PLAINTIFF'S EXHIBIT

CT-1541

RTI REPORT
- EXECUTIVE SUMMARY
- PIPE SECTION

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Phase I Report

Regulatory Analysis of the Proposed OSHA Standard on Asbestos

for

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S.0 Executive Summary

S.1 INTRODUCTION

This section summarizes the results of Phase I of a regulatory impact analysis of a proposed OSHA standard on asbestos. The study investigated four segments of the asbestos industry: primary manufacturing, secondary fabrication, the automotive aftermarket, and shipbuilding and repair. The objectives of the Phase I study were: to define the asbestos industry in terms of number of plants, workers exposed, exposure levels, and current practices; to investigate the feasibility of reducing workplace exposure to airborne asbestos fibers to levels of 0.5, 0.2 and 0.1 fibers per cubic centimeter (f/cc); and to estimate the compliance activities and costs of reducing fiber levels to each of the three levels.

S.2 INDUSTRY PROFILE

Resesarch Triangle Institute (RTI) used a variety of information sources to estimate the numbers of establishments in each of the industry segments listed above. Among the sources used were: computerized data bases, government data files, literature sources, census of manufacturers, Standard and Poor's Index of Corporations, the Thomas Register, and contacts with trade associations and individuals. Information from these sources was summarized into lists of plants in various categories. These lists were used as a basis for conducting a survey of each industry segment to solicit information regarding current practices, workers exposed, and exposure levels.

Table S-1 shows the estimated numbers of plants in each industry segment by major product line as determined from this investigation.

S.3 POPULATION EXPOSED AND EXPOSURE LEVELS

RTI used mail and telephone contacts with numerous plants within each industry segment to estimate workers exposed. In many cases, the ratio of

Table S-1 Estimated Number of Establishments by Industry Segment/Product Line

Establishment Type	Estimated Number of Establishments
Primary Manufacturing	
A/C Pipe	5
A/C Sheet	6
Friction Materials	44
Textiles	3
Flooring	3
Gaskets/Packings	21
Paper	22
Coatings	78
Plastics	4
Secondary Fabricators	
A/C Sheet	23
Friction Materials	38
Gaskets	289
Textiles	51
Plastics	245
Automotive Aftermarket	
Remanufacturing	181
Service and Repair	285, 188
Shipyards	179

workers exposed to production at surveyed plants was multiplied by nationwide production to estimate workers exposed nationwide. In other cases, data reported by the U.S. Bureau of the Census were used to estimate workers exposed.

Exposure levels were estimated mostly using data from the plant surveys and from OSHA's Management Information System (MIS). Data were available from published literature for some industry segments. Table S-2 presents the estimates of workers exposed, the reported range of exposure levels obtained during this study, and the geometric mean of the reported monitoring data.

S.4 FEASIBILITY AND COST ANALYSES

During the data collection phase of this study, RTI visisted a number of establishments considered to be well controlled. These visits were made to observe what might be considered best available control technology. Information obtained during these visits was used along with information obtained from the mail and telephone surveys to estimate the feasibility of achieving worker exposure levels of 0.5, 0.2, and 0.1 f/cc in various segments of the industry.

As proposed, any new OSHA standard would allow plants to achieve compliance with the PEL ". . . using any feasible combination of engineering controls, work practices, and personal protective equipment and devices." If this wording is retained, there is no doubt that achieving any of the three exposure levels is feasible. However, if respirators are selected as the primary means of compliance, worker acceptability may become an issue.

RTI's analysis revealed that, when technically and economically feasible to do so, most establishments will choose engineering controls and work practices as the preferred methods of reducing worker exposure. Based on industry supplied data, RTI estimates that, with the possible exception of

Table S-2 Estimated Workers Exposed and Exposure Levels
by Industry Segment/Product Line

Industry Segment/ Product Line	Workers Exposed	Exposure Levels (f/cc) Range	Geometric Mean
Primary Manufacturing			
A/C Pipe	742	0.01-1.0	0.09
A/C Sheet	209	N/D*-1.6	0.29
Friction Materials	4,908	N/D-3.36	0.38
Textiles	581	.05-1.72	0.35
Flooring	368	N/D-0.30	0.008
Gaskets/Packings	420	0.03-2.06	0.14
Paper	944	N/D-0.50	0.05
Coatings	657	N/D-2.71	0.04
Plastics	469	N/D-1.11	0.13
Secondary Fabricators			
A/C Sheet	345	N/D-2.0	0.5
Friction Materials	1,446	N/D-0.75	0.12
Gaskets	11,080	N/D-0.77	0.03
Textiles	427	N/D-1.8	0.35
Plastics	2,450	N/D-0.29	N/D
Automotive Aftermarket			
Remanufacturing	4,750	N/D-1.6	0.08
Service and Repair	546,461	N/D-0.94	N/D
Shipyards	1,485	0.01-2.72	0.06

*N/D--Non detectable fiber concentrations primary textile manufacturing, all segments of the industry can achieve fiber concentrations of 0.5 f/cc without the routine use of respirators. Some non-routine jobs would require the use of respirators, however. RTI also estimates that to achieve fiber concentrations of 0.2 f/cc, respirators would have to be used routinely at some work stations in most industry segments and that widesperead routine use of respirators would be required to achieve fiber concentrations of 0.1 f/cc. Table S-3 presents RTI's estimate of the compliance activities that would be required in model plants for each industry segment/product line.

To estimate compliance costs for the three alternative PEL's, RTI developed model plants to represent each industry segment/product line. The compliance activities that each model would need to implement to comply with each PEL was then estimated based on information obtained from an industry survey. Finally, the capital and annual costs of each compliance activity was calculated and summed to obtain total compliance costs for each model plant and the model plant costs were escalated to total cost for an industry segment or product line. Table S-4 presents the estimated capital, operating, and annualized costs for each industry segment/product line and Table S-5 presents estimates for the industry as a whole.

Compliance activities that would be required for each PEL

Table S-3. Compliance Activities in Model Plants

Plants Model	PEL, f/cc	Workers Exposed	LEV cfm[a]	Controls Required: Make-up Air	Controls Required: Vacuum Cleaners	Controls Required: Monitoring	Controls Required: Change Rooms	Controls Required: Training	Controls Required: Regulated Areas	Controls Required: Respiratory Program[b]
PRIMARY MANU-FACTURING MODELS										
A/C Pipe	0.5	175								10%
	0.2									50%
	0.1									100%
A/C Sheet	0.5	50	36,250	X						
	0.2		36,250	X						100%
	0.1		36,250	X						100%
Textiles	0.5	200	95,000	X						
	0.2		95,000	X						100%
	0.1		95,000	X						100%
Floor Tile	0.5	125								10%
	0.2									50%
	0.1									100%
Coatings (small)	0.5	5	1,000	X						10%
	0.2		1,000	X						50%
	0.1		1,000	X						100%
Coatings (medium)	0.5	25	2,500	X						10%
	0.2		2,500	X						50%
	0.1		2,500	X						100%
Friction (medium)	0.5	25	50,000	X						10%
	0.2		50,000	X						50%
	0.1		50,000	X						100%
Friction (Large)	0.5	100	83,000	X						10%
	0.2		83,000	X						50%
	0.1		83,000	X						100%
Paper (small)	0.5	15	-							
	0.2		8,750	X	1			X	X	
	0.1		8,750	X	1			X	X	
Paper (medium)	0.5	50	-							
	0.2		21,250	X	2			X	X	
	0.1		21,250	X	2			X	X	
Gaskets (small)	0.5	15	8,300	X						
	0.2		8,300	X						50%
	0.1		8,300	X						100%
Gaskets (medium)	0.5	50	25,000	X						
	0.2		25,000	X						50%
	0.1		25,000	X						100%
Plastics (small)	0.5	5	3,000							
	0.2		3,000		1					50%
	0.1		3,000		1					100%
Plastics (medium)	0.5	50	15,000							
	0.2		15,000		2					50%
	0.1		15,000		2					100%

continued

Table S-3. Compliance Activities in Model Plants (Continued)

Plants Model	PEL, f/cc	Workers Exposed	LEV cfm[a]	Make-up Air	Controls Required: Vacuum Cleaners	Monitoring	Change Rooms	Training	Regulated Areas	Respiratory Program[b]
SECONDARY MANU-FACTURING MODELS										
Textile (small)	0.5	10			1	X	X	X	X	100%
	0.2					X	X	X	X	100%
	0.1		4,750			X	X	X	X	100%
Gasket (small)	0.5	3	-							
	0.2				2	X	X	X	X	50%
	0.1				1	X	X	X	X	100%
Gasket (medium)	0.5	50	-							
	0.2					X	X	X	X	50%
	0.1					X	X	X	X	100%
Gasket (large)	0.5	150	-							
	0.2		75,000	X		X		X		
	0.1		100,000	X		X		X	X	100%
AC Sheet (small)	0.5	5	-							
	0.2		-							
	0.1		3,700	X						
AC Sheet (medium)	0.5	20	-							
	0.2		-							
	0.1		14,500	X						
SHIPYARD MODELS										
Small	0.5	3								100%
	0.2									Cartridge
	0.1									Cartridge
Large	0.5	225								100%
	0.2									Cartridge
	0.1									Cartridge

Continued

Table S-3. Compliance Activities in Model Plants (Continued)

Plants Model	PEL	Workers Exposed	LEV cfm	Make-up Air	Controls Required: Vacuum Cleaners	Monitoring	Change Rooms	Training	Regulated Areas	Respiratory Program
AUTO AFTER-MARKET MODELS										
Remanufacturing (small)	0.5	5	-			X	X	X	X	100%
	0.2					X	X	X	X	100%
	0.1					X	X	X	X	100%
Remanufacturing (medium)	0.5	35	-							
	0.2		8,000	X						
	0.1					X	X	X	X	100%
Remanufacturing (large)	0.5	70	-							
	0.2		16,000	X						
	0.1		16,000	X						
Repair (small)	0.5	3	-							
	0.2					X	X	X	X	100%
	0.1					X	X	X	X	100%
Repair (medium)	0.5	10	-							
	0.2					X	X	X	X	100%
	0.1					X	X	X	X	100%
Repair (Large)	0.5	20	-							
	0.2					X	X	X	X	100%
	0.1					X	X	X	X	100%

[a] A dash indicates that compliance now exists at the indicated PEL. When LEV is used, the additional capacity needed is estimated to be 25% of existing capacity (except for primary textile manufacturing where a 100% increase is estimated). Existing capacity was determined from actual plant data.

