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. <u>Producers and Importers of Asbestos-Cement Shingles</u>

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. <u>Trends</u>

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
<u>Siding Substitutes</u>					
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
<u>Roofing Substitutes</u>					
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

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[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. Asbestos-Cement Roofing Shingle Substitutes

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).

<u>Siding</u>. 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).

<u>Roofing</u>. 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.

ATTACHMENT

(1) Calculation of percent of asbestos in domestic asbestos-cement shingles.

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) Calculation for imports of asbestos-cement shingles.

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) Cost of wood roofing.

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
18" = $58/square
Average = $61/square

(c) Cost of wood siding and roofing

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) Cost for asphalt standard strip shingles.

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 square x (11.4674/7.0400) x (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 square x (11.4674/7.0400) x (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 square x (4.3219/7.0400) x (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 square x (4.3219/7.0400) x (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 square x (2.6533/7.0400) x (7.0400 - 1)/(2.6533 - 1)
= \$67.47 = \$67/square

(g) Tile roofing

TC = \$173/square
N_b = 50 years
B = $(1.05)^{50}$ = 11.4674

PV = \$173 square x (11.4674/7.0400) x (7.0400 - 1)/(11.4674 - 1)
= \$162.61 = \$162/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

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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		References
		Asbestos	Non-Asbestos	
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 Asbestos	 Non-Asbestos	References
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

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[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,

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[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.

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