automobile Importers of America 1986

N/A = Information not available.

[a]Since Raymark refused to provide information, Raymark's corporate headquarters is given as the location.

Table 3. Production and Fiber Consumption for
Asbestos-Based Automatic Transmission Friction Components

	1981		1985		
	Production (pieces)	Asbestos Fiber Consumption (tons)	Production (pieces)	Asbestos Fiber Consumption (tons)	References
Total	N/A	N/A	585,500[a]	2.5[a]	TSCA 1982b ICF 1986a

N/A = Information not available.

[a] Raymark Corp. refused to provide production and fiber consumption data. This data has, therefore, been estimated using a method described in the Appendix A to this RIA.

fiberglass and/or aramid fiber and/or carbon or graphite filler, depending on the application (ICF 1986a).[7] S.K. Wellman, Borg-Warner, and Raymark produce cellulose-based automatic transmission components for agricultural tractors containing either:

- Cotton fiber, with carbon fiber, cellulite, graphite filler, and phenolic resin; or
- Cellulose fiber, with cellulite and phenolic resin (Deere and Co. 1986).

Industry experts agree that if asbestos were no longer available, the original equipment market (OEM) would switch entirely to cellulose-based components (ICF 1986a, DuPont 1986, Mead 1986). Borg-Warner stated, and repair shops (previously interviewed by ICF in 1983) agreed, that cellulose-based components are also entirely interchangeable in the automobile aftermarket with no loss of performance (Borg-Warner 1986, ICF 1985). Deere and Company, a major manufacturer of tractors, indicated that cellulose-based components were not interchangeable with asbestos components in the tractor aftermarket because these transmissions were designed for the particular coefficient of friction of the asbestos components. Deere and Company has redesigned transmission systems specifically for cellulose-based components. The company stated that it was unlikely that suppliers would develop substitutes in the tractor aftermarket because of the relatively low volume of the market (which is also diminishing) and the extreme technical difficulty of engineering a substitute for a transmission system that was designed specifically for asbestos components (Deere and Co. 1986).

Table 4 provides the data for the regulatory cost model.

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[7] Armstrong World Industries stated its non-asbestos friction paper contained cellulose fibers and inorganic fillers; it did not indicate any additional fibers (ICF 1986a).

Table 4. Data Inputs on Automatic Transmission Friction Components for Asbestos Regulatory Cost Model

Product	Output	Product Asbestos Coefficient	Consumption Production Ratio	Price	Useful Life	Equivalent Price	Market Share	References
Asbestos Mixture	585,500 pieces	0.0000043 tons/piece	1.0	$1.60/piece	4-7 years	$1.60/piece	N/A	ICF 1986a, ICF 1985
Cellulose	N/A	N/A	N/A	$2.00/piece	4-7 years	$2.00/piece	100%	ICF 1986a, DuPont 1986, Mead 1986

N/A: Not Applicable.

[a]See Attachment, Items 2-4.

E. Summary

Automatic transmission friction components are either friction clutch plates or transmission band linings. Friction clutch plates are made from thin pieces of friction paper and cover friction clutches which are small metal rings found in each automatic transmission. A transmission band is a metal band that houses the gears and friction clutches; a lining made of friction paper is bonded to the inside of the transmission band (Mead 1986, Borg-Warner 1986).

Two companies consumed 2.5 tons of asbestos to produce 585,500 pieces of automatic transmission friction components in 1985 (ICF 1986a). In March, 1987 one of these companies ceased production of asbestos-based automatic transmission friction components, leaving one remaining U.S. producer (ICF 1986a). There are more than 14 companies importing asbestos-based components (ICF 1984, Automobile Importers of America 1986). Approximately 25 percent of the OEM for automatic transmission friction components is still asbestos based. The major substitute for asbestos-based components are made from cellulose-based friction paper, which contains cotton and possibly other fibers in smaller proportions (Mead 1986). If asbestos were no longer available, the OEM would switch entirely to cellulose-based components. There is disagreement as to whether asbestos-based automatic transmission friction components are completely interchangeable with cellulose-based components for all vehicle types in the replacement/repair market.

ATTACHMENT

1. According to a representative from Borg-Warner, the largest producer of automatic transmission friction components (all non-asbestos), asbestos-based components now account for roughly 50 percent of the OEM, but this share is rapidly declining (Borg-Warner 1986). Representatives from DuPont and Mead Corporation both stated that replacement of asbestos-based components in the OEM is now nearly 100 percent (DuPont 1986, Mead 1986). Using an average of the above estimates, and the fact that Borg-Warner is the largest producer, it is assumed that approximately 25 percent of the OEM is still asbestos-based.

2. The product asbestos coefficient was determined by dividing the total tons of asbestos fiber consumed by the number of pieces of components produced shown in Table 2.

3. The consumption production ratio was calculated assuming no imports for 1985. Importers did not provide information for 1985.

4. Since Raymark, the only remaining U.S. producer of asbestos-based components, did not provide information, the asbestos product price and useful life is assumed to be the same as that reported in 1984 in Appendix H (ICF 1985). Borg-Warner stated the purchase price of cellulose-based components was 25 percent higher than the asbestos product, thus the cellulose product price in the table is 1.25 times the asbestos product price. Borg-Warner also indicated that the useful life of the cellulose components was the same as the asbestos product (Borg-Warner 1986).

REFERENCES

Automobile Importers of America. 1986. Comments of Automobile Importers of America on Proposed Asbestos Ban Rule. EPA Document Control No. OPTS-62036.

Borg-Warner. T. Longtin. 1986 (November 20). Frankfort, IL. Transcribed telephone conversation with Richard Hollander, ICF Incorporated, Washington, D.C.

Deere and Co. R. Grotelueschen. 1986 (October 30). Moline, IL. Transcribed telephone conversation with Richard Hollander, ICF Incorporated, Washington, D.C.

DuPont. T. Merriman. 1986 (November 5). Wilmington, DE. Transcribed telephone conversation with Richard Hollander, ICF Incorporated, Washington, D.C.

ICF Incorporated. 1984. Imports of Asbestos Mixtures and Products. Washington, D.C.: Office of Pesticide and Toxic Substances, U.S. Environmental Protection Agency. EPA CBI Document Control No. 20-8600681.

ICF Incorporated. 1985. Appendix H: Asbestos Products and Their Substitutes, in Regulatory Impact Analysis of Controls on Asbestos and Asbestos Products. Washington, D.C.: Office of Pesticides and Toxic Substances, U.S. Environmental Protection Agency.

ICF Incorporated. 1986a (July-December). Survey of Primary Processors of Automatic Transmission Friction Components. Washington, D.C.

ICF Incorporated. 1986b (July-December). Survey of Secondary Processors of Automatic Transmission Friction Components. Washington, D.C.

Mead Corp. L. McDonnold. 1986 (December 15). Dayton, OH. Transcribed telephone conversation with Richard Hollander, ICF Incorporated, Washington, D.C.

Raymark Corp. 1986. Comments of Raymark Corp. on Proposed Asbestos Ban Rule. EPA Document Control No. OPTS-62036.

S.K. Wellman. B. Laditka. 1986 (October 29). Bedford, OH. Transcribed telephone conversation with Richard Hollander, ICF Incorporated, Washington, D.C.

TSCA Section 8(a) submission. 1982a. Production Data for Primary Asbestos Processors, 1981. Washington, D.C.: Office of Toxic Substances, U.S. Environmental Protection Agency. EPA Document Control No. 20-8601012.

TSCA Section 8(a) submission. 1982b. Production Data for Secondary Asbestos Processors, 1981. Washington, D.C.: Office of Toxic Substances, U.S. Environmental Protection Agency. EPA Document Control No. 20-8670644.

XXIV. FRICTION MATERIALS

A. Product Description

Friction materials are used as braking and gear-changing (clutch) components in a variety of industrial and commercial machinery.[1] Applications include agricultural equipment such as combines, mining and oil-well-drilling equipment, construction equipment such as cranes and hoists, heavy equipment used in various manufacturing industries (e.g., machine tools and presses), military equipment, marine engine transmissions, elevators, chain saws, and consumer appliances such as lawn mowers, washing machines, and vacuum cleaners (Raymark 1986b, Design News 1984, ICF 1986a, 1985).

Friction materials are either molded or woven products for use in wet or dry friction systems (Design News 1984, ICF 1985, DuPont 1986, Deere and Co. 1986, Krusell and Cogley 1982).[2] Molded products include thin segments, blocks, and other components used as brake linings, as well as rings[3] and other molded components used as clutches (H.K. Porter 1986, Design News 1984). Brake linings may also be woven bands (Design News 1984, Krusell and Cogley 1982). Band applications range from large band brakes for oil-well-drilling equipment, cranes, and hoists, to light-duty general-purpose bands for a variety of commercial and industrial machines (Design News 1984).

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[1] This product category includes all brake and clutch applications other than automobiles, trucks, and off-road vehicles (including tractors and earth-moving equipment).

[2] Heavy industrial equipment often use oil-cooled clutches and brakes, sometimes referred to as wet friction products, because of severe operating conditions and design considerations. Fluids facilitate the transfer of heat away from the working surface of the friction material providing superior durability and resulting in longer life between major overhauls and replacement. Large band brakes for oil-well drilling equipment, cranes, and hoists require a special fluid system (Design News 1984). Wet friction systems may also be used in other lighter-duty commercial and industrial applications (DuPont 1986).

[3] One producer, H.K. Porter, considers these molded rings to be washers (ICF 1986a).

Asbestos is used in friction materials for the following reasons:

- Stable friction properties under heat;
- Strength;
- Wear resistance;
- Flexibility (asbestos-based materials can be shaped or bent easily); and
- Relatively low cost (ICF 1985, Raymark 1986b).

Asbestos-based friction materials contain an average 0.37 lbs. of asbestos fiber per piece (ICF 1986a).[4]

Manufacturing methods for friction materials vary depending on the type and application of the material. For example, woven asbestos band-brakes for heavy-duty uses are produced by passing asbestos cord, possibly reinforced with wire, through a wet-mix to pick up resin and modifiers. The saturated cord is then woven into tapes. The tapes are heated to partially cure the resin, and then may be further cured to form flexible bands or rigid segments (Krusell and Cogley 1982). Information on secondary processing, as well as rebuilding and repair of worn friction materials, was not available.

B. Producers and Importers of Friction Materials

Table 1 lists the seven producers of (asbestos and non-asbestos) friction materials in 1985. All producers, except for Scan Pac, produced an asbestos product in 1985 (ICF 1986a, PEI Associates 1986). All firms except Virginia Friction Products currently produce non-asbestos-based materials (ICF 1986a, PEI Associates 1986). Gatke Corporation is a relatively small producer, making asbestos products for cranes, hoists, and oil-well-drilling equipment

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[4] See Attachment, Item 1.

Table 1. 1985 Primary Processors of Friction Materials

Company	Plant Location(s)	Product		References
		Asbestos	Non-Asbestos	
Raymark	Manheim, PA	X	X	ICF 1986a, TSCA 1982a
	Stratford, CT[a]	N/A	N/A	
National Friction Products	Logansport, IN	X	X	ICF 1986a, TSCA 1982a
Virginia Friction Products	Houston, TX	X		PEI Associates 1986
Gatke Corp.	Warsaw, IN	X	X	ICF 1986a, TSCA 1982a
Wheeling Brake Block	Bridgeport, CT	X[b]	X	ICF 1986a, TSCA 1982a
H.K. Porter	Huntington, IN	X[c]	X	ICF 1986a, TSCA 1982a
Scan Pac	Menomonee Falls, WI		X	ICF 1986a, ICF 1985

N/A = Information not available.

[a]This plant refused to respond to our survey. It is assumed that they made asbestos friction materials in 1985.

[b]Wheeling Brake Block completely replaced its asbestos-based friction materials with non-asbestos products in 1986 (Wheeling Brake Block 1986).

[c]H.K. Porter stated it would phase out its asbestos-based friction materials by the end of 1986 (ICF 1986a, PEI Associates 1986).

(ICF 1986a, PEI Associates 1986). Information was not available on the size of Virginia Friction Products' production volume; however, the firm only makes asbestos-based friction materials for oil-well rigs and giant cranes (PEI Associates 1986). Wheeling Brake Block indicated it completely replaced its asbestos-based friction materials with non-asbestos products in 1986 (Wheeling Brake Block 1986). H.K. Porter stated it would phase out its asbestos-based friction-materials by the end of 1986, making only non-asbestos materials (ICF 1986a, PEI Associates 1986).

Table 2 lists the two secondary processors of friction materials in 1985. Hoover Company stopped consuming asbestos-based friction materials in 1986. The firm had purchased, and possibly further processed, asbestos brake linings for use in its vacuum cleaners (ICF 1986b).[5] Information is not available on the type of secondary processing in which Western Gasket Packing Company is involved.[6] Gasko Fabricated Products of Medina, OH (not listed in Table 2), discontinued secondary processing of its asbestos-based product prior to 1985 (ICF 1986b).[7]

There were no imports of asbestos-based friction materials in 1985 or in 1981 (ICF 1986a, 1986b, 1984).

C. Trends

Table 3 gives the production of asbestos-based friction materials and the corresponding consumption of asbestos fiber. The 1985 production value is 51

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[5] Information is not available on the non-asbestos brake lining used by Hoover Co.

[6] Information is also not available on whether Western Gasket Packing Co. processes a non-asbestos product.

[7] The asbestos-based product was a vacuum cleaner control disc; information is not available on whether the firm consumes a non-asbestos product (TSCA 1982b).

Table 2. 1985 Secondary Processors of Friction Materials

Company	Plant Location	Product		References
		Asbestos	Non-Asbestos	
Hoover Co.	North Canton, OH	X	X	ICF 1986b, TSCA 1982b
Western Gasket Packing Co.	Los Angeles, CA	X	N/A	ICF 1986b, TSCA 1982b

N/A = Information not available.

Table 3. Production and Fiber Consumption of Asbestos-Based Friction Materials

	1981	1985	References
Production (pieces)	17,604,160	8,719,541[a]	ICF 1986a, TSCA 1982a
Asbestos Fiber Consumption (tons)	2,461.1	1,602.5[b]	ICF 1986a, TSCA 1982a

[a] Does not include production volume of Virginia Friction Products' Houston, TX, plant. Raymark's Stratford, CT plant and Wheeling Brake Block's Bridgeport, CT plant refused to provide production data for their asbestos friction materials. Data for these Raymark and Wheeling Brake Block plants were estimated using method described in Appendix A of this RIA.

[b] Does not include asbestos fiber consumption of Virginia Friction Products' Houston, TX, plant. Raymark's Stratford, CT plant and Wheeling Brake Block's Bridgeport, CT plant refused to provide fiber consumption data for their asbestos friction materials. Data for these Raymark and Wheeling Brake Block plants were estimated using the method described in Appendix A of this RIA.

percent less than that of 1981. The 1985 value does not include Virginia Friction Products' Houston, TX, plant; however, the production volume of this plant is probably small. The 1985 value for fiber consumption is 45 percent less than that of 1981; however, the 1985 value does not include consumption for Virginia Friction Products' plant.

Raymark, probably the largest producer of friction materials (asbestos and non-asbestos products combined)[8] stated that non-asbestos substitutes have been developed for most industrial applications, but not all of these substitutes are yet produced in sizeable quantities. Many of these substitutes must still undergo extensive field testing before they are accepted by customers (Raymark 1986b).

Other sources indicate that substitutes have been developed for many commercial and consumer applications, such as machine tools, chain saws, lawn mowers, washing machines, and vacuum cleaners (Design News 1984, Hoover 1986). DuPont, a major supplier of materials for friction products, e.g., Kevlar(R), stated that most friction materials are now non-asbestos (DuPont 1986). Thus, the current asbestos-based share of the total friction materials market is estimated to be 30 percent.[9]

D. Substitutes

Because of the large variety of friction material applications and the reluctance on the part of producers to reveal much more than one or two ingredients in their substitute formulations, it is very difficult to make price and performance comparisons between specific substitute and asbestos-based products, or to estimate market shares for specific substitutes

[8] Raymark, which produces mostly friction materials, stated that 40 percent of all of its friction products are now non-asbestos (Raymark 1986b). (Raymark also manufactures clutch facings, automatic transmission friction components, and brake blocks (ICF 1986a).)

[9] See Attachment, Item 2 for a full explanation of this estimate.

(ICF 1986a).[10] Nevertheless, all producers of substitute friction materials, except for Gatke Corporation,[11] indicated that their non-asbestos formulations contained fiberglass, Kevlar(R), or both, and other fibers (often mineral fibers) (ICF 1986a).[12] National Friction Products, which manufactures a broad range of friction materials, stated that these combinations would capture 80-85 percent of the friction materials market in the event of an asbestos ban. The remaining 15-20 percent of asbestos-based applications (application areas not specified) could not be replaced immediately (ICF 1986a).[13]

One example of a combination substitute product is Raymark's fiberglass and Kevlar(R) brake block used in large cranes and oil-well drilling equipment. The block is priced the same as its asbestos-based product and has the same service life, but does not perform as well at high temperatures (Raymark 1986a). H.K. Porter manufactures heavy-duty clutch components made of fiberglass and Nydag wollastonite board. These components, which are used for hoists, agricultural equipment, and large marine motors, are priced the same as asbestos-based clutches and have improved wear (ICF 1986a).

Gatke Corporation manufactures molded clutch facings, made chiefly from fiberglass, for use in cranes, hoists, and oil-well drilling equipment (ICF 1986a, PEI Associates 1986). The firm, however, considers these products to

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[10] Producers often would not elaborate on the friction materials they produced, and often were vague or uncertain about the performance of their substitutes compared to asbestos-based products (ICF 1986a).

[11] Gatke produces clutch components chiefly made of fiberglass for use in heavy machinery (ICF 1986a).

[12] These formulations may be similar to formulations used in clutch facings for automotive and off-road vehicles, and similar to the non-asbestos-organic (NAO) compounds used in automotive drum brake linings and brake blocks for heavy trucks and off-road vehicles.

[13] Until other replacements can be found for the remaining 15-20 percent of asbestos-based applications, it is assumed that for the present that the Kevlar(R) and fiberglass combination substitute will replace 100 percent of the asbestos market if asbestos were no longer available.

be inferior. The facings are less heat-resistant, more expensive, and heavier than asbestos-based facings. Furthermore, the fiberglass facings are abrasive to the transmission systems, and they are difficult to manufacture (ICF 1986a).

DuPont indicated that brake and clutch components made chiefly from fiberglass would not be used in wet friction systems because the glass fibers tend to break loose, travelling through the fluid-filled environment and causing abrasion (DuPont 1986).

Table 4 provides the data for the regulatory cost model. The substitute product is a general mixture containing fiberglass and/or Kevlar(R) in combination with other fibers.. It is assumed that the market share for friction materials made chiefly from fiberglass will be negligible.

E. Summary

Asbestos friction materials are used as braking and gear-changing (clutch) components in a variety of industrial and commercial machinery (ICF 1985). There were six primary processors of asbestos friction materials in 1985 which consumed 1,602.5 tons of asbestos to produce 8,719,541 pieces of asbestos friction material. Since 1985, Wheeling Brake Block and H.K. Porter have stopped producing asbestos friction materials, leaving four remaining producers of the asbestos product (ICF 1986a). The primary substitute is a Kevlar(R) and fiberglass combination which is projected to take 100 percent of if the asbestos products were no longer available. The Kevlar(R) and fiberglass combination substitute costs the same as asbestos friction materials (ICF 1986a).

Table 4. Data Inputs on Friction Materials for Asbestos Regulatory Cost Model[a]

Product	Output	Product Asbestos Coefficient	Consumption Production Ratio	Price	Useful Life	Equivalent Price	Market Share	References
Asbestos Mixture	8,719,541 pieces	0.00018 tons/piece	1.0	$34.65/piece	0.5 years	$34.65/piece	N/A	ICF 1986a, ICF 1985 Raymark 1986a
Fiberglass and Kevlar(R)	N/A	N/A	N/A	$34.65/piece	0.5 years	$34.65/piece	100%	Raymark 1986a, National Friction Products 1986

N/A: Not Applicable.

[a]See Attachment, Items 3-6.

ATTACHMENT

1. The value for asbestos fiber per piece was determined by dividing the total asbestos fiber consumption, 1,602.5 tons, by total pieces produced, 8,719,541 pieces. This equals 0.000184 tons/piece or 0.37 lbs./piece.

2. A conservative estimate for the asbestos-based share of the market in 1981 would be 95 percent (non-asbestos substitutes were, in fact, available in 1981 for various applications) (ICF 1985). If it is also assumed that the overall friction materials market (asbestos and non-asbestos) remained constant from 1981 to 1985, then since the decline in asbestos-based production of friction materials was approximately 51 percent from 1981 to 1985, the 1985 asbestos-based share of the total market would have been 49 percent of 95 percent, or 47 percent. H.K. Porter, furthermore, stated that by the end of 1986 it should have completely replaced its asbestos-based materials with non-asbestos substitutes. H.K. Porter's approximate share of the asbestos-based market in 1985 was 11 percent (the production volume of Virginia Friction Products' plant is not available; however, it is probably small) (ICF 1986a). Thus, if it is assumed that the total friction materials market remained constant from the end of 1985 to the end of 1986, then perhaps another 10 percent can be subtracted from the asbestos-based share of the market, to account for the loss of H.K. Porter's asbestos-based production. This would make the asbestos-based share of the market as of January 1, 1987, 37 percent. Finally, taking into account Raymark's statement that substitutes have been developed for most industrial applications and DuPont's statement that most friction materials are not non-asbestos, it is reasonable to assume the present asbestos-based share is even smaller than 37 percent. A share of 30 percent is thus assumed.

3. The product asbestos coefficient is the same number given in Item 1 above, shown in tons per piece.

4. Given the variety of friction material applications, it is very difficult to compute a weighted average asbestos product price or a substitute product price. The asbestos and substitute mixture prices are for Raymark's brake blocks used in large cranes and oil-well drilling equipment (stated in the text).

5. The useful life of the asbestos mixture is assumed to be the same as that reported in 1984 (in Appendix H) for an asbestos friction block (ICF 1985). The useful life of the substitute mixture is assumed to be the same as the asbestos mixture, since Raymark stated its substitute friction block had the same service life as its asbestos product.

6. A market share of the Kevlar(R) and fiberglass combination substitute of 80-85 percent is given by National Friction Products (stated in the text). However, until other replacements can be found for the remaining 15-20 percent of the market it is assumed that for now the Kevlar(R) and fiberglass combination substitute will replace 100 percent of the asbestos market.

REFERENCES

Deere and Co. R. Grotelueschen. 1986 (October 30). Moline, IL. Transcribed telephone conversation with Richard Hollander, ICF Incorporated, Washington, D.C.

Design News. 1984 (March 26). Asbestos Substitutes in Friction Applications. S. Scott.

DuPont. T. Merriman 1986 (November 5). Wilmington, DE. Transcribed telephone conversation with Richard Hollander, ICF Incorporated, Washington, DC.

H.K. Porter Co. F. Donnell. 1986 (November 20). Huntington, IN. Transcribed telephone conversation with Richard Hollander, ICF Incorporated, Washington, D.C.

Hoover Co. A. McMullen. 1986 (July-December). North Canton, OH. Transcribed telephone conversation with Richard Hollander, ICF Incorporated, Washington, D.C.

ICF Incorporated. 1984. Imports of Asbestos Mixtures and Products. Washington, D.C.: Office of Pesticides and Toxic Substances, U.S. Environmental Protection Agency. EPA Doc. Control No. 20-8600681.

ICF Incorporated. 1985. Appendix H: Asbestos Products and Their Substitutes, In Regulatory Impact Analysis of Controls on Asbestos and Asbestos Products. Washington, D.C.: Office of Pesticides and Toxic Substances, U.S. Environmental Protection Agency.

ICF Incorporated. 1986a (July-December). Survey of Primary Processors of Disc Brake Pads (Heavy Vehicles). Washington, D.C.

ICF Incorporated. 1986b (July-December). Survey of Secondary Processors of Disc Brake Pads (Heavy Vehicles). Washington, D.C.

Krusell N., Cogley D. 1982. GCA Corp. Asbestos Substitute Performance Analysis, Revised Final Report. Washington, D.C.: Office of Pesticides and Toxic Substances, U.S. Environmental Protection Agency. Contract 68-02-3168.

National Friction Products. E. Sydor. 1986 (July-December). Logansport, IN. Transcribed telephone conversation with Richard Hollander, ICF Incorporated, Washington, D.C.

PEI Associates, Inc. 1986. OTS Survey of Asbestos Products Manufacturers. Washington, D.C.: Office of Pesticides and Toxic Substances, U.S. Environmental Protection Agency.

Raymark Corp. G. Houser. 1986a (July-December). Manheim, PA. Transcribed telephone conversation with Richard Hollander, ICF Incorporated, Washington, D.C.

Raymark Corp. 1986b. Comments of Raymark Corp. on Proposed Asbestos Ban Rule. EPA Document Control No. OPS-62036.

TSCA Section 8(a) submission. 1982a. Production Data for Primary Asbestos Processors, 1981. Washington, D.C.: Office of Toxic Substances, U.S. Environmental Protection Agency. EPA Document Control No. 20-8601012.

TSCA Section 8(a) submission. 1982b. Production Data for Secondary Asbestos Processors, 1981. Washington, D.C.: Office of Toxic Substances, U.S. Environmental Protection Agency. EPA Document Control No. 20-8670644.

Wheeling Brake Block. G. Beckett. 1986 (November 20). Bridgeport, CT. Transcribed telephone conversation with Richard Hollander, ICF Incorporated, Washington, D.C.

XXV. ASBESTOS PROTECTIVE CLOTHING

A. Introduction

This chapter describes the uses and applications for asbestos protective clothing, the producers of these garments and the fibers that can substitute for asbestos in the production of alternative protective clothing.

B. Product Description

Asbestos clothing is formed by sewing asbestos cloth with asbestos thread. The asbestos cloth consists of any of the standard ASTM textile grades available (varying between 75 and 100 percent asbestos), that may contain wire, organic, or inorganic reinforcing strands (ATI 1967).

Asbestos cloth is woven from plied, twisted, and metallic yarns. Depending on the type of yarns used, asbestos cloth of five basic types is available. The classes of asbestos cloth are (ATI 1967):

- Class A -- cloth constructed of asbestos yarns containing no reinforcing strands;
- Class B -- cloth constructed of asbestos yarns containing wire reinforcing strands;
- Class C -- cloth constructed of asbestos yarns containing organic reinforcing strands;
- Class D -- cloth constructed of asbestos yarns containing non-metallic, inorganic reinforcing strands; and
- Class E -- cloth constructed of two or more of the yarns used i cloth Classes A through D.

The most widely used asbestos fabrics are woven from Class A and Class B yarns.

The asbestos thread that is used to sew the various grades of asbestos cloth can be either wire-inserted or non-metallic. Depending on the tensile strength and thermal stability requirements, asbestos thread is available in different grades, although the majority is 80-85 percent asbestos. These threads are often coated with an acrylic or wax coating to increase its strength and to facilitate the sewing of asbestos fabrics.

Traditionally, asbestos protective clothing has been used to ensure the health and safety of workers exposed to very high temperatures, molten metal splash, or the presence of fire. The use of asbestos gloves and mittens as well as coats and overalls has been widespread in laboratories, steel mills, and glass blowing and welding shops where these hazards are likely to be encountered (Utex 1986). In addition, there are other areas where fully-covering asbestos suits have been used to protect workers in very hazardous environments. Some examples of these more exotic job descriptions are oil-well firemen, steel furnace workers, race care drivers, military aircraft pilots, and astronauts (Garlock 1986).

C. Producers

The 1982 TSCA Section 8(a) survey of asbestos processors identified one company as a secondary processor (there were no primary processors) of asbestos textiles used as protective clothing. This company, A-Best Products Company, located in Cleveland, Ohio was involved in the manufacture of asbestos-containing safety clothing (TSCA 1982). A-Best Products Company manufactured gloves, mittens, coats, and coveralls by sewing asbestos cloth with asbestos thread (A-Best 1986). They ceased production of asbestos-containing protective clothing at the end of 1984 and since that time have used substitute fibers in the production of protective clothing (ICF 1986a).

Small quantities of asbestos gloves and mittens have been and continue to be imported from foreign countries such as Taiwan, South Korea, and Mexico (Aztec 1986), but no specific data could be identified.

D. Substitutes

The substitute materials that can replace asbestos fiber in protective clothing are: ceramics, fiberglass, carbon, aramid, and polybenzinidazole

(PBI) fibers. These fibers are used alone or in blends depending on the specific requirements of each application. Although fiberglass and ceramic fibers have very high temperature use ranges, the inflexibility of these materials make them unsuitable for protective clothing if abrasion resistance, durability, or flexibility are important characteristics. As higher temperatures are reached and the need for flexibility and integrity of the material increases (e.g., space suits, and fire-fighting equipment) it becomes necessary to blend these fibers with other more expensive, but more resilient fibers. Blends of ceramic or fiberglass with carbon, aramid, and PBI fibers can be formulated that meet or exceed the performance of any existing asbestos product, although the cost may be significantly higher (Utex 1986). In many applications, however, the added cost is insignificant when weighted against other costs. For example, the cost of a space suit, of any type, is insignificant in comparison to the cost of a space vehicle.

E. Summary

There are currently no domestic processors of asbestos-containing protective clothing, although some finished articles (e.g., gloves and mittens) continue to be imported in small quantities. Substitute fiber blends can be used to produce alternate protective clothing that meets or exceeds the quality standards required for asbestos protective clothing. To a large extent this replacement has already occurred in the protective clothing market. The demand for asbestos in this market is, therefore, negligible.

REFERENCES

A-Best Products Company. M. Knauzs. 1986 (October 28). Cleveland, OH, 44111. Transcribed telephone conversation with Mark Wagner, ICF Incorporated, Washington, D.C.

ATI. 1967. Handbook of Asbestos Textiles. American Textiles Institute.

Aztec Industries. W. Outcalt. 1986 (November 4). North Brookfield, MA, 01535. Transcribed telephone conversation with Mark Wagner, ICF Incorporated, Washington, D.C.

Garlock Inc. F. Piccola. 1986 (October 17). Sodus, NY, 14551. Transcribed telephone conversation with Mark Wagner, ICF Incorporated, Washington, D.C.

ICF Incorporated. 1986a (July-December). Survey of primary and secondary processors of asbestos textiles. Washington, D.C.

TSCA Section 8(a) submission. 1982. Production Data for Secondary Processors, 1981. Washington, D.C.: Office of Toxic Substances, U.S. Environmental Protective Agency. EPA Document Control No. 20-8670644.