[b] Disposable respirators are used except where indicated.

Table S-4. Total Cost of Control by Industry Segment/Product Line

Industry Segment & Model	PEL	Capital Cost for Industry Segment, $	O & M Cost for Industry Segment, $/yr	Annual Cost for Industry Segment, $/yr
Primary				
AC Pipe	0.5	29,884	157,995	169,638
	0.2	"	226,000	237,644
	0.1	"	311,008	322,647
AC Sheet	0.5	743,831	387,152	506,014
	0.2	752,195	481,197	603,320
	0.1	"	"	"
Textiles	0.5	1,374,661	651,168	870,838
	0.2	1,398,005	885,167	1,113,931
	0.1	"	"	"
Floor Tile	0.5	14,994	98,346	104,188
	0.2	"	132,027	137,868
	0.1	"	174,130	179,969
Coatings	0.5	678,221	404,996	520,629
	0.2	"	465,222	580,876
	0.1	"	540,514	656,124
Friction	0.5	25,658,805	13,440,465	17,585,143
	0.2	"	13,890,265	18,034,906
	0.1	"	14,452,470	18,597,109
Paper	0.5	-	-	-
	0.2	2,410,582	1,488,779	1,892,405
	0.1	"	"	"

Table S-4. Total Cost of Control by Industry Segment/Product Line (Continued)

Industry Segment & Model	PEL	Capital Cost for Industry Segment, $	O & M Cost for Industry Segment, $/yr	Annual Cost for Industry Segment, $/yr
Gaskets	0.5	1,137,690	525,695	707,499
	0.2	1,150,616	714,643	903,289
	0.1	"	"	"
Plastics	0.5	20,089	153,455	162,130
	0.2	764,539	760,432	926,170
	0.1	"	"	"
Secondary				
Textile	0.5	196,505	645,966	684,139
	0.2	"	575,084	613;215
	0.1	1,247,523	1,089,277	1,295,390
Gasket	0.5	-	-	-
	0.2	20,270,612	15,582,546	18,936,226
	0.1	24,502,196	78,377,222	25,473,873
AC Sheet	0.5	-	-	-
	0.2	-	-	-
	0.1	1,775,577	889,493	1,173,221
Friction[a]	0.5	62,814	650,642	675,166
	0.2	"	"	"
	0.1	"	"	"
Plastics[a]	0.5	173,460	1,102,500	1,170,120
	0.2	1,991,850	5,292,490	5,857,460
	0.1	"	"	"
Ship repair	0.5	332,674	3,185,229	3,314,791
	0.2	409,270	6,752,761	6,912,194
	0.1	"	"	"

Table S-4. Total Cost of Control by Industry Segment/Product Line (Continued)

Industry Segment & Model	PEL	Capital Cost for Industry Segment, $	O & M Cost for Industry Segment, $/yr	Annual Cost for Industry Segment, $/yr
<u>Automotive Aftermarket</u>				
Remanufacturing	0.5	297,654	853,165	913,045
	0.2	5,726,184	3,948,992	4,963,716
	0.1	4,760,938	4,994,035	5,923,497
Repair	0.5	-	-	-
	0.2	139,443,044	337,635,080	365,330,406
	0.1	"	"	"

[a]A separate model was not developed for this product line. The equivalent primary model, adapted to use disposable respirators in place of an LEV system, was used to obtain costs.

Table S-5. Summary of Costs by Industry Segment

Industry Segment & PEL, f/cc	Capital Cost, $ (Millions)	Capital Cost, $/Worker	O & M Cost $/yr (Millions)	O & M Cost $/Worker	Annual Cost $/yr (Millions)	Annual Cost $/Worker
Primary						
0.5	30	3,200	16	1,700	21	2,200
0.2	33	3,500	19	2,000	24	2,600
0.1	33	3,500	20	2,100	25	2,700
Secondary						
0.5	0.4	25	2	150	3	160
0.2	23	1,400	22	1,400	26	1,700
0.1	30	1,900	29	1,900	35	2,200
Automotive Aftermarket						
0.5	0.3	1	0.8	3	0.9	4
0.2	150	580	340	1,400	370	1,500
0.1	140	570	340	1,400	370	1,500
Ship Repair						
0.5	0.3	37	3.2	390	3.3	400
0.2	0.4	49	6.8	830	6.9	800
0.1	0.4	49	6.8	830	6.9	800
All Segments						
0.5	31	110	21	74	27	96
0.2	200	710	390	1,400	430	1,500
0.1	200	730	400	1,400	440	1,500

1.0 Industry Profile

1.1 INTRODUCTION

The term asbestos is used to describe a group of minerals defined as fibrous silicates. Asbestos fibers are characterized by their resistance to chemical attack and moisture, by their strength and dimensional stability, and by their thermal and electrical insulating properties. Because of these desirable properties, asbestos has been used in many different products. It has proven to be especially valuable where products are used in corrosive atmospheres and environments subject to chemical attack.

The asbestos industry is organized in the following manner. First, asbestos ore is mined and then milled to achieve a homogenous, graded input, which is shipped to primary industries. These primary industries then process and modify the raw asbestos fiber to produce an intermediate or finished product. Secondary industries may then be required to complete the final processing of the product into a finished good. Finally, this finished good or product is sold to consumer industries which then apply, install, erect, or consume the product without further modification. Industries that use or process asbestos products are generally categorized into five major groups: primary manufacturers, secondary fabricators, shipbuilding and ship repair, automotive aftermarket, and construction. The construction segment includes demolition, renovation, and maintenance activities as well as new construction.

When asbestos fibers are inhaled into the lungs, they can cause a variety of diseases including asbestosis, lung cancer, mesothelioma, and other types of cancers. Consequently, it is necessary to protect workers in the asbestos industries against excessive exposures to airborne asbestos fibers. Toward this end, OSHA has regulated the asbestos fiber concentrations to which workers can be exposed in the workplace, and has imposed other requirements on employers to further insure that workers are not harmed by workplace asbestos exposure. The current OSHA standard regarding workplace exposure to asbestos requires that 8-hour time-weighted-average (TWA) fiber concentrations be kept below 2.0 fibers per cubic centimeter (f/cc), requires that workers have access to yearly medical exams at the expense of the employer, and specifies other protective measures that are to be taken.

OSHA is now considering modifications to the existing standard that would reduce the permissible exposure limit (PEL) to a lower level. Alternatives being considered for the new PEL are 0.5, 0.2, and 0.1 f/cc on an 8-hour time-weighted basis. This report documents phase 1 of a regulatory impact analysis for each of the three regulatory alternatives. The major objectives of the study are to define the asbestos industry as it currently exists, including employee exposures to asbestos fibers and protection programs; and to investigate the feasibility and costs of achieving each of the lower levels specified in the regulatory alternatives.

The remainder of Section 1.0 describes the processes and products of four of the industry segments mentioned above (construction is not included). Subsequent sections of the report discuss current activities by employers to protect employees, discuss the numbers of workers exposed to asbestos in the workplace and the levels to which they are exposed, and present the estimated costs of achieving compliance with the alternative PELs for each industry segment.

1.2 PRIMARY MANUFACTURERS

Primary manufacturers use asbestos fiber as a raw material in the production of an intermediate product to be further processed or fabricated into a finished product. The use of asbestos by domestic primary manufacturers has declined significantly in recent years; apparent domestic consumption was about 25 percent lower in 1982 than in 1981 and approximately 12 percent lower in 1983 than in 1982.[2] Although this trend is expected to continue, many primary manufacturers are continuing to use this mineral fiber in product lines where adequate substitute materials are either not available or not cost-effective.

The affected industries in primary manufacturing and their Standard Industrial Classification (SIC) codes include the following:

- Asbestos Products (SIC 3292)
- Gaskets, Packings, and Sealing Devices (SIC 3293)
- Building Paper and Building Board Mills (SIC 2661)
- Linoleum Asphalt-Felt Base and Other Hard Surface Floor Coverings (SIC 3996)
- Asphalt Felts and Coatings (SIC 2952)
- Miscellaneous Plastic Products (SIC 3079).

More than 100 individual asbestos-containing products can be identified within these six SIC classifications. However, these individual products can be categorized into the following 10 basic product lines:

- Asbestos-cement pipe (SIC 3292)
- Asbestos-cement sheet (SIC 3292)
- Asbestos friction materials (SIC 3292)
- Asbestos textile products (SIC 3292)
- Asbestos resilient flooring (SIC 3292 and 3996)
- Asbestos gaskets, packings, and sealing devices (SIC 3293)
- Asbestos paper products (SIC 2952, 2661)
- Asbestos adhesives, sealants, and coatings (SIC 2952)
- Asbestos-reinforced plastic products (SIC 3079)
- Miscellaneous asbestos products not elsewhere classified.

Several industrial processes are used by primary manufacturers to create these diverse product lines, and many potential sources of airborne asbestos fiber can be identified throughout each process. However, two operations that are common to all processes have a high potential for generating airborne asbestos fiber--and consequently human exposure. These operations are fiber introduction and product finishing.

The fiber introduction stage includes those operations necessary to prepare the asbestos fiber for subsequent mixing or blending. Broken bags and spills in the fiber receiving and storage area account for many of the airborne fibers during this operation.[3] Fibers may also become airborne when compacted asbestos fiber is removed mechanically (or manually) from the supplier's sealed containers in preparation for mixing. Depending on the product line, the compacted fiber may be "willowed" or "fluffed" to facilitate mixing. In a dry-mix process, fibrous asbestos may become airborne as the batch is weighed and when additional materials are added. Once the fiber has been wetted with water or other substances, encapsulated, or bonded with other materials, fiber release is significantly reduced. However, asbestos fiber may become airborne due to leakage or spillage during mixing, mixer unloading, or processing operations.[4]

In product finishing operations, asbestos fibers become airborne when they are torn loose from the parent product as it is cut, sawed, drilled, texturized, shaped, or otherwise modified to form a finished product.[4] Occupational exposures may also occur after the finishing operation, during the handling and disposal of asbestos-containing wastes.

RTI identified 186 plants currently engaged in the primary manufacture of asbestos products. In 1981, these plants employed approximately 12,160 production workers and 6,160 shipping and maintenance employees who could be potentially exposed to airborne asbestos fiber.[5] This estimate was derived from an independent review and confirmation of data available through numerous information sources. In the initial identification process, lists of manufacturers available from Federal agency management information systems were reviewed and compiled. These sources included the U.S. Environmental Protection Agency (EPA) Compliance Data System (CDS) and the EPA Toxic Substances Control Act (TSCA) Section 8(a) reporting file. The Occupational Safety and Health Administration (OSHA) Management Information System (MIS) also was accessed. The resulting compilation was compared with the information reported in other recent literature and business information series, (such as Standard and Poor's Index of Corporations and the Thomas Register) to reconcile conflicting information and to obtain additional data. Through this process more than 400 potential primary manufacturers were identified. RTI surveyed the companies identified to solicit information regarding asbestos operations. At same establishments, company or plant personnel indicated that only asbestos-free products were made; in that case, the company or plant was deleted from the listing. Companies believed to be out-of-business also were deleted. The lists of primary manufacturers provided in this report may not include all manufacturers, however, the current major manufacturers are listed as are many smaller firms not identified in previous studies.

The following subsections provide a profile of the nine major product lines within the primary manufacturing segment of the asbestos industry. The companies and plant locations associated with each product line are listed in separate tables in Appendix A (Tables A-1 through A-10).

1.2.1 Asbestos-Cement Pipe

Asbestos-cement (A/C) pipe is used principally for water mains, sewer lines, and electrical cable conduits. Its composition is chiefly Portland cement (42 to 53 percent by weight), asbestos fibers (15 to 25 percent by weight), and finely ground silica sand (34 to 40 percent by weight).[6] In these pipe products, asbestos provides the necessary flexural strength that allows deflection without failure. Chrysotile is the principal type of asbestos used in A/C pipe; fiber grades 4 and 5 are most common. At the present time, substitutes for asbestos fiber are not considered cost-competitive.[6]

The basic steps in the manufacture of A/C pipe are materials preparation (fiber introduction), materials mixing, pipe forming, curing, and finishing.[7] A wet-mechanical production process is most common. In A/C pipe manufacture, most exposure to airborne asbestos fiber occurs during fiber introduction and finishing.

A total of five plants owned by three companies currently produce A/C pipe; this is down from nine plants in 1981.[8] Factors contributing to this recent decline include competitive pressures from manufacturers of polyvinyl chloride pipe, the drop in sewer system construction since EPA construction grant cutbacks in 1978, and the overall drop in housing starts.[8] However, waterworks construction is expected to result in renewed demand for A/C pipe during coming years.[9] The three primary producers of A/C pipe at five plant locations are listed in Appendix A, Table A-1.

1.2.2 Asbestos-Cement Sheet

Asbestos is used as a reinforcing material in cement sheet products because of its high tensile strength, flexibility, thermal resistance, and chemical inertness. A/C sheet also has the wet strength necessary for molding into complex shapes at the end of the production process.[10]

Flat A/C sheet is used in the construction industry for wall linings in factories and agricultural buildings, fire-resistant walls, industrial

3.0 Compliance Status and Current Practices

This chapter describes the compliance status of each industry segment. Current levels of exposure to airborne asbestos fiber and the practices or controls used to achieve those levels are discussed. In the discussion of each industry segment, one section describes the processes that generate airborne asbestos fibers, the most recent data regarding the resulting exposure levels, and the number of workers exposed. Another section describes the practices and controls applied to achieve current exposure levels.

3.1 PRIMARY MANUFACTURERS

3.1.1 Compliance Status

Several means were used to evaluate the current compliance status of the primary manufacturing industry segment. First, RTI conducted a survey of all identified primary manufacturers. The approach used to identify these firms is discussed in Chapter 1. RTI also visited one plant manufacturing each of seven primary manufacturing product lines to become familiar with plant processes. Plants considered to have the best exposure controls (based on recommendation of the Asbestos Information Association) were visited to evaluate the lower limit of asbestos exposure achievable by current practices. The information gathered from well-controlled plants and the manufacturers responding to the survey were major data sources.

The survey data were supplemented by current OSHA inspection records reported by the Agency's Management Information System (MIS). Inspection records for the years 1979 to 1984 were examined to determine the ranges of fiber concentrations reported by process or job category. These ranges then were combined with the ranges reported by the survey respondents. Overall exposure ranges reported by surveyed manufacturers, the OSHA data, and the combined results are reported. The raw data forming these ranges has been verified by OSHA and is retained in confidential files of the OSHA contractor.

The estimated overall exposure ranges reported in this section are compared, where possible, to other data reported in recent literature. These data were obtained by means of a literature search, coupled with information supplied by industry contacts and trade associations. The estimated current exposure levels also are compared to exposure levels reported during the period 1976 through 1978 to approximate the reductions in ranges of fiber concentration achieved in recent years.

The survey data supplied by primary manufacturers were used to estimate the number of workers exposed, by process operation, for each major product line. These estimates were calculated by constructing a ratio of the number of workers exposed at a surveyed plant to actual plant production. This ratio then was multiplied by the most recent estimates available for nationwide production to estimate workers exposed. The following equation was used:

$$\text{Total workers exposed} = \frac{\text{(Workers exposed in surveyed plants)}}{\text{(Production in Surveyed Plant)}} \times \text{(Nationwide Production).}$$

Unless reported otherwise, the most current industrywide estimates of asbestos production are for the year 1981. The nationwide production estimate was obtained from a 1982 study prepared for the U.S. Environmental Protection Agency (EPA).[1] The production ranges reported in that study were based on confidential information supplied by primary manufacturers pursuant to the Section 8(a) reporting requirements of the Toxic Substances Control Act. The average resulting from the ranges reported was used to approximate current production levels, which have declined in recent years due to the use of asbestos substitutes and plant closures. These data are summarized in Table 3-1 along with the resulting estimates of population exposed.

Table 3-1. Summary Data for Primary Manufacturers

Product Line	Annual[a] Production	Production Per[b] Exposed worker	Estimated Exposed Workers	Estimated[b] Plants	Estimated[bc] Levels (f/cc)
A/C Pipe	374,000 tons	504 Tons	742	5	0.01 - 1.0
A/C Sheet	623,000 squares	2,981 squares	209	6	N/D - 1.6
Friction Material	250,000,000 pieces	50,937 pieces	4,908	44	N/D - 3.36
Textiles	6,650 Tons	11.45 Tons	581	3	.05 - 1.72
Flooring	10^9 ft^2	2.72 (10^6) ft^2	368	3	N/D - 0.3
Gaskets	47.7 (10^6) ft^2	167,400 ft^2	285	21	0.03 - 2.06
Packings	68.5 Tons	1,014 lbs	135		
Paper	176,400 Tons	187 tons	944	22	N/D - 0.5
Coatings	87.6 (10^6) gallons	133.3 (10^3) gallons	657	78	N/D - 2.71
Plastics	12,187 Tons	26 Tons	469	4	N/D - 1.11

Notes:

a. From Reference 3 — 1981 PROD. DATA
b. From RTI Survey data — 1981 - 9 PLTS, 1984 - 5 PLTS.
c. From OSHA's MIS Files — 1979 - 1984

3.1.1.1 Asbestos-Cement Pipe

Raw materials used for the production of A/C pipe include asbestos fiber, Portland cement, silica sand, and water. After bag opening and fiber introduction to the process, conveying equipment carries the raw fiber to a dry mixing step. Agitation in this step serves two purposes; opening or fluffing the fiber, and mixing the cement constituents. Sand and portland cement are added at this point, typically being conveyed pneumatically at an enclosed, live-bottom mixer. In this manufacturing process, the fiber introduction operation, which includes dry-mixing, usually generates the highest levels of airborne fiber.

The dry mix next passes by conveyor to a wet-mixing operation just upstream of the pipe-forming machine. The wet mortar flows to the pipe-forming machine vats, where the asbestos cement slurry is picked up on a rotating, screened cylinder mold and transferred on a traveling belt over suction boxes, where, as a wet mat, it is wrapped on a mandrel. Wrapping continues until proper thickness is attained. Pipe sections generally are cast in 10- to 15-foot lengths. After an intial setting time, the pipe is stripped from the mandrel, air cured, and then final-cured in an autoclave using saturated steam.

Cured pipe sections are cut to uniform lengths, machined in a variety of ways (sawing, lathing, drilling), and outfitted with a coupling. To insure a tightly fitted pipe joint, the ends of the pipe sections are machined smooth on a lathe. The finished pipe is inspected, and each section of "pressure pipe" (pipe used for conveying water under pressure) is tested hydrostatically.

Pipe plants also produce a variety of standard and special fittings. Pipe coupling is the most widely used fitting. To mate with the machined pipe, inside surfaces of the coupling must be grooved to hold a rubber seal.

Other fittings (tees, elbows, reducers, etc.) are produced on a less frequent schedule. Most pipe plants also produce specialty fittings and pieces on an individual basis. Operations required for fittings producton include sawing, drilling, machining, boring, and bonding. Some specialty applications require pipe lengths to be machined over their entire length with a lathe.

The main operations in the manufacture of asbestos-cement pipe are shown on Figure 3-1. Operations with the greatest potential to produce airborne asbestos fiber are the introduction stage and the pipe finishing (and fittings finishing) stage. Other operations that generate exposure are scrap and waste grinding for recycling, and cleaning and disposal of wastes from dust control systems.

Current levels of airborne asbestos fiber during A/C pipe manufacturing were estimated using the combined results of RTI's 1984 survey and available inspection data reported by the OSHA's MIS. The survey results for 3 A/C pipe plants are shown in Table 3-2; Table 3-3 displays available MIS ranges and measurements. Table 3-2 shows fiber concentrations ranging from 0.01 to 0.61 f/cc while Table 3-3 shows ranges of 0.34 to 1.0 f/cc.