Utex Industries. E.B. Pippert. 1986 (July-December). Houston, TX, 77279. Transcribed telephone conversation with Mark Wagner, ICF Incorporated, Washington, D.C.

XXVI. ASBESTOS TEXTILES

A. Product Description

Asbestos textiles are produced by standard textile production techniques involving carding, combing, and spinning of the asbestos fibers. Asbestos fibers can be blended with other types of fibers to give the resulting textile products added tensile strength. The manner in which asbestos fibers are processed into asbestos yarn and cloth products is illustrated in Figure 1.

There are two basic processes employed in asbestos textile manufacturing: the conventional and wet processes. Although most textiles are manufactured by the conventional process, each of these methods will be described.

1. Conventional Processing of Asbestos Fibers to Form Textile Products

In the conventional process, raw asbestos fibers of various grades are blended and mixed according to the fiber characteristics, manufacturing and finished product requirements, and intended use. The different grades of asbestos fiber received are placed in the fiber blender where they are mixed according to the requirements specified for the finished product. The selected fibers are then fed into a hopper where they are blended. Finally, the blended material is sent to the carding operation.

In the carding operation, asbestos fibers are combed into a relatively parallel arrangement called a fiber mat. This mat is pressed and layered into a lap consisting of alternating perpendicular arrangements of fiber mats. The lap is then slit into thin, continuous ribbons called roving. Cotton, rayon or other material may be added at this stage to strengthen the roving.

Roving, which has been mechanically twisted and spun to give it greater tensile strength, forms a single yarn. This yarn may be twisted with other single yarns, wire or other material to produce plied yarn that can be coated to produce thread or treated yarns. Plied yarns may be woven to produce

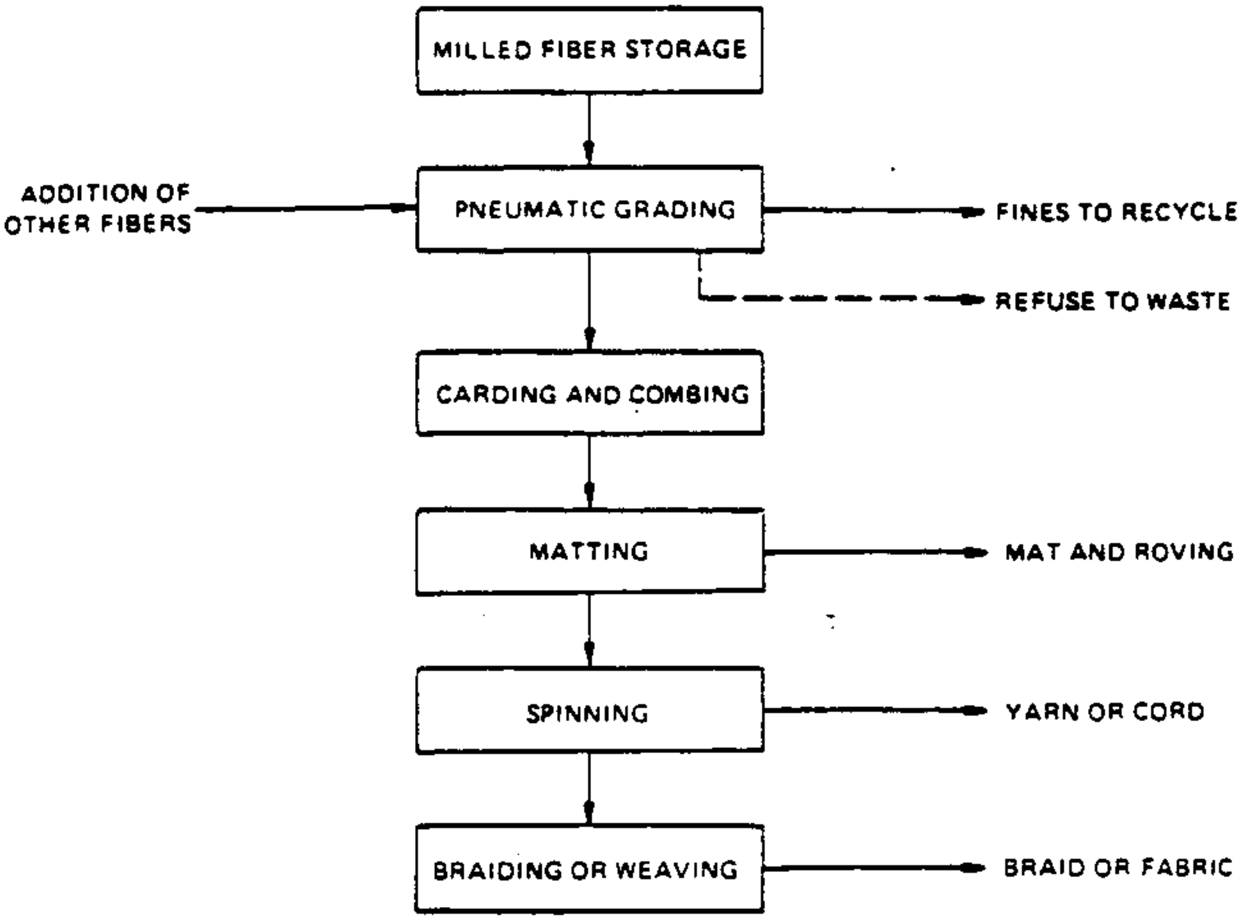

Figure 1. Manufacturing steps for asbestos textiles.

Source: NTIS 1975.

fabric, tubing (sleeving), or tape, as seen in Figure 2. Alternately, plied yarns may be twisted to form wicking and twisted rope, or braided to form braided rope or sleeving.

The conventional process of asbestos yarn manufacture can either be a dry or a damp method. These two methods are identical except that during the damp method the yarn is moistened either by contact with water on a roller or by a mist spray. This moistening of the yarns reduces the amount of fiber that becomes airborne and also aids the processing of fibers into yarn.

2. Wet Processing of Asbestos Fibers to Form Textile Products

The wet process is based on forming single filament fibers by extrusion. The process consists of making a gelatinous mixture of fine asbestos fibers in water with a volatile dispersant. The mass is then extruded through small dies to form asbestos thread. The extruded thread is spun to form yarn which is fabricated into various plied yarn products as in the conventional process.

The textile products formed using this wet technique tend to hold asbestos fibers better than those produced by the conventional processes, thus reducing workplace fiber levels, but the yarn formed has the disadvantage of poor absorption and impregnation characteristics.

3. Asbestos Textile Subcategories

There are eight main subcategories of asbestos textiles that are used in the various applications covered within this section. Each textile subcategory can be grouped into one of the two main categories, asbestos yarn or cloth, as follows:

- asbestos yarn;
  - yarn;
  - thread;
  - wick;
  - cord;
  - braided and twisted rope; and
  - braided tubing (sleeving).

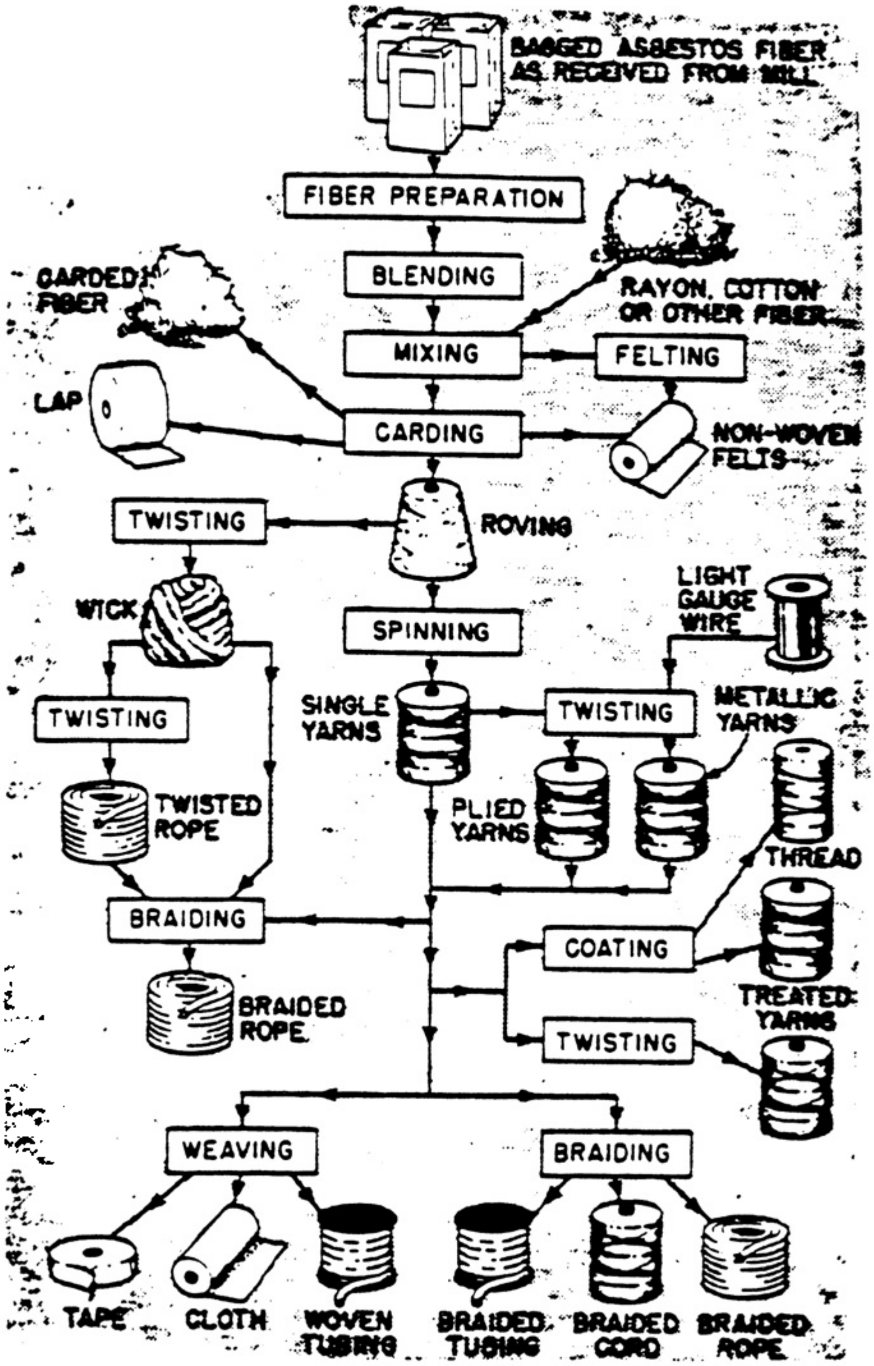

Figure 2. Manufacturing operations for asbestos textiles.

Source: Handbook of Asbestos Textiles. American Textile Institute. 1967.

- asbestos cloth
  - -- cloth;
  - -- slit and woven tape; and
  - -- woven asbestos tubing (sleeving).

The manufacturing process for each of these textile subcategories is briefly described, and some of the typical dimensions of the products are included. In addition, some of the typical fillers, carrier yarns, and inserts that are used in conjunction with asbestos containing materials are described (American Textile Institute 1967).

- Asbestos yarns are commonly reinforced with nylon, cotton, polyester, or wire. The asbestos yarns produced are made in various sizes and plies and serve as the basic components in the fabrication of many other asbestos textiles: twisted, woven, and braided. The amount of asbestos contained in asbestos yarns is the basis for designating asbestos textile grades as listed in Table 1. The American Society for Testing of Materials (ASTM) has designated various grades for asbestos textiles that differ slightly with each textile form.

- Asbestos threads are produced in both metallic (wire-inserted) and plain (non-metallic) classes. Depending on the tensile strength and thermal stability requirements, asbestos thread is furnished in different grades, although most of it is underwriters' grade (80-85 percent asbestos). Asbestos thread is often coated with an acrylic or wax coating to increase its strength and to facilitate the sewing of asbestos fabrics.

- Asbestos wick consists of several strands of asbestos yarn twisted together to form a general utility product with varied industrial applications (e.g., packing, or upon further processing the making of rope and braid).

- Asbestos cord is usually twisted asbestos yarn (a predetermined number of strands) that forms a cord of desired diameter and tensile strength. The yarns used may be sized or unsized, plain or wire-inserted, single or plied, depending on the end use of the product. Asbestos cord is manufactured in all standard ASTM grades and ranges in diameter from 0.06 inches to 0.38 inches.

- Asbestos rope is available in two styles: twisted and braided. Twisted asbestos rope is made by twisting two or more strands of asbestos wick tightly together. Heavier ropes contain a binder to hold the twist. Braided asbestos rope can be manufactured by three different processes: (1) by braiding one or more jackets of asbestos yarn over a

Table 1. Asbestos Textile Grades

Grades[a]	Asbestos Content by Weight
Commercial	75% up to but not including 80%
Underwriters'	80% up to but not including 85%
Grade A	85% up to but not including 90%
Grade AA	90% up to but not including 95%
Grade AAA	95% up to but not including 99%
Grade AAAA	99% up to and including 100%

[a]Asbestos textile grades differ with each asbestos textile form.

Source: Handbook of Asbestos Textiles. American Textile Institute. 1967.

core of asbestos rope or wick; (2) by braiding asbestos yarn braid over asbestos braid; and (3) by plaiting asbestos yarn into a square cross section (square braid). Asbestos rope is available in all ASTM grades and varies in diameter from 0.25 to 2.0 inches.

- Asbestos tubing (sleeving) can be made from asbestos yarns by braiding. Braided tubings are manufactured in all of the ASTM grades and range from 0.02 inches to several inches inner diameter (i.d.). The wall thickness varies from 0.03 inches to approximately 0.13 inches.

- Asbestos cloth is woven from various plied, twisted, and metallic yarns. There are five classes of asbestos yarns that can be used to produce asbestos cloth. The different classes of asbestos cloth are:

  -- Class A -- Cloth constructed of asbestos yarns containing no reinforcing strands.

  -- Class B -- Cloth constructed of asbestos yarns containing wire reinforcing strands.

  -- Class C -- Cloth constructed of asbestos yarns containing organic reinforcing strands.

  -- Class D -- Cloth constructed of asbestos yarns containing non-metallic inorganic reinforcing strands.

  -- Class E -- Cloth constructed of two or more of the yarns used in cloth classes A through D.

  The most widely used asbestos fabrics are woven from Class A (non-metallic) and Class B (wire-inserted) yarns.

- Asbestos tape is manufactured mostly as plain or non-metallic tape in all of the standard ASTM grades. It is a narrow woven fabric manufactured from plied yarn containing selvage edges (finished to prevent raveling). Additionally, tape may be slit from cloth (slit tape). Depending upon the application, the type of tape and the associated manufacturing process varies. For tapes requiring heat reflectivity, aluminum layers may be sprayed on or bonded to the cloth by a thermosetting resin. The thicknesses of plain tape range from 0.01 inches to 0.03 inches. Metallic tapes can be 0.06 inches and thicker. Standard widths of asbestos tape range from 0.5 inches to 6.0 inches.

- Asbestos tubing (sleeving) can also be made in a woven form. Asbestos yarns can be woven to form a tubing that has a significantly greater inner diameter than the braided tubings. Woven tubings are manufactured in all of the ASTM grades in diameters of less than one inch up to 24 inches.

Two additional asbestos textile subcategories are non-woven products that have been used for electrical insulation purposes, but do not fall into the two designated textile categories. Although these products were not produced by any companies identified during the analysis, brief descriptions are included:

- Asbestos roving is simply non-twisted strands of asbestos fibers that have been carded. Roving can be twisted to form wick or spun to form yarn. Asbestos roving is blended with cotton or other organic fibers to meet specific end-user requirements. It is supplied in the five standard ASTM grades. Asbestos roving has been used as electrical insulation, but no current applications could be found.

- Asbestos lap consists of parallel arrangements of asbestos fibers that have been combed and blended with organic fibers. Asbestos lap is a non-woven fabric and has been used in electrical insulation. No current uses of asbestos lap have been identified.

4. Current Application Areas for Asbestos Textiles

Historically, asbestos textiles have been used in a wide range of products, but many of the traditional products are no longer in production. Substitute fibers have taken up the bulk of the market for electrical and thermal insulation, fire resistant materials, and protective clothing.

The products that continue to be made in significant quantities using asbestos textiles are:[1]

- Woven friction materials;
- Packings and gaskets; and
- Specialty products.

Woven friction materials account for the majority of the asbestos textile products made from asbestos yarn and include woven brake blocks and clutch

[1] It should be noted that products made from asbestos textiles are different than similar products made from non-woven asbestos fibers. Woven friction materials and packings/gaskets made from asbestos textiles are not included in the non-woven asbestos product categories, but rather are included in the asbestos textiles category. A careful review of the processors data has been performed in order to ensure that no duplication of information has occurred.

facings. Typically, these woven products have better performance characteristics than molded products and are used in large industrial equipment such as oil well drilling rigs and cranes.

The two largest processors of asbestos textile materials are Standco Industries and Raymark Corporation. These companies are producers of woven friction materials and account for almost 90 percent of the asbestos textile market, although the trend in woven friction materials is away from asbestos containing materials in original equipment markets (OEM). In 1985, 50 percent of all OEM vehicular friction materials were expected to be asbestos free (Scott 1984).

Packings and gaskets made from asbestos textiles[2] include both yarn and cloth products. Asbestos yarn products, braid and rope, are used extensively in pump and valve packings and as seals for oven doors, boilers, and furnaces. Asbestos cloth is used to manufacture manhole and flange gaskets as well as seals in incinerator (hot-air) piping, nuclear power plant cooling water towers, and distillation columns.

Although some gasket and packing products continue to be made from asbestos textile materials, the general trend is to move away from asbestos containing products (Garlock 1986, Darco Southern 1986). Most gasket and packing manufacturers have stated that they will be completely out of the asbestos market by 1990 because of the availability of good substitutes.

Finally, specialty products continue to be made from asbestos textile materials, both asbestos cloth and asbestos yarn. It is often difficult to find substitute materials for these specialized applications, but products of this type are usually produced in relatively small volumes (less than 5,000

[2] The majority of companies involved in the production of asbestos textiles are gasket and packing manufacturers, although they do not account for a very large proportion of the asbestos textile market (11 percent).

pounds). Some products made from asbestos textiles that fall into this category are:

- Mantles for gas lanterns (yarn);
- Wicks for catalytic heaters (yarn);
- Rotor vanes and impellar blades for pumps and compressors used in air tools (cloth);
- Ring type seals for valve and compressor plates (yarn); and
- Bearings for high temperature applications requiring water lubrication (cloth).

It is more difficult to find substitute materials for some applications of asbestos textiles that may require several of the favorable characteristics that asbestos can impart to textile products. For these types of applications, substitute materials may necessitate the use of a mixture of substitute fibers to impart all of the required characteristics to the substitute material. Companies that produce specialty products from asbestos are actively looking for substitute materials if none exist at present.

B. <u>Producers and Importers of Asbestos Textiles</u>

Asbestos textiles account for less than one percent of the total amount of asbestos fibers consumed for end-use products in the United States. In 1985, domestic consumption of asbestos fiber in the form of asbestos textiles was estimated to be approximately 919 tons (ICF 1986a). The majority of this fiber was Grade 3 chrysotile fiber. This figure is 16 percent of the 5,800 tons of fiber consumed in 1981 (ICF 1984a) in this category.

The quantity of asbestos fiber contained in asbestos textile products varies significantly, but an average figure of between 70 and 80 percent is a reasonable estimate of the asbestos content (Garlock 1986) for most asbestos textiles. The total amount of asbestos-containing textiles targeted for consumption in the U.S. is, therefore, estimated to be 1,690 tons of end-use textile products for 1985 (ICF 1986a).

Asbestos textile products consumed in the United States come from two sources: domestic processing of asbestos fibers into yarn and cloth and imports of yarn and cloth. Table 2 compares the imports of asbestos textiles and the domestic output of asbestos textile products for 1981 and 1985. Consumption and output have decreased by over 70 percent for both textile segments over the time period 1981 to 1985 (ICF 1986a).

The two processors involved in the manufacture of asbestos textiles for woven friction materials have stated that their products contain about 50 percent asbestos by weight. The amount of fiber consumed by these companies is estimated to be less than 800 tons.

As other asbestos yarn products are approximately 70 percent asbestos,[3] the remaining products can be estimated to contain less than 100 tons of asbestos fiber. An estimate of less than 900 tons of asbestos fiber consumed in the production of asbestos yarn products for companies that reported using asbestos in 1985 can therefore be made. Although no data for the asbestos content of specific asbestos cloth products were available, an estimate of 80 percent (Garlock 1986) asbestos content has been used to calculate the asbestos fiber consumption for asbestos cloth textiles. It is estimated that the companies that produced asbestos cloth products in 1985 consumed less than 200 tons of fiber. The total amount of fiber consumed in the production of all asbestos textiles in 1985 is therefore less than 1300 tons for 1985.[4]

The discrepancy between the asbestos fiber consumption estimated in Table 2 and the figure presented by the Bureau of Mines (1,344 tons) (Virta 1986) can partially be explained by incomplete reporting or identification of

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[3] The amount of fiber consumed in the production of asbestos textiles other than woven friction materials can only be estimated because the secondary processors were not willing to release or did not know the asbestos concentration figures for their products.

[4] Includes estimated fiber consumption of imported products.

Table 2. Asbestos Fiber Consumption for Textile Products and Output of Textile Products for 1981 and 1985

	Domestic Fiber Consumption[c] (tons)	Total Fiber Consumption[d] (tons)	Domestic Production of Textile Products (tons)	Imports of Textile Products (tons)
<u>Asbestos Yarn</u>				
1981[a]	3,920	5,040	5,600	1,600
1985[b]	558	823	1,125	455
<u>Asbestos Cloth</u>				
1981[a]	440	760	550	400
1985[b]	0	96	0	120
<u>Total</u>				
1981[a]	4,360	5,800	6,150	2,000
1985[b]	558	919	1,125	575

NOTE: The table identifies production only for those companies for which data have been collected during the survey. Some companies, especially those that import small quantities from small countries, may not have been identified.

[a]TSCA 1982.

[b]ICF 1986a.

[c]This calculation is based on confidential business information.

[d]Estimated total fiber consumption figures for 1981 are calculated using average asbestos concentration figures: Asbestos yarn is approximately 70 percent asbestos and asbestos cloth is approximately 80 percent asbestos.

companies processing asbestos textiles. The asbestos textile imports that have been accounted for totalled about 600 tons in 1985. The U.S. Imports for Consumption Schedule FT 246, published by the U.S. Department of Commerce (DOC 1985), however, indicates that approximately 1,100 tons of asbestos yarn, slivers, etc. (TSUSA 518.2100) were imported from 17 countries.[5]

Most of the secondary processors of asbestos yarn and cloth receive their materials from foreign companies and process the imported textile mixtures into end-use products. Several companies, however, receive textile mixtures from domestic sources. At least one company, Amatex Corporation, imports asbestos textile mixtures from plants in Mexico. Amatex does not do any secondary processing of these mixtures, but distributes them to other companies that are secondary processors (Amatex 1986).

There are other companies that have similar import/distribution practices (A.W. Chesterton 1986), and this may help to account for the discrepancy between imports identified in the survey and those reported by the Department of Commerce. Some companies are neither primary nor secondary processors, but rather importers and distributors. Data on these companies were not available for the initial 1982 EPA survey (ICF 1984b).

Some of the companies identified in the survey are involved in the processing of both asbestos cloth and yarn into end-products. In addition, the materials used by these companies are sometimes from several sources. Of the companies that have been identified, five are secondary processors of both

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[5] The TSUSA commodity code for yarn and related materials probably includes some products that are not considered textiles or are already finished products not requiring any processing, but the higher figure tends to indicate that information is missing regarding textile products imported from some countries. None of the companies that were contacted during the course of the survey indicated that any asbestos textiles were imported from any countries other than Canada, Mexico, and South Korea (Aztec 1986). Although these three countries account for the bulk of U.S. asbestos imports, other countries are exporting asbestos textiles to the U.S.

asbestos cloth and asbestos yarn. Tables 3 and 4 present quantities of yarn and cloth consumed and imported in secondary processing.

C. Trends

Thirteen companies involved in the production and distribution of asbestos textiles in 1985 have been identified. These 13 companies can be grouped into four categories based on their particular involvement in the asbestos textile market. The categories and the companies that fall under them are listed in Table 5.

In 1981, there were 21 processors of asbestos textiles (four primary, 17 secondary) as identified in the 1982 TSCA Section 8(a) survey. By 1985 the number of processors had dropped to six (one primary and five secondary). The change in processors identified in the survey is a 75 percent drop for primary processors[6] (from four in 1981 to one in 1985) and a 71 percent drop for secondary processors (from 17 in 1981 to five in 1985) (ICF 1986a, TSCA 1982).

In addition to processors identified in the survey, seven out of 16 companies (a 56 percent drop) identified as importers in 1982 (ICF 1984a) continued to import in 1985 (ICF 1986a).

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[6] The only domestic primary processor of asbestos textiles, Raymark Corporation, produces asbestos yarn from asbestos fiber at its plant in Marshville, North Carolina. Subsequently, the yarn is shipped to other Raymark plants where secondary processing to form woven brake blocks and clutch facings is performed (Raymark 1986). This production sequence is slightly different than that used by most manufacturers of woven friction materials. Most processors of these types of friction materials do primary and secondary processing at the same facility, and output is classified as woven friction materials. Raymark does not follow this pattern (the primary and secondary processing facilities are at different locations), so the output of the Marshville facility is classified as asbestos yarn. The yarn is then shipped to other Raymark facilities for secondary processing where it is fabricated into woven friction materials.

Table 3. Quantity of Asbestos Yarn Consumed by Secondary Processors

	Quantity of Domestic Asbestos Mixture Consumed[a] (short tons)	Quantity of Imported Asbestos Mixture Consumed (short tons)
Total	13.4	431.8

[a]The sources of domestic asbestos yarn are companies that import the mixture, but do not perform secondary processing. Only one company of this type could be identified importing 25 short tons of asbestos yarn for distribution to other companies that subsequently do the secondary processing.

Source: ICF 1986a.

Table 4. Quantity of Asbestos Cloth Consumed by Secondary Processors

	Quantity of Domestic Asbestos Mixture Consumed[a] (short tons)	Quantity of Imported Asbestos Mixture Consumed (short tons)
Total	9.4	94.8

[a]The sources of domestic asbestos cloth are companies that import the mixture, but do not perform secondary processing. Only one company of this type could be identified importing 25 short tons of asbestos cloth for distribution to other companies that subsequently do the secondary processing.

Source: ICF 1986a.

Table 5. Companies Involved in Asbestos Production and Distribution in 1985

Category	Company Name and Address	Asbestos Textile Product/Intended Use
Primary Processor of Asbestos Textiles from Asbestos Fibers	Raymark Corporation Marshville, NC	Asbestos yarn/woven brake blocks and clutch facings
Importer of Asbestos Textiles for Distribution Only	Amatex Corporation Norristown, PA	Asbestos yarn and cloth/ distribution to domestic secondary processors
Secondary Processor of Asbestos Textiles Received Directly from Foreign Sources	A.W. Chesterton Woburn, MA	Asbestos yarn and cloth/ packings and gaskets
	Arcy Manufacturing New York, NY	Asbestos cloth/welding blankets
	Aztec Industries N. Brookfield, MA	Asbestos cloth/gaskets
	The Coleman Company Wichita, KS	Asbestos yarn/mantles for gas lanterns
	Darco Southern Independence, VA	Asbestos cloth/gaskets
	Gatke Corporation Warsaw, IN	Asbestos cloth/high-temperature bearings
	Martin Merkel Houston, TX	Asbestos yarn/packings
	Standco Industries Houston, TX	Asbestos yarn/woven brake blocks and clutch facings
	Utex Industries Weimar, TX	Asbestos yarn/packings

Table 5 (Continued)

Category	Company Name and Address	Asbestos Textile Product/Intended Use
Secondary Processor of of Asbestos Textiles Received from Domestic Distributors	A.W. Chesterton Woburn, MA	Asbestos yarn/packings
	General Gasket Corp. St. Louis, MO	Asbestos yarn and cloth/ gaskets
	Rhopac, Inc. Skokie, IL	Asbestos yarn and cloth/ packings and gaskets
	Standco Industries Houston, TX	Asbestos cloth/gaskets
	Utex Industries, Inc. Weimar, TX	Asbestos cloth/packings

Source: ICF 1986a.

D. Substitutes

Asbestos has been used in textile products because it imparts desirable characteristics to the materials that are made from it. Asbestos based textile products have the following characteristics that make them ideally suited for use in high temperature and corrosive environments:

- Fire/acid resistance;
- Non-flammability;
- Low thermal conductivity; and
- Molten metal resistance.

Asbestos is also easily fabricated and exhibits great tensile strength and abrasion resistance. It is a flexible material in its fabricated form and is used for sealing applications especially when good compressibility and recovery are required.

Due to health concerns regarding asbestos inhalation, there has been a major effort to develop substitute materials that exhibit some of the characteristics of asbestos textiles. The major fibers used in the formulation of substitute textile products are:

- Fiber glass;
- Ceramics;
- Carbon/graphite;
- Aramids; and
- Polybenzimidazole (PBI).

In addition, some other fibers have been used to produce small amounts of textile materials that can be substituted for asbestos in some applications. Cotton and wool blends have been used in textile products as substitutes for asbestos, but in general they are not very resistant to heat. Quartz and other mineral fibers have also been used in small volumes. The five major substitute fibers mentioned above, however, account for the majority of the substitute materials that can replace asbestos.

Substitute textile products have already replaced asbestos to a certain extent and can be expected to replace most of the remaining segments of the market. An approximate breakdown of asbestos substitute markets and the percentage of the asbestos market that each has been able to assimilate is listed in Table 6.

1. Fiberglass Textiles

Fiberglass is used preferentially when looking for substitute products due to its good workability, durability, and cost (50-70 percent less than similar asbestos based textiles) (Darco Southern 1986). Other substitute materials tend to be more expensive than asbestos and typically are not used to the same extent as fiberglass (Utex 1986).

Fiberglass textile products have been widely used as substitutes for asbestos, but they do have several major shortcomings. For replacement products requiring abrasion or flux resistance, fiberglass alone is not an adequate substitute. Manufacturers have dealt with this problem by blending glass with other materials. For example, glass can be blended with aramids to produce textile materials that can withstand fairly high temperatures (500°F) and show good abrasion resistance (Chemical Business 1984).