Table 3-2. Aggregated Survey Data for Primary Manufacturers of A/C Pipe

Year	Operations Surveyed	8-h TWA Fiber Concentration Range (f/cc)
1984	Fiber introduction/mixing	0.07-0.2
1984	Wet-mechanical operations	0.03-0.2[a]
1984	Dry-mechanical/finishing	0.01-0.61
1984	Other workers	0.02-0.19

[a]Average concentration

Source: 1984 RTI Survey Data

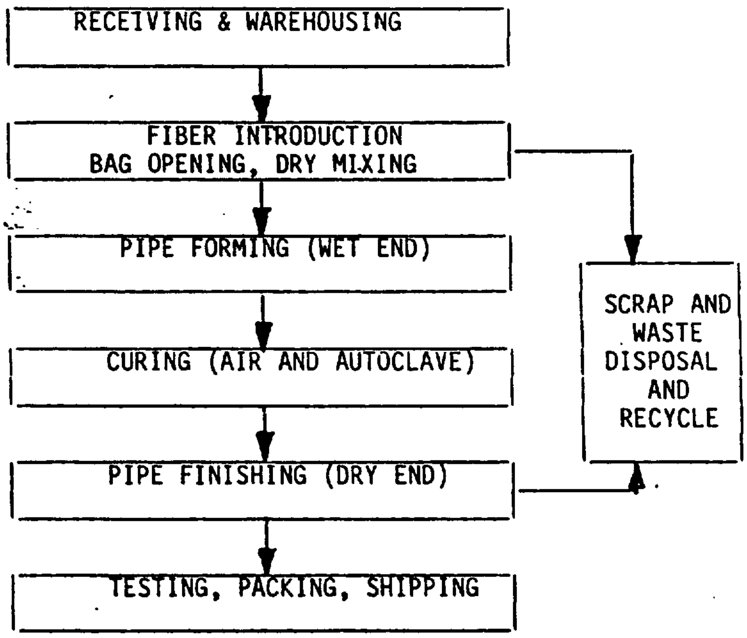

Figure 3-1. Asbestos-Cement Pipe Manufacture

Table 3-3 OSHA Inspection Data for Primary Manufacturers of A/C Pipe

Year of Inspection	Plant Code[a]	Operations Surveyed	8-hr. TWA Fiber Concentration Range (f/cc)
1982	A	Wet-mechanical operations	0.19
		Dry-mechanical/ finishing	.034-1.0
		Other	0.070-0.177
1979	B	Fiber introduction/ mixing	0.035
		Dry-mechanical/ finishing	0.04-0.09
		Other workers	0.05-0.16

[a]Confidential

Source: OSHA Management Information System

These current levels of exposure at A/C pipe plants show a distinct reduction from exposure levels reported during the period 1976-1978. Table 3-4 includes fiber concentration ranges reported by two sources for this period.

It is estimated that a total of 742 workers are exposed to airborne asbestos fibers at A/C pipe plants and that their exposure ranges from

Table 3-4 Fiber Concentrations for Primary Manufacturers of A/C Pipe Reported During 1976-1978

Year of Inspection	Source	Operation	8-hr. TWA Fiber Concentration Range (f/cc)
1978	GCA	Fiber receiving/storage	0.2-2.5
		Fiber introduction/mixing	0.1-4.8
		Wet-mechanical operations	0.1-1.4
		Dry-mechanical/finishing operations	0.1-2.9
		Other workers[b]	0.1-0.3

Table 3-4 Fiber Concentrations for Primary Manufacturers of A/C Pipe Reported During 1976-1978 (continued)

Year of Inspection	Source	Operation	8-hr. TWA Fiber Concentration Range (f/cc)
1976	Versar	Fiber receiving/storage	0.25-2.5
		Fiber introduction/mixing	0.5-3.5
		Wet-mechanical operations	0.5-4.5
		Dry-mechanical/finishing	0.5-2.25

Source: Exposure Assessment for Asbestos (Draft Final Report), Versar, Inc., EPA Contract No. 68-01, 6271, September 30, 1983, p. 126.

Life Cycle of Asbestos in Commercial and Industrial Use Including Estimates of Releases to Air, Water, and Land, GCA Corporation, EPA Contract No. 68-02-3168, February 1982, p. 125.

0.01 to 1.0 f/cc. A 1981 production estimate of 374,000 tons was used to make this estimate.[2] The estimated number of workers exposed in plants currently manufacturing A/C pipe is shown in Table 3-5 for each process operation.

Table 3-5. Estimated Workers Exposed and Exposure Levels in A/C Pipe Manufacturing

Operation or Job	No. of Workers Exposed	Asbestos Exposure (f/cc)
Fiber Introduction/Mixing	21	0.035 - 0.07
Wet-mechanical operations	245	0.03 - 0.19
Pipe/coupling Finishing	322	0.01 - 1.0
Other workers	154	0.02 - 0.19
Total	742	0.01 - 1.0

3.1.1.2 Asbestos-Cement Sheet

A/C sheets are manufactured in sizes that range from roof-shingles to wall panels. Two basic processes are used, the wet and the dry processes. In the wet

It is estimated that 469 workers at 4 plants producing asbestos-reinforced plastics are exposed to fiber concentrations ranging from N/D to 1.11 f/cc. A 1981 production estimate of 12,187 tons was used to calculate exposed workers.[14] The estimated numbers of workers exposed by process operation are shown in Table 3-37.

Table 3-37. Estimated Workers Exposed and Exposure Levels in Reinforced Plastics Manufacturing

Operation or Job	No. of Workers Exposed	Asbestos Exposure Levels (f/cc)
Fiber Introduction/mixing/ blending	77	0.04-0.13
Wet-mechanical operations	105	N/D-0.13
Dry-mechanical/finishing	133	0.03-0.05
Other workers	154	N/D-1.11
Total	469	N/D-1.11

3.1.1.10 Miscellaneous Asbestos Products

As described in Section 1.2.10 of this report, many asbestos products that are not covered by this study have been identified. Examples of these products include electrical insulation, abrasive products, and fiber repackaging. An accurate estimate of current exposure levels or number of exposed workers in this miscellaneous category is not possible given the small amount of information available. It is likely that exposure levels are highest in the fiber introduction and milling stages of manufacturing and that exposure levels are comparable to those in other industries.

3.1.2 Current Practices

This section describes the various methods that are used to control asbestos exposure in the nine primary manufacturing industry segments. This information was compiled from plant visits and the mail survey of the industry.

Some administrative and personal hygiene practices were so consistently practiced in all industry segments that they are summarized here and not included in the discussion of each industry segment. These practices include:

- Provision of uniforms or disposable clothing and respirators for workers in dusty jobs (e.g., fiber introduction and baghouse maintenance), and provision of respirators for voluntary use by any employee
- Provision of showers and locker facilities
- Employee training and education on hazards and control procedures for asbestos exposure
- Medical surveillance with periodic chest X-ray and pulmonary function tests
- Routine periodic monitoring of exposure to asbestos dust
- Complete prohibition of smoking in plants, or restriction of smoking to break areas.

3.1.2.1 Asbestos-Cement Pipe

The engineering control used most extensively is local exhaust ventilation (LEV) with hooding. This system is used at operations wherever fibers may be released to the air. These controls are used in bag opening areas, at fiber introduction, dry mixing and willowing (fluffing) operations, at all dry finishing operations of both pipe and fittings, and at scrap grinding for recycling.

For finishing operations, "wet" sawing is used to control the generation of dust. Single point cutting tools (in dry finishing) are also used to reduce the generation of asbestos dust.

Exhaust air is cleaned before discharge by filtration (usually in baghouses) and dust is typically removed in closed containers for recycle or disposal. While the mortar is wet, little fiber becomes airborne. A significant portion of the fiber emitted between fiber introduction and wet mixing may result from material handling equipment (such as screw conveyors and bucket elevators). Dust control in conveying equipment is achieved by using continuous exhaust of hoods and maintaining negative pressure within the closed mixing equipment. No special control equipment is typically used during pipe formation, air curing, and steam curing.

Housekeeping and work practices are also used extensively, and those include the following:

- Minimum handling of asbestos bags prior to bag opening and fiber introduction
- Continuous use of wet vacuum machines to keep floors clean
- Banning of brooms; use of squeeges for floor cleaning
- Central vacuum system with flexible-hose pickups at work stations vulnerable to asbestos spillage (such as at bag opening)
- Provision of negative pressure vented "air shower" booths with pressurized air hose for cleaning dust from clothing
- No recirculation of local exhaust air.

Respirators are required for mixing and baghouse maintenance personnel and wet sweeper operators. Respirators are made available to all other employees.

3.1.2.2 Asbestos-Cement Sheet

Local exhaust ventilation is the primary engineering control. It is used at the bag opening and fiber introduction operation, at several points on the forming line (press roller, veneer, cutting, and embossing), at the punching and trimming operation, and at the brushing operation.

The willowing and mixing operations take place in closed vessels maintained under negative pressure, and these may be isolated in a restricted

4.0 Feasibility and Cost Analyses

This section presents an assessment of the feasibility of achieving fiber concentrations of 0.5, 0.2, and 0.1 f/cc in each of the industry segments. Conclusions regarding feasibility are based on site visit and survey data collected during this study. The activities that plants in each industry segment would implement to comply with PEL's of 0.5, 0.2, and 0.1 f/cc are also estimated as is the cost of implementation.

4.1 FEASIBILITY ASSESSMENT

4.1.1 Primary Manufacturing

Visits were made to seven primary asbestos manufacturing plants, representing the following products:

- A/C Pipe and fittings
- A/C Sheet (shingles)
- Friction materials
  - drum brake linings
  - disc brake pads
  - clutch facings
  - automatic transmission parts
- Asbestos textiles (yarn)
- Vinyl-asbestos tile
- Asbetos sheet gaskets and packing
- Asbestos sealants and coatings

No visit was made to an asbestos-reinforced plastic product plant. However, some of the automatic transmission parts were made with asbestos-reinforced phenolic resins, and the processes were in some respects similar to those in the manufacture of asbestos-reinforced plastic products.