Fiberglass fibers can be treated by chemical leaching with sulfuric acid to form a continuous-filament, amorphous silica product with the thermal performance of a refractory material. After treatment with acid, the resulting filament is almost pure silica (SiO_2) and can be woven to form textile materials with excellent thermal resistance. The temperature limit for ordinary fiberglass materials is around 1000°F, at which point they lose tensile strength and begin to melt. The amorphous silica products, however, retain their strength and flexibility to temperatures of 1800°F and will continue to provide thermal protection up to 3100°F, although some degree of shrinkage and embrittlement does occur as temperatures approach the upper limit (Armco 1979).

Table 6. Existing Market Shares for Asbestos Substitute Fibers

Substitute Fiber	Percentage of Asbestos Market
Glass	50%
Ceramic .	15%
Aramid	15%
PBI	10%
Carbon	10%

Note: As more substitute products are becoming available, the market share for glass is beginning to dwindle.

Source: Garlock 1986.

Amorphous silica textiles have seen widespread use as thermal and electrical barriers and have replaced asbestos products to a great extent in these applications. The cost of high-temperature refractory silica textiles is not much greater than fiberglass textiles (Armco 1979) and only slightly greater than asbestos textiles used in similar applications. As the performance with regard to temperature limit is better than asbestos for the refractory glass products in nonabrasive applications (Amatex 1986a), substitution has taken place to a large degree.

In high temperature applications where compression and abrasion are likely to be encountered, other materials or blends of glass, silica, and other fibers are used. If only slight abrasion resistance is required, the refractory silicas do quite well. Rope gasketing for partial grooves in oven or furnace doors and sealing elements in all types of manufacturing equipment that handle heat (e.g., ovens, furnaces, boilers) can be made from refractory silicas.

Refractory silica textiles are not ideally suited for applications requiring a great deal of abrasion resistance, but their abrasion resistance capability can be augmented by specially treating the material with a hydrocarbon finish (Armco 1979). In general, however, refractory silica textiles are not used in areas where abrasive conditions would be encountered.

2. <u>Ceramic Fiber Textiles</u>

Ceramic fiber, consisting of high purity alumina and silica in various percentages, can be used to produce ceramic textile products. These ceramic textiles are similar to amorphous and textured silica products in that they exhibit refractory characteristics and can be used in high-temperature applications (up to 2300°F).

Fiberfrax yarn, a representative type of ceramic fiber yarn, contains approximately 20 percent organic fiber and is spun around corrosion resistant alloys of nickel and chromium (temperature limit 2000°F) or 1200°F monofilament glass strands. These inserts provide maximum tensile strength at elevated temperatures (Carborundum 1986).

Although ceramic fiber yarns have a high temperature limit in continuous use, the textiles made from them lose tensile strength after exposure to heat for extended periods of time. The temperature limit of the insert material must be considered in determining whether a ceramic fiber textile product can be used in applications where tensile strength is important.

In the application areas where substitution is incomplete, ceramic fiber textiles are viable substitutes for some applications currently using asbestos: furnace and oven door seals, flange and burner gaskets, and static packings. Ceramic fiber textile products have a higher temperature limit, are more flexible, conform to the shape required, and often have a longer service life than comparable asbestos based products. In general the costs of ceramic fiber products are comparable to asbestos products.

There are some drawbacks associated with the use of ceramic fiber for asbestos replacement cloth and yarn products. The ceramic cloth used in expansion joints, a gasket application, exhibits slightly more permeability at low temperatures and may be slightly more expensive (10-15 percent) in some product application areas (Carborundum 1986).

Ceramic rope products made from yarn are less dense than comparable asbestos products, are not as packable (too resilient), and therefore do not exhibit the required characteristics for some gasket applications. Ceramic fiber rope also exhibits poorer performance in some oven furnace door applications. Due to the low density and lower abrasion resistance of the ceramic products, they do not meet the standards of the traditional asbestos based products (Carborundum 1980).

Finally, static packings made from ceramic rope usually perform very well as asbestos replacement products, but there are not as many forms available, so complete substitution for all asbestos packings is not possible.

3. Aramid Fiber Textiles

Other substitute fibers that can replace asbestos in some textile applications are aramid fibers. By spinning a polymeric solution of aramids, a fiber can be produced that is a good replacement for asbestos. Aramid fiber is stronger on a by-weight basis than asbestos and can be used in pump packings, brake linings, and gaskets (DuPont 1980).

Aramids can also be blended with other fibers to produce asbestos replacement textiles that exhibit the favorable characteristics of each fiber type incorporated into the textile material. Amatex Corporation produces a heat-resistant textile that is made from Nomex and Kevlar fibers mixed with small amounts of polybenzimidazole (PBI) and glass fibers to raise the temperature limit of the material (Amatex 1986). The material, NOR-FAB , shows excellent abrasion- and heat-resisting characteristics, is lightweight, and is not susceptible to most acid and alkali solutions. By blending the aramid fibers with other synthetics and glass fibers, the favorable characteristics of aramids can be incorporated into products with higher temperature limits. In the case of NOR-FAB , excellent protection up to 650°F is possible with intermittent protection at much higher temperatures.

4. Carbon Fiber Textiles

Carbon fibers, another asbestos replacement fiber, are characterized by extremely high strength and high temperature resistance. Carbon fibers are made by controlled carbonization of an already formed fibrous structure based on an appropriate organic polymer. The organic polymers most commonly used in the production of carbon fibers are homopolymers of acrylonitrile and viscose rayon multifilament yarns.

The polyacrylonitrile (PAN) based fibers consist of 92-95 percent carbon (the rest being mostly nitrogen), and the higher strength rayon based fibers can be up to 99 percent carbon (Kirk-Othmer 1977). In general, the carbon fiber yarns and cloths are used in applications requiring strength and light weight (e.g., aerospace and industrial applications). Carbon fiber textiles often include other fibers, such as glass, along with a matrix resin (e.g., polyesters, epoxies, or polyimides).

Although there is some ambiguity regarding the term carbon fiber, it should be noted that this term does not include graphite fibers which are materials exhibiting the three-dimensional characteristic of polycrystalline graphite. Essentially all commercial carbon based textiles are made from carbon fibers (Kirk-Othmer 1977).

Carbon fibers have been used as an asbestos replacement in the production of friction materials. Even though the performance is superior to the asbestos goods that they replace, carbon fiber tends to be very expensive and availability can be a factor. In this and other substitution areas, the tradeoff between additional cost and improved performance must be evaluated. Some applications that require a specific level of performance may, therefore, use a more expensive fiber regardless of expense. In other application areas (e.g., aerospace), the cost of the fiber may be insignificant compared to the cost of the finished product in which the textile material is being used.

5. <u>Polybenzimidazole Fiber Textiles</u>

Polybenzimidazole (PBI) fibers can also be used to form asbestos replacement textiles. Based on the reaction of 3,3'-diaminobenzidine and diphenyl isophthalate, these aromatic polymers are prepared by conventional condensation techniques. The resulting polyimides can be fabricated into heat- and flame-resistant fibers that exhibit a unique property for synthetic polymers. Most synthetic polymers do not reabsorb moisture after being exposed to high temperatures. PBI, however, does regain moisture (up to 13 percent) and is therefore not as subject to degradation in some applications.

PBI fibers can be spun into yarns and then woven to form fabrics that are heat resistant up to 932°F. In addition, fabrics made from PBI fibers show good acid resistance, good cryogenic characteristics, and are readily processed on conventional textile equipment (Kirk-Othmer 1977).

Although PBI fibers exhibit excellent characteristics for very specialized applications (e.g., aerospace and other industries requiring high performance products), they tend to be very expensive. Most industries cannot afford to use PBI containing textiles in their asbestos replacement application areas because of the high cost and must either settle for other available substitute fibers or blend PBI fibers with other fibers to reduce the costs.

6. Asbestos Replacement

Typically, less expensive fibers such as fiberglass or ceramic are used to make up the bulk of any asbestos replacement textile, and the more expensive aramid, carbon, and PBI fibers are added to impart favorable properties on an application-by-application basis. For applications in which readily available substitute fiber textiles are available (i.e., commercially available single fiber products and relatively simple blends), the amount of fiber in the substitute product can be determined. In these application areas, however, substitution is considered to be complete.

The simple textile types (non-blended) are not considered to be replacements for the remaining asbestos textile applications as they do not meet the performance requirements for critical uses. For high performance application areas the amount of each fiber that is used in an asbestos replacement textile is determined by experimental procedure. By varying the concentrations of the available substitute fibers, a substitute textile product can be formulated that exhibits all of the required characteristics for a particular application.

The experimental nature of asbestos replacement procedures makes it difficult to speculate on the exact types of fibers that would be used in any given application area. Substitute products can be found for all asbestos textiles even though the exact nature of substitution is complicated. For example, the amount of fiber of a particular type and the weight of the finished product would be different than for a similar product made with asbestos.[7] In addition, actual formulations are often considered confidential and it is difficult to find data on product make-up.

As the level of detail needed to characterize specific replacement textile products is not readily available, some simplifying assumptions must be made for the asbestos textiles market. These assumptions are:

- All asbestos yarn and cloth products will be grouped into one product area (textiles);
- The blends of fibers in replacement textiles will be assumed to equal the market share for existing, asbestos replacement textiles that are made exclusively with one fiber (see Table 6);
- Service life will be assumed to be equal for all asbestos and replacement textiles (actual service life can vary for specific applications from one to 20 times that of asbestos, depending on the application);[8]

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[7] As opposed to other products that use asbestos as an additive, asbestos textiles are comprised of up to 100 percent asbestos. Thus, formulations made with substitute fibers may vary significantly in weight from asbestos products. The relative density of the fiber compared to asbestos and the relative amount used as compared to asbestos determine the weight of the finished product made with substitute fibers.

[8] The actual service life is very dependent on the environment in which the asbestos-containing product and its substitute product would be contained. Depending on various conditions encountered in a particular use scenario (e.g., abrasiveness, high temperature) the possible substitute products would have greatly varying useful lives. Without performing an involved technical assessment of use conditions it is not possible to accurately predict the differences in the actual service life for the various substitute fiber-containing products relative to their asbestos counterparts.

- Unusual and unrepresentative products (e.g., aerospace replacement products that are 1,000 times as expensive as the asbestos product) will be excluded from the cost analysis.[9]

Attachment A contains a discussion of the calculations used in this analysis. The inputs for the Asbestos Regulatory Model for textile products are also presented.

E. Summary

Asbestos textiles can be grouped into two categories: asbestos cloth and asbestos yarn. A third category, asbestos protective clothing, has been eliminated because no producers could be identified.

Production and imports of these materials dwindled significantly between 1981 and 1985, and substitute products have taken over a large portion of the market. All segments of the asbestos textile industry for 1985 were down 70 percent or more compared to 1981 figures.

Substitution is complete for most product areas, but products are still made from asbestos in the following areas: woven friction materials, packings and gaskets, and specialty products. The major fibers that are used as substitutes are glass, ceramic, aramid, polybenzimidazole, and carbon fibers.

Analysis of the asbestos textile market and identification of substitute materials makes it possible to estimate the cost of substitute materials for remaining asbestos markets. The cost range for substitute products varies significantly depending on the application. Limited information makes it difficult to exactly constrain the costs, but average costs based on cost ranges established during the course of this analysis are presented in Table 7 (see Attachment A).

[9] These products tend to be produced in very small volumes and data are generally not available concerning their cost and performance relative to asbestos products.

ATTACHMENT A

The relevant information used to calculate the costs of substitute textile materials relative to representative asbestos products is contained in this attachment.

As has been mentioned, for the application areas where substitution has taken place, the substitute textiles tend to use relatively simple blends of fibers. The remaining product areas are very diverse and replacement products differ significantly. If, however, essentially pure fiber products were made to replace the remaining asbestos textile markets, their costs would be in the ranges identified in Table 7.

Cost ranges are given because there are application-specific factors determining the actual cost of a substitute fiber textile. As the specifications of a particular application may include requirements regarding the quality as well as the quantity of substitute fiber that is used in the final product, the actual end-product costs will vary from application to application.

The cost of replacement for remaining asbestos products will be assumed to be the same for asbestos yarn and cloth products. An average textile product will, therefore, be the basis for determining the costs of substitution.

The average cost of an asbestos textile mixture that was being produced in 1985 was calculated to be $1.65/lb. (ICF 1986a). The equivalent prices for substitute products are given in Table 8.

Table 7. Costs of Substitute Fiber Textiles

Substitute Fiber	Cost Range of Fiber Relative to Asbestos for All Applications	Normalized[a] Weight of Fiber Used Relative to Asbestos	Cost Range of Finished Product Relative to Asbestos	Average Cost Relative to Asbestos
Glass	1-2	0.7	0.7-1.4	1.05
Ceramic	1-5	0.8	0.8-4.0	2.40
Aramid	6-9	0.8	4.8-7.2	6.00
Carbon	4-12	2.0	8.0-24.0	16.00
PBI	10-30	1.2	12.0-36.0	24.00

[a]Normalized with respect to amount used and weight of finished product.

Sources: Chemical Business 1984, Carborundum 1980, Industrial Minerals 1984, Spaulding 1986, Amatex 1986.

Table 8. Data Inputs for Asbestos Regulatory Cost Model for Textiles

Product	Output (tons)	Product Asbestos Coefficient (tons/ton)[a]	Consumption Production Ratio	Price ($/ton)	Useful Life	Equivalent Price ($/ton)	Market Share	Reference
Asbestos Mixtures	1,125	0.4960	1.511	3,300	1 year	3,300	N/A	ICF 1986a
Glass Fiber Mixtures	N/A	N/A	N/A	3,460	1 year	3,460	50%	Carborundum 1986
Ceramic Fiber Mixtures	N/A	N/A	N/A	7,920	1 year	7,920	15%	Chemical Business 1984
Aramid Fiber Mixtures	N/A	N/A	N/A	19,800	1 year	19,800	15%	Scott 1984
Carbon Fiber Mixtures	N/A	N/A	N/A	52,800	1 year	52,800	10%	Spaulding 1986
PBI Fiber Mixtures	N/A	N/A	N/A	79,200	1 year	79,200	10%	Garlock 1986

[a]Tons of fiber per ton of textile output.

N/A: Not Applicable.

REFERENCES

Amatex Inc. W. Maaskant. 1986 (November 23). Norristown, PA. Transcribed telephone conversation with Mark Wagner, ICF Incorporated, Washington, D.C.

Amatex Inc. 1986a. Product literature on Thermoglass(R) heat-resistant textiles.

Armco Inc. 1979. Product literature on Refrasil(R) heat-resistant textiles.

ASTM. 1982. Annual Book of ASTM Standards: Part 32. Textiles -- Yarns, Fabrics, and General Test Methods. American Society for Testing and Materials. Philadelphia, PA.

American Textile Institute. 1967. Handbook of Asbestos Textiles. American Textiles Institute.

A.W. Chesterton. H. Torrey. 1986 (December 5). Woburn, MA, 01801. Transcribed telephone conversation with Mark Wagner, ICF Incorporated, Washington, D.C.

Aztec Industries. W. Outcalt. 1986 (November 4). North Brookfield, MA, 01535. Transcribed telephone conversation with Mark Wagner, ICF Incorporated, Washington, D.C.

Carborundum. 1980. Product literature on Fiberfrax(R) heat-resistant textiles.

Chemical Business. 1984. Improved fibers put heat on asbestos, in Chemical Business (April 1984). pp. 40-42.

Darco Southern. B. McAllister. 1986 (October 15). Independance, VA, 24348. Transcribed telephone conversation with Mark Wagner, ICF Incorporated, Washington, D.C.

DOC. 1985. Schedule FT 246. U.S. Imports for Consumption. Department of COmmerce.

DuPont. 1980. Product literature on Kevlar(R) heat-resistant textiles.

Garlock Inc. F. Piccola. 1986 (October 17). Sodus, NY, 14551. Transcribed telephone conversation with Mark Wagner, ICF Incorporated, Washington, D.C.

ICF Incorporated. 1984a. Importers of asbestos mixtures and products. Washington, D.C.: Office of Pesticides and Toxic Substances, U.S. Environmental Protection Agency. EPA CBI Document Control No. 20-8600681.

ICF Incorporated. 1984b. Appendix H: Asbestos Products and Their Substitutes, In Regulatory Impact Analysis of Controls on Asbestos and Asbestos Products. Washington, DC: Office of Pesticides and Toxic Substances, U.S. Environmental Protection Agency.

ICF Incorporated. 1986a (July-December). Survey of primary and secondary processors of asbestos textiles. Washington, D.C.

Industrial Minerals. 1984. Asbestos Replacement in Industrial Minerals (June, 1984). pp. 53-55.

Kirk-Othmer. 1981. Encyclopedia of Chemical Technology. Volumes 4, 7, and 12. John Wiley and Sons. New York, NY.

NTIS. 1975. Economic Analysis of Effluent Guidelines: The Textile, Frictioned Sealing Materials Segment of the Asbestos Manufacturing Industry. U.S. National Technical Information Service. PB-250-682.

Raymark Corp. L. Williams. 1986 (July-December). Marshville, NC, 28013. Transcribed telephone conversation with Mark Wagner and Peter Tzanetos, ICF Incorporated, Washington, D.C.

Scott, S.W. 1984. Asbestos Substitutes in Friction Applications. Design News (3/26/84). pp. 44-50.

Spaulding Co., Inc. J. Mileham. 1986 (October 28). Buffalo, NY, 14225. Transcribed telephone conversation with Mark Wagner, ICF Incorporated, Washington, D.C.

TSCA Section 8(a) submission. 1982. Production Data for Secondary Processors, 1981. Washington, D.C.: Office of Toxic Substances, U.S. Environmental Protection Agency. EPA Document Control No. 20-8670644.

Utex Industries. E. Pippert. 1986 (July-December). Houston, TX, 77279. Transcribed telephone conversation with Mark Wagner, ICF Incorporated, Washington, D.C.

Virta, R. 1986 (October 9). Bureau of Mines. Washington, D.C., 20006. Transcribed telephone conversation with Mark Wagner, ICF Incorporated, Washington, D.C.

XXVII. SHEET GASKETS

A. Product Description

Gaskets are materials used to seal one compartment of a device from another in static applications. Asbestos gaskets, used to seal and prevent the leakage of fluids between solid non-moving surfaces, can be classified into two categories: compressed sheet and beater-add. Beater-add gaskets are discussed under the Beater-Add Gaskets category.

Compressed sheet gaskets use longer fibers, are more dense, and have a higher tensile strength than beater-add gaskets. They are manufactured on a special calender, known as a "sheeter", in such a manner that the compound is built up under high load, on one role of the "sheeter" to a specific thickness (Union Carbide 1987). Compressed sheet gaskets are used in heavy duty applications where severe temperatures and pressures are likely to exist. Different grades of asbestos sheet gasketing are available for different temperature use limits, and the proportion of fiber to binder in the gasket varies with the intended temperature use range. Fiber content increases as intended range of temperature use increases (Krusell and Cogley 1982). Sheet gaskets are suitable for use with steam, compressed air and other gases, chemicals, fluids, and organic compounds to temperatures of 950°F and pressure to 1500 psi (A.W. Chesterton 1983).

Wire inserted asbestos sheet is also available for use in pipe flanges that has slightly higher temperature and pressure limits (1000°F and 2000 psi, respectively). General service asbestos sheet is usually recommended for temperatures around 700°F and can be used in superheated or saturated steam service, or with weak acids and alkalies (A.W. Chesterton 1982).

Compressed asbestos gaskets are temperature and pressure dependent. As temperature increases their pressure capability decreases. It is difficult, therefore, to give exact pressure and temperature ranges, but Table 1 illustrates the useful fluid temperature and fluid ranges for compressed asbestos gasketing (Union Carbide 1987).

Asbestos sheet gaskets are used in exhaust systems and turbo chargers, cylinder head and intake manifolds, and high load/high extrusion applications. The most common sheet gaskets are used in engines, gear cases, and pipe flanges.[1]

Asbestos is the primary constituent for making compressed sheet gaskets (varying upwards from 75 percent by weight, depending on the application). Elastomeric binders such as neoprene, silicone based rubber, natural rubber, nitrile rubber, Teflon, or styrene-butadiene are used to ensure that gasketing material remains intact.

B. Producers of Sheet Gasketing

In 1985, five companies produced 2,848,308 square yards of compressed sheet gasketing. These companies consumed 4,041 tons of asbestos fiber (ICF 1986a).

In addition, a sixth company produced an estimated 759,000 square yards of compressed asbestos sheet gasketing from 1400 tons of asbestos fiber.[2] The total estimated consumption for this category is, therefore, estimated to be 3,607,408 square yards of sheet gasketing from 5,441.1 tons of fiber. Table 2 presents the production volume and fiber consumption for gaskets in 1985. Known imports make up a small percentage of the total gaskets consumed in the U.S. There were 506.35 tons of sheet gasketing imported in 1985 (ICF 1986a). The asbestos compressed sheet gasketing market was estimated to be worth

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[1] Due to the wide variety of gasketing shapes, sizes, compositions, and sheathing materials available, an all-inclusive list of fabricated products is not available.

[2] Based on the methodology for allocating consumption to survey non-respondents in Appendix A.

Table 1. Fluid and Pressure Ranges for Compressed Asbestos Sheet Gasketing Material

Temperature and Pressure	Product[a]
750-1000°F, Vacuum -- 1500 psi	Premium Compressed Asbestos Sheet
250-750°F, Atmos -- 1500 psi	Service Compressed Asbestos Sheet
-70-250°F, Atmos -- 1500 psi	Economy Compressed Asbestos Sheet

[a]Premium indicates the highest grade of compressed asbestos sheet, usually wire inserted. Service indicates general use compressed asbestos sheet and economy is the lowest grade of asbestos sheet available.

Source: Union Carbide 1987.

Table 2. Production of Asbestos Sheet Gasketing and Asbestos Fiber Consumption

	1985 Fiber Consumption (short tons)	1985 Production (sq. yd.)	References
Total	5,441.1	3,607,408.0	TSCA 1982, ICF 1986a, ICF 1987

$20.5 million in 1985, based on an average price of $5.69 per square yard (ICF 1986a).

C. Trends

Between 1981 and 1985, two manufacturers of compressed asbestos sheet gasketing, Jenkins Brothers (Bridgeport, CT) and Manville Sales Corporation (Manville, NJ and Waukegan, IL) discontinued their operations. During those four years, total production fell 44 percent from 6,472,879 square yards to 3,607,408 square yards (see Table 2). Currently, non-asbestos gaskets hold less than 50 percent of the gasket market, but as concerns about asbestos and its health effects grow, the use of asbestos in compressed sheet gaskets is expected to decline (ICF 1986a).

D. Substitutes

Asbestos has been used in sheet gaskets because it is chemically inert, nearly indestructible and can be processed into fiber. Asbestos fibers partially adsorb the binder with which they are mixed during processing; they then intertwine within it and become the strengthening matrix of the product. Since the product contains as much as 80 percent asbestos fiber, manufacturers are also employing it as a filler. The balance of the product is the binder which holds the asbestos in the matrix (Kirk-Othmer 1981).

A single substitute for asbestos is not available. Manufacturers have, therefore, been forced to replace the asbestos fiber with a combination of substitute materials. The formulations of the substitute products most often include a combination of more than one type of substitute fiber and more than one filler in order to reproduce the properties of asbestos necessary for that application. Formulation of substitute products is done on an application-by-application basis by each manufacturer (ICF 1986a). For the purposes of this analysis, the substitute products will be grouped into six major categories according to the type of non-asbestos substitute used (Table 3 presents properties of the substitute fibers):

- aramid mixtures,
- fibrous glass mixtures,
- graphite mixtures,
- cellulose mixtures, and
- PTFE mixtures (ICF 1986a, Palmetto Packing 1986).

The current market share of the different substitute formulations is estimated to be as indicated in Table 4. Industry experts have indicated that asbestos sheet gaskets account for approximately 50 to 60 percent of the current market. It is evident, however, from the survey that the market share of asbestos free sheet gaskets is increasing rapidly, as companies replace asbestos in some applications. One obstacle to complete replacement of asbestos gaskets by substitute products is military contract specifications that stipulate the use of asbestos gaskets. This includes aerospace and Naval specifications. A 100 percent asbestos-free market is impossible to achieve if military specifications continue to require asbestos products.[3]

1. <u>Aramid Mixtures</u>

Aramid fiber products are produced by numerous companies from DuPont's Kevlar(R) and Nomex(R) fibers. Kevlar(R) and Nomex(R) were introduced in late 1980 to act as reinforcing fibers in asbestos free gaskets and other materials. They are highly heat resistant and strong (ten times stronger than steel, by weight). They are about twenty times more expensive than asbestos, by weight. Because it is less dense and stronger, however, less is needed for reinforcement purposes. At high temperatures (above 800°F), the fiber physically degrades, but it is very strong and can withstand very high pressure up to the temperature limit (A.W. Chesterton 1983).

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[3] Department of Defense branches seem willing to follow EPA requirements and recommendations for new equipment, but for existing equipment, revalidation with a new gasketing material would be very costly (DOD 1986).

Table 3. Substitutes for Asbestos Sheet Gasketing

Product	Advantages	Disadvantages	Remarks	References
Aramid	Very strong. Year resistant. High tensile strength.	Hard to cut. Wears out cutting dyes quickly. 800°F temperature limit.		ICF 1986a, ICF 1985, Mach. Des., July 10, 1986
Fibrous Glass	Good tensile properties. Chemical resistant.	More expensive than asbestos.	Often used in the auto industry.	ICF 1986a, ICF 1985, Mach. Des., July 10, 1986
Graphite	Heat resistant to 5000°F. Chemical resistant. Light weight.	Expensive. Brittle. Frays.	Fastest growing substitute in the auto market in high temperature seals.	ICF 1986a, ICF 1985, Mach. Des., July 10, 1986
Cellulose	Inexpensive. Good carrier web.	Not heat resistant. Useful to 350°F. Not chemically resistant.	Useful for low temperature applications only.	ICF 1986a, ICF 1985, Mach. Des., July 10, 1986
PTFE	Low friction. Chemical resistant. FDA approved to contact food and medical equipment.	Not as resilient as asbestos. Deforms under heavy loads.	Used primarily in the chemical industry.	ICF 1986a, Palmetto Packing 1986a
Ceramic	High temperature limit. Flexible.	Incompatible with some binders. No test data.	Secret Filler.	ICF 1986a

Table 4. Estimated Market Shares for Substitute Fibers Replacing Compressed Asbestos Sheet

Substitute Fiber	Estimated Market Share	Reference
Aramid	30	Palmetto Packing 1986
Glass Fiber	25	Palmetto Packing 1986
Graphite	15	Union Carbide 1987
Ceramic	5	ICF 1986a
Cellulose	15	Palmetto Packing 1986
PTFE	10	ICF 1986a

Aramid gaskets are usually composed of 20 percent aramid fiber, by weight, and 60 to 65 percent fibers and fillers such as silica and clay. The remaining 20 to 25 percent is the binder which keeps the fibers in a matrix. Typical applications include off-highway equipment, diesel engines, and compressors. These applications require a very strong gasketing material that will withstand moderate temperatures (A.W. Chesterton 1982).

Aramid gaskets as a substitute for asbestos sheet gaskets are used because of the fiber's strength and high temperature resistance. Formulations also include mineral fillers and elastomeric binders. Aramid product costs 1.7 times as much as the asbestos product for some applications, resulting in gaskets that cost $9.72 per square yard.

Industry officials project 30 percent of the total asbestos market will be captured by this substitute (ICF 1986a, Palmetto Packing 1986).

2. Fibrous Glass Mixtures

Fibrous glass is generally coated with a binder such as neoprene, TFE, or graphite in the manufacturing process to make gaskets. Glass fibers are relatively easy to handle and reduce the costs of product formulation. Fibrous glass gaskets are usually divided into two groups, "E" glass gaskets, and "S" glass gaskets, depending upon the type of glass fiber used in the formulation. "E" glass is one of the more common glass fibers, and is occasionally manufactured into a gasketing which is used as a jacket around a plastic core of carbon or aramid fibers and other materials (OGJ 1986).

"E" glass gaskets are suitable for general service applications where the operating temperature is below 1000°F. Above this temperature, the gasketing loses 50 percent of its tensile strength. The materials can be used with most fluids except strong acids and alkalies (A.W. Chesterton 1982).

The second type of glass fiber, "S" glass, was developed by NASA and is recognized as the superior glass fiber in use today (OGJ 1986). This material is occasionally used as a jacket around a core of graphite and other fibers. The sheet gasketing is caustic resistant and can be used in applications with operating temperatures that reach 1500°F. (OGJ 1986).

Industry representatives project that glass gaskets will capture 25 percent of the total asbestos sheet gasketing market. They estimate that the glass material will cost twice as much as the asbestos material. Thus, the price will be $11.38 per square yard (Palmetto Packing 1986, ICF 1986a).

3. Graphite Mixtures

Flexible graphite, developed by Union Carbide Corp. is made from natural flake graphite, which is expanded several hundred times into a light, fluffy material by mixing it with nitric or sulfuric acid. It is then calendered into a sheet (without additives or binders) (Chem. Eng. News 1986). In addition, graphite based materials can be formed by removing all of the elements except carbon from polyacrylnitrile polymers or viscose rayon (Kirk-Othmer 1981).

These materials are extremely heat resistant and inherently fire-safe. Graphite gaskets are suitable for applications where the operating temperatures reach 5000°F. in non-oxidizing atmospheres. In the presence of oxygen, the material is limited to use below 800°F. (Chem. Eng. News 1986). The gasketing has excellent chemical resistance with the exception of strong mineral acids. Graphite packings can be used in most applications up to 1500 psi and unlike asbestos sheet gasketing do not show as great a temperature/pressure dependence[4] (Union Carbide 1987).

Graphite material is often used in oil refinery and oil field applications (e.g., oil-well drilling equipment) because of its high temperature

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[4] Flexible graphite temperature limits are independent of gasket compressive load and therefore fluid pressure, whereas all compressed asbestos gaskets are temperature and pressure dependent.

resistance. A wire insert is often added for increased strength in these high temperature, high pressure applications (OGJ 1986).

Graphite is an expensive material, but the addition of various fillers helps keep the cost competitive with other substitute materials (Palmetto Packing 1986). The cost of replacement gaskets made from graphite are approximately two times that of the asbestos gaskets they will replace based on fiber requirements and processing costs (Union Carbide 1987). The price of the substitute material is, therefore, $11.38 per square yard. Industry officials project this substitute's market share to be 15 percent of the total asbestos gasketing market (Palmetto Packing 1986, Union Carbide 1987, ICF 1986a).

4. Cellulose Fiber Mixtures

Cellulose fibers are generally milled from unused or recycled newsprint or vegetable fiber in the presence of additives which ease grinding and prevent fires during processing.