The primary purposes of the plant visits were to observe state-of-the-art control methods and to discuss with knowledgeable plant personnel the feasibility of achieving proposed more stringent asbestos exposure limits. Therefore, an effort was made to visit plants which had the most effective control programs; including utilization of engineering controls, housekeeping, and ancillary controls and programs aimed at reducing exposures to asbestos dust. Plants were selected on the basis of discussions with staff of the Asbestos Information Association and personnel of individual companies and plants. The plants visited depended primarily on local exhaust ventilation and housekeeping to control asbestos dust. Most plants had several characteristics in common:

- Local exhaust ventilation at all operations with potential for airborne fiber release, with effective dust collection and disposal systems.
- No recirculation of exhaust ventilation air.
- Availability of respirators for employees, but reluctance on managements part to depend heavily on respiratory protection for exposure control.
- Minimal handling of received asbestos fibers prior to introduction into process.
- Manual bag opening and fiber introductin; all had local exhaust ventilation at fiber introduction; some provided additional enclosures or isolation of the opening operation.
- Bag disposal; often accomplished inside the bag opening hood, or the plastic or paper bags mixed into the process.
- Comprehensive housekeeping programs.
- Total prohibition of smoking in the plant or restriction of smoking to break and rest areas.
- Warning signs in areas of high potential asbestos dust concentrations.

This section discusses each of the nine primary manufacturing sectors in terms of the questions:

- the magnitude of reduction in asbestos dust exposure required to meet permissible exposure limits of 0.5, 0.2 and 0.1 f/cc,
- feasible methods of achieving these reductions;
- the Compliance activities most establishments will choose.

In these discussions the reader should distinguish between achieving specific concentrations of asbestos dust in air (without regard to the use of respirators) and achieving specific permissible exposure limits (air concentration divided by rated protection factor of respiratory protection utilized).

4.1.1.1 Asbestos-Cement Pipe

Three asbestos-cement pipe manufacturing plants responded to the 1984 survey. Plant data and very limited OSHA compliance sampling data indicate that plants are achieving an average asbestos air concentration of <0.5 f/cc, and a maximum of 1.0 f/cc. These concentrations are considerably lower than air concentrations found in the 1976-1978 period, in which maximum concentrations found ranged from 1.4 to 4.8 among various plant operations.

Pipe plants are not now consistently achieving concentrations of 0.2 or 0.1 f/cc. It is judged on the bases of the survey of plants and OSHA data that an average asbestos air concentration of 0.2 f/cc during normal operations could be achieved by extensive use of local exhaust ventilation, and stringent housekeeping and scrap and waste processing procedures. It will not be possible to achieve even 0.5 f/cc air concentrations at all times even in the best-run plants; this level will be exceeded during some cleanup and maintenance procedures; for example, bag-house cleaning, and cleaning and maintenance of engineering control systems. Further engineering controls and housekeeping improvements would be expected to achieve only marginal reduction in air concentrations in the best-run plants, where these controls are already utilized to the limit of their effectiveness.

Controls which may be feasible to achieve reductions in air concentrations in other plants are:

- Ventilated enclosure or isolation of the fiber introduction process, in addition to local exhaust ventilation at the point of introducton; or automatic ventilated bag opening as an alternate means.
- Wetting of fibers at an earlier stage in processing.
- Receipt of asbestos in uncompressed state, to reduce need for milling (willowing) to open fibers.
- Extensive use of wet pickup and vacuum cleaning systems for housekeeping.

It is judged that plants will use respiratory protection to meet any reduction in permissible exposure limits below 2 f/cc. At a PEL of 0.5 f/cc, single-use respirators would be used as needed to reduce exposures in non-routine dusty operations.

At PEL's of 0.2 and 0.1 f/cc, single-use respirators would be used routinely in some production operations and full-facepiece air purifying or air-supplied respirators would be used where needed in non-routine dusty operations.

4.1.1.2 Asbestos-Cement Sheet

Three of the 6 U.S. sheet plants completed the 1984 survey forms, and sampling data from one 1983 OSHA compliance inspection are available. In addition, 1979 sampling results are available from one plant.

On the basis of available data, plants appear to be meeting the current 2 f/cc exposure limit routinely. The best run plants are meeting the proposed 0.5 f/cc limit in all operations except dry finishing and scrap and waste processing. Plants are not achieving asbestos air concentrations of 0.2 or 0.1 f/cc; although one plant reported concentrations of 0.2 f/cc at fiber introduction and 0.1 f/cc in wet mechanical operations.

Plants depend primarily on local exhaust ventilation at points of dust generation to control asbestos dust. Wet agglomeration of scrap and waste may reduce dust levels to 0.3 f/cc. Additional local exhaust ventilation and further enclosure of dusty processes were the only engineering controls identified as having the potential to further reduce dust levels. One plant indicated that it is questionable whether engineering controls alone can reduce exposures to 0.2 f/cc or below.

Plants surveyed would choose further engineering controls to achieve a dust concentration of 0.5 f/cc. Reduction of exposure below this

4.2 COST ANALYSIS

For a given level of asbestos control to be reasonable it must be both technically achievable and economically suitable. This section presents cost information about 16 actions or systems that are considered capable of reducing worker exposure to airborne asbestos fibers. Some of the actions are required by OSHA regulations when asbestos fiber concentrations exceed specified levels; others are options that a plant manager could choose to implement at his plant. The 16 items are:

1. Medical surveillance
2. Automatic bag opener
3. Mobile vacuum sweeper
4. Vacuum cleaner
5. Make-up air system
6. Lunch room
7. Shower room
8. Change room
9. Employee training program
10. Protective clothing
11. Regulated areas
12. Monitoring program
13. Disposable respirator
14. Cartridge respirator
15. Supplied-air respirator
16. Local exhaust ventilation system.

This chapter describes the 16 items used for control, and the costs of control (capital, operating and maintenance, and annual) by each industry segment, and fiber level. The chapter concludes with summary cost tables for each industry segment and for the total industry to achieve PEL's of 0.5, 0.2, and 0.1 f/cc levels.

4.2.1 Methodology

RTI chose a model plant approach to estimating compliance costs. The use of model plants allows for varying circumstances among different industry segments and plant sizes and allows evaluation of potential differences in economic impacts on small versus large facilities. For example, large plants may obtain quantity discounts not available to smaller plants and large plants may have easier access to investment capital.

Models were developed for each major product line in primary manufacturing and secondary fabrication and were developed for two segments of the automotive aftermarket and for shipyards. Model plant sizes were selected based on data obtained from the industry survey. After the model plants were developed for each industry segment, the total number of employees in the segment was used to compute the number of model plants needed to describe the segment. The distribution of sizes and all other attributes of the model plants are based on industry profile information.

4.2.2 Compliance Costs

The initial step in estimating compliance costs for the alternative PEL's was to develop unit costs for each of the compliance activities listed above. These unit costs were obtained from a variety of sources and are presented in Table 4-1 for all activities except local exhaust ventilation (LEV). The series of footnotes to Table 4-1 identifies sources of information for the unit costs and provides the rationale for any assumptions made regarding implementation of a compliance activity. Costs for LEV systems were calculated using procedures developed by Vatavuk and Neveril (see footnote m

Table 4-1. Control Elements, Costs, and Sources

1. Medical Surveillance	Unit Cost	Source[a]
Preemployment physical:		Duke
history	$45.00	
roentgenogram	43.00	
pulmonary function test	32.00	
1 hour travel time (employee[b])	14.88	
1 hour examination time (employee)	14.88	
0.2 hours recordkeeping time (admin. asst.)	2.30	
Annual physical:		Duke
roentgenogram	43.00	
pulmonary function test	32.00	
1 hour travel time (employee)	14.88	
0.25 hours examination time (employee)	3.72	
0.2 hours recordkeeping time (admin. asst.)	2.30	
Termination physical: once/yr		Duke
history	45.00	
roentgenogram	43.00	
pulmonary function test	32.00	
1 hour travel time (employee)	14.88	
1 hour examination time (employee)	14.88	
0.2 hours recordkeeping time (admin. asst.)	2.30	
2. Automatic Bag Opener		
purchase price: (15 year life)	$100,000	CertainTeed[c]
operating energy: 18 hp[d], 1,000 hrs/yr	763/yr	
maintenance[e]: 5 hrs/week (maintenance), materials	8,512/yr	
3. Mobile Vacuum Sweeper		
purchase price: (100,000 ft^2/hr, 5-year life)	20,000	Tennant[c]
operating labor: 2 hrs/day, 250 days/yr (employee)	7,440/yr	
operating energy: 15 hp, 2 hrs/ day, 250 hrs/yr	318/yr	
maintenance: 2 hrs/week (maintenance), materials	3,405/yr	
4. Vacuum Cleaner		
purchase price: (10 ft. hose, drum adapter, 100 liners, 5-year life)	3,989.21	ACTI
HEPA filters: 1/yr	106.00/yr	
micro filters: 4/yr	36.00/yr	
polyvinyl liners: 80/yr	136.00/yr	
operating labor: 2 hrs/day, 250 days/yr (employee)	7,440.00/yr	
operating energy: 1.5 hp, 2 hrs/day, 250 days/yr	46.92/yr	
maintenance: 2 hrs/mo (maintenance), materials	785.76/yr	

Table 4-1. Control Elements, Costs, and Sources (Continued)

	Unit Cost	Source
5. Make-up Air System[f]		
operating energy: 0.304 Q	$304/1000 acfm-yr	ACGIH
maintenance: 15% of operating energy	45.60/1000 acfm-yr	
6. Lunch Room[g]		
Construction of interior room (15-year life)	$24.15/ft^2	RSM[c]
tables, chairs, trash cans (10-year life)	$224.51-255.01/5 man unit depending on number of units	
janitor services: 0.1 hr/employee day, 250 days/yr (janitor)	187.50/employee-yr	
7. Shower Room[g]		
construction of interior room (20-year life)	$60.39/ft^2	RSM[c]
water heater (20-year life)	$510-625/5 man unit depending on number of units	RSM
operating energy: $.34/shower-man, 235 days/yr	$79.60/year-employee	
lost time: 0.1 hrs/man-day (employee), 235 days/yr	349.68/year-employee	
8. Change Room[g]		
construction of interior room (15 year life)	$ 24.15/ft^2	RSM[c]
lockers: (2 per man) (15 year life)	91.70/locker	
benches: (1 per 5 men)	149.31/bench	
lost time: 0.2 hrs/man-day, 235 days/yr	699.36/year-employee	
9. Employee Training		
employee time: 3 hrs/yr	$ 44.64/yr	
instructor time: 3 hrs/yr plus 3 hrs preparation plus 3 hrs/replacement (admin.)	$ 23.00/hr	
recordkeeping: 0.1 hrs/employee-yr (admin. asst.)	1.15/employee	
materials: 50 pages at $0.10/page	5.00/employee	
10. Protective Clothing[h]		
Tyvek coveralls with hood and shoe covers: $2.89 ea, 235/yr-employee	$679.15/yr-employee	ACTI
latex gloves: $7.60/day, 470/yr-employee	$297.67/yr-employee	ACTI
11. Regulated Areas[i]		
11 x 17 in. caution signs: 200	$28.00	ACTI
caution tape: 1,000 ft roll	44.84	ACTI
12. Monitoring[j]		
technician time: $300/day	$80-96/yr-employee	RTI
sampling: $50/sample		RTI

Table 4-1. Control Elements, Costs, and Sources (Continued)

	Unit Cost	Source
13. Disposable Respirator		
respirator: $19.50/20, 235/yr-employee	$229.13/yr-employee	LSS[c]
14. Cartridge Respirator		
respirator: (3-year life)	$14.05 ea.	ACTI[c]
100 cartridges/yr-employee	$241.00/yr-employee	ACTI[c]
cleaning kit: $8.95/30 packs, 235 days/yr	70.11/yr-employee	LSS
0.1 hrs/day-employee, 235 days/yr	349.68/yr-employee	
15. Type C, Supplied Air Respirator		
respirator: (3-year life) 1 per 5 employees	$218.50 ea.	LSS[c]
hoses: 100 ft (5 year life)	138.50	
air purifier/regulator (for 6 people) (10 year life)	546.00	
replacement air filter	124.60	
cleaning kit: $8.95/30 packs, 200 days/yr	59.67/yr-employee	
0.1 hrs/day-employee, 200 days/yr	297.60/yr-employee	
compressed air energy cost: 15 hp, 200 hrs/yr	187.73/yr	
Respirator Programs Administration[k]		
develop standard operating procedures: 10 hrs (admin)	$230.00	
designate and use a program administrator[l]:	$171.10-230.00/yr-employee	
fit testing - annually		
employee time: 0.5 hrs	$7.44	
admin. time: 0.2 hrs	4.60	
test smoke: $33.20/dozen	2.77 ea.	McM-C
training		
employee time: 3 hrs initially	$44.64	
1 hr annually thereafter	14.88/yr-employee	
trainer time: 0.2 hrs/employee hr. (Admin.)	4.60/yr-employee	
16. Local Exhaust Ventilation[m]	Variable	

a. Sources are:
ACGIH: American Conference of Governmental Industrial Hygienists, Lansing, MI
ACTI: Asbestos Control Technology, Inc., Maple Shade, NJ
ANSI: American National Standards Institute, New York, New York
CertainTeed: CertainTeed Corporation, Valley Forge, PA
Duke: Duke-Pickens Medical Clinic, Durham, N.C.
LSS: Lab Safety Supply, Janesville, WI
McM-C: McMaster-Carr Supply Co., New Brunswick, NJ
MSA: Mine Safety Appliance Co., Pittsburgh, PA
RTI: Research Triangle Institute, Research Triangle Park, NC
RSM: 1984 Means Construction Cost Data, R.S. Means COmpany, Inc., Kingston, MA
Tennant: Tennant Co., Minneapolis, Minn.

Footnotes to Table 4-1. (continued)

b. When employee time is required as part of a control element, it is charged at the hourly rates shown below.

Pay 1: $14.88, labor rate for asbestos workers. This rate was formed from the pay rate for asbestos workers (SIC code 3292) for November 1983 ($9.27/hr) reported in the January 1984 issue of Employment and Earnings published by the Bureau of Labor Statistics, U.S. Dept. of Labor. Fringe benefits were added based on the U.S. Chamber of Commerce publication, Employee Benefits, 1982, which reported average fringe benefits as 37.3 percent of total compensation. The resulting wage was then corrected to January 1984 with the CE plant cost index published in Chemical Engineering. An employee replacement rate of 26 percent per year was used as reported in an untitled draft report on regulatory analysis of proposed asbestos standards by JRB Co., p. VI-35.

Pay 2: $16.37, labor rate for maintenance workers. This rate was taken as 10 percent greater than the asbestos worker's rate based on "Estimating Costs of Air-Pollution Control Systems, Part II: Factors for Estimating Capital and Operating Costs", by W. V. Vatavuk and R. B. Neveril, Chemical Engineering, November 3, 1980, pp. 157-162.

Pay 3: $17.11, supervisory rate. This rate was taken as 15 percent higher than the asbestos worker's rate.

Pay 4: $23.00, administrative rate. Salary for an administrator for asbestos programs was set at $30,000 annually with fringe benefits as discussed for Pay 1. Training and respirator program time used this value.

Pay 5: $11.50, administrative assistant rate. This rate, set at half the administrative rate, was used for recordkeeping and technician time.

Pay 6: $7.50, janitor rate. The janitor rate was set from rates obtained in Raleigh, N.C.

c. Although only one source is listed, others were contacted for confirmation or to establish a range of costs about the value reported.

d. Rates for electricity and heating oil were adjusted from the December 1983 issue of Monthly Energy Review, pp. 87-94. Values used were $0.0713/kwh for commercial service, $0.0483/kwh for industrial service, and $1.052/gal for heating oil. Electric motors were assumed to be 85 percent efficient.

e. Materials costs for maintenance are taken as equal to wage costs. See Vatavuk and Neveril as referenced in footnote b, pay 2.

f. Make-up air consists only of additional energy to heat replacement air for that lost to ventilation systems that exhaust air outside the plant, and additional maintenance for the existing plant heating system.

Footnotes to Table 4-1. (continued)

The yearly energy cost is calculated from

$$\text{yearly cost} = \frac{0.154\ Q\ D\ dg}{q} \times c$$

where:

Q = cfm of make-up air	(depends on model)
D = operating time, hrs/week	(40)
q = available heat/unit of fuel	(106,500 BTU/gal)
dg = annual degree days	(5,000)
c = cost of fuel, $/unit	($1.052/gal #2 oil)

Values in parentheses were chosen as being representative. The equation was taken from "Industrial Ventilation," 14th Edition, American Conference of Governmental Industrial Hygienists, Lansing, MI, 1977, p. 7-11.

g. All construction was based on an estimated square foot size for the room being considered. Construction cost was taken from square foot estimates supplied by Raleigh area building contractors and divided by 0.828 to obtain a national average value. The 0.828 factor was taken from Building Construction Cost Data 1984 by R.S. Means Co., Kingston, Mass. as the weighted city cost index for Raleigh, N.C. Shower room construction consists of built-up walls with plywood exteriors and tile interiors; change rooms and lunch rooms have gypsum board walls. All rooms are assaumed to be built inside existing buildings. Areas for the various model plants are given below:

Model Plant (by no. of employees)	Lunch Room (ft^2)	Shower (ft^2)	Change Room (ft^2)
(5)	100	45	40
(10)	300	120	80
(15)	300	120	80
(20)	500	180	160
(25)	500	180	160
(35)	600	195	220
(50)	970	350	310
(75)	1,410	510	450
(100)	1,880	510	600
(125)	2,350	510	750
(150)	2,820	510	900
(175)	3,190	510	1,020
(200)	3,650	630	1,165
(225)	3,950	630	1,245

Footnotes to Table 4-1. (continued)

Energy for showers was estimated from water usage of 20 gal/shower, a 52° F temperature rise, and 30 percent thermal efficiency.

h. Employees were estimated to use one pair of Tyvek coveralls and one pair of latex gloves per day.

i. One package of warning signs and one roll of caution tape per year were estimated to be sufficient for all plant sizes less than 100 asbestos workers. For larger plants, the quantities were doubled.

j. Plants with 15 employees were estimated to require 2 days of testing per year with 6 samples taken each day. Plants with 25 employees were estimated to require 4 days of testing and 6 samples each day. The associated costs were calculated on a per employee basis ($80 and $96 per employee for 15 and 25 man plants respectively). Plants smaller than 15 employees used the $80/employee cost and larger plants used the $96/employee cost.

k. Respirator programs were based on American National Standards Institute standard Z88.2-1969 American National Standard Practices for Respiratory Protection. An annual employee replacement rate of 26 percent was used.

l. A half-time program administrator was used for plants with more than 100 employees. For smaller plants supervisory time was used at the rate of 10 hrs/employee-year.

m. Costs for local exhaust ventilation were derived from "Estimating Costs of Air Pollution Control Systems by W.V. Vatavuk and R.B. Neveril. A series of articles with this title was presented from October 6, 1980 through May 16, 1983 in Chemical Engineering. Costs for baghouses smaller than 40,000 acfm were modified as indicated by Vendor contacts.

to Table 4-1). These procedures were computerized on an in-house computer at RTI. A listing of the computer program is included in Appendix B. Some of the design parameters of the LEV systems are given in Table 4-2 along with parameters used to estimate costs of other activities.

To estimate compliance costs for model plants and industry segments, the following steps were performed:

- The compliance activities to be used in each model plant were estimated using information presented in the feasibility analysis (Section 4.1). These activities are presented in Table 4-3.
- The cost of each compliance activity was calculated for each model plant using the unit cost data given in Table 4-1.
- The total cost of compliance for each model plant was obtained by summing the costs of the individual compliance activities. These are given in Table 4-4 as both total capital cost and cost per exposed employee, (Appendix B contains cost tables showing the cost of each compliance activity for each model plant.)
- Costs for an industry segment were estimated by multiplying model plant costs by the number of model plants needed to define the segment. Costs by industry segment are given in Table 4-5.
- Costs for each major industry sector were calculated by summing the costs of the different segments or product lines. These costs are given in Table 4-6.

All costs are reported in January 1984 dollars. Precision is difficult to assess. While some unit costs are available to the nearest penny, other estimates may vary by thousands of dollars from one plant to another. For plants where the retrofit of local exhaust ventilation systems is difficult, costs might be 50 to 100 percent higher. In other cases (especially in small plants), a manager or maintenance foreman may identify ways to implement a control option at a reduced cost. Table entries are given to the nearest dollar as generated by computer models, however the number of significant figures is probably not more than two.