Manufacturers of sheet gaskets that contain cellulose fiber consider their specific formulations proprietary. These producers, however, indicate that these fibers are generally used with a combination of clay and mineral thickeners. The gaskets made from cellulose products have a content of between 20 and 25 percent cellulose fiber and 50 to 55 percent fillers and thickeners. The remaining 25 percent is usually an elastomeric binder (ICF 1986a).

Traditionally, cellulose fiber gaskets are only used at low pressure (<250 psi) and methods to reinforce the fibers, however, increase their use limits, resulting in excellent crush resistance, excellent dimensional stability, and good sealability below 350°F. Cellulose gaskets can substitute for asbestos sheet gaskets in low temperature applications such as with oil, gas, organic solvents, fuels, and low pressure steam (Union Carbide 1987).

Reinforced cellulose based gaskets have increased in popularity in the past few years. These gaskets can duplicate all asbestos performance parameters, except high temperature resistance. Although they can be used at a maximum continuous operating temperature of 350°F, their life is substantially shortened in temperatures over 95°F. Despite this, manufacturers indicate that the service life of these asbestos free gaskets is the same as for asbestos gaskets (Carborundum 1986).

Cellulose fiber formulations in combination with clay and mineral thickeners are estimated to capture 15 percent of the sheet gasketing market in the event of an asbestos ban. Prices would be expected to rise 20 percent to $6.83 per square yard due to increased material and production costs (ICF 1986a).

5. PTFE

PTFE fibers offer chemical resistance to all but the most powerful oxidizing agents, acids, and alkalies in temperatures ranging from -450°F to 500°F (Chem Eng. News 1986). This material has good dielectric strength and impact resistance.

PTFE can be used in specialized applications because it has been approved by the FDA for contact with food and in medical equipment. In addition, it does not stain the fluid with which it has contact (Krusell and Cogley 1982).

PTFE, and PTFE and graphite mixtures can be formulated into gasketing material easily, reducing the price of the gasketing that would otherwise be quite high (PTFE is twenty times as expensive as asbestos). The final product, however, is only 3.5 times as expensive as the asbestos product. PTFE gasketing is, therefore, $19.91 per square yard. Industry officials indicated that PTFE gaskets will capture 10 percent of the total asbestos market in the case of an asbestos ban (Palmetto Packing 1986, ICF 1986a).

6. Ceramic Fiber Mixtures

Ceramic fibers, composed of alumina-silica blends are used in the manufacture of gasketing material to replace compressed asbestos sheet, although their performance has not been outstanding (Union Carbide 1987). These fibers impart high temperature resistance to gaskets made from them, but little information is available on the performance characteristics of these materials. Costs are expected to be the same as for other ceramic based products that can replace asbestos products (two times as expensive), but it is unlikely that ceramic products will occupy more than five percent of the market in the event of an asbestos ban (ICF estimate).

E. Summary

It appears that substitutes for asbestos containing sheet gaskets currently exist. However, these products cost more to produce and may not perform as well. Substitute fiber formulations include aramid, glass, graphite, cellulose, PTFE, and ceramic fibers. The substitute materials are a combination of fibers and fillers designed on an application-by-application basis. The substitute materials are classified by the fiber with the highest content.

The estimation of market shares and prices of the substitute formulations in the event of an asbestos ban and the data inputs for the Asbestos Regulatory Cost Model are presented in Table 5.

Table 5. Data Inputs for Asbestos Regulatory Cost Model
Sheet Gasketing

Product	Output	Product Asbestos Coefficient	Consumption Production Ratio	Price (sq. yd.)	Useful Life	Equivalent Price (sq. yd.)	Market Share	References
Asbestos Gasketing	3,607,408 sq. yds.	0.00151 tons/ton	1.07	$5.69	5 years	$5.69	N/A	ICF 1986a
Aramid	N/A	N/A	N/A	$9.72	5 years	$9.72	30%	ICF 1986a, Palmetto Packing 1986a
Fibrous Glass	N/A	N/A	N/A	$11.38	5 years	$11.38	25%	ICF 1986a, Palmetto Packing 1986a
Graphite	N/A	N/A	N/A	$11.38	5 years	$11.38	15%	ICF 1986a, Palmetto Packing 1986a
Cellulose	N/A	N/A	N/A	$6.83	5 years	$6.83	15%	ICF 1986a, Palmetto Packing 1986a
PTFE	N/A	N/A	N/A	$19.91	5 years	$19.91	10%	ICF 1986a, Palmetto Packing 1986a
Ceramic	N/A	N/A	N/A	$11.38	5 years	$11.38	5%	ICF 1986a, Carborundum 1986

N/A: Not Applicable.

REFERENCES

Carborundum. 1986. Product literature on Fiberfrax(R) heat-resistant materials.

Chemical Engineering. 1986 (October 27). Asbestos Users Step Up Search for Substitutes. McGraw-Hill.

A.W. Chesterton. 1982. Product literature on sealing devices.

A.W. Chesterton. 1983. Product literature on environmental packings.

DOD. 1986. G.D. West. 1986 (July 1). Department of Defense, Department of the Air Force. Letter to the Document Control officer, Office of Toxic Substances, Environmental Protection Agency. OPTS Document No. 62036-Asbestos Ban.

ICF Incorporated. 1985. Appendix H: Asbestos Products and their Substitutes, in Regulatory Impact Analysis of Controls on Asbestos and Asbestos Products. Washington, DC: Office of Pesticides and Toxic Substances, U.S. Environmental Protection Agency.

ICF Incorporated. 1986a (July-December). Survey of Primary and Secondary Processors of Asbestos Sheet Gasketing. Washington, DC.

Kirk-Othmer. 1981. Encyclopedia of Chemical Technology. Volume 16. Wiley and Sons. New York, NY.

Krusell N, Cogley D. 1982. GCA Corp. Asbestos Substitute Performance Analysis. Revised Final Report. Washington DC: Office of Pesticides and Toxic Substances, U.S. Environmental Protection Agency. Contract 68-02-3168.

Machine Design. 1986 (July 10). Better Gaskets Without Asbestos. pp. 67-70.

Oil and Gas Journal. 1986 (May 26). Refining Technology: Substitute Materials to Replace Asbestos in Refinery-Service Gaskets and Packings. PennWell Publication. Tulsa, OK. Pp.47-51.

Palmetto Packing. S. Matt. 1986 (January 8 and 19). North Wales, PA. Transcribed telephone conversations with Linda Carlson, ICF Incorporated, Washington, D.C.

TSCA Section 8(a) Submission. 1982. Production Data for Primary Asbestos Processors, 1981. Washington, DC: Office of Toxic Substances, U.S. Environmental Protection Agency. EPA Document Control No. 20-8601012.

Union Carbide Corporation. P. Petrunich. 1987 (March 4). Cleveland, OH. Letter with enclosures addressed to Tony Bansal, ICF Incorporated, Washington, D.C.

XXVIII. ASBESTOS PACKINGS

A. Product Description

The term packings is generally assigned to the subset of packings that are designated as dynamic (static packings are gaskets). These dynamic or mechanical packings are used to seal fluids in devices where motion is necessary. Examples where these packings have traditionally been used are in pumps, valves, compressors, mixers, and hydraulic (piston-type) cylinders (Kirk-Othmer 1981). Within the mechanical packing segment there are various types of packings (e.g., compression, automatic, and floating packings), but only compression packings are or have been made using asbestos fibers (FSA 1983).

Asbestos-containing compression packings can be formed into various shapes for different uses as illustrated in Figure 1. The simplest form of compression packings (hence forward packings) is of the loose bulk type. Bulk formulations consist of blends of loose fibers and dry lubricants that are bound with a liquid or wax binder. These simple packings have only limited applications (e.g., packings for injection guns) and are not considered in the remainder of this report. Fiber mixtures are more often extruded with a binder and lubricant and used as a core in packings that have a braided yarn jacket that imparts greater durability to the packing (Kirk-Othmer 1981).

The braided variety of packings are the most prevalent and all of the well-known packing manufacturers produce them by similar methods of construction. Asbestos packings are braided of strong, highest quality pure asbestos yarn. In addition, they may be constructed using an Inconel(R) or other wire insert around a resilient asbestos core impregnated with graphite. They are lubricated throughout and surfaced with anti-frictional dry lubricant graphite (EPRI 1982). The simplest form of braided packing is the square braided variety that utilizes asbestos yarns of the six grades defined

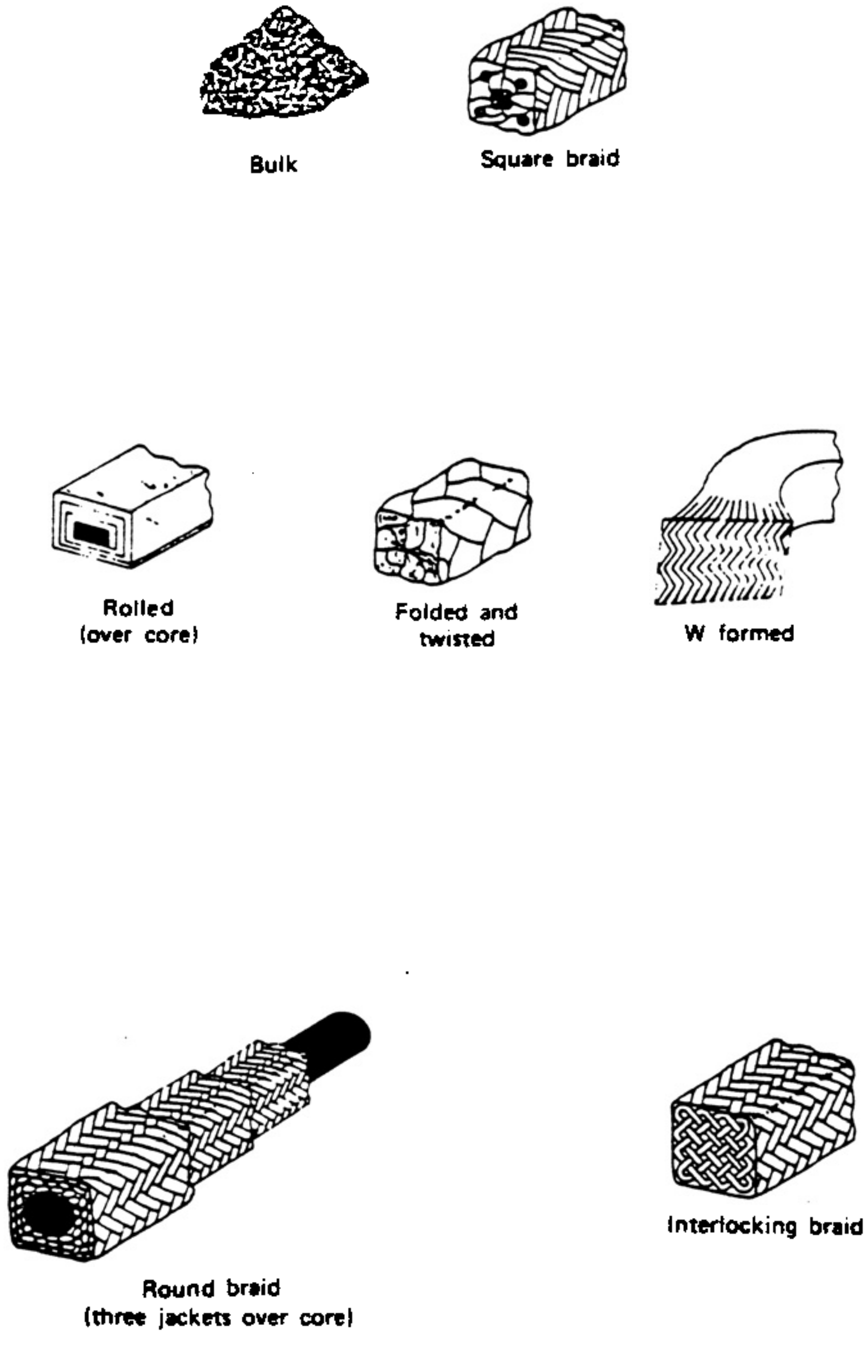

Figure 1. Common Types of Compression Packings. (Source: Kirk-Othmer 1981).

according to ASTM D 299, the standard for such materials. These grades are listed in Table 1 (ASTM 1982). The dimensions of the packing are controlled by the size and number of yarns selected (Kirk-Othmer 1981).

Another type of braided packing, braid-over-braid packing, consists of individually braided jackets layered over a core. These packings use wire-inserted yarns that offer greater strength to the packing material. Rolled compression packings are constructed of woven cloth that is coated with a rubber binder and then cut in strips along the bias to impart maximum cloth stretch during forming. The rubber-saturated strips are wound around a soft rubber core and then formed into the desired final shape. The final cutting, forming, and compression operations for all packing types are usually performed by secondary processors (FSA 1983).[1]

All of the packing formation processes have some characteristics in common. First, impregnation of dry asbestos yarn with a lubricant. After lubricant impregnation, the yarns are braided into a continuous length of packing which in turn is calendered to a specific size and cross-sectional shape. The formed product may then be coated with more lubricant or another material. At this stage packings can be packaged and sold for maintenance operations or they can be further processed by pressing into the required shape (GCA 1980).

Finally, packings can be die-formed directly into solid rings to facilitate handling and installation. The packings that have been formed into a designated shape are referred to as plastic packings (Kirk-Othmer 1981).

The uses and applications of asbestos packings are quite varied, but some of the major areas in which asbestos-containing packing materials have been

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[1] Secondary processing usually occurs at the facility where the gaskets will be used and consists of cutting and compressing the packings as they are needed to replace worn packings already in service in various pumps, valves, etc.

Table 1. Standards of Asbestos Yarns Used in Asbestos Packings

Grade	Asbestos Content (percent)
Commercial	75-80
Underwriters'	80-85
A	85-90
AA	90-95
AAA	95-99
AAAA	99-100

Source: ASTM 1982.

used are valves and pumps employed in the electric power, petroleum refinery, petrochemical, chemical, nuclear power, and pulp and paper industries (Union Carbide 1987). Depending on the scale of these operations, asbestos packings of various shapes and sizes are required. As described earlier, the design of a packing is to control the amount of leakage of fluid at shafts, rods or valve systems and other functional parts or equipment requiring containment of liquids or gases. Packings are used in rotary, centrifugal, and reciprocating pumps, valves, expansion joints, soot blowers, and many other types of mechanical equipment (FSA 1983). Figures 2 and 3 illustrate the design of a typical pump with a packing set and the configuration of a packing, respectively.

Depending on the conditions of use, various types of asbestos packings are used. The temperature and pressure of the system in which the packing is used determine the style of packing that is used and the type of additional constituents incorporated in the packing (e.g., other fibers, binders, fillers). Other factors that affect the composition and configuration of the packing system include: the rotation speed of the valve or pump member, the type of fluid being contained (i.e., caustic, acid, alcohol, petrochemical), and the amount of time between scheduled maintenance operations (FSA 1983).

Table 2 identifies the different packing types traditionally made from asbestos fibers, their service areas, and the conditions under which typical operations are performed.[2]

Asbestos is used in packings because of its unique combination of heat and chemical resistance as well as its low price. The important attributes of asbestos fiber for this application are the following:

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[2] It should be noted that packings can be used in varying applications and are not strictly limited to certain operating conditions. Table 2 gives likely use areas and conditions, but these are not limiting designations.

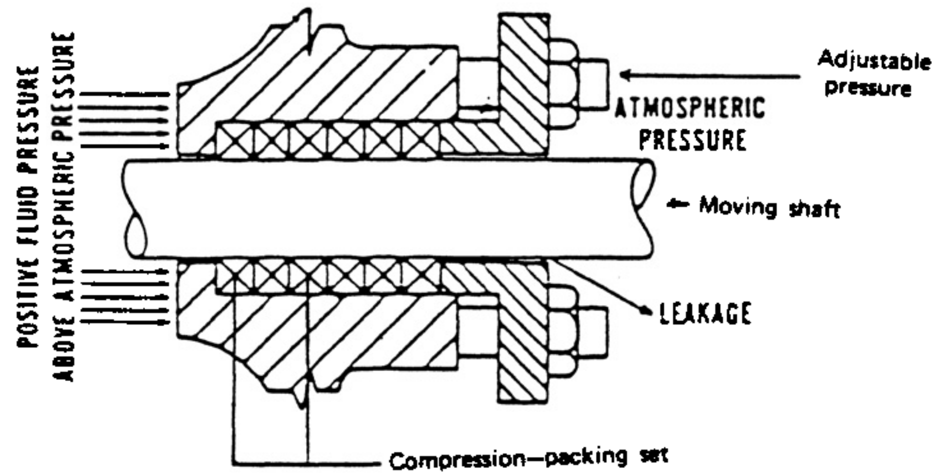

Figure 2. Typical Stuffing Box Construction Utilizing Compression Packings for Effecting a Dynamic Seal. (Source: FSA 1983).

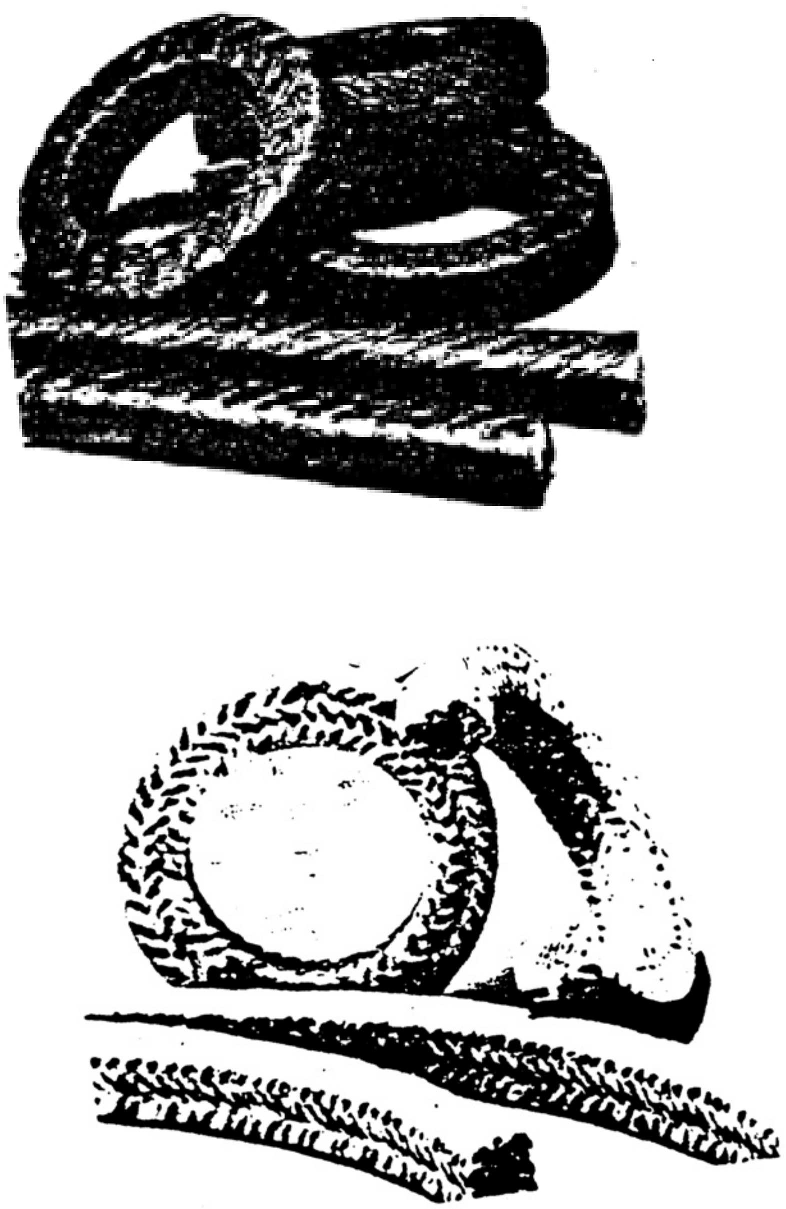

Figure 3. Typical Asbestos-Containing Packing Illustrating the Coil and Pre-Compressed Forms. (Source: A.W. Chesterton 1982).

NOTE: Most packings, although available in pre-compressed ring form, are purchased as a coil and cut and formed on site.

Table 2. Operating Conditions and Use Areas for Various Braided Packing Types

Packing Type	Advantages	Operating Conditions*	Use Area
Square Braid	Wide spectrum sealing ability	High-speed rotation Low pressure <600 psi	Pumps and valves of all types
Braid-Over-Braid	Better sealing than conventional square braid	Slow-speed rotation High pressure >600 psi Hot liquids	Valve stems, expansion joints
Braid-Over-Core	Better shaft sealing More resilient Variations in density	High pressure Steam applications Low-speed rotation	Nuclear powerplants, when congealing or crystalizing liquids are present, turbines and values in powerplants
Interlocking Braid	Denser and more stable	General service High temperature/pressure	Reciprocating and centrifugal pumps, agitators, valves, expansion joints

Source: FSA 1983, A.W. Chesterton 1982, Klein 1987.

NOTE: General service temperature for all types of braided packings are in the range of 500°F although depending on the use conditions, asbestos packings can withstand temperatures between 1200-1500°F.

- heat resistance to prevent thermal decomposition of the packing due to elevated shaft speeds and high temperature fluids;
- chemical resistance to prevent deterioration of the packing due to contact with caustic and potentially explosive fluids;
- durability to provide long lasting control of fluid flow; and,
- low cost (ICF 1986a).

B. Producers and Importers of Asbestos Packing

Table 3 lists the fiber consumption and quantity of packings produced in 1985. (Raymark Corporation refused to provide production and fiber consumption data for 1985, but was a producer in 1981 and so was assumed to have continued production of asbestos packing.) The values for domestic asbestos fiber consumption in the production of asbestos packings and the total amount of asbestos packings produced have been changed to account for the output of Raymark Corporation using the methodology described in Appendix A to this RIA. The adjusted values are 2.1 tons and 3 tons for fiber consumption and packings production, respectively (ICF 1986a).

The secondary processors of asbestos packings in 1983 include: FMC Corporation in Houston, Texas and WKM Division of ACF Industries, Inc. in Missouri City, Texas. While WKM Division imported its asbestos mixture, FMC Corporation used domestic supplies in 1985. These companies received packings and further processed them in order to meet specifications of their customers (ICF 1986a).

C. Trends

Three manufacturers, Johns-Manville Corporation (now Manville Sales Corporation) in Manville, New Jersey, Rockwell International in Pittsburgh, Pennsylvania, and John-Crane Houdaille (now Crane Packing) in Morton Grove, Illinois, ceased production of asbestos packings between 1981 and 1985.

Table 3. Production of Asbestos Packing and Asbestos Fiber Consumption

	1985 Asbestos Fiber Consumption	1985 Production of Asbestos Packings
Total	2.1 tons	3 tons

Values for fiber consumption and packing production for Raymark Corporation have been estimated based on the methodology for non-respondents described in Appendix A to this RIA.

Sources: ICF 1986a.

During this time period, estimated domestic production declined 99.7 percent, from 952.34 to 3 short tons and fiber consumption declined 99.8 percent, from 877.54 to 2.1 short tons (ICF 1986a, ICF 1985, TSCA 1982).

In 1986, Durametallic Corporation, which accounted for two-third of the total output for asbestos packings in 1985, ceased processing because of costly insurance premiums and the possibility of regulatory action (ICF 1986a).

D. Substitutes

Asbestos-containing packings, the large majority of which are based on various compositions and configurations of braided yarn, have dominated the market until very recently. A typical high performance braided asbestos packing includes an alloy wire reinforcement, various lubricants, a zinc powder corrosion inhibitor, and a graphite powder lubricant coating on the yarn itself (Union Carbide 1987). In addition, these packings may contain various binders (e.g., elastomers or resins), fillers (e.g., mica, clay, or asbestos) and dry lubricants (Monsanto 1987).

Asbestos fibers have been used to make the braided jackets for packings because of the favorable qualities that asbestos imparts to products made from it. Asbestos-containing packings are ideally suited for high temperature and pressure, as well as corrosive environments. Braided asbestos packings show good acid/fire resistance, low thermal conductivity, and molten metal resistance. Asbestos also withstands fairly high pressures (up to 4500 psi at room temperature) and exhibits good tensile strength and abrasion resistance (Klein 1987). Another property of asbestos packings that has made them a standard in the packing industry is their good compressibility and recovery (EPRI 1982).

The packing industry has been unable to find a single substitute for asbestos that can reproduce its numerous qualities. Hence, manufacturers have been forced to replace the asbestos fiber with a combination of substitute materials, including cellulose, aramid, PBI, PTFE, glass, and graphite fibers. The formulations of the substitute products most often include a combination of more than one type of substitute fiber and fillers in order to reproduce the properties of asbestos necessary for a particular application.

Formulation of substitute products is done on an application-by-application basis by each manufacturer (ICF 1986a) and for the purposes of this analysis, substitute products will be classified according to the fiber with the largest percentage in content. The substitute products can be grouped into six major categories according to the type of non-asbestos substitute used:[3]

- Aramid fiber mixtures,
- Glass fiber mixtures,
- PBI fiber mixtures,
- PTFE mixtures,
- Graphite mixtures, and
- Other fiber mixtures including cellulose, phosphate, and ceramic (ICF 1986a, Palmetto Packing 1986, Monsanto 1987).

The current market share for the different substitute formulations has been estimated as indicated in Table 4.

1. <u>Aramid Mixture</u>

Aramid fibers act as a reinforcing fiber in asbestos free packings and other materials. They are not as heat resistant as asbestos (500°F), but are quite strong and flexible and can withstand mild acids and alkalies (A.W. Chesterton 1982). Kevlar(R) and Nomex(R) produced by DuPont Corporation are

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[3] The grade or the fiber and style of the packing used (e.g., square braid, braid-over-braid) determine the pressure rating for all applications. Any substitute fiber can be formulated into a packing that will meet most pressure requirements, but temperature and chemical limitations may dictate the selection of a particular fiber for a particular application.

about twenty times more expensive than asbestos, by weight, but because they are less dense and stronger, less is needed for reinforcement purposes. At higher temperatures, the fibers physically degrade and thus are not good replacements for asbestos products for high temperature applications.

Aramid packings are usually 20 percent aramid fiber, by weight, and 60 to 65 percent filler, while the remaining 20 to 25 percent is binder to keep the fibers in a matrix. Typical applications for valves and pumps require a very strong packing material that will withstand moderate temperatures and pressures without deteriorating.

Raymark Corporation, in Stratford, CT, was the only asbestos packing manufacturer to cite aramid packings as a substitute for asbestos products. They can be used for general service in most plants (A.W. Chesterton 1983). Aramid-based products are likely to be 1.5 to 3 times as expensive as the asbestos products they replace, therefore aramid packings cost between $45.30 and $90.60 per pound. The price increase is due to production and material cost increases (ICF 1986a).

There are no performance disadvantages due to the dilution of the aramid fiber with mineral fillers and this helps to reduce the price of packings. The service life is estimated to be the same as the life of the asbestos product. Industry estimates indicate that aramid products will capture 20 percent of the total packings market. The average price for an aramid-based packing is estimated to be $67.95 per pound (ICF 1986a, Palmetto Packing 1986).

2. Fibrous Glass Mixtures

Fibrous glass is generally coated with a binder such as neoprene, TFE, or graphite in the manufacturing process to make packings. Glass fibers are relatively easy to process into packing materials and are used extensively in packing materials.

Table 4. Estimated Market Share for Substitute Fibers that can Replace Existing Asbestos Products in Compression Packings

Substitute Fiber	Market Share (percent)	Reference
Glass	30	Palmetto Packing 1986
Graphite	10	Union Carbide 1987
Aramids	30	ICF 1986a
PBI	15	ICF 1986a
PTFE	15	Union Carbide 1987

NOTE: The market shares indicated are estimates based on communications with industry representatives and are likely to change over time. For example, the share of graphite products is likely to increase over the next five years. New products (e.g., phosphate based fibers) are likely to penetrate the market to a certain extent (Monsanto 1987).

Fibrous glass packings are usually divided into two groups, "E" glass packings, and "S" glass packings, depending upon the type of glass fiber used in the formulation. "E" glass is one of the more common glass fibers, and is often manufactured into a packing which is used as a jacket around a plastic core of carbon or aramid fibers, and other materials (OGJ 1986).

"E" glass packings are suitable for applications where the operating temperature is below 1000°F. Above this temperature, the packing loses 50 percent of its tensile strength. Also, the material can be used with most fluids except strong caustics.

The second type of fiber, "S" glass, was developed by NASA and is recognized as the superior glass fiber in use today (OGJ 1986). This material is generally used as a jacket around a core of graphite and other fibers. The packing is caustic resistant and can be used in applications with operating temperatures of 1500°F (OGJ 1986).

One disadvantage of glass packings is the abrasive nature of the material. In high shaft-speed applications, the abrasiveness of glass wears down the shaft stem requiring frequent replacement of the stem. Glass packings will capture 30 percent of the total asbestos packing market and will cost twice as much as the asbestos material. Thus, the price will be $60.40 per pound (Palmetto Packing, ICF 1986a).

John Crane-Houdaille, previously one of the major producers of asbestos packings, offers an "S"-glass yarn packing replacement that it claims is better than the asbestos packings it replaces. It has a higher temperature limit, good service life in caustics, steam, oil, liquid petroleum, and chemicals, a high pressure limit of 7700 psi and will not score valve stems or other pieces of equipment in which it is used (John-Crane 1987).

3. <u>PBI Mixtures</u>

PBI (polybenzimidazole) is produced by Celanese Engineering. It has a useful temperature limit of approximately 1000°F and has high chemical resistance. It is designed to be used in high temperature, high pressure applications, and it is easy to work with because it can be formed into rings with little difficulty. The non-asbestos packing costs approximately three times as much as the asbestos product, making the cost about $90.60 per pound (ICF 1986a). The service life is the same as the asbestos product.

The non-asbestos product has poorer wettability (is less porous), but this problem can be compensated for in the design of the application. PBI packings will capture 15 percent of the total asbestos packing market with a price of $90.60 per pound (ICF 1986a).

4. PTFE Fibers

Many forms of polytetrafluoroethylene fibers (PTFE) are used as substitutes for asbestos in packings, but the most popular is Dupont's Teflon(R) (Palmetto Packing 1986). PTFE offers chemical resistance to all but the most powerful oxidizing agents, acids, and alkalies in temperatures ranging from -450°F to 500°F (Chem. Eng. News 1986). This material has good dielectric strength and impact resistance.

PTFE can be used in specialized applications because it has been approved by the FDA for contact with food and in medical equipment. In addition, it does not stain the fluid with which it has contact (Krusell and Cogley 1982) which makes it ideal for use in paper mill applications (A.W. Chesterton 1982).

Palmetto Packing representatives cited PTFE, and PTFE and graphite mixtures as materials they manufacture into packing. PTFE fibers are twenty times as expensive as asbestos, but ease of handling and durability make the product only 3.5 times as expensive as the asbestos product. PTFE packing material, therefore, costs $105.70 per pound (ICF 1986a). Industry officials indicate that PTFE packings will capture 15 percent of the total asbestos market in the case of an asbestos ban (Palmetto Packing 1986, ICF 1986a).

5. Graphite

Flexible graphite was developed by Union Carbide Corp. about twenty years ago. The material is made from natural flake graphite, which is expanded several hundred times into a light, fluffy material by mixing it with nitric or sulfuric acid. It is then calendered into a sheet (without additives or binders) (Chem. Eng. News 1986). It can then be processed into packings by standard techniques. Other forms of graphite are also available (e.g., carbonized viscose rayon and other fibrous graphite materials) that have similar properties. All graphite materials will be grouped together for convenience and because their properties are similar.

Graphite materials are extremely heat resistant and inherently fire-safe (because it does not contain binders). Graphite packings are suitable for applications where the operating temperatures reach 5000°F in non-oxidizing atmospheres. In the presence of oxygen, the material is limited to use below 800°F (Chem. Eng. News 1986). The packing has excellent chemical resistance with the exception of strong mineral acids.

Graphite-containing packings are often used in oil refineries and oil fields because of its high temperature resistance. Often, in these high temperature, high pressure applications, a wire insert is added for increased strength (OGJ 1986).

Graphite materials are fairly expensive, but the addition of various fillers helps keep the cost competitive with other substitute materials (Palmetto Packing 1986). Graphite packings cost about two times as much as asbestos packings on a per weight basis and costs are estimated to be $60.40 per pound (Union Carbide 1987). Industry officials project this substitute's market share as 10 percent of the total asbestos packing market (Palmetto Packing 1986, ICF 1986a).

6. Other Substitute Fibers

Other fiber products made from cellulose, phosphate, or ceramic fibers have very small market shares and are not seen as viable replacement for asbestos in general service areas at this time. Ceramic fibers have been used for packing materials, but do not see widespread use due to their abrasive nature and brittleness (Union Carbide 1987). Phosphate fibers may see an increased market share in the future, but currently are only in developmental stages[4] (Monsanto 1987). Cellulose fibers occupy a very limited market share although for applications demanding little in the way of high performance they can be used (ICF 1986a).

E. Summary

It appears that substitutes for asbestos containing packings currently exist. These products, however, cost more to produce and may not perform as well. Since no across the board substitute fiber exists, manufacturers have been forced to replace asbestos with a combination of substitute materials, including graphite, PTFE, glass, aramid, and PBI fibers. The substitute materials are a combination of fibers and fillers designed on an application-by-application basis. The materials are classified by the fiber with the highest content. Table 5 summarizes the characteristics of the asbestos substitutes.

The estimation of market shares, prices of the substitute formulations in the event of an asbestos ban, and data inputs for the Asbestos Regulatory Cost Model are summarized in Table 6.

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[4] Although these fibers seem promising there is little industry data on their performance in field applications.

Table 5. Substitutes for Asbestos Packings

Product	Advantages	Disadvantages	Remarks	References
Aramid	Very strong. Tear resistant. High tensile strength.	Unable to handle strongly acidic or basic fluids. 500°F temperature limit.	Widely known. Used in the paper industry.	ICF 1986a, ICF 1985
Fibrous Glass	Withstands temperature to 1000°F. Good tensile properties.	Abrasive.	Market is growing for glass.	ICF 1986a, OGJ 1986, Chem. Eng. News 1986
Polybenzimidazole (PBI)	Withstands temperature to 1000°F.	Poorer wettability premium premium price.	Used in high temperature, high pressure applications.	ICF 1986a, OGJ 1986
PTFE	Low friction. FDA approved to contact food and medical equipment.	Not as resilient as asbestos. Deforms under heavy loads.	Temperature resistance to 500°F.	ICF 1986a, OGJ 1986, Palmetto Packing 1986
Graphite	Heat resistant up to 5000°F. Chemical resistance.	Brittle. Frays. Premium price.	Usually with a wire insert. Used in high temperature, applications.	Palmetto Packing 1986,

Table 6. Data Inputs for Asbestos Regulatory Cost Model
(028) Packing

Product	Output	Product Asbestos Coefficient	Consumption Production Ratio	Price ($/ton)	Useful Life	Equivalent Price ($/ton)	Market Share	References
Asbestos Packing	3 tons	0.70 tons/ton	1	60,400	1 year	60,400	N/A	ICF 1986a
Aramid	N/A	N/A	N/A	135,900	1 year	135,900	30%	ICF 1986a
Fibrous Glass	N/A	N/A	N/A	120,800	1 year	120,800	30%	ICF 1986a, Palmetto Packing 1986
PTFE	N/A	N/A	N/A	211,400	1 year	211,400	15%	ICF 1986a, Palmetto Packing 1986
Graphite	N/A	N/A	N/A	120,800	1 year	120,800	10%	ICF 1986a, Palmetto Packing 1986
PBI	N/A	N/A	N/A	181,200	1 year	181,200	15%	ICF 1986a

N/A: Not Applicable.

REFERENCES

ASTM. 1982. Annual Book of ASTM Standards: Part 32. Textiles -- Yarns, Fabrics, and General Test Methods. American Society for Testing and Materials. Philadelphia, PA.

Chemical Engineering. October 27, 1986. Asbestos Users Step Up Search for Substitutes. McGraw-Hill.

A.W. Chesterton. 1982. Product Literature on Sealing Devices.

A.W. Chesterton. 1983. Product Literature on Environmental Packings.

John Crane-Houdaille. 1987. Production literature on asbestos and non-asbestos packing materials.

EPRI. 1982. Valve Stem Packing Improvement Study. Electric Power Research Institute. Boston, MA. EPRI NP-2560.

FSA. 1983. Compression Packings Handbook. Fluid Sealing Association.

GCA Corporation. 1980. Asbestos Substitute Performance Analysis. Submitted to the U.S. Environmental Protection Agency, Office of Toxic Substances. Washington, D.C. In partial fulfillment of EPA Contract No. 68-02-3168.

ICF Incorporated. 1985. Appendix H: Asbestos Products and Their Substitutes, in Regulatory Impact Analysis of Controls on Asbestos and Asbestos Products. Washington DC: Office of Pesticides and Toxic Substances, U.S. Environmental Protection Agency.

ICF Incorporated. 1986a (July-December). Survey of Primary and Secondary Processors of Asbestos Packing. Washington, DC.

Kirk-Othmer. 1981. Encyclopedia of Chemical Technology. Volume 16. John Wiley and Sons. New York, NY.

Klein, J. Consultant. 1987 (June 23). Transcribed telephone conversation with Mark Wagner, ICF Incorporated, Washington, D.C.

Krusell N, Cogley D. 1982. GCA Corp. Asbestos Substitute Performance Analysis. Revised Final Report. Washington, DC: Office of Pesticides and Toxic Substances, U.S. Environmental Protection Agency. Contract 68-02-3168.

Monsanto Company. 1987. Product Literature on phosphate fiber based products.

Oil and Gas Journal. May 26, 1986. Refining Technology: Substitute Materials to Replace Asbestos in Refinery-Service Gaskets and Packings. PennWell Publication. Tulsa, OK. Pp.47-51.

Palmetto Packing. S. Matt. 1986 (January 8 and 19). North Wales, PA. Transcribed telephone conversation with Linda Carlson, ICF Incorporated, Washington, D.C.

TSCA Section 8(a) submission. 1982. Production Data for Primary asbestos Processors., 1981. Washington, DC: Office of Toxic Substances, U.S. Environmental Protection Agency. EPA Doc. Control No. 20-8601012.

Union Carbide Corporation. P. Petrunich. 1987 (March 4). Cleveland, OH. Letter with enclosures addressed to Tony Bansal, ICF Incorporated, Washington, D.C.

XXIX. ROOF COATINGS AND CEMENTS

A. Product Description

Roof coatings and roofing cements together accounted for 90 percent of the asbestos containing adhesives, sealants, and coatings produced in the United States in 1985. Other more specialized asbestos containing compounds used by the construction, automobile, and aerospace industries accounted for the remaining 10 percent. They are discussed separately under the Non-Roofing Adhesives, Sealants, and Coatings category.

Roof coatings are cold-applied liquids which may be brushed or sprayed on roofs or foundations to perform a variety of functions such as waterproofing, weather resistance, and surface rejuvenation. Asphalt based, thinned with solvents, and bodied with 5 to 10 percent asbestos fiber, roof coatings are applied to most types of roofs except the typical shingled roof. Commercial and industrial structures such as stores, shopping centers, and office and apartment buildings are common users. Usually black, these coatings may be pigmented with aluminum paste to create a silver coating with high heat reflectance (ICF 1986; Krusell and Cogley 1982).

Roofing cements are more viscous roof coatings. Usually consisting of solvent thinned asphalt and bodied with 15 to 20 percent asbestos, roofing cements are trowel-applied with the consistency of a soft paste. Applied to all types of roofs, they are used to repair and patch roofs, seal around projections such as chimneys and vent pipes, and bond horizontal and vertical surfaces (ICF 1986; Krusell and Cogley 1982).

Asbestos is used in roofing compounds for its unique combination of strength, viscosity control, and price. The important attributes of asbestos fiber for this application are: (ICF 1986, Krusell and Cogley 1982):

- asphalt reinforcement to prevent cracking due to factors such as temperature change;

- viscosity control for waterproofing since asbestos content aids in the application of an even coat without gaps or holes;
- sag resistance to ensure that the compound remains stationary on steep surfaces, and does not melt and run in the event of a fire;
- maintenance of surface protection since asbestos fiber prevents the liquefied asphalt from penetrating the resident surface;
- asphalt affinity to provide uniform asbestos dispersion without bunching or settling of fibers;
- weathering resistance to retard oxidation and deterioration of the asphalt; and,
- low cost.

Companies that manufacture roof coatings also manufacture roofing cements. Production is typically a batch process. Bagged asbestos (usually grade 7 chrysotile) is moved from storage and dumped into a fluffing machine which is used to separate the fibers that may have been compressed together. The fibers are then generally transferred to a batch mixing tank where other ingredients are mixed until the desired consistency is obtained. Finally the mixture is sent for packaging or containerizing, usually into tank trucks and five gallon metal pails with sealed lids. In both products asbestos fibers are thought to be completely encapsulated by other product constituents (ICF 1986; Krusell and Cogley 1982).

B. Producers of Roof Coatings and Cements

In 1985, 31 firms operating 68 plants nationwide produced approximately 76 million gallons[1] of asbestos containing roof coatings and cements. These companies consumed 29.6 thousand tons of fiber accounting for 20.4 percent of

[1] Four of the 31 companies producing asbestos containing roof coatings and cements in 1985 refused to provide production and fiber consumption data for their 10 plants in operation; their production volume and fiber consumption have been estimated using the method described in Appendix A and are included in the totals presented here.

145.3 thousand tons[2] of total asbestos consumed in 1985 for all product categories. Table 1 lists the total number of plants and the estimated gallons of coatings and cements produced in 1985. There are no importers of these products (ICF 1986).

Asbestos containing roof coating and cement production was estimated to be 76 million gallons. At an average price of $2.49/gallon, this market is estimated to be worth $189.2 million (ICF 1986).

C. Trends

The number of asbestos-based roof coating and cement manufacturers declined steadily from 1981 until 1985. During those four years 13 companies (30 percent), formerly producing asbestos containing roofing compounds, either substituted asbestos with other materials or discontinued their operations. In 1986, 14 of the 31 companies remaining in 1985, accounting for more than 24 percent of 1985 output, ceased processing asbestos because of rising insurance premiums, customer pressure to remove asbestos, and the possibility of regulatory action (ICF 1986).

D. Substitutes

Asbestos is unique among known raw minerals because it is a chemically inert, durable mineral that can be processed into a fiber. By partially adsorbing the asphalt into which it is placed, the fiber becomes an integral component of the mixture without settling or floating. The addition of one pound of asbestos fiber per gallon of thinned asphalt (only 10 percent by weight) imparts a large degree of body and turns the liquid into a soft paste. Industry leaders indicate that they have been unable to find a substitute for asbestos that can simultaneously reproduce the numerous qualities of the

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[2] 145.3 thousand tons of asbestos fiber is the ICF total. The Bureau of Mines (BOM) total is 172 thousand tons. Therefore, asbestos fiber used in roof coatings and cements (accounted for by ICF) will be 17 percent of the BOM total.

Table 1. Production of Asbestos Roof Coatings and Cements

	Number of Plants	Gallons Produced (1985)
TOTAL	68	75,977,365

Source: ICF 1986

mineral. Hence, manufacturers have been forced to replace asbestos with a combination of substitute materials, including cellulose, polyethylene, and ceramic fibers, and clay, talc, wollastonite, calcium carbonate (limestone) and silica gel thickeners (ICF 1986; Krusell and Cogley 1982). The substitute products can be grouped into three major categories according to the type of non-asbestos substitute used:

- cellulose fiber mixtures,
- polyethylene fiber mixtures, and
- other mixtures (ICF 1986).

The current market share of the different substitute formulations is presently unknown and our attempt to project the market shares in the event of an asbestos ban relies more on the informed judgement of industry experts rather than hard numbers. Industry has indicated that asbestos-free roof coatings and cements account for between 20 and 50 percent of the market today. Nevertheless, it is evident from the survey that the market share of asbestos-free roofing products is increasing rapidly as more and more companies replace asbestos. In an effort to gain a portion of the growing non-asbestos market, many manufacturers price their non-asbestos formulations the same as the traditional asbestos-containing products, even though non-asbestos formulations cost from 2 to 37 percent more to produce (ICF 1986).

The description of substitute mixtures is divided into two parts: a description of the fiber replacing asbestos (section a), followed by a description of the roof coatings and cements formulations made using that fiber (section b).

1. Cellulose Fiber Mixtures

a. Cellulose Fibers

Cellulose fibers are generally milled from recycled or unused newsprint in the presence of such additives as kaolin clay, calcium carbonate, or talc. The additives ease grinding, prevent fires during processing, and are normally at least 10 percent by weight of the final product. Fiber lengths vary from 0.02 to 0.5 inch lengths depending on the desired viscosity and ease in dispersion -- the greater the length of fiber, the greater the viscosity, yet the harder the dispersion in asphalt (American Fillers & Abrasives 1986).

Two of the largest producers of cellulose fibers for roof coatings and cements are Custom Fibers International of Los Angeles and American Fillers and Abrasives of Bangor, Michigan. Custom Fibers International produces cellulosic fibers for asbestos replacement in coatings and cements. Their current total capacity for three plants nationwide is approximately 10,000 tons per year (Custom Fibers International 1986). Their product, CF-32500 (R) fiber, is a 75 percent cellulose fiber which has extremely high oil absorbtion capabilities and is used as a substitute fiber in asphalt roof coatings and cements. It is recommended for improving the viscosity, sag resistance, and fiber reinforcement of coating compounds to which it is added (Custom Fibers California 1986). American Fillers & Abrasives of Bangor, Michigan manufactures a range of cellulose fiber products, of which the Kayocel KA690 (R) is a superfine, rapid dispersing fiber containing 90 percent cellulose and 10 percent calcium carbonate. According to the manufacturer, Kaocel fibers can be used to manufacture a stable and uniform roof coating (American Fillers & Abrasives 1986).

b. Cellulose Fibered Roof Coatings and Cements

Manufacturers of cellulose fibered roof coatings and cements consider their specific formulations proprietary. However, producers of cellulose fibers indicate that their fibers are usually used, in combination with clay and mineral thickeners, in concentrations of between 1 and 3 percent for roof coatings, and 3 and 5 percent for roofing cements (American Fillers &

Abrasives 1986; Custom Fibers International 1986). Custom Fibers suggest a starting formulation for an asbestos-free roof coating includes the following:

Asphalt cutback
Surfactant
Attapulgite clay
Talc or calcium carbonate
CF Fibers 32500 (R)

The CF-32500 (R) cellulose fiber, at increased concentration, can also be used for asbestos replacement in an asphalt plastic roof cement in the following formulation: (Custom Fibers California 1986).

Asphalt cutback
Surfactant
Bentonite clay
Talc
CF Fibers 32500

More than 16 companies currently produce cellulose containing roof coatings and cements. Table 2 identifies additional manufacturers of cellulose containing roofing compounds (ICF 1986).

Gardner Asphalt produces asbestos free products that contain a proprietary formulation of cellulose fibers and inorganic thickeners. According to company officials, the formulation costs more to produce and yields an inferior product. However, they do indicate that consumers could switch completely to the substitute formulation if the asbestos product was made unavailable (Gardner Asphalt 1986).

Gibson-Homans Corporation of Twinsburg, Ohio, substituted for asbestos in both their aluminum and standard black roofing products with a mixture of cellulose fibers, kaolin clays, crushed limestone, sodium silicates and water in April, 1986. Initially losing some of their sales due to adhesion,

Table 2. Manufacturers of Cellulose Fibered Roof Coatings and Cements

Manufacturer	Location
American Lubricants Company	Dayton, Ohio
American Tar Company	Seattle, Washington
Asphalt Products Oil Corporation	Long Beach, California
Elixir Industries	Elkhart, Indiana
Gardner Asphalt	Tampa, Florida
The Garland Company	Cleveland, Ohio
Gibson-Homans Corporation	Twinsburg, Ohio
Grundy Industries	Joliet, Illinois
Kool Seal Incorporated	Twinsburg, Ohio
Midwest/Gulf States Incorporated	Chicago, Illinois
National Varnish Company	Detroit, Michigan
Parr Incorporated	Cleveland, Ohio
Russel Standard Corporation	Atlanta, Georgia
Southwestern Petroleum Corporation	Fort Worth, Texas
S.W. Petro-Chem Incorporated	Olathe, Kansas
Tremco Incorporated	Cleveland, Ohio

Source: ICF 1986

reinforcement, and application problems, company officials indicate that reformulations with the same ingredients are expected to retrieve previous customers by early 1987. While production costs have increased due to added material, freight, and maintenance costs, profit margins have been trimmed to retain the same price charged for previously produced mixtures containing asbestos (Gibson-Homans 1986).

Midwest/Gulf States no longer produces asbestos containing products and agrees that consumers could switch to cellulose containing roofing compounds if asbestos was banned. However, prices would probably rise. Currently, cellulose containing roof coatings and cements are priced higher than their previous asbestos containing counterparts (Midwest/Gulf States 1986).

American Tar Company produces both asbestos and cellulose based roof coatings. They indicate that the cellulose containing coating costs more to produce but is currently priced the same as the asbestos based product (American Tar Company 1986).

Although cellulose fiber roof coatings are gaining in popularity, manufacturers of these products have cited some problems with the production and result of these cellulose formulations:

- the cellulose fibers formulations are difficult to mix requiring additional ingredients such as clays and talcs;
- the formulations may sag and run on a steep surfaces;
- the formulations may require additional application time, and;
- the formulations cost between 2 and 37 percent more to produce than asbestos mixtures.

Despite these problems manufacturers of asbestos containing roof coatings and cements recommend cellulose fibered formulations more than any other non-asbestos mixture (ICF 1986a).

Cellulose bodied roof coatings and cements have been in production for only six years. However, both the producers of cellulose fibers and those manufacturers who mix the fibers into roofing compounds indicate that successful formulations have so far lasted six years with no sign of deterioration or sag. Consequently, they claim that cellulose fibered roofing compounds are likely to have the same life as asbestos containing products.

Cellulose fibered formulations in combination with clay and mineral thickeners are estimated to capture 87 percent of the roof coating and cement market as a result of an asbestos ban (see Attachment A). Prices would be expected to rise 18.5 percent (see Attachment B) to $2.95 per gallon due to increased material and production costs (ICF 1986).

2. Polyethylene Fiber Mixtures

a. Polyethylene Fibers

Polyethylene fibers are strong, durable, high surface area, short length fibrils that increase viscosity and improve crack and slump resistance in all types of coatings and cements. Hercules of Wilmington, Delaware and Minifibers of Johnson City, Tennessee are two of the largest producers of raw polyethylene fibers used by manufacturers of non-asbestos roof coatings and cements. Hercules produces Pulpex polyolefin pulps at its Deer Park, Texas plant. The capacity of this single plant is approximately 27,500 tons per year. Pulpex E (R) (Grades D-H) is a dry fluff polyethylene pulp that is an effective replacement for asbestos in roof coatings and cements formulated with thickening clays (Hercules 1983). Minifibers' Short Stuff (R) are high density, highly branched polyethylene fibers. These fibers also increase viscosity and impart significant crack resistance. Minifibers' current output is approximately 4,000 tons per year, although they indicate the potential to quadruple this output within 180 days (Minifibers 1986a).

b. Polyethylene Fibered Roof Coatings and Cements

While roof coatings and cements manufacturers consider their asbestos free formulations proprietary, Hercules and Minifibers, suppliers of these fibers, indicate that polyethylene fibers are used in concentrations of between 1 and 3 percent and in conjunction with clays and other fillers (Minifibers 1986b; Hercules 1983).

According to Hercules, a possible starting formulation for an asbestos-free roof coating includes:

Asphalt cutback (65% solids)
Surfactant
Attapulgite clay
Talc
Pulpex E (R) (D-H)

(Hercules 1983). Minifibers recommends a slightly different formulation for an asbestos-free roof coating containing:

Asphalt cutback (65% solids)
Bentonite clay
Rubber (30 mesh)
Calcium carbonate
Mineral Spirits
Short Stuff (R) Polyethylene

(Minifibers 1986b). Pulpex E (R) (D-H) is recommended at increased levels as a replacement fiber in an asphalt roofing cement formulation containing the following:

Asphalt cutback (65% solids)
Surfactant
Attapulgite clay
Talc
Pulpex E (R) (D-H)

(Hercules 1983).

At least 8 manufacturers of roof coatings and cements have either partially or completely substituted asbestos with polyethylene fibers, in combination with clay and talc fillers, in their roof coatings and cements. While the raw fibers cost 3 or 4 times more than cellulose fibers on an equivalent basis, they are favored by manufacturers of aluminum roof coatings. Unlike cellulose fibers, polyethylene fibers do not contain water which can react with aluminum, forming a dangerous hydrogen gas, eventually resulting in the lids of containers blowing after only six months of storage (Missouri Paint & Varnish 1986). To guarantee a long shelf life many manufacturers of aluminum roof coatings such as Missouri Paint & Varnish and Columbia Paint Corporation use polyethylene fiber formulations (ICF 1986). Table 3 identifies some of the numerous manufacturers of polyethylene fibered roof coatings and cements.

Missouri Paint & Varnish has discontinued asbestos processing completely in 1986 and substituted it with polyethylene fibers in combination with clay and talc fillers. They estimate that aluminum roof coatings with polyethylene fibers cost one-third more to produce than asbestos bearing counterparts (Missouri Paint & Varnish 1986). Columbia Paint Corporation estimates that the prices of the roof coatings and cements have increased over 25 percent as a result of their decision to reformulate their asbestos containing products with polyethylene fibers (Columbia Paint 1986).

Manufacturers of non-asbestos roof coatings and cements whose formulations include polyethylene fibers have indicated some problems producing the formulations.

- The polyethylene fiber formulations are difficult to mix requiring other ingredients such as clay and talc;
- The formulations are not as strong due to the reduced tensile strength of the fibers;
- The formulations cost more to produce; and,
- Their long term performance is still unknown since their life on the market has been relatively short -- 5 yrs.

Many current and former asbestos processors have encountered difficulties in replacing asbestos formulations with polyethylene formulations in some roofing

Table 3. Manufacturers of Polyethylene Fibered Roof Coatings and Cements

Manufacturer	Location
Columbia Paint Corporation	Huntington, West Virginia
Missouri Paint & Varnish Company	St. Louis, Missouri
Parr Incorporated	Cleveland, Ohio
Russel Standard Corporation	Bridgeville, Penn.
Sampson Coatings Incorporated	Richmond, Virginia
S.W. Petro-Chem Incorporated	Olathe, Kansas
Texas Refinery Corporation	Fort Worth, Texas
Tremco Incorporated	Cleveland, Ohio

Source: ICF 1986.

compounds. These formulations have, however, been successful in replacing asbestos in aluminum roof coatings. As more manufacturers of aluminum roof coatings decide to replace asbestos (either due to increased insurance costs or fear of government regulation), the use of polyethylene formulations is expected to increase (ICF 1986).

Polyethylene fibers in combination with clay and mineral thickeners are estimated to account for 15 percent of the roof coatings and cements market as a results of a ban on asbestos (see Attachment A). Manufacturers of aluminum roof coatings are expected to be the largest producers of these formulations. Prices of roof coatings and cements bodied with polyethylene fibers would possibly rise 35 percent (see Attachment B) to $3.36 per gallon reflecting the increased material and production costs (ICF 1986).

3. Other Mixtures

a. Clays, Mineral Fillers, Silica Gels, and Ceramic Fibers

Clays, such as attapulgite, bentonite, and kaolin, are all excellent thixotropes.[3] However, they make poor reinforcers and hence, are usually used in combination with substitutes such as cellulose and polyethylene fibers to produce a desired viscosity in asbestos-free roof coatings and cements. Clay thickeners are used at levels ranging from 2 to 8 percent, by weight, and are almost always used with surfactants[4] (Engelhard, n.d.). Engelhard Corporation of Menlo Park, New Jersey and Floridin Company

[3] Thixotropy is the property exhibited by certain gels that causes a mixture to liquefy when stirred and reharden when left stationary. The gelling or thixotropic characteristics of these clay additives impart high viscosity at low shear rates which helps in maintaining mix uniformity during processing, packaging, and application; and low viscosity at high shear rates making application easier (Floridin 1986).

[4] Surfactants, such as cationic quarternarium salts, are required to modify the surface charge of the attapulgite thickener aiding optimal wetting and dispersion of the clay in the asphalt (Engelhard n.d.).

of Berkeley Springs, West Virginia are the major producers of clay thickeners used by manufacturers of non-asbestos roof coatings and cements.

Engelhard produces Attagel 36 (R), a low cost thixotrope used frequently by manufacturers of non-asbestos roof coatings and cements. Derived from attapulgite clay, the thickener provides thixotropic properties in asphalt coatings and cements superior to asbestos. According to Engelhard, roof coatings and cements exhibit better sag resistance, easier application, and better spraying characteristics than comparable asbestos containing formulations (Engelhard n.d.). Min-U-Gel AR (R), is a similar attapulgite based gelling product manufactured by Floridin Company. Designed for thickening asphalt based coatings and cements, the product delivers superior stability, application, and sag resistance to roofing products than asbestos according to Floridin (Floridin 1986). Southern Clay Products' Claytone 34 (R), and NL Chemicals' Bentone 34 (R), both processed from bentonite clay, are more expensive thixotropes used in asbestos-free roof coatings and cements (ICF 1986).

Mineral fillers such as talc, wollastonite, and limestone are not thixotropes, but act as inexpensive thickeners. They do not have strong reinforcing characteristics and are usually used, at concentrations ranging from 10 to 25 percent, in combination with cellulose and polyethylene fibers to replace asbestos (ICF 1986; American Fillers & Abrasives 1986; Hercules 1983).

Silica gels, such as Cab-o-Sil (R) fumed silica, are good thixotropes, providing the necessary viscosity control in asphalt compounds. However, the gels do not possess the reinforcing capability of either asbestos or substitute fibers (Cabot 1986).

Ceramic fibers are used to increase viscosity and provide asphalt reinforcement.

b. Other Roof Coatings and Cements

Only three companies are currently producing substitute roof coatings and cements that do not contain cellulose or polyethylene fibers. Coopers Creek Chemical Corporation, a small manufacturer of asbestos containing roof coatings in 1985, has completely replaced asbestos with attapulgite clay in 1986. They indicate that the performance of the coating is comparable to the previous asbestos based one, but that the formulation is slightly more expensive to produce (Coopers Creek Chemical 1986). Silica has replaced asbestos in all roof coatings and cements produced by Douglas Chemical of Richmond, Virginia (Douglas Chemical 1986). B.F. Goodrich, Akron, Ohio, indicated that ceramic fibers have been used to formulate an asbestos-free counterpart to their asbestos roof coating. Company officials reported that the mixture costs 5 percent more to produce (B.F. Goodrich 1986). No manufacturers are currently producing roof coatings and cements solely with mineral fillers (ICF 1986).

Formulations not containing either cellulose or polyethylene fibers, but rather clay thickeners, mineral fillers, silica gels, and ceramic fibers are estimated to have only 7 percent of the market resulting from an asbestos ban (see Attachment A). Prices of these compounds could rise perhaps 21.5 percent (see Attachment B) to $3.03 per gallon (ICF 1986).

E. Summary

It appears that substitutes for asbestos containing roof coatings and cements currently exist. However, these products cost more to produce and may not perform as well. Asbestos is unique among known raw minerals because of its combination of strength, viscosity control, and price. Since no across the board substitute fiber exists for the mineral, manufacturers have been forced to replace asbestos with a combination of substitute materials, including cellulose, polyethylene, and ceramic fibers, and clay, talc, wollastonite, calcium carbonate, and silica gel thickeners.

The estimation of market shares and prices of the substitute formulations in the event of an asbestos ban relies to a large degree upon educated judgments of industry experts. Table 4 summarizes the findings of this analysis, and presents the data for the Asbestos Regulatory Cost Model.

If asbestos was made unavailable, perhaps 87 percent (see Attachment A) of the asbestos containing roofing compounds market would be taken by formulations containing cellulose fibers in combination with clay and mineral thickeners. Identified most often by current and former asbestos processors and Gardner Asphalt, a company with a large share of asbestos containing roofing products market, this replacement fiber is cheaper than polyethylene fiber and seems to perform adequately in reinforcement. Prices would be expected to rise 18.5 percent (see Attachment B) to $2.95 per gallon due to increased costs of production (ICF 1986). Formulations containing polyethylene fibers, in conjunction with clay and mineral thickeners, are estimated to account for 8 percent of the asbestos-based roofing compounds (see Attachment A). These fibers costing 3 or 4 times more than cellulose on an equivalent basis tended to be favored by manufacturers of aluminum roof coatings. Prices of formulations bodied with polyethylene fibers would likely rise 35 percent (see Attachment B) to $3.36 per gallon due to increased costs (ICF 1986). The remaining 5 percent would be divided between other formulations containing clays, mineral fillers, silica gels, and ceramic fibers (see Attachment A). Prices of these compounds could be expected to rise 21.5 percent (see Attachment B) to $3.03 per gallon (ICF 1986).

Table 4. Data Inputs for Asbestos Regulatory Cost Model

Product	Output	Product Asbestos Coefficient	Consumption Production Ratio	Price	Useful Life	Equivalent Price	Market Share	Reference
Asbestos Mixture	75,977,365	0.00039 tons/gal	1.0	$2.49/gal	10 years	$2.49/gal	N/A	ICF 1986[a]
Cellulose Fiber Mixture	N/A	N/A	N/A	$2.95/gal	10 years	$2.95/gal	87.42%	ICF 1986[a]
Polyethylene Fiber Mixture	N/A	N/A	N/A	$3.36/gal	10 years	$3.36/gal	7.62%	ICF 1986[a]
Other Mixtures[b]	N/A	N/A	N/A	$3.03/gal	10 years	$3.03/gal	4.95%	ICF 1986[a]

N/A: Not Applicable.

[a]See Appendix A and B.

[b]Includes clay, silica, and ceramic fiber mixtures.

ATTACHMENT A

PROJECTED MARKET SHARES ANALYSIS BASED ON 1985 PRODUCTION OF ASBESTOS ROOF COATINGS AND CEMENTS

Substitute Fiber/Material	Manufacturer(s)	Production Which Would Likely Switch to Substitute	Projected Market Share (subtotal/Grant Total x 100)
Cellulose	American Lubricants		
	American Tar		
	Asphalt Products		
	Elixir (Elkhart, IN)		
	Gardner Asphalt		
	Gibson-Homans		
	Grundy		
	Kool Seal		
	Midwest-Gulf States		
	National Varnish		
	Parr, Inc.[a]		
	Russel[a]		
	Southwestern Petroleum		
	S.W. Petrochemical[b]		
	Tremco[a]		
	Subtotal 1	44,082,488	87.42%
Polyethylene	Columbia Paint		
	Koch Asphalt		
	Missouri Paint and Varnish		
	Parr, Inc.[a]		
	Russel[a]		
	Schaefer Manufacturing		
	S.W. Petrochemical[a]		
	Tremco[a]		
	Subtotal 2	3,844,678	7.62%
Other	B.F. Goodrich		
	Coopers Creek Chemical		
	Elixir (Gardena, CA)		
	Parr, Inc.[a]		
	Russel[a]		
	Tremco[a]		
	Subtotal 3	2,498,318	4.95%
	Grand Total	50,425,484	100.00%

[a]These companies indicated they use all three substitute materials depending upon the product. For the purpose of this analysis, we have divided their production equally between the three substitutes.

[b]This company indicated that it uses cellulose and polyethylene as a substitute material depending upon the product. For the purposes of this analysis, we have divided their production equally between the two substitutes.

ATTACHMENT B

PROJECTED PRICES ANALYSIS BASED ON AVAILABLE PRICE DIFFERENTIALS BETWEEN ASBESTOS CONTAINING AND NON-ASBESTOS ROOFING COATINGS AND CEMENTS

Substitute Fiber/Material	Manufacturer(s)	Production (1985)	Current or Probable Price Increase[a] (%)	Average Price Increase[b] (%)
Cellulose	American Lubricants			
	American Tar			
	Asphalt Products			
	Gardner Asphalt			
	Gibson-Homans			
	Grundy			
	Kool Seal			
	Midwest-Gulf States			
	National Varnish		—	
	Subtotal 1	40,732,635		18.5
Polyethylene	Columbia Paint and Oil			
	Missouri Paint and Varnish		—	
	Subtotal 2	256,000		35.0
Other	B.F. Goodrich			
	Coopers Creek Chemical			
	Elixir (Gardena, CA)		—	
	Subtotal 3	373,000		21.5

[a] Many manufacturers currently price non-asbestos formulations the same as asbestos containing mixtures. For the purpose of this analysis, we have inserted the increase cost of production when necessary.

[b] The average price increase was determined by calculating a weighted average of individual price increases of non-asbestos over asbestos containing roof coatings and cements using 1985 asbestos containing production levels.

REFERENCES

American Fillers & Abrasives Inc. E Neckerman. 1986 (October 30). Bangor, MI. Transcribed telephone conversations with Jeremy Obaditch, ICF Incorporated, Washington, DC.

American Tar Co. D. Distler. 1986 (July-December). Seattle, WA. Transcribed telephone conversations with Jeremy Obaditch and Peter Tzanetos, ICF Incorporated, Washington, DC.

B.F. Goodrich Co. R. Hefner. 1986(July-December). Akron, OH. Transcribed telephone conversations with Jeremy Obaditch and Peter Tzanetos, ICF Incorporated, Washington, DC.

Cabot Corp. S. Jesseph. 1986 (October 28). Tuscola, IL. Transcribed telephone conversation with Jeremy Obaditch, ICF Incorporated, Washington, DC.

Columbia Paint Corp. R. Flowers. 1986 (July-December). Huntington, WV. Transcribed telephone conversations with Jeremy Obaditch and Rick Hollander, ICF Incorporated, Washington, DC.

Coopers Creek Chemical Co. A. Morris. 1986 (July-December). West Conshohocken, PA. Transcribed telephone conversations with Rick Hollander, ICF Incorporated, Washington, DC.

Custom Fibers California. 1986. Product Literature. Asbestos Replacement Fibers for Industry. Benecia, CA.

Custom Fibers International. Representative. 1986 (November 3). Los Angeles, CA. Transcribed telephone conversation with Jeremy Obaditch, ICF Incorporated, Washington, DC.

Douglas Chemical Company Inc. M. Clarke. 1986 (July-December). Richmond, VA. Transcribed telephone conversations with Rick Hollander, ICF Incorporated, Washington, DC.

Engelhard Corporation. (n.d.). Product Literature. Attagel(R)-36 Asphalt Thickener For Use In Cutback Coatings. Menlo Park, NJ.

Floridin Company. 1986. Product Literature. Min-U-Gel(R) AR - A Specialty Attapulgite Thickener For Asphalt Cutbacks. Berkeley Springs, WV.

Gardner Asphalt Corp. A. Perry. 1986(July-December). Tampa, FL. Transcribed telephone conversations with Eric Crabtree and Jeremy Obaditch, ICF Incorporated, Washington DC.

Gibson-Homans Corp. J. Slovski. 1986(July-December). Twinsburg, OH. Transcribed telephone conversations with Eric Crabtree and Jeremy Obaditch, ICF Incorporated, Washington, DC.

Hercules Inc. 1983 (April 11). Wilmington, DE. Letter to C Carter, General Services Administration, Office of Federal Supply and Services, Washington, DC.

ICF Incorporated. 1986 (July-December). Survey of Primary and Secondary Processors of Asbestos Roof Coatings and Cements. Washington, DC.

Krusell N, Cogley D. 1982. GCA Corp. Asbestos Substitute Performance Analysis. Revised Final Report. Washington, DC: Office of Pesticides and Toxic Substances, U.S. Environmental Protection Agency. Contract No. 68-02-3168.

Midwest/Gulf States Inc. B. Reed. 1986(July-December). Chicago, IL. Transcribed telephone conversations with Michael Geschwind, ICF Incorporated, Washington, DC.

Minifibers Inc. R. Lawson. 1986a (November 3). Johnson City, TN. Transcribed telephone conversation with Jeremy Obaditch, ICF Incorporated, Washington, DC.

Minifibers Inc. 1986b. Product Literature. Minifibers. Johnson City, TN.

Missouri Paint & Varnish. A. Gross. 1986 (July-December). St. Louis, MO. Transcribed telephone conversations with Michael Geschwind and Jeremy Obaditch, ICF Incorporated, Washington, DC.

XXX. NON-ROOFING ADHESIVES, SEALANTS, AND COATINGS

A. Product Description

Asbestos containing non-roofing[1] adhesives, sealants, and coatings are used primarily in the building construction, automobile, and aerospace industries. These products are in most cases specialty products that are manufactured for specific applications.

The construction industry is one of the largest consumers of asbestos containing adhesives, sealants, and coatings. These include:

- Adhesives and cements, generally containing 1 to 5 percent asbestos, manufactured to bond a variety of surfaces such as brick, lumber, mirror, and glass.
- Liquid sealants, containing 1 to 5 percent asbestos, used for waterproofing and sound deadening interior walls.
- Semi-liquid glazing, caulking, and patching compounds, containing 5 to 25 percent asbestos, applied with a caulking gun or putty knife, to seal around glass in windows, joints in metal ducts, and bricks adjacent to other surfaces.
- Asphalt based coatings, containing 5 to 10 percent asbestos, produced to prevent the decay of underground pipes, and corrosion of structural steel in high humidity environments, such as paper mills.

Asbestos is used as a filler because it has a low price, high strength characteristics, fibrous network that prevents sagging in application, and excellent viscosity control (ICF 1986a; Krusell and Cogley 1982).

The automobile industry historically used asbestos in a wide variety of adhesive, sealant, and coating applications. However, the industry has been able to find effective substitutes for most of the general uses, and the remaining uses of asbestos are limited to specialized products such as:

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[1] Since roof coatings and cements account for 90 percent of all asbestos containing adhesives, sealants and coatings compounds in 1985 (ICF 1986a), these products are discussed separately under the Roof Coatings and Cements category in Chapter XXIX (ICF 1986a).

- Epoxy adhesives, containing 5 percent asbestos, used for specialized bonding, such as hood braces.
- Butyl rubber and vinyl sealants containing 2 to 5 percent asbestos, applied over welds for corrosion protection and aesthetic purposes.
- Vehicle undercoatings to prevent corrosion and excessive road noise.

Asbestos content in these compounds provides the necessary viscosity control, corrosion resistance, and sound deadening characteristics (ICF 1986a).

The aerospace industry uses asbestos in extremely specialized applications such as firewall sealants and epoxy adhesives. Asbestos content varies between 5 and 20 percent depending upon use and military specification. The excellent heat resistant characteristics of the fiber make it a useful filler in these high temperature adhesives, sealants, and coatings (ICF 1986a).

Traditional asbestos-containing products such as texture paints[2] and block filler paints[3] no longer contain the fiber. In many cases this is the result of the 1977 Consumer Product Safety Commission ban[4] on consumer patching compounds containing respirable freeform asbestos. Many of the same companies that were manufacturing patching compounds were also producing asbestos containing paints. Faced with the prospect of removing asbestos from one product line, they decided to remove asbestos from all products, as far as feasible, because of the potential liability involved in placing an asbestos containing product in the consumer marketplace (NPCA 1986; ICF 1986a; Krusell and Cogley 1982).

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[2] Texture paints are heavily bodied paints which can be patterned or textured to simulate a stucco surface on interior ceilings and walls for aesthetic design.

[3] Block filler paints are used to coat masonry and other stone surfaces.

[4] Consumer Product Safety Commission. Title 16, Chapter IV, Part 1304. Ban of Consumer Patching Compounds Containing Respirable Freeform Asbestos.

Adhesives, sealants, and coatings are all manufactured by essentially similar processes. There may be one or more production lines, each dedicated to a specific product for the length of time necessary to produce the required inventory of that product. Production is normally a batch process. Bagged asbestos is moved from storage and dumped into a fluffing machine that is used to separate the fibers that may be compressed together. The fibers are then generally transferred to a batch mixing tank and combined with other dry ingredients such as pigments, fillers, and stabilizers. Solvents or resins are added and all the ingredients are mixed until even dispersion is obtained. The batch is then sent to a packaging operation where the mixture may be placed in 5 or 55 gallon metal pails with lids, or in smaller containers and tubes. Batch sizes vary from a few gallons to several thousand gallons depending on the size and number of production lines, the order or inventory size necessary to satisfy projected sales, the type of the product, and the packaging method (ICF 1986a; Krusell and Cogley 1982).

B. Manufacturers of Non-Roofing Adhesives, Sealants, and Coatings

In 1985, 51 companies operating 66 plants nationwide produced approximately 9.6 million gallons[5] of asbestos containing non-roofing adhesives, sealants and coatings. These companies consumed 2,951 tons of fiber (less than 2 percent of the 145,300 tons of total asbestos consumed in 1985 for all product applications).

The percentage of fiber consumed per unit output varied considerably because almost every company manufactured a different product. Table 1

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[5] Four of the 51 companies producing asbestos containing non-roofing adhesives, sealants, and coatings in 1985 refused to provide production and fiber consumption data for their 13 plants in operation. Their production volume and fiber consumption have been estimated using the method described in Appendix A and are included in the totals listed above.

Table 1. Production of Asbestos Non-Roofing Compounds

	Tons Fiber Consumed (1985)	Gallons Produced (1985)
Total	2,951.4	9,612,655

Source: ICF 1986a.

lists the tons of fiber consumed and the total gallons produced in 1985 (ICF 1986a).

Non-roofing asbestos containing adhesives, sealants, and coatings production was estimated to be 9.6 million gallons. At an average price of $13.90/gallon, this market is estimated to be worth $133.6 million. While actual prices varied greatly from a low of $1.90 to a high of $3,824, 80 percent of the products were priced at less than $30 per gallon (ICF 1986a).

C. Trends

The number of asbestos-based non-roofing adhesives, sealants, and coatings manufacturers declined steadily from 1981 until 1985. During those four years 28 companies (35 percent), formerly producing asbestos containing compounds, either substituted asbestos with other materials or discontinued their operation. By the end of 1986, 21 of the 51 companies that processed asbestos in 1985 had ceased processing asbestos because of rising insurance premiums, customer pressure to remove asbestos, and the possibility of regulatory action. These companies, while only accounting for 15 percent of output, were some of the largest consumers of asbestos (accounting for 29 percent of fiber consumption in 1985) (ICF 1986a).

D. Substitutes

Asbestos is unique among known raw minerals because it is a chemically inert, durable mineral that can be processed into a fiber. The fibrous quality of this mineral delivers both strength and viscosity control to a liquid or semi-liquid medium. The strong fibrous network and adsorption ability of asbestos binds the mixture together preventing a compound from running or sagging in application. Asbestos also imparts thixotropic[6] properties causing a mixture to gel. No one substitute has been found to simultaneously duplicate the unique characteristics of asbestos. Hence, manufacturers attempting substitution have been forced to replace asbestos with a combination of substitute fibers and fillers. Fibers such as polyolefin, aramid, cellulose, processed mineral, glass, carbon, and phosphate have been used to provide reinforcement and sag resistance. Fillers, such as clay, talc, wollastonite, mica, calcium carbonate (limestone), and silica gels have been used to provide viscosity control.

Since non-roofing mixtures containing asbestos are produced for numerous specialty applications, the current market share of non-asbestos substitutes is unknown. Our attempt to project the market shares in the event of an asbestos ban relies more on informed judgement of industry experts rather than hard numbers. Nevertheless, it is evident from the survey, that the market share of asbestos-free formulations is increasing rapidly as more and more companies replace asbestos in their formulations.

Manufacturers use a trial and error procedure to arrive at an adequate substitute formulation for their product. Hence, it is impossible to project the possible substitute formulations at this stage when industry is still struggling to find adequate substitutes. This analysis attempts to classify the likely substitute formulations by separating them into two categories according to the dominant type of non-asbestos material used:

- fiber mixtures, and
- non-fiber mixtures (ICF 1986a).

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[6] Thixotropy is the property exhibited by certain gels which causes mixture to liquefy when stirred and reharden when left stationary. Asbestos, as a thixotrope, imparts high viscosity at low shear rates helping to maintain mix uniformity during processing, packaging and storage; and low viscosity at high shear rates making application easier.

The description of each substitute mixture is divided into two parts: a description of the substitute fiber(s) or material(s) replacing asbestos (section a), and a description of the actual formulations (and manufacturers) of non-asbestos adhesives, sealants and coatings (section b).

1. Fiber Mixtures

a. Synthetic, Cellulose, and Other Fibers

Synthetic fibers, such as polypropylene and polyethylene, aramid, and polyester fibers have all been used to increase viscosity and lend strength and sag resistance to sealant and coating compounds so that they remain stationary on vertical surfaces and do not melt or run as a result of heat. They are frequently used in conjunction with fillers such as talc and clay in amounts one-tenth that of asbestos (Hercules 1983; DuPont 1986). Hercules and DuPont of Wilmington, Delaware and Minifibers of Johnson City, Tennessee are three of the largest manufacturers of synthetic fibers used by manufacturers of asbestos-free non-roofing adhesives, sealants, and coatings.

Hercules' Pulpex (R) polyolefin pulps are high surface area, short length fibrils that increase viscosity and improve crack and slump resistance in many types of applications (Hercules 1983). Minifibers' Short Stuff (R) fibers are similar high density, highly branched polyethylene fibers that increase viscosity and impart significant crack resistance. Used at levels between 1 and 2 percent, by weight, in conjunction with talc and thickening clays, these fibers are frequently used substitutes for asbestos in various adhesives, sealants, and coatings formulations (Minifibers 1986). DuPont's Kevlar (R) aramid pulp is finding increased usage as an effective replacement for asbestos in a number of different applications. In tire sealants and oil well seals, Kevlar provides the necessary viscosity control at concentrations of about 1 percent. DuPont also indicates that Kevlar(R) pulp has been specified for use in 5 rocket programs with others currently under review (Dupont, 1986).

Cellulose fibers are another popular substitute fiber. These high liquid absorbing fibers, milled from recycled and unused newsprint provide viscosity control, sag resistance, and fiber reinforcement. Cellulose fibers are often used at concentrations of about 3 to 5 percent, in conjunction with thickening clays and talcs (American Fillers & Abrasives 1986). American Fillers & Abrasives of Bangor, Michigan, Custom Fibers International of Los Angeles, and James River Corporation of Hackensack, New Jersey all produce cellulose fibers for asbestos replacement in non-roofing adhesives, sealants, and coatings.

Other fibers such as fiberglass, ceramic, carbon, phosphate and processed mineral have also been used to replace asbestos in products where strength, sag, heat, and fire resistance are needed.

b. <u>Substitute Fibrous Adhesives, Sealants, and Coatings</u>

More than 23 companies currently produce non-asbestos substitutes for their currently or previously produced asbestos containing products using polyolefin, polyester, aramid, cellulose, processed mineral, glass, ceramic, carbon or phosphate fibers.

The major manufacturers of non-roofing compounds that substitute some or all of their asbestos with these fibers are Mameco International, Palmer Products, Pecora, Gibson-Homans, and Flamemaster. Table 2 identifies additional manufacturers of non-asbestos fibered compounds (ICF 1986a).

Mameco International, a manufacturer of specialty caulking compounds, indicated that substituting asbestos has been extremely difficult. None of the substitute fibers both adsorb and absorb the semi-liquid medium used in their formulations. As a result, sagging has occurred after a period of time on hot surfaces. Polyethylene fibers are currently being used in substitute

Table 2. Manufacturers of Substitute Fibered Non-Roofing Compounds

Manufacturer	Location
Bacon Industries Inc. of California	Irvine, California
Chemseco Incorporated	Kansas City, Missouri
Cobitco Incorporated	Denver, Colorado
Dolphin Paint & Chemical Company	Toledo, Ohio
Flamemaster Corporation	Sun Valley, California
Frost Paint & Oil Corporation	Minneapolis, Minnesota
The Garland Company	Cleveland, Ohio
Gibson-Homans Corporation	Ennis, Texas
H.B. Egan Manufacturing Company	Muskogee, Oklahoma
Hercules Incorporated	McGregor, Texas
Industrial Gasket & Shim Company	Meadowlands, Pennsylvania
Intercostal Division	Union City, California
J.C. Dolph Company	Monmouth Junction, NJ
Kent Industries	Fort Worth, Texas
Maintenance Incorporated	Wooster, Massachusetts
Mameco International	Cleveland, Ohio
Palmer Products Corporation	Louisville, Kentucky
Pecora Corporation	Harleysville, PA
Pfizer Incorporated	Easton, Pennsylvania
Products Research & Chemicals Corp.	Glendale, California
Protective Treatments Incorporated	Dayton, Ohio
Russel Standard Corporation	Atlanta, Georgia
Sterling-Clark-Lurton Corp.	Malden, Massachusetts

Source: ICF 1986a.

products which are clearly inferior, according to company officials, but which cost only fractionally more to produce (Mameco International 1986).

Palmer Products hopes to discontinue asbestos processing in 1987. Currently, they produce an asbestos-free formulation of their popular mirror and structural glass adhesive using a combination of Kevlar (R) and cellulose fibers. Company officials report that the asbestos-free formulation costs no more to produce and that consumers could switch completely to the substitute formulation with no loss in performance if the asbestos product were made unavailable (Palmer Products 1986).

Pecora Corporation produces both asbestos and cellulose fibered industrial glazing putties. Currently,.the cellulose putties are priced above the asbestos containing products. Pecora indicated that since their substitute product has been on the market for only one year, they are unsure, at this time, whether consumers could completely switch to the asbestos-free formulations if the asbestos product were made unavailable. However, they expect accelerated testing results to reveal a comparable service life for the non-asbestos compounds (Pecora 1986).

Gibson-Homans recently replaced asbestos in their sewer joint compound with a combination of cellulose fibers, kaolin clay, crushed limestone, sodium silicates and water. Company officials indicated that the reformulated compound had no shortcomings in performance and that its introduction did not result in any lost sales. However, company officials indicated that the new formulation costs more to produce. As a result, profit margins have been trimmed to retain the same price charged for the previously produced mixtures containing asbestos (Gibson-Homans 1986).

Flamemaster has replaced 70 percent of their asbestos containing high temperature military coatings in 1985. The coatings are applied to ground support vehicles to shield heat from missile firings. Asbestos has so far been substituted with carbon fibers. The remaining asbestos is expected to be replaced with phosphate fiber pending military specification testing, and clearance (Flamemaster 1986).

Although non-asbestos fibered compounds are rapidly replacing the remaining specialty formulations that still contain asbestos, manufacturers have encountered several difficulties:

- The formulations are difficult to mix and require additional ingredients such as clays and talc.
- The formulations may sag or run in application.
- The formulations lack corrosion and fire resistance requiring additional chemical additives.
- The formulations may dry too quickly because the synthetic fibers do not absorb water.
- The formulations cost from 1 to 42 percent more to product (ICF 1986a).

Regardless of these problems, manufacturers of asbestos containing non-roofing compounds recommend these fibered formulations more than any other substitute material for asbestos containing adhesives, sealants, and coatings (ICF 1986a).

Formulations containing synthetic, cellulose, and other various fibers, in combination with thickening clays and talcs, are estimated to capture 70 percent of the non-roofing adhesives, sealants, and coatings market as a result of an asbestos ban (see Attachment A). Prices would be expected to be 8.9 percent (see Attachment B) higher than the existing price of asbestos containing products. This increase, reflecting added material and production costs, would result in an estimated average price of $15.14 per gallon for the substitutes (ICF 1986a).

2. Clay and Mineral Filler Mixtures

a. Clays, Silica Gels and Other Fillers

While clay, talc, and calcium carbonate are being used in combination with various non-asbestos fibers by manufacturers of asbestos-free non-roofing adhesives, sealants, and coatings, they are also frequently being used on their own. Other similar fillers such as mica, wollastonite, and silica gel are also being used as substitutes for asbestos. Although fillers do not have the strong reinforcing characteristics of the substitute fibers, they can provide adequate viscosity control (ICF 1986a). Clay thickeners, in combination with surfactants,[7] are able to gel formulations when used at levels ranging from 2 to 8 percent by weight (Engelhard n.d.). Engelhard's Attagel (R), and Floridin's Min-U-Gel (R) are two of the most popular attapulgite-derived thickeners used by manufacturers of asbestos-free compounds. Southern Clay Products' Claytone (R) and NL Chemicals' Bentone (R) are derived from bentonite clay and possess similar characteristics to attapulgite-derived thickeners, but cost more. Silica gels, such as Cab-o-Sil (R) fumed silica by Cabot Corporation, are also used by a small number of non-roofing compounds manufacturers. The fumed silica, in concentrations of between 1 and 3 percent, acts predominantly as a thixotropic thickener, although it may be used to provide mild reinforcement to rubber sealants when used at levels greater than 5 percent (Cabot, 1986).

Other mineral thickeners, such as talc, wollastonite, calcium carbonate, and mica, provide adequate bulk and increase viscosity at a low cost to manufacturers of asbestos-free compounds. However, these fillers do not

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[7] Surfactants, such as cationic quarternarium salts, are required to modify the surface charge of a clay thickener, aiding optimal wetting and dispersion of the clay in the medium (Engelhard n.d.).

posses the thixotropic properties of either asbestos, clays, or silica gels, and are consequently unable to gel a formulation.

b. Substitute Non-Fibrous Adhesives, Sealants, and Coatings

At least 18 companies currently produce asbestos-free, non-fibered substitutes to their currently or previously produced asbestos-containing products. The major manufacturers that substitute some or all of their asbestos with clays, silica gels, and mineral thickeners are Contech, Pecora, and Widger Chemical. Table 3 identifies some additional manufacturers using these products to replace asbestos in non-roofing compounds (ICF 1986a).

Contech plans to completely discontinue the use of the fiber in 1986. Asbestos will be replaced with a washed clay that is not yet commercially available. According to Contech, the clay adhesive exhibits slightly better tensile strength for dry lumber applications, but poorer strength for wet lumber. The new formulation only costs a fraction more to produce and will be priced the same as the asbestos-based adhesive (Contech 1986).

Pecora Corporation uses bentonite clay and wollastonite in their asbestos-free caulking and patching compounds. The substitute products, which have been on the market for only one year, cost more than their asbestos-containing counterparts. Company officials indicated that these substitute products, like the substitute fibered putties, are likely to have comparable service lives to asbestos containing products (Pecora 1986).

Companies such as Riverain, Dayton Chemicals, and Hysol Aerospace have used silica gel formulations to replace some or all of their previous asbestos containing specialty compounds. Riverain Corporation currently produces some asbestos-free automotive seam sealants using fumed silica in combination with bentonite clay (Riverain 1986). Dayton Chemicals has completely replaced asbestos in their metal coating with silica in 1986, although the company officials indicated that the product does not perform as well and costs 8

Table 3. Manufacturers of Non-Fibered Substitute Non-Roofing Compounds

Manufacturer	Location
American Abrasive Metals Company	Irvington, New Jersey
Amicon Division, W.R. Grace Inc.	Danvers, Massachusetts
Contech Incorporated	Mattawan, Michigan
Dayton Chemicals Div., Whittaker Corp.	West Alexandria,
Franklin Chemical Industries	Columbus, Ohio
Futura Coatings Incorporated	Hazelwood, Missouri
Hardman Incorporated	Belleview, New Jersey
Hysol Aerospace & Industrial Adhesive Co.	Pittsburgh, California
Parr Incorporated	Cleveland, Ohio
Pecora Corporation	Harleysville, PA
PPG Industries	Adrian, Michigan
Products Research & Chemicals Corp.	Dayton, Ohio
Republic Powdered Metals Inc.	Medina, Ohio
Riverain Corporation	Dayton, Ohio
Rockwell International	Pittsburgh, Pennsylvania
Smooth-On Incorporated	Gillette, New Jersey
S.W. Petro-Chem Incorporated	Olathe, Kansas
Thiem Corporation	Dayton, Ohio
Widger Chemical Corporation	Warren, Michigan

Source: ICF 1986a.

percent more than the previous asbestos formulation (Dayton Chemicals 1986). Hysol Aerospace and Industrial Adhesives Division has substituted asbestos with a proprietary silica formulation in 80 percent of their products. Full substitution is expected in 1987 (Hysol 1986).

Widger Chemical Corporation of Warren, Michigan indicates that customer pressure from General Motors, Ford, and Chrysler has forced substitution of asbestos in all their adhesives, sealants and coatings. They have replaced asbestos with ground mica, ground talc, and dolamitic limestone. Although the final products cost more to produce, the company officials indicated that the switch to the mineral filler formulations did not result in any loss in performance (Widger Chemical 1986).

Non-fibered mixtures containing clays, silica gels, or mineral fillers are estimated to account for 30 percent of the non-roofing compounds market as a result of a ban on asbestos (see Attachment A). The price of these formulations would be expected to be 4.1 percent (see Attachment B) more than the current price of an asbestos containing counterpart. This price increase results in an estimated average price of $14.47 per gallon for non-fibered substitute adhesives, sealants and coatings (ICF 1986a).

E. Summary

Asbestos is unique among known raw minerals because of its strength, fire and heat resistance, viscosity control, and price. Since no across the board substitute fiber can duplicate the many properties of the mineral, the range of different substitute formulations appears endless. Companies use a myriad of substitute materials such as polyethylene, polypropylene, aramid, polyester, glass, ceramic, carbon, and phosphate fibers, and clay, silica gel, talc, wollastonite, mica, and calcium carbonate fillers (ICF 1986a).

The asbestos containing specialty adhesive, sealant, and coating market is extremely diverse. The large number of different applications for these products makes the task of deriving projected market shares for substitute mixtures, resulting from an asbestos ban, almost impossible. Consequently, the estimation of market shares and prices of the substitute formulations relies to a large degree upon educated judgments of industry experts. Table 4 summarizes the findings of this analysis, and presents the data for the Asbestos Regulatory Cost Model.

If asbestos were made unavailable, perhaps 70 percent of the non-roofing adhesives, sealants, and coatings market would be taken by formulations containing substitute fibers (see Attachment A). The average price of these formulations is estimated to be $15.14 per gallon, reflecting an 8.9 percent increase (see Attachment B) above the current average price of asbestos containing products (ICF 1986a). Non-fibered formulations, containing clays, silica gels, and various fillers are estimated to account for the remaining 30 percent of the substitute market (see Attachment A). The average price of these products is estimated to be $14.47, reflecting a 4.1 percent increase (see Attachment B) over the current average price for asbestos containing adhesives, sealants, and coatings (ICF 1986a).

Table 4. Data Inputs for Asbestos Regulatory Cost Model

Product	Output	Product Asbestos Coefficient	Consumption Production Ratio	Price	Useful Life*	Equivalent Price	Market Share	Reference
Asbestos Mixture	9,612,655	0.00031 gals/ton	1.0	$13.90/gal	10 yrs	$13.90/gal	N/A	ICF (1986a)**
Fiber Mixture	N/A	N/A	N/A	$13.10/gal	10 yrs	$15.10/gal	70%	ICF (1986a)**
Non-Fiber Mixture	N/A	N/A	N/A	$14.42/gal	10 yrs	$14.42/gal	30%	ICF (1986a)**

N/A: Not applicable.

* The useful life was estimated to be ten years. However, due to the extreme diversity in products actual values varied greatly.

** See Appendices A and B.

ATTACHMENT A

PROJECTED MARKET SHARES ANALYSIS BASED ON 1985 PRODUCTION OF NON-ROOFING ADHESIVES, SEALANTS, AND COATINGS[a]

Substitute Material	Manufacturer(s)	Production Which Would Likely Switch to Substitute	Projected Market Share (Subtotal/Grant Total x 100)
Synthetic, Cellulose, and Other Fibers	Bacon		
	Bitucote		
	Dolphin		
	Flamemaster		
	Gibson-Homans		
	Hercules		
	Industrial Gasket and Shim		
	Kent		
	Mameco		
	Palmer		
	Pecora[b]		
	Products Research[b]		
	Protective Treatments		
	Royston		
	Sterling Clarke		
	Subtotal 1	2,552,057	70.31%
Clay and Mineral Fillers	American Abrasives		
	Contech		
	Dayton		
	Franklin		
	Futura		
	Hysol		
	Pecora[b]		
	Products Research[b]		
	Riverain		
	Widger		
	Subtotal 2	1,077,783	29.69%
	Grand Total	3,629,840	100.00%

[a]This analysis is based on firms which were willing or able to provide us with information on how they would react to an asbestos ban. It is assumed that all remaining firms (in aggregate) will substitute for asbestos in the same relative proportions.

[b]These companies indicated they use both fibers and fillers as the primary substitute material depending upon the product. For the purpose of this analysis, we have divided their production equally between the two substitutes.

ATTACHMENT B

PROJECTED PRICES ANALYSIS BASED ON AVAILABLE PRICE DIFFERENTIALS BETWEEN ASBESTOS CONTAINING AND NON-ASBESTOS NON-ROOFING ADHESIVES, SEALANTS AND COATINGS

Substitute Material	Manufacturer(s)	Production (1985)	Current or Probable Price Increase[a] (%)	Average Price Increase[b] (%)
Synthetic, Cellulose, and Other Fibers	Cobitco	c		
	Dolphin			
	Gibson-Homans			
	Hercules			
	J.C. Dolph	c		
	Mameco			
	Palmer			
	Sterling-Clarke			
	Subtotal 1	1,487,429		8.9%
Clay and Mineral Fillers	American Abrasives			
	Contech			
	Dayton			
	Franklin			
	Futura			
	Republic Powdered Metals	c		
	Widger			
	Subtotal 2	930,687		4.1%

[a]Many manufacturers currently price non-asbestos formulations the same as asbestos containing mixtures. For the purpose of this analysis, we have inserted the increased cost of production when necessary.

[b]The average price increase was determined by calculating a weighted average of individual price increases of non-asbestos over asbestos containing roof coatings and cements using 1985 asbestos containing production levels.

[c]When 1985 production quantities were unknown, a value corresponding to the average production of a 1985 plant (according to survey data) was inserted.

REFERENCES

American Fillers & Abrasives Inc. E. Neckerman. 1986 (October 30). Bangor, MI. Transcribed telephone conversation with Jeremy Obaditch, ICF Incorporated, Washington, D.C.

Cabot Corp. S. Jesseph. 1986 (October 28). Tuscola, IL. Transcribed telephone conversation with Jeremy Obaditch, ICF Incorporated, Washington, D.C.

Contech Inc. L. Labelle. 1986 (July-December). Mattawan, MI. Transcribed telephone conversations with Rick Hollander, ICF Incorporated, Washington, D.C.

Dayton Chemicals Division. D. Eby. 1986 (July-December). West Alexandria, OH. Transcribed telephone conversations with Jeremy Obaditch and Rick Hollander, ICF Incorporated, Washington, D.C.

DuPont, E.I. De Nemours And Co. J. Lynn. 1986 (June 25). Wilmington, DE. Comments provided to Docket No. EPA OPTS-62036.

Engelhard Corporation. (n.d.). Product Literature. Attagel(R)-36 Asphalt Thickener for Use In Cutback Coatings. Menlo Park, N.J.

Flamemaster Corp., The. 1986 (July-December). Transcribed telephone conversations with Jeremy Obaditch and Eric Crabtree, ICF Incorporated, Washington, D.C.

Floridin Company. 1986. Product Literature. Min-U-Gel(R) AR - A Specialty Attapulgite Thickener For Asphalt Coatings. Berkeley Springs, WV.

Gibson-Homans Corp. J. Slovski. 1986 (July-December) Twinsburg, OH. Transcribed telephone conversations with Jeremy Obaditch And Eric Crabtree, ICF Incorporated, Washington, D.C.

Hercules Inc. 1983 (April 11). Wilmington, DE. Letter to C Carter, General Services Administration, Office of Federal Supply and Services, Washington, DC.

Hysol Aerospace and Industrial Adhesives Division. D. Jackson. 1986 (July-December). Transcribed telephone conversations with Jeremy Obaditch and Eric Crabtree, ICF Incorporated, Washington, D.C.

ICF Incorporated. 1986a (July-December). Survey of Primary and Secondary Processors Of Asbestos Non-Roofing Adhesives, Sealants and Coatings. Washington, D.C.

Krusell N, Cogley D. 1982. GCA Corp. Asbestos Substitute Performance Analysis. Revised Final Report. Washington, D.C.: Office Of Pesticides and Toxic Substances, U.S. Environmental Protection Agency. Contract No. 68-02-3168.

Mameco International. H. Myers. 1986 (July-December). Cleveland, OH. Transcribed telephone conversations with Jeremy Obaditch And Michael Geschwind, ICF Incorporated, Washington, D.C.

MiniFibers Inc. 1986. Product Literature. Minifibers. Johnson City, TN.

National Paints and Coatings Association. R. Conner. 1986 (October 21). Transcribed telephone conversation with Jeremy Obaditch, ICF Incorporated, Washington, D.C.

Palmer Products Corp. S. Palmer-Ball. 1986 (July-December). Louisville, KY. Transcribed telephone conversations with Jeremy Obaditch and Michael Geschwind, ICF Incorporated, Washington, D.C.

Pecora Corp. W. Waters. 1986 (July-December). Harleysville, PA. Transcribed telephone conversations with Jeremy Obaditch and Peter Tzanetos, ICF Incorporated, Washington, D.C.

Riverain Corp. J. Durst. 1986 (July-December). Dayton, OH. Transcribed telephone conversations with Jeremy Obaditch and Peter Tzanetos, ICF Incorporated, Washington, D.C.

Widger Chemical Corp. J. Montgomery. 1986 (July-December). Warren, MI. Transcribed telephone conversations with Jeremy Obaditch, ICF Incorporated, Washington, D.C.

XXXI. ASBESTOS-REINFORCED PLASTICS

A. Product Description

Asbestos-reinforced plastic is typically a mixture of some type of plastic resin (usually phenolic or epoxy), a general filler (often chalk or limestone), and raw asbestos fiber. In general, the raw asbestos fiber is 17 percent of the weight of the plastic.[1] Asbestos-reinforced plastics are used for electro-mechanical parts in the automotive and appliance industries and as high-performance plastics for the aerospace industry. The use of asbestos enhances the thermal and mechanical properties of plastic by improving heat resistance, stiffness, strength, dielectric strength, and processability (ICF 1986a).

In the past asbestos had been used in plastics not only for its unique combination of chemical properties, but also as a general filler or extender of the plastic resin because of its low cost. As the severity of asbestos-related health hazards became known, asbestos was gradually replaced with other fillers such as talc and clay (ICF 1985). Asbestos is now only used in plastics when the presence of the asbestos-imparted reinforcing properties is critical to the performance of the plastic. Such applications include:

- Electro-mechanical parts for the automotive and appliance industries; i.e., commutators, switches, circuit breaker and motor starter casings, terminal boards, thermoplugs, and arc chutes.
- Parts for the aerospace industry; i.e., heat shields and missile casings.

B. Producers and Importers of Asbestos-Reinforced Plastics

Table 1 lists the total production and fiber consumption in this market.

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[1] See Attachment, Item 1.

Table 1. Primary Production of Asbestos-Reinforced Plastic -- 1985

Primary Processors	1985 Production (short tons)	1985 Fiber Consumption (short tons)	Reference
Total	4,835	812.1	ICF 1986a

Six of the eight 1985 primary processors used asbestos to manufacture electro-mechanical plastics and only two processors (Narmco Materials Incorporated and the Raymark Corporation), manufactured asbestos-containing plastics for the aerospace industry (ICF 1986a).

In 1985 there were four secondary processors of asbestos-reinforced plastics, two of which (Ametek and the West Bend Company) imported almost all their plastic from Japan. The secondary processors buy finished asbestos-reinforced plastic parts for assembly, and do not manufacture any asbestos-reinforced plastic themselves. Ametek and the Hoover Company purchase commutators made of asbestos-reinforced plastic that they place in electric motors (Ametek 1986, Hoover 1986). The West Bend Company purchases an asbestos-reinforced plastic thermoplug that is then attached to its kitchen appliances (West Bend 1986). United Technologies purchases an asbestos-reinforced plastic sheet and then places the sheet in missiles to serve as a heat shield (United Technologies 1986). Consumption of fiber and total 1985 imports of product for secondary processors are listed in Table 2 (ICF 1986b).

C. Trends

Asbestos use in plastics is declining as manufacturers move towards non-asbestos compounds. Even though the U.S. production of reinforced plastic has been rising since 1981, the production of asbestos-reinforced plastic has been declining (Table 3). The production of asbestos-reinforced plastic has fallen from 12,187 short tons in 1981, to 4,835 short tons in 1985. This represents a 60 percent decline in four years.[2]

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[2] See Attachment, Item 2.

Table 2. Secondary Production of Asbestos-Reinforced Plastic -- 1985

Secondary Processors	Consumption of Asbestos-Reinforced Plastic (short tons)	Quantity of Asbestos-Reinforced Plastic Imported (short tons)	Reference
Total	156.8	127.5	ICF 1986b

Table 3. U.S. Production of Reinforced Plastics and Asbestos-Reinforced Plastics (short tons)

	1981	1985	References
Production of Reinforced Plastic	920,000	1,105,000	Automotive News 1985
Production of Asbestos-Reinforced Plastic	12,187[a]	4,835[b]	ICF 1985, ICF 1986a
Asbestos-Reinforced Plastic as a Percentage of Total Reinforced Plastic	1.3%	0.4%	See Attachment Item 3

[a]1981 production from ICF 1985.

[b]1985 production from ICF 1986a.

Since 1985, three asbestos-reinforced plastic producers, (Meriden Molded Plastics, Inc., Resinoid Engineering Corp., and Rostone Division Allan-Bradley Co.), have stopped using asbestos (Table 1). Celanese Engineering Resins, the largest producer in 1985, plans to stop using asbestos by the second quarter of 1987 (Celanese 1986). The replacement of asbestos in plastics is likely to continue at an increasing rate.

D. Substitutes

While there are many potential substitutes for asbestos in the manufacture of reinforced plastic, the discussion of the substitutes will focus on the six substitutes that would be expected to replace the remaining asbestos-reinforced plastics market in the event of a ban. The six substitutes, listed in order of importance, are fibrous glass, teflon, Product X, porcelain, silica, and carbon. Manufacturers of these substitutes are listed in Table 4. Table 5 lists the advantages, disadvantages and some general remarks about each of the substitutes. The following discussion of each of the substitutes will include the justification of the predicted market shares of the substitutes in the event that asbestos use is banned.

1. Fibrous Glass

Fibrous glass, which is essentially chopped glass, is currently the leading reinforcer of plastic in the United States and industry experts agree that glass-reinforced plastic would capture the largest share of the asbestos-reinforced plastic market in the event that asbestos use is banned. The majority of the asbestos-reinforced plastics produced in the U.S. is used in electro-mechanical applications and fibrous glass has proven to be a good replacement for asbestos in such applications (commutators, circuit breakers, electric motor casings, thermoplugs, and arc chutes.) The glass-reinforced plastics are strong enough to be molded into thin-walled parts and have the required heat resistance and dielectric strength for these products. The main

Table 4. Producers of Substitute Materials

Glass Fibers[a]	Porcelain[b]
Advance Coatings	Relmech Manufacturing (Canada)
Armco Steel Corp.	
Certainteed Corp, Fiber Glass Reinforcements Division	Cab-O-Sil[b]
Compounding Technology Inc.	
Durkin Chemicals, Inc.	Cabot Corporation
Fiber Glass Industries, Inc.	
Fibre Glass Development	
GLS Fiberglass Div., Great Lakes Terminal & Transport	Teflon Fiber[b]
Kristal Kraft, Inc.	Celanese Engineering Resins
LNP Corp.	
Manville, Filtration and Minerals Div.	
Mead Paper, Specialty Paper Div.	Product X
Miles, A.L. Company	
Nicofibers, Inc.	Raymark Corporation
Owens-Corning Fiberglas Corp.	
PPG Industries, Inc., Fiber Glass Div.	
Reichold Chemicals, Inc.	
Techni-Glas, Inc.	
Trevarno Div., Hexcel Corp.	
United Merchants & Mfrs., Inc.	
Wilson-Fiberfil International	
Carbon Fibers[a]	
Avco Specialty	
Compounding Technology Inc.	
Fibre Glass Development	
Great Lakes Carbon Corp.	
Hercules, Inc., Aerospace Div.	
Hi-Tech Composites, Inc.	
Hysol Grafil Co.	
LNP Corp.	
Mead Paper	
Stackpole Corp.	
Trevarno Div., Hexcel Corp	
Union Carbide Corp.	
Wilson-Fiberfil International	

[a]From World Plastics Directory 1986.

[b]From ICF 1986a.

Table 5. Substitutes for Asbestos in Reinforced Plastics
(Listed in Order of Importance)

Substitute	Advantages	Disadvantages	Remarks
Asbestos	Good impact resistance. Fire and heat resistance. Low shrinkage and warpage. Ease of handling during processing.	Environmental and occupational problems.	Specialty uses only. Phased out in general purpose uses.
Fibrous Glass	Light weight. Can be used in thin-walled parts. Good heat resistance.	May require some processing changes. Processing equipment wears more quickly.	Has been used for many years. Well-suited for use in commutators, flat-iron skirts, motor housings, transmission components.
Teflon Fiber	Good dielectric strength. Good impact resistance.	Poor wear resistance. High price. Can only be used in low temperature ranges (below 500°F).	Celanese plans to use in electro-mechanical applications.
Porcelain	Temperature use to 1800°F.	Brittle. High price.	This is the only non-plastic substitute cited for asbestos-reinforced plastic. Used to make high temperature (1500-1800°F) arc chutes.
Fumed Silica Powder	Good dielectric strength.	Poor processing characteristics. More expensive.	Used with epoxy resins. Trade name Cab-O-Sil.
Carbon Fiber	Light weight. High strength. High chemical resistance. Good heat resistance.	Very high price. Conducts electricity.	Used in aircraft parts, sporting goods, textile machine parts. Used in molding compounds.

Source: ICF 1986a.

disadvantages of fibrous glass as an asbestos substitute are that it is not as heat resistant as asbestos and it is more difficult to process because of its abrasive characteristics. Because of its lower heat resistance, fibrous glass is unable to replace asbestos in any of the aerospace applications still using asbestos reinforced-plastics (missile casings and heat shields) or in the switchgears of power plants that require high temperature (1500-1800°F) electro-mechanical plastics (ICF 1986a).

Resinoid Engineering Corporation and the Rostone Division of the Allan-Bradley Company now use fibrous glass in the manufacture of electro-mechanical plastics for the automotive and appliance industries (Resinoid 1986, Rostone 1986). Meriden Molded Plastics Incorporated stated that 70 percent of its 1985 asbestos- reinforced plastics have been replaced with glass-reinforced plastics. Rogers Corporation, the second largest asbestos-reinforced plastic processor, plans to eventually replace all asbestos with fibrous glass in electro-mechanical plastics (Rogers 1986). Based on these substitutions, the predicted share that glass-reinforced plastic will gain of the 1985 asbestos-reinforced plastic market is over 40 percent.[3]

2. Teflon

The second most important substitute is teflon. Teflon's chemical resistance, dielectric strength, heat resistance, and impact resistance make it an adequate replacement for asbestos in relatively low temperature (below 500°F) electro-mechanical applications. The largest asbestos-reinforced plastic processor, Celanese Engineering Resins, plans to use Teflon K-10 (teflon powder) to reinforce its electro-mechanical plastics. Celanese has cited the high cost of the teflon powder ($8.00/lb.) as a disadvantage,

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[3] See Attachment, Item 4.

although the planned sale price of the teflon-based plastic ($2.25/lb) is the same as the company's asbestos- reinforced plastic. Celanese has stated that it plans to replace all its asbestos with teflon by 1987 (Celanese 1986).

3. Porcelain

Porcelain, the only non-plastic substitute for asbestos-reinforced plastics, is an effective substitute for extremely high temperature electro-mechanical applications. Porcelain, which is a high-quality ceramic, can withstand temperatures up to 1800°F and also has high dielectric strength. These characteristics enable it to be used in the extremely high temperature arc chutes (high-temperature arc chutes guide the electric current in large electric motors or generators used in power plants). The main disadvantages of porcelain are that it is difficult to mold and it costs about 50-60 percent more than asbestos-reinforced plastics (Relmech 1986).

High-temperature arc chutes accounted for about 30 percent of Meriden Molded Plastics' asbestos product market and the company was unable to find an effective substitute for that portion of its market. However, Meriden Molded Plastic sold its plastics operations to Relmech Manufacturing in 1986 and Relmech Manufacturing has stated that porcelain has already replaced some of Meriden's high-temperature arc chute market and could replace all asbestos in these arc chutes (Relmech 1986). Porcelain is expected to capture less than 5 percent of the market in the event of a ban. (Meriden 1986).

4. Fumed Silica Powder

The fourth substitute to be discussed is Cab-O-Sil(R), a fumed silica powder. One processor, Magnolia Plastics Incorporated, cited the product as a substitute for asbestos in reinforced plastic used in electro-mechanical applications. While Magnolia Plastics Incorporated stated that the Cab-O-Sil(R) could replace 100 percent of their asbestos-reinforced plastic, the company cited some disadvantages of the substitute, such as its high cost and poor processing characteristics. The silica-containing plastic exhibits lower viscosity during manufacturing than the asbestos mixture.[4] The only advantage Magnolia cited was that the Cab-O-Sil(R) is not a health hazard. Total replacement of Magnolia's market gives Cab-O-Sil(R) less than 5 percent of the market (ICF 1986a).

5. Carbon

Carbon (usually a graphite fiber) is very strong, extremely heat resistant, and chemically inert. These properties make carbon-reinforced plastics well-suited for use as missile casings and heat shields, the only remaining asbestos-reinforced plastic products in the aerospace industry. The two major disadvantages of carbon are its cost and its low dielectric strength. Carbon fibers can cost more than 100 times as much as asbestos fiber, effectively restricting the use of carbon-reinforced plastic to high performance applications (Narmco 1986). In addition, because of carbon's low dielectric strength, carbon-reinforced plastics are generally not used to make electro-mechanical parts (ICF 1986a). One 1985 processor, Narmco Materials Inc., has substituted carbon for asbestos in some of its plastic.

The substitute plastic is used to make missile casings and costs only 25 percent more than the asbestos-reinforced plastic that it is replacing (Narmco 1986). Even though carbon fibers are much more expensive than asbestos fibers, the cost difference is mitigated by the fact that reinforcing fibers are usually a small part of the cost of aerospace plastics and they are required in smaller amounts for providing the same kind of reinforcement as asbestos fibers. The company has stated that the only reason that it has not switched completely to carbon-reinforced plastic is that the DOD

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[4] Viscosity is a measure of the fluidity of a substance. Reinforced plastics are manufactured by injecting fluid plastic into a pressure mold. The lower viscosity imparted by Cab-O-Sil(R) makes the setting of the mold more difficult.

specifications for the missile casing require the use of asbestos. Replacement of Narmco's market would give carbon-reinforced plastic less than 5 percent of the market (Narmco 1986).

Raymark Corporation, the other producer of asbestos-reinforced plastics used in aerospace, did not specify which substitute could replace asbestos in its plastics. The company did, however, state that it has a potential substitute (Product X) under development and estimated that the cost of plastic made with this substitute would be 100 percent higher than the cost of Raymark's asbestos-reinforced plastic. The Raymark Corporation's asbestos-reinforced plastic product is a heat-shield used in aerospace applications and the company would not release further information about substitutes or product applications because Product X is part of a military contract (Raymark 1986).

Table 6 lists the data inputs to the asbestos regulatory cost model, including substitute prices and projected market shares as well as information concerning the asbestos-reinforced plastic.

E. Summary

Asbestos has been replaced as a general filler of plastic, but asbestos is still used in plastic when the presence of the asbestos imparted reinforcing properties is critical to the performance of the plastic. Asbestos-reinforced plastics are now only used for electro-mechanical parts in the automotive and appliance industries and as high-performance plastics for the aerospace industry. In 1985 there were eight primary processors, four secondary processors and two importers of asbestos-reinforced plastic in the United States. Since 1985, three of the primary processors and one of the secondary processors have stopped processing asbestos. The replacement of asbestos in plastics is likely to continue at an increasing rate. The six substitutes expected to replace the remaining asbestos-reinforced plastics market in the event of a ban (listed in order of importance) are: fibrous glass, teflon, Product X, porcelain, silica and carbon.

Table 6. Data Inputs for Asbestos Regulatory Cost Model
(031) Asbestos-Reinforced Plastic

Product	Output	Product Asbestos Coefficient	Consumption Production Ratio	Price	Useful Life[g]	Equivalent Price	Market Share	Reference
Asbestos-Reinforced Plastic	4,835 tons	0.17 lbs./ton[a]	1.03[b]	$2.63/lb.[c]	1 year	$2.63/lb.	N/A	ICF 1986a
Glass-Reinforced Plastic	N/A	N/A	N/A	$1.40/lb.[d]	1 year	$1.40/lb.	47.9%	ICF 1986a
Teflon-Reinforced Plastic	N/A	N/A	N/A	$2.25/lb.	1 year	$2.25/lb.	42.5%	Celanese 1986
Product X	N/A	N/A	N/A	$11.22/lb.[e]	1 year	$11.22/lb.	7.4%	Raymark 1986
Porcelain	N/A	N/A	N/A	$4.08/lb.[f]	1 year	$4.08/lb.	1.4%	Relmech 1986
Silica-Reinforced Plastic	N/A	N/A	N/A	$3.00/lb.	1 year	$3.00/lb.	0.5%	Magnolia 1986
Carbon-Reinforced Plastic	N/A	N/A	N/A	$47.25/lb.	1 year	$47.25/lb.	0.3%	Narmco 1986

N/A: Not Applicable.

[a]See Attachment, Item 1.

[b]See Attachment, Item 8.

[c]See Attachment, Item 5.

[d]See Attachment, Item 6.

[e]See Attachment, Item 10.

[f]See Attachment, Item 7.

[g]See Attachment, Item 9.

ATTACHMENT

1. Calculation of Product Asbestos Coefficient. A weighted average (using market shares as weight) of the product coefficient by company yielded an average of 0.1678 lbs./lb. or about 0.17 lbs./lb.

Company	(A) Product Asbestos Coefficient, by Company (lbs. of Asbestos/lbs. of Plastic)[a]	(B) Market Share 1985	Weighted Product Coefficient, (A) x (B)/100
Celanese Engineering Resins	0.027		
Magnolia Plastics Inc.	0.030		
Meriden Molded Plastics Inc.	0.390		
Narmco Materials Inc.	0.020		
Raymark Corporation	0.600		
Resinoid Engineering Corp.	0.350		
Rogers Corporation	0.185		
Rostone Division Allan-Bradley	0.150		
		Total:	0.1678 lbs./lb.

[a]From ICF 1986a.

2. Percentage Decrease in Asbestos-Reinforced Plastics Production from 1981 to 1985.

   (/1985 Production - 1981 Production//1981 Production) x 100
   = Percentage Change '81-'85.
   (/4,835 - 12,187//12,187) x 100 = -60%.

3. Asbestos-Reinforced Plastic Production as a Percentage of Total Reinforced Plastic Production. (From Table 3.)

   1981. (12,187/920,000) x 100 = 1.3
   1985. (4,835/1,105,000) x 100 = .4

4. Projected Market Share of Fibrous Glass.

Combined market shares of Resinoid Engineering Corp., Rogers Corporation, Rostone and 70 percent of Meriden's share:

5. Price of Asbestos-Reinforced Plastic.

Company	(A) Price of Asbestos-Reinforced Plastic[a]	(B) Market Share 1985	Weighted Price (A) x (B)/100
Celanese			
Magnolia			
Meriden			
Narmco			
Raymark			
Resinoid			
Rogers			
Rostone			
	Weighted Average Price		2.630/lb.

[a]From ICF 1986a.

6. Price of Glass-Reinforced Plastic.

The largest primary processor that is using glass-reinforced plastic as a substitute for asbestos-reinforced plastic is the Rogers Corporation. The average price of their most important substitute glass-reinforced plastic is was used in the analysis.

7. Price of Porcelain.

Relmech Manufacturing stated that, on average, porcelain cost about 50-60 percent more than asbestos-reinforced plastic.

8. Consumption/Production Ratio.

Domestic production of asbestos-reinforced plastic in 1985 was 4,835 short tons (see Table 1). 1985 imports of asbestos-reinforced plastic totaled 127.5 tons (see Table 3).

$$\text{Consumption} = \text{Production} + \text{Imports}$$
$$4{,}962.5 = 4{,}835 + 127.5$$

$$\text{Consumption/Production} = 4{,}962.5/4{,}835 = 1.03$$

9. Useful Life of Products.

Useful life of asbestos-reinforced plastic from ICF (1984a). Respondents to survey stated that substitute products had the same expected service life as asbestos-reinforced plastic.

10. Price of Product X.

Raymark Corporation reported that it has a potential substitute under development as part of a defense contract. Raymark did not release the name of this product and ICF has referred to the substitute as Product X. Raymark provided ICF with the relative price of Product X and their asbestos product.

REFERENCES

Ametek/Lamb Electronic Division. Gary Davenport. 1986 (July-December). Cambridge, OH. Transcribed telephone conversations with Peter Tzanetos and Eric Crabtree, ICF Incorporated, Washington, D.C.

Automotive News: 1985 Market Data Book, "Reinforced Plastics Shipments By Markets" p. 82.

Celanese Engineering Resins. Jaime Garza. 1986 (July-December). Bishop, TX. Transcribed telephone conversations with Rick Hollander and Eric Crabtree, ICF Incorporated, Washington, D.C.

The Hoover Company. A.R. McMullen. 1986 (July-December). North Canton, OH Transcribed telephone conversations with Eric Crabtree, ICF Incorporated, Washington, D.C.

ICF Incorporated. 1985. Appendix H: Asbestos Products and Their Substitutes, in Regulatory Impact Analysis of Controls on Asbestos and Asbestos Products. Washington DC: Office of Pesticides and Toxic Substances, U.S. Environmental Protection Agency.

ICF Incorporated. 1984b. Imports of Asbestos Mixtures and Products. Washington DC: Office of Pesticides and Toxic Substances, U.S. Environmental Protection Agency. EPA CBI Doc. Control No. 20-8600681.

ICF Incorporated. 1986a (July-December). Survey of Primary Processors of Asbestos-Reinforced Plastic. Washington, DC.

ICF Incorporated. 1986b (July-December). Survey of Secondary Processors of Asbestos-Reinforced Plastic. Washington, DC.

Krusell N, Cogley D. 1982. GCA Corp. Asbestos Substitute Performance Analysis. Revised Final Report. Washington DC: Office of Pesticides and Toxic Substances, U.S. Environmental Protection Agency. Contract 68-02-3168.

Magnolia Plastics Incorporated. Robert Andrews. 1986 (July-December). Chamblee, GA. Transcribed telephone conversations with Michael Geschwind and Eric Crabtree, ICF Incorporated, Washington DC.

Meriden Molded Plastics Incorporated. Robert Grossman. 1986 (July-December). Meriden, CT 06450. Transcribed telephone conversations with Michael Geschwind and Eric Crabtree, ICF Incorporated, Washington DC.

Modern Plastics, July 1985.

Narmco Materials Incorporated. Thomas Confer. 1986 (July-December). Anaheim, CA. Transcribed telephone conversations with Michael Geschwind and Eric Crabtree, ICF Incorporated, Washington DC.

Raymark Corporation. George Houser. 1986 (July-December). Manheim, PA. Transcribed telephone conversations with Peter Tzanetos and Eric Crabtree, ICF Incorporated, Washington DC.

Relmech Manufacturing. William Dueck. 1986 (December 1). Elmyra, Canada. Transcribed telephone conversation with Eric Crabtree, ICF Incorporated, Washington, DC.

Resinoid Engineering Corporation. Robert Denes. 1986 (July-December). Skokie, IL. Transcribed telephone conversations with Peter Tzanetos and Eric Crabtree, ICF Incorporated, Washington DC.

Rogers Corporation. William Whitely. 1986 (July-December). Manchester, CT. Transcribed telephone conversations with Peter Tzanetos and Eric Crabtree, ICF Incorporated, Washington DC.

Rostone Division Allan-Bradley Co. Mr. Jay Floyd. 1986 (July-December). Layfayette, IN. Transcribed telephone conversations with Peter Tzanetos and Eric Crabtree, ICF Incorporated, Washington DC.

United Technologies, Chemical Systems. Steven Green. 1986 (July-December). San Jose, CA. Transcribed telephone conversations with Jeremy Obaditch and Eric Crabtree, ICF Incorporated, Washington, DC.

The West Bend Company. E.T. Hackney. 1986 (July-December). West Bend, WI. Transcribed telephone conversations with Jeremy Obaditch and Eric Crabtree, ICF Incorporated, Washington DC.

World Plastics Directory, 1986.

XXXII. MISSILE LINER

A. Product Description

Missile liner is a rubber compound which is used to coat the interior of "rocket motors". Because a rocket is propelled purely by the burning of rocket fuel, it has no observable engine. Therefore, the term rocket motor refers to the entire chamber which the fuel occupies as it is being burned. Rockets and rocket boosters are used to propel a number of objects including military weapons and the space shuttle (ICF 1986).

The missile liner's main function is to insulate the outer casing of the rocket from the intense heat being generated in the rocket motor while the rocket fuel is being burned. This is where the need for asbestos arises. Asbestos is mixed into the rubber liner because of its excellent heat and fire resistance properties. In addition, the excellent thixotropic[1] characteristics of asbestos fiber facilitate the processing of the liner (ICF 1986).

B. Producers and Importers of Missile Liner

There are currently five companies which process asbestos for use in missile liner. A complete list of the six plants these companies operate is presented in Table 1.

These companies consumed approximately 700 tons of asbestos in 1985 in producing 4,667 tons of missile liner (ICF 1986).[2] The cost of this liner was not revealed by any of the companies either because it was considered proprietary or because it was considered classified military information.

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[1] Thixotropic characteristics refer to a gel's ability to liquefy when stirred or shaken and to harden when left stationary.

[2] See Attachment for explanation of calculations. These totals include estimated values for the Koch Asphalt Company because they refused to respond to our survey. In 1981, this plant (which was owned by Allied Corporation) produced insulation material. It is not clear whether that insulation material was missile liner or some other type of insulation, but we have decided to include it here because all other types of insulation are no longer made using asbestos.

Table 1. Producers of Asbestos Missile Liner

Company	Location
Aerojet Liquid Rocket Company	Sacramento, CA
Hercules, Incorporated	McGregor, TX
Kirkhill Rubber Company	Brea, CA
Koch Asphalt Company	Stroud, OK
Morton Thiokol Corporation	Elkton, MD Brigham City, UT

Furthermore, it is not clear that prices would have any meaning in this context because they would likely be arbitrary internal transfer prices rather than market generated prices. A company which now produces only a substitute liner revealed that its price of asbestos liner was $7.00/lb. in 1985 (Uniroyal 1986).

No importers of this asbestos product were identified (ICF 1984, ICF 1986). Because this product is used extensively in military applications it is likely that it is all produced domestically.

C. Trends

1981 production of asbestos missile liner was 4,006 tons (TSCA 1982), and 1985 production is estimated to have been 4,667 tons. This suggests that missile liner production increased by approximately 16 percent. However, there is considerable uncertainty associated with the 1985 figure. First of all, the largest processor, accounting for approximately 75 percent of 1981 production, refused to respond to our survey. Thus, we were forced to estimate this company's production. Second, most respondents did not tell us how much liner they produced. They only told us how much asbestos they consumed. Hence, production is estimated based on product coefficients that range from 5 percent to 30 percent. Nonetheless, it seems fair to say that production of missile liner probably remained constant or increased slightly, but it probably did not decline appreciably.

D. Substitutes

There are currently two substitutes for asbestos in missile liner. They are Kevlar(R) and ceramic fibers. The Kevlar(R) liner is produced by Uniroyal, Inc. and by Hercules, Inc., while the ceramic fiber liner is produced by Olin Corp. Although these substitute liners are more expensive than asbestos liner, industry experts believe that they can completely replace asbestos use in this product if EPA decides to ban asbestos. They also note that the cost of the liner will be an extremely small portion of the total cost of the final product.

The projected market shares for the substitute liners were computed by looking at past production of liner and taking prices into consideration. The data inputs for the Regulatory Cost Model are presented in Table 2.

Substitution away from asbestos has been limited because government specifications stipulate that missile liners must be made with asbestos. Exemptions can be obtained by having the substitute pass a series of tests which guarantee that it will perform as well as the asbestos product. The process of developing a substitute mixture and having it pass these tests is very expensive. As a result, some companies have decided to continue producing the asbestos product even though substitutes are available.

The substitution that has occurred has taken place for one of two reasons. First, the company may have decided that it wished to avoid any potential future liabilities associated with asbestos usage. As a result, it would incur the costs of switching to a substitute. Alternatively, if a company is developing a new missile, it is free to design the liner in any way it sees fit as long as it functions properly and passes all the appropriate tests. In this case, substituting for asbestos is not very costly.

E. Summary

Asbestos is used to produce a rubber product which lines the interior of "rocket motors". There are currently five producers of asbestos missile liner, and their output is estimated to be 4,667 tons. This estimate is, however, subject to uncertainty because some producers were unable to provide us with all the necessary data because they felt the information may have been classified. No importers of this product were identified.

Companies that have already formulated asbestos-free mixtures believe that complete substitution can take place. They note that the primary obstacle to

Table 2. Data Inputs for Asbestos Regulatory Cost Model

Product	Output	Product Asbestos Coefficient	Consumption Production Ratio	Price[a]	Useful Life	Equivalent Price	Market Share	Reference
Asbestos Liner	4,667 tons	0.15 tons/ton[b]	1.0	$14,000/ton	1 use	$14,000/ton	N/A	ICF 1986
Kevlar(R) Liner	N/A	N/A	N/A	$29,000/ton[b]	1 use	$29,000/ton[b]	60%	ICF 1986
Ceramic Fiber Liner	N/A	N/A	N/A	$140,000/ton	1 use	$140,000/ton	20%	Olin 1986

N/A: Not Applicable.

[a]Prices in the text are given on a per pound basis, but they have been converted to prices per ton for use in the ARCM.

[b]See Attachment for explanations.

eliminating asbestos is government contracts that mandate the use of asbestos. Based on the opinions of industry experts, liners containing Kevlar(R) fiber are projected to capture 80 percent of the market at a price of $14.50/lb., while liners containing ceramic fiber are projected to capture 20 percent of the market at a price of $70.00/lb.

ATTACHMENT

The four companies that responded to our survey indicated that they consumed 151.2 tons of asbestos fiber in 1985, but three of them did not tell us how much missile liner they produced. The only company still producing missile liner that also reported its missile liner production was Morton Thiokol Corp. However, two companies which are no longer producing asbestos missile liner, B.F. Goodrich, Inc. and Uniroyal Corp., did supply us with their past ratios of fiber consumption to missile liner output. We found these values to be considerably different than Morton Thiokol's value. As a result, we computed a simple average of the three available ratios for use in our analysis. The information is summarized in Table A-1.

Once we had the value of the consumption-output ratio (0.15) and the amount of asbestos fiber consumed by the respondents, we were able to compute 1985 asbestos missile liner output for these four companies. As noted earlier, Koch Asphalt refused to respond to our survey. Because insulation material is a separate Bureau of Mines (BOM) asbestos fiber consumption category, we decided to use the total for the four companies to estimate Koch Asphalt's consumption by subtracting the consumption of the four respondents from 700 (the BOM estimate for total consumption in this category). This results in an estimate of fiber consumption for Koch Asphalt. If we then divide fiber consumption by the consumption-output ratio, we compute an estimate of output.

The price of the Kevlar(R) linear was computed by averaging the prices of the two liners. The average of Hercules, Inc.'s liner and Uniroyal, Inc.'s liner is $14.50/lb. A weighted average could not be computed because we did not have production data for either company.

Table A-1. Consumption-Output Ratio in Asbestos Missile Liner

	Ratio	Reference
Average	15%	ICF 1986

REFERENCES

ICF Incorporated. 1984. Imports of Asbestos Mixtures and Products. Washington, D.C.: Office of Pesticides and Toxic Substances, U.S. Environmental Protection Agency. EPA CBI Document Control No. 20-8600681.

ICF Incorporated. 1986 (July-December). Survey of Primary and Secondary Processors of Asbestos Missile Liner. Washington, D.C.

Olin Corp. 1986. Marion, IL 62959. Completed Survey of Primary Processors of Asbestos sent to Peter Tzanetos, ICF Incorporated, Washington, D.C.

TSCA Section 8(a) Submission. 1982. Production Data for Primary Asbestos Processors. Washington, DC: Office of Toxic Substances, U.S. Environmental Protection Agency. EPA Document Control No. 20-8601012.

Uniroyal, Inc. R. Carpenter. 1986 (July-October). Mishawaka, IN. Transcribed telephone conversations with Jeremy Obaditch and Peter Tzanetos, ICF Incorporated, Washington, D.C.

XXXIII. EXTRUDED SEALANT TAPE

A. Product Description

Sealant tape is made from a semi-liquid mixture of butyl rubber and asbestos (usually 80 percent butyl rubber and 20 percent asbestos by weight) that is contained in 55-gallon metal drums (Tremco 1986). On exposure to air, the sealant solidifies forming a rubber tape, that is typically about an inch wide and about an eighth of an inch thick. The product usually is sold to customers in linear feet. The tape acts as a gasket for sealing building windows, automotive windshields, and mobile home windows. It is also used in the manufacture of parts for the aerospace industry and in the manufacture of insulated glass. Asbestos is used in the tape for its strength, heat resistance, and dimensional stability (ICF 1986a).

B. Producers and Importers of Extruded Sealant Tape

In 1985 there were four processors with five plants nationwide that manufactured the tape. The four primary processors consumed 1,660.2 tons of asbestos fiber in 1985, which is 1.1 percent of total domestic asbestos fiber consumption for all product categories.[1] Table 1 shows the total fiber consumption and output for this product in 1985. There are no known importers of the tape (ICF 1986a, ICF 1986b).

C. Trends

Despite a drop in the number of processors from seven to four, the production of sealant tape increased 22.5 percent between 1981 and 1985, while fiber consumption in sealant tape increased only about 9.5 percent.[2] The

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[1] See Attachment, Item 1.

[2] 1981 figures from Parr Inc., one of the two firms (the other is Concrete Sealants Inc.) that have ceased production of asbestos sealant tapes, are not available, resulting in the percentage increase in production volumes and fiber consumption for 1985 to be slightly overstated. See Attachment, Item 2, for calculations.

Table 1. Primary Production of Extruded Sealant Tape -- 1985

Primary Production	Production (feet)	Fiber Consumed (short tons)	Reference
Total	423,048,539	1,660.2	ICF 1986a

difference in the growth rates between production volumes and fiber consumption can be explained by the fact that one of the processors that stopped using asbestos, Concrete Sealants Inc., manufactured a relatively high asbestos content tape in 1981 (Concrete 1986).

Industry experts expect a significant decline in the asbestos extruded sealant tape market over the next several years due to the development of cost effective substitutes, particulary in the area of automotive applications. (MB Associates 1986, Essex 1986). Table 2 illustrates the market trends of extruded sealant tape.

D. Substitutes

Effective non-asbestos substitutes for almost all the applications of asbestos sealant tape are available. The substitutes include cellulose-tape (butyl rubber containing cellulose fibers), structural urethane, carbon-based tape (butyl rubber containing carbon black), and non-curing tape (butyl rubber with calcium carbonate filler). The four substitutes, their manufacturers, relative advantages and disadvantages, and their potential market shares are listed in Table 3. The following discussion of the substitutes will include a justification of the predicted market shares for each of the substitutes in the event that asbestos use is banned.

1. Cellulose Tape

The most important substitute is cellulose tape. It would capture the largest share of the asbestos sealant tape market if asbestos were to be banned. Cellulose tapes are used to seal building windows, automobile windshields in the after-market (cellulose tapes are usually unable to meet the Original Equipment Market (OEM) safety specifications), and to seal windows in mobile homes and recreational vehicles. Cellulose tapes are not as strong or as heat resistant as asbestos sealant tapes and as a result they generally have shorter service life (15 yrs.) than an asbestos tape (20 yrs.)

Table 2. Market Trends of Extruded Sealant Tape, 1981-1985

	Production of Tape (feet)	Consumption of Fiber (short tons)	Reference
1981	345,480,853	1,516.0	ICF 1986a[a]
1985	423,048,539	1,660.2	ICF 1986a

[a]See Attachment, Item 1.

Table 3. Substitutes for Asbestos Sealant Tape

Product	Manufacturer(s)	Price (f.o.b.)	Potential Market Share	Advantages	Disadvantages	Remarks	Reference
Asbestos-Sealant Tape	See Table 1	a	N/A	Strength (sheer strength 50 psi). Dielectric strength. Heat resistance.	Health hazards. Liability costs.	Market expected to decline.	ICF 1986a
Structural Urethane	Essex Specialty Products			Less expensive. No health hazard. Stronger than asbestos tapes (sheer strength 700-800 psi).		Essex is only producer of structural urethane. This product has captured 90 percent of OEM market of automobile windshields; PTI confirmed product as potential substitute.	Essex 1986, PTI 1986
Cellulose-Fiber Tape	Concrete Sealants Inc. Parr Inc. Tremco Inc.			Less expensive. No health hazard.	Not as strong. Not as heat resistant. Shorter service life.	Parr markets product for sealing windows on mobile homes and RVS. Tremco and concrete market product to seal windows.	Parr 1986 Tremco 1986
Carbon-Based Tape (Non-Asbestos Swiggle Tape(R))	Tremco Inc.			No health hazard.	Increased cost.	Product under development. Asbestos is replaced with carbon black (soot).	Tremco 1986
Non-Curing Tape	Fiber-Resin Corp.			No health hazard. Longer shelf life.	Not as heat resistant. Unable to replace 20 percent of fiber-resin's asbestos-tape applications.	Tape is composed of butyl rubber with calcium carbonate filler. Tape is used to manufacture aerospace parts.	Fiber-Resin 1986

(Tremco 1986). However, they are generally cost-competitive with asbestos tapes and have an added advantage in not being considered hazardous (ICF 1986a).

Three producers of cellulose tapes have been identified in the survey, two former processors of asbestos, Concrete Sealants Inc. and Parr Inc., and one current processor, Tremco Inc. Concrete Sealants and Tremco market cellulose tapes that are used to seal glass in the large metal frames of building windows. Tremco's cellulose tape is also used to seal automobile windshields (after-market only). Parr Inc., which has stopped processing asbestos, produces a cellulose-tape that is used to seal windows on mobile homes and recreational vehicles (ICF 1986a).

Two current processors of asbestos have cited cellulose tape as a potential substitute for their asbestos sealant tape markets. Tremco has stated that its cellulose tape could replace the entire market of the asbestos sealant tape produced at Tremco's Kentucky plant for the sealing of windows and windshields (Tremco 1986). Elixir Industries, which produces an asbestos tape for sealing windows on mobile homes and recreational vehicles, stated that cellulose tape could replace its entire asbestos tape market, although Elixir cited the poorer performance of the cellulose tapes as a disadvantage (Elixir 1986). If the expected substitutions were to occur at Elixir and Tremco, cellulose tapes would gain a majority market share of the existing asbestos sealant tape market.

2. Structural Urethane

Structural urethane, produced by Essex Specialty Products, would capture the second largest share of the asbestos sealant tape market if asbestos was banned. Structural urethane is mainly used to seal automobile windshields and has the largest share of the market for windshield sealers (90 percent of the domestic OEM market and 60 percent of the after-market of windshield sealers.) (Essex 1986). Essex expects the market share of the structural urethane to increase and considers structural urethane as capable of replacing 100 percent of the windshield sealer market. In terms of service life, structural urethane's expected 20 years of service is the same as the expected service life of an asbestos tape. Structural urethane's main advantages over the other sealers are its strength (sheer strength is 700-800 psi, compared to about 50 psi for asbestos tapes), and lower costs (Essex 1986, Protective Treatments Inc. 1986).

Protective Treatments Inc. markets the most popular asbestos sealant tape and has confirmed that its entire market could be replaced by the structural urethane. Even without an asbestos ban, Protective Treatments Inc. anticipates a decline in the demand for their sealant tape in both the OEM and after-market of windshield sealers. If structural urethane were to replace asbestos, 100 percent of Protective Treatment's market would be captured by the structural urethane (Protective Treatments Inc. 1986).

3. Carbon-based Tape

At its Columbus, Ohio plant, Tremco Incorporated manufactures an asbestos containing tape called Swiggle Tape(R), a product that has revolutionized the manufacture of insulated glass.[3] The asbestos in Swiggle Tape(R) provides thermal stability and Tremco is developing a substitute Swiggle Tape(R) that contains carbon black in place of asbestos. The anticipated cost of the carbon-based Swiggle Tape(R) is 39 percent higher than the current price of the asbestos Swiggle Tape(R), however, Tremco does not foresee any major obstacles to complete replacement of asbestos in its Swiggle

[3] Swiggle Tape(R) allows the production of insulated glass to be a one-step process of inserting the tape between two sheets of glass. The older method was a multi-stepped, labor intensive process of lining each side of glass with separate pieces of aluminum and then applying several layers of adhesives before adding a second glass sheet.

Tape(R). Total substitution of Tremco's asbestos Swiggle Tape(R) market would give the carbon-based tape a market share of less than 10 percent (Tremco 1986).

4. Non-Curing Tape

The fourth substitute, the non-curing tape, which is butyl rubber with calcium carbonate as a filler, is manufactured by the smallest asbestos sealant tape processor, Fiber-Resin Corp. The non-curing tape is used in the manufacture of plastic parts for the aerospace industry. When setting a plastic mold, a vacuum is created to force the plastic around the mold and the non-curing tape is used to seal the mold and maintain a vacuum. As the name implies, the non-curing tape is not used when the molds have to be heated. The potential market share of the non-curing tape is less than 5 percent of the market (Fiber-Resin 1986).

The salient features of the available substitutes for asbestos sealant tapes and their potential market shares in the event of an asbestos ban are presented below. Cellulose tapes would gain a 56.3 percent market share, replacing the asbestos sealant tapes produced by Elixir Industries and the asbestos tape produced at Tremco's Kentucky plant. Structural urethane would replace Protective Treatment's entire market. Tremco Incorporated is developing a carbon-containing version of its Swiggle Tape (R) that would capture less than 10 percent of the market if asbestos is banned. The non-curing tape would replace 80 percent of Fiber-Resin's market. The market substitutions are presented in Table 3. The data inputs for the model are presented in Table 4.

E. Summary

Sealant tape is made from a semi-liquid mixture of butyl-rubber and asbestos and is used for sealing building windows, automotive windshields, and mobile home windows. The tape is also used in the manufacture of parts for

Table 4. Data Inputs for Asbestos Regulatory Cost Model
(033) Sealant Tape

Product	Output	Product Asbestos Coefficient	Consumption Production Ratio	Price	Useful Life	Equivalent Price	Market Share	References
Asbestos Tape	423,048,539 ft.[a]	0.0000039 tons/ft.[b]	1	$0.07/ft.[c]	20 years	$0.07/ft.	N/A	ICF 1986a
Cellulose Tape	N/A	N/A	N/A	$0.05/ft.[d]	15 years	$0.06/ft.[f]	56.4%	ICF 1986a, Parr 1986
Structural Urethane	N/A	N/A	N/A	$0.07/ft.	20 years	$0.07/ft.	36.8%	ICF 1986a, Essex 1986
Carbon-Based Tape	N/A	N/A	N/A	$0.32/ft.	20 years	$0.32/ft.	6.6%	Tremco 1986
Non-Curing Tape	N/A	N/A	N/A	$0.10/ft.	N/A[e]	$0.10/ft.	0.2%	Fiber-Resin 1986

N/A: Not Applicable.

[a]See Attachment Item 7.

[b]See Attachment Item 4.

[c]See Attachment Item 3.

[d]See Attachment Item 5.

[e]Fiber-Resin's asbestos tape is used in a manufacturing process that takes minutes to complete and once complete the tape is discarded.

[f]See Attachment Item 6.

[g]Due to rounding error, the actual total of the market shares was 99.9 percent. To adjust for the rounding error, 0.1 percent was added to the cellulose tape market share.

the aerospace industry and in the manufacture of insulated glass. In 1985 there were four processors with five plants nationwide that manufactured the tape. There are no known importers of the tape. Although the production of the asbestos sealant tape increased 22.5 percent between 1981 and 1985, industry experts expect a significant erosion of the asbestos extruded sealant tape market over the next several years due to the development of cost-effective substitutes, particularly in the area of automotive applications. Effective non-asbestos substitutes for almost all the applications of asbestos sealant tape are available. The substitutes include cellulose-tape, structural urethane, carbon-based tape and non-curing tape.

ATTACHMENT

1. Fiber Consumption In Production of Asbestos Sealant Tapes as Percentage of Total Asbestos Fiber Consumed.

   According to ICF survey data, 145,123.3 short tons of asbestos fiber were consumed in the United States in 1985. A total of 1,660.2 tons were consumed in the production of sealant tapes in 1985. The percentage of sealant fiber consumption in 1985 is (1,660.2/145,123.3) x 100 = 1.1 percent.

2. 1981 Fiber Consumption and Sealant Tape Production.

1981	Fiber Consumption (short tons)	Production (feet)	Reference
Total	1,516	345,480,853	ICF 1986a

From the above 1981 data, two calculations were performed:

(a) Percentage change in production volume between 1981 and 1985 = (/1985 production - 1981 production//1981 production) x 100 = (/423,048,539 - 345,480,853//345,480,853) x 100 = 22.5 percent

(b) Percentage change in fiber consumption between 1981 and 1985 = (/1985 consumption - 1981 consumption//1981 consumption) x 100 = (/1660-1516//1516) x 100 = 9.5 percent

3. Calculation Of Average Price Of Asbestos Sealant Tape.

Company	Price of Asbestos Tape[a]
Average Price	$0.07/ft.

[a]From ICF 1986a.

The average price was calculated as a weighted average using the market share of each separately priced asbestos tape as the weight:

4. Calculation of the Product Asbestos Coefficient.

Company	Product Asbestos Coefficient[a]
Coefficient	0.009 lbs./ft.

[a]From ICF 1986a.

The product asbestos coefficient was calculated as a weighted average using the market share of each asbestos tape as the weight.

5. Calculation of Price of Cellulose Tape.

   Two processors identified cellulose tape as a potential substitute. Tremco stated that the cellulose tape that it produces could replace 100 percent of the market of its Kentucky plant. Elixir Industries stated that a cellulose tape could replace their entire asbestos sealant tape market and it is assumed that the cellulose tape produced by Parr (used for the same applications as Elixir's tape) is a good estimate of the price of any potential replacement at Elixir.

   The combined output of Elixir's plant and Tremco's Kentucky plant represents 100 percent of the expected share cellulose tapes would gain of the existing asbestos tape market. The total production replaced by cellulose tapes is the sum of Elixir's and Tremco's 1985 production. The average price of the cellulose tape can be calculated by taking a weighted average (using cellulose tape market shares as a weight) of the prices of the two substitute tapes.

6. Calculation of Equivalent Price of Cellulose Tape.

   The equivalent prices were calculated using a present value formula assuming a 5 percent real interest rate. The equivalent price of cellulose tape was calculated to be $0.06/ft.

   Let:

   TC = total cost of cellulose tape = $0.05/ft.
   PV = present value price of substitute product calculated for the life of the asbestos product.
   Na = Useful life of asbestos sealant tape = 20 yrs.
   Ns = Useful life of cellulose tape = 15 yrs.

   In the following present value formula:

   $$PV = TC \times (a/b) \times (b-1)/(a-1)$$

where

$$a = (1.05)^{Ns} \text{ and } b = (1.05)^{Na}$$
$$a = 1.05^{15} = 2.08 \text{ and } b = (1.05)^{20} = 2.65$$
$$PV = 0.05 \times (2.08/2.65) \times (2.65 - 1)/(2.08 - 1)$$
$$PV = 0.06$$

7. Fiber-Resin Corp. reported that one liquid gallon of the butyl rubber asbestos mixture is equivalent to 275-300 feet of sealant tape and this works out to an average of 287.5 feet per gallon. This information may be desirable for conversion purposes.

REFERENCES

Concrete Sealants, Inc. Mr. Robert J. Haman. 1986 (July-December). New Carlisle, OH 45344. Transcribed telephone conversations with Rick Hollander and Eric Crabtree, ICF Incorporated, Washington, DC.

Elixir Industries. Paul Elswick. 1986 (July-December). Elkhart, IN. Transcribed telephone conversations with Eric Crabtree, ICF Incorporated, Washington, DC.

Essex Specialty Products. Robert Rozlinski. 1986 (December 12). Clifton, NJ. Transcribed telephone conversation with Eric Crabtree, ICF Incorporated, Washington, DC.

Fiber-Resin Corporation. 1986 (July-December). Burbank,CA. Transcribed telephone conversation with Eric Crabtree, ICF Incorporated, Washington, DC.

ICF Incorporated. 1986a (July-December). Survey of Primary Processors of Asbestos-Reinforced Plastic. Washington, DC.

ICF Incorporated. 1986b (July-December). Survey of Secondary Processors of Asbestos-Reinforced Plastic. Washington, DC.

MB Associates. Tony Depaulif. 1986 (December 9). Detroit, MI. Transcribed telephone conversation with Eric Crabtree, ICF Incorporated, Washington, DC.

Parr Incorporated. John Burry. 1986 (December 9). Cleveland, OH. Transcribed telephone conversation with Eric Crabtree, ICF Incorporated, Washington DC.

Protective Treatments Incorporated. Steve Short. 1986 (July-December). Dayton, OH. Transcribed telephone conversations with Peter Tzanetos and Eric Crabtree, ICF Incorporated, Washington DC.

Tremco Inc. David L. Trimble. 1986 (July-December). Columbus, OH. Transcribed telephone conversations with Jeremy Obaditch and Eric Crabtree, ICF Incorporated, Washington DC.

XXXIV. ASBESTOS SEPARATORS IN FUEL CELLS AND BATTERIES

A. Product Description

In very specialized aerospace applications, asbestos functions as an insulator and separator between the negative and positive terminals of a fuel cell/battery. The porous nature of the 100 percent woven-asbestos material allows it to adsorb the liquids used in fuel cells and batteries. The liquids used in these fuel cells/batteries are highly corrosive and reach very high temperatures. The properties of asbestos that are desirable in this function are its porosity, heat resistance, anti-corrosiveness, strength and dielectric strength (ICF 1986).

B. Producers and Importers of Asbestos Separators

Currently, two companies in the country use asbestos in fuel cells and batteries. Eagle-Pitcher Industries sells its batteries to the Defense Department for use on ICBMs and Power Systems Division sells its fuel cells to NASA for use on the Space Shuttle (Eagle-Pitcher 1986, Power 1986). Table 1 lists the total fiber consumed in 1981 and 1985 in this market. Neither Eagle-Pitcher nor Power Systems were able to state with certainty the number of asbestos-containing fuel cells/ batteries they produced, however, given that the separators are 100 percent asbestos, the record of fiber consumption gives a good indicator of the market (ICF 1986). There are no known importers of asbestos containing batteries/fuel cells (ICF 1986, ICF 1984).

C. Trends

Since 1981, asbestos use in this function has declined slightly from 2,150 lbs. to 2,046 lbs. Neither company anticipates a change in the government specifications that require the use of asbestos in their batteries/fuel cells and thus do not expect any drastic changes in the asbestos separator market (ICF 1986).

Table 1. Asbestos Fiber Consumption in Batteries/Fuel Cells

	1981 Fiber Consumed (pounds)	1985 Fiber Consumed (pounds)	Reference
Total	2,150	2,046	ICF 1986

D. Substitutes

Eagle-Pitcher Industries has developed a substitute for asbestos that could replace about two-thirds of its asbestos battery market. The substitute material is aluminum silicate. The aluminum silicate batteries cost the same as the asbestos batteries and show no performance differences for two-thirds of the asbestos battery market. Eagle-Pitcher would not elaborate on why the remaining one-third of their asbestos batteries could not be replaced with non-asbestos substitutes. Power Systems Division claims that asbestos is required for the unique conditions encountered in outer space and reports that there are no available substitutes (ICF 1986).

This product category, a part of the miscellaneous asbestos mixture category, was deemed too small to be included in the asbestos regulatory cost model. The 1 ton of asbestos fiber consumed in this category accounted for an extremely small percentage of the total domestic consumption (145,123.3 tons) in 1985 (ICF 1986).

E. Summary

In very specialized aerospace applications, asbestos functions as an insulator and separator between the negative and positive terminals of a fuel cell/battery. Currently, two companies in the country use asbestos separators in fuel cells and batteries. Since 1981, the market for asbestos separators has been stable and no dramatic changes in the market are expected in the near future. One of the processors, Eagle-Pitcher Industries, has developed a substitute battery containing aluminum silicate that could replace two-thirds of its asbestos containing batteries.

REFERENCES

Eagle-Pitcher Industries, Inc. Richard Cooper. 1986 (July-December). Joplin, MO 64801. Transcribed telephone conversations with Eric Crabtree, ICF Incorporated, Washington, DC.

ICF Incorporated. 1984. Imports of Asbestos Mixtures and Products. Washington, D.C.: Office of Pesticides and Toxic Substances, U.S. Environmental Protection Agency. EPA CBI Document Control No. 20-8600681.

ICF Incorporated. 1986 (July-December). Survey of Primary and Secondary Processors of Asbestos-Reinforced Plastic. Washington, D.C.

Power Systems Division. Helvin Hecht. 1986 (July-December). South Windsor, CT 46224. Transcribed telephone conversations with Peter Tzanetos and Eric Crabtree, ICF Incorporated, Washington, D.C.

XXXV. ASBESTOS ARC CHUTES

A. Product Description

Ceramic arc chutes containing asbestos are produced by General Electric and are used to guide electric arcs in motor starter units in electric generating plants. Asbestos is used in the arc chutes for its strength, heat resistance, and dielectric strength (General Electric 1986).

B. Producers and Importers of Asbestos Arc Chutes

General Electric Company is the only processor of asbestos-containing ceramic arc chutes. There are, however, other processors of asbestos arc chutes, but they manufacture plastic arc chutes that have been classified in the asbestos-reinforced plastic category (031). Generally, the plastic arc chutes are smaller and are not able to withstand as high a temperature (above 1500°F) as the ceramic arc chutes. The plastic arc chutes are used in smaller electric motors, often in the automotive and appliance industries (ICF 1986).

C. Trends

Production of asbestos arc chutes has fallen dramatically from 9,400 arc chutes in 1981 to 900 in 1985. Fiber consumption has fallen correspondingly from 141 tons in 1981 to 13.5 tons in 1985. (General Electric 1986). Table 1 shows production of asbestos arc chutes and consumption of asbestos fiber in 1981 and 1985.

D. Substitutes

General Electric is converting their ceramic blast breaker, which contains the asbestos arc chutes, to a vacuum breaker which does not require any arc chutes. General Electric expects to be asbestos-free within a few years and total replacement of this asbestos product market is predicted. General Electric did not cite any cost or performance differences of the vacuum breaker versus the ceramic blast breaker (General Electric 1986).

Table 1. Asbestos-Containing Ceramic Arc Chutes, Production and Fiber Consumption 1981-85

Year	Production of Arc Chutes	Fiber Consumption (short tons)	Reference
1981	9,400	141.0	ICF 1986
1985	900	13.5	ICF 1986

This product category, a part of the miscellaneous asbestos mixture category, was deemed too small to be included in the asbestos regulatory cost model. The 13.5 tons of asbestos fiber consumed in this category accounted for an extremely small percentage of the total domestic consumption (145,123.3 tons) in 1985 (ICF 1986).

E. Summary

One company, General Electric in Philadelphia, produces a ceramic arc chute containing asbestos. The arc chutes are used to guide electric arcs in motor starter units in electric generating plants. Production of asbestos arc chutes has fallen dramatically since 1981. General Electric is converting from using a blast breaker to using a vacuum breaker that does not require any asbestos. Total replacement of this asbestos product is expected within a few years.

REFERENCES

General Electric Company. Richard York. 1986 (July-December). Philadelphia, PA 19142. Transcribed telephone conversations with Eric Crabtree, ICF Incorporated, Washington, D.C.

ICF Incorporated. 1986 (July-December). Survey of Primary and Secondary Processors of Asbestos-Reinforced Plastic. Washington, D.C.