Total costs of control for each industry segment/product line are given in Table 4-5. These costs are summed and presented in Table 4-6 for each of the four major industry segments, and for all segments combined. Model

Table 4-2. Cost Estimating Parameters for Model Plants

Compliance Element	Estimating Parameters
Medical Surveillance	Based on no. of exposed workers and replacement rate of 26% annually.
Vacuum Cleaner	One cleaner for plants with fewer than 50 exposed workers and two cleaners for larger plants.
Make-up Air	Based on volume flow of local exhaust ventilation system.
Change Room	Floor area (square feet) of room to be constructed inside existing building was estimated based on no. of exposed workers.
Employee Training	Based on no. of exposed workers and replacement rate of 26% annually.
Regulated Areas	One set of tapes and signs for plants with fewer than 100 exposed workers, 2 sets for larger plants.
Monitoring	Plant has up to 15 exposed workers, or else has more than 15.
Respirator Program	Based on no. of exposed workers and an estimated percentage of exposed workers (10%, 50%, or 100%) required to wear respirators. Supervisory time is used to administer a respirator program in plants with fewer than 100 exposed workers. Larger plants hire a half-time administrator.
Local Exhaust Ventilation	For each 4,000 acfm the plant has 1 hood with a 2 ft. x 0.25 ft. opening and metal thickness of 0.1875 in.; 15 ft. of 14-in. diameter duct; 2 14-in. elbows; and 1 14-in. tee. For each 8,000 acfm the plant has an additional 30 ft. of 20-in. duct, 1 20-in. elbow, and 1 20-in. tee. For each 24,000 acfm the plant has an additional 30 ft. of 36-in. duct, 1 36-in. elbow, and 1 36-in. tee. Volumetric flow rates and numbers of dust collectors are chosen to be consistent with industry segment usage as reported in this survey. Each dust collector has 1 fan.

Table 4-3. Compliance Activities in Model Plants

Plants Model	PEL, f/cc	Workers Exposed	LEV cfm[a]	Make-up Air	Vacuum Cleaners	Monitoring	Change Rooms	Training	Regulated Areas	Respiratory Program[b]
			Controls Required							
PRIMARY MANU- FACTURING MODELS										
A/C Pipe	0.5	175								10%
	0.2									50%
	0.1									100%
A/C Sheet	0.5	50	36,250	X						
	0.2		36,250	X						100%
	0.1		36,250	X						100%
Textiles	0.5	200	95,000	X						
	0.2		95,000	X						100%
	0.1		95,000	X						100%
Floor Tile	0.5	125								10%
	0.2									50%
	0.1									100%
Coatings (small)	0.5	5	1,000	X						10%
	0.2		1,000	X						50%
	0.1		1,000	X						100%
Coatings (medium)	0.5	25	2,500	X						10%
	0.2		2,500	X						50%
	0.1		2,500	X						100%
Friction (medium)	0.5	25	50,000	X						10%
	0.2		50,000	X						50%
	0.1		50,000	X						100%
Friction (Large)	0.5	100	83,000	X						10%
	0.2		83,000	X						50%
	0.1		83,000	X						100%
Paper (small)	0.5	15	-							
	0.2		8,750	X	1			X	X	
	0.1		8,750	X	1			X	X	
Paper (medium)	0.5	50	-							
	0.2		21,250	X	2			X	X	
	0.1		21,250	X	2			X	X	
Gaskets (small)	0.5	15	8,300	X						
	0.2		8,300	X						50%
	0.1		8,300	X						100%
Gaskets (medium)	0.5	50	25,000	X						
	0.2		25,000	X						50%
	0.1		25,000	X						100%
Plastics (small)	0.5	5	3,000							
	0.2		3,000		1					50%
	0.1		3,000		1					100%
Plastics (medium)	0.5	50	15,000							
	0.2		15,000		2					50%
	0.1		15,000		2					100%

continued

Table 4-3. Compliance Activities in Model Plants (Continued)

Plants Model	PEL, f/cc	Workers Exposed	LEV cfm[a]	Make-up Air	Vacuum Cleaners	Controls Required: Monitoring	Change Rooms	Training	Regulated Areas	Respiratory Program[b]
SECONDARY MANU-FACTURING MODELS										
Textile (small)	0.5	10			1	X	X	X	X	100%
	0.2					X	X	X	X	100%
	0.1		4,750			X	X	X	X	100%
Gasket (small)	0.5	3	-							
	0.2				2	X	X	X	X	50%
	0.1				1	X	X	X	X	100%
Gasket (medium)	0.5	50	-							
	0.2					X	X	X	X	50%
	0.1					X	X	X	X	100%
Gasket (large)	0.5	150	-							
	0.2		75,000	X		X		X		
	0.1		100,000	X		X		X	X	100%
AC Sheet (small)	0.5	5	-							
	0.2		-							
	0.1		3,700	X						
AC Sheet (medium)	0.5	20	-							
	0.2		-							
	0.1		14,500	X						
SHIPYARD MODELS										
Small	0.5	3								100%
	0.2									Cartridge
	0.1									Cartridge
Large	0.5	225								100%
	0.2									Cartridge
	0.1									Cartridge

Continued

Table 4-3. Compliance Activities in Model Plants (Continued)

Plants Model	PEL	Workers Exposed	LEV cfm	Make-up Air	Controls Required: Vacuum Cleaners	Controls Required: Monitoring	Change Rooms	Training	Regulated Areas	Respiratory Program
AUTO AFTER-MARKET MODELS										
Remanufacturing (small)	0.5	5	-			X	X	X	X	100%
	0.2					X	X	X	X	100%
	0.1					X	X	X	X	100%
Remanufacturing (medium)	0.5	35	-							
	0.2		8,000	X						
	0.1					X	X	X	X	100%
Remanufacturing (large)	0.5	70	-							
	0.2		16,000	X						
	0.1		16,000	X						
Repair (small)	0.5	3	-							
	0.2					X	X	X	X	100%
	0.1					X	X	X	X	100%
Repair (medium)	0.5	10	-							
	0.2					X	X	X	X	100%
	0.1					X	X	X	X	100%
Repair (Large)	0.5	20	-							
	0.2					X	X	X	X	100%
	0.1					X	X	X	X	100%

[a] A dash indicates that compliance now exists at the indicated PEL. When LEV is used, the additional capacity needed is estimated to be 25% of existing capacity (except for primary textile manufacturing where a 100% increase is estimated). Existing capacity was determined from actual plant data.

[b] Disposable respirators are used except where indicated.

Table 4-4. Costs of Compliance in Model Plants

Model	PEL	Workers Exposed	Models with LEV	Capital Cost $/yr	Capital Cost $/worker	Annualized Cost $/yr	Annualized Cost $/worker
Primary Manufacturing							
A/C Pipe	0.5	175		7,048	40	40,009	229
(large)	0.2			7,048	40	56,048	320
	0.1			7,048	40	76,096	435
A/C Sheet	0.5	50	X	177,950	3,559	121,056	2,421
(medium)	0.2		X	179,951	3,599	144,335	2,887
	0.1		X	179,951	3,599	144,335	2,887
Textiles	0.5	200	X	472,392	2,362	299,257	1,496
(large)	0.2		X	480,414	2,402	382,794	1,914
	0.1		X	480,414	2,402	382,794	1,914
Floor Tile	0.5	125		5,100	41	35,348	284
(large)	0.2			5,100	41	46,894	375
	0.1			5,100	41	61,214	490
Coatings	0.5	5	X	12,656	2,531	7,300	1,460
(small)	0.2		X	12,656	2,531	7,759	1,552
	0.1		X	12,656	2,531	8,331	1,666
Coatings	0.5	25	X	18,313	733	16,473	659
(medium)	0.2		X	18,313	733	18,765	751
	0.1		X	18,313	733	21,629	865
Friction	0.5	25	X	228,439	9,138	156,355	6,254
(medium)	0.2		X	228,439	9,138	158,646	6,346
	0.1		X	228,439	9,138	161,510	6,460
Friction	0.5	100	X	425,122	4,251	291,560	2,916
(large)	0.2		X	425,122	4,251	300,725	3,007
	0.1		X	425,122	4,251	312,181	3,122
Paper	0.5	15		-	-	-	-
(small)	0.2		X	49,103	3,274	39,492	2,633
	0.1		X	49,103	3,274	39,492	2,633
Paper	0.5	50		-	-	-	-
(medium)	0.2		X	116,915	2,338	90,839	1,817
	0.1		X	116,915	2,338	90,839	1,817
Gaskets	0.5	15	X	48,220	3,215	29,444	1,963
(small)	0.2		X	48,940	3,263	36,474	2,432
	0.1		X	48,940	3,263	36,474	2,432
Gaskets	0.5	50	X	127,893	2,558	80,076	1,602
(medium)	0.2		X	129,894	2,598	103,354	2,067
	0.1		X	129,894	2,598	103,354	2,067
Plastics	0.5	5	X	18,869	3,774	10,245	2,049
(small)	0.2		X	22,934	4,587	22,199	4,440
	0.1		X	22,934	4,587	22,199	4,440
Plastics	0.5	50	X	77,912	1,558	43,967	879
(medium)	0.2		X	87,336	1,747	86,379	1,728
	0.1		X	87,336	1,747	86,379	1,728

(continued)

Table 4-4. Costs of Compliance in Model Plants (Continued)

Model	PEL	Workers Exposed	Models with LEV	Capital Cost $/yr	Capital Cost $/worker	Annualized Cost $/yr	Annualized Cost $/worker
Secondary Fabrication							
Textile (small)	0.5	10		4,602	460	16,022	1,602
	0.2			4,602	460	14,361	1,436
	0.1		X	29,216	2,922	30,337	3,034
Gasket (small)	0.5	3		-	-	-	-
	0.2			5,598	1,866	13,790	4,597
	0.1			5,598	1,866	14,134	4,711
Gasket (medium)	0.5	50		-	-	-	-
	0.2			20,151	403	63,803	1,276
	0.1			20,151	403	69,531	1,391
Gasket (large)	0.5	150		-	-	-	-
	0.2		X	376,625	2,511	261,619	1,744
	0.1		X	464,783	3,099	388,559	2,590
AC Sheet (small)	0.5	5		-	-	-	-
	0.2			-	-	-	-
	0.1		X	21,167	4,233	13,166	2,633
AC Sheet (medium)	0.5	20		-	-	-	-
	0.2			-	-	-	-
	0.1		X	107,498	5,375	71,850	3,593
Shipyard Model							
Small	0.5	3		281	94	1,459	486
	0.2			309	103	2,779	926
	0.1			309	103	2,779	926
Large	0.5	225		8,996	40	90,978	404
	0.2			11,104	49	189,976	844
	0.1			11,104	49	189,976	844
Automotive Aftermarket Model							
Remanufacturing (small)	0.5	5		2,386	477	7,319	1,464
	0.2			2,386	477	7,319	1,464
	0.1			2,386	477	7,319	1,464
Remanufacturing (medium)	0.5	35		-	-	-	-
	0.2		X	45,496	1,300	44,190	1,263
	0.1			14,229	407	48,767	1,393
Remanufacturing (large)	0.5	70		-	-	-	-
	0.2		X	88,608	1,266	55,876	798
	0.1		X	96,030	1,372	75,009	1,072
Repair (small)	0.5	3		-	-	-	-
	0.2			1,887	629	4,568	1,523
	0.1			1,887	629	4,568	1,523
Repair (medium)	0.5	10		-	-	-	-
	0.2			4,602	460	14,361	1,436
	0.1			4,602	460	14,361	1,436
Repair (large)	0.5	20		-	-	-	-
	0.2			9,032	452	28,125	1,406
	0.1			9,032	452	28,125	1,406

Table 4-5. Total Cost of Control by Industry Segment/Product Line

Industry Segment & Model	PEL	No. of[a] Model Plants	Capital Cost for Industry Segment, $	O & M Cost for Industry Segment, $/yr	Annual Cost for Industry Segment, $/yr
Primary					
AC Pipe (large)	0.5	4.24	29,884	157,995	169,638
	0.2		"	226,000	237,644
	0.1		"	311,008	322,647
AC Sheet (med.)	0.5	4.18	743,831	387,152	506,014
	0.2		752,195	481,197	603,320
	0.1		"	"	"
Textiles (large)	0.5	2.91	1,374,661	651,168	870,838
	0.2		1,398,005	885,167	1,113,931
	0.1		"	"	"
Floor Tile (large)	0.5	2.94	14,994	98,346	104,188
	0.2		"	132,027	137,868
	0.1		"	174,130	179,969
Coatings (small)	0.5	21.90	277,166	113,792	159,870
	0.2		"	123,845	169,922
	0.1		"	136,393	182,449
Coatings (med.)	0.5	21.90	401,055	291,204	360,759
	0.2		"	341,377	410,954
	0.1		"	404,121	473,675
Friction (med.)	0.5	39.26	8,968,515	4,695,496	6,138,497
	0.2		"	4,785,478	6,228,442
	0.1		"	4,897,921	6,340,883

Table 4-5. Total Cost of Control by Industry Segment/Product Line (Continued)

Industry Segment & Model	PEL	No. of[a] Model Plants	Capital Cost for Industry Segment, $	O & M Cost for Industry Segment, $/yr	Annual Cost for Industry Segment, $/yr
Primary					
Friction (large)	0.5	39.26	16,690,290	8,744,969	11,446,646
	0.2		"	9,104,787	11,806,464
	0.1		"	9,554,549	12,256,226
Paper (small)	0.5	14.52	-	-	-
	0.2		712,976	453,343	573,423
	0.1		"	"	"
Paper (medium)	0.5	14.52	-	-	-
	0.2		1,697,606	1,035,436	1,318,982
	0.1		"	"	"
Gaskets (small)	0.5	6.46	311,501	140,427	190,208
	0.2		"	184,032	235,622
	0.1		"	"	"
Gaskets (medium)	0.5	6.46	826,189	385,268	517,291
	0.2		839,115	530,611	667,667
	0.1		"	"	"
Plastics (small)	0.5	8.53	3,020	10,398	11,575
	0.2		19,563	153,804	189,357
	0.1		"	"	"
Plastics (med.)	0.5	8.53	17,069	143,057	150,555
	0.2		744,976	606,628	736,813
	0.1		"	"	"

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Table 4-5. Total Cost of Control by Industry Segment/Product Line (Continued)

Industry Segment & Model	PEL	No. of[a] Model Plants	Capital Cost for Industry Segment, $	O & M Cost for Industry Segment, $/yr	Annual Cost for Industry Segment, $/yr
Secondary					
Textile (small)	0.5	42.70	196,505	645,966	684,139
	0.2		"	575,084	613,215
	0.1		1,247,523	1,089,277	1,295,390
Gasket (small)	0.5	143.30	-	-	-
	0.2		802,193	1,776,060	1,976,107
	0.1		"	1,825,499	2,025,402
Gasket (med.)	0.5	69.00	-	-	-
	0.2		1,390,419	4,137,654	4,402,407
	0.1		"	4,532,955	4,797,639
Gasket (large)	0.5	48.00	-	-	-
	0.2		18,078,000	9,668,832	12,557,712
	0.1		22,309,584	15,018,768	18,650,832
AC Sheet (small)	0.5	13.80	-	-	-
	0.2		-	-	-
	0.1		292,105	135,019	181,691
AC Sheet (med.)	0.5	13.80	-	-	-
	0.2		-	-	-
	0.1		1,483,472	754,474	991,530
Sec. friction (med.)[b]	0.5	57.84	62,814	650,642	675,166
	0.2		"	"	"
	0.1		"	"	"

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Table 4-5. Total Cost of Control by Industry Segment/Product Line (Continued)

Industry Segment & Model	PEL	No. of[a] Model Plants	Capital Cost for Industry Segment, $	O & M Cost for Industry Segment, $/yr	Annual Cost for Industry Segment, $/yr
Sec. plastics (small)[b]	0.5	490.00	173,460	1,102,500	1,170,120
	0.2		1,991,850	5,292,490	5,857,460
	0.1		*	*	*
Ship Repair					
Small	0.5	35.86	10,077	48,411	52,320
	0.2		11,081	95,352	99,655
	0.1		*	*	*
Large	0.5	35.86	322,597	3,136,818	3,262,471
	0.2		398,189	6,657,409	6,812,539
	0.1		*	*	*
Automotive Aftermarket					
Reman. (small)	0.5	124.75	297,654	853,165	913,045
	0.2		*	*	*
	0.1		*	*	*
Reman. (med.)	0.5	40.48	-	-	-
	0.2		1,841,678	1,481,001	1,788,811
	0.1		575,990	1,864,064	1,974,088
Reman. (large)	0.5	38.71	-	-	-
	0.2		3,586,852	1,614,826	2,261,860
	0.1		3,887,294	2,276,806	3,036,364

Table 4-5. Total Cost of Control by Industry Segment/Product Line (Continued)

Industry Segment & Model	PEL	No. of[a] Model Plants	Capital Cost for Industry Segment, $	O & M Cost for Industry Segment, $/yr	Annual Cost for Industry Segment, $/yr
Repair (small)	0.5	52,734	-	-	-
	0.2		99,509,058	220,849,992	240,888,912
	0.1		"	"	"
Repair (med.)	0.5	2,929	-	-	-
	0.2		13,479,258	39,447,772	42,063,369
	0.1		"	"	"
Repair (large)	0.5	2,929	-	-	-
	0.2		26,454,728	77,337,316	82,378,125
	0.1		"	"	"

[a]Fractional Model plants were obtained by comparing existing and model plant populations. Fractional plants were used to obtain increased precision in resulting costs.

[b]A separate model was not developed for this product line. The equivalent primary model, adapted to use disposable respirators in place of an LEV system, was used to obtain costs.

Table 4-6. Summary of Costs by Industry Segment

Industry Segment & PEL, f/cc	Capital Cost, $ (Millions)	Capital Cost, $/Worker	O & M Cost $/yr (Millions)	O & M Cost $/Worker	Annual Cost $/yr (Millions)	Annual Cost $/Worker
Primary						
0.5	30	3,200	16	1,700	21	2,200
0.2	33	3,500	19	2,000	24	2,600
0.1	33	3,500	20	2,100	25	2,700
Secondary						
0.5	0.4	25	2	150	3	160
0.2	23	1,400	22	1,400	26	1,700
0.1	30	1,900	29	1,900	35	2,200
Automotive Aftermarket						
0.5	0.3	1	0.8	3	0.9	4
0.2	150	580	340	1,400	370	1,500
0.1	140	570	340	1,400	370	1,500
Ship Repair						
0.5	0.3	37	3.2	390	3.3	400
0.2	0.4	49	6.8	830	6.9	800
0.1	0.4	49	6.8	830	6.9	800
All Segments						
0.5	31	110	21	74	27	96
0.2	200	710	390	1,400	430	1,500
0.1	200	730	400	1,400	440	1,500

predictions indicate that incremental costs to the nation of controlling asbestos at the 0.5 f/cc level would be about $30 million in both capital investment and annual costs. At the 0.2 and 0.1 f/cc level incremental capital costs (from the 2 f/cc level) increase to about $200 million, and annualized costs increase to over $400 million. These larger costs at the 0.2 and 0.1 f/cc levels arise primarily from the application of controls (generally disposable respirators and associated programs) to the nearly 300,000 automotive remanufacturing and repair stations in the U.S.

The existing OSHA regulation requires that engineering controls be used to the extent possible to achieve compliance and allows the use of respirators only under certain restricted conditions. The proposed regulation, however, allows compliance by any feasible combination of engineering controls, work practices, and respirators to meet the proposed emission limit. Examination of the compliance activities in Table 4-3 indicates that a number of plants will choose engineering controls (LEV) to reduce workplace exposures. Most of these plants could substantially reduce compliance costs if they chose respirators instead of LEV. Tables 4-7 and 4-8 present compliance costs with and without the use of LEV's for the total industry and by industry segment, respectively. The tables show that using respirators is generally much less expensive than using LEV, although the secondary manufacturing sector presents several exceptions. Not shown in the tables are figures indicating that the use of disposable respirators instead of local exhaust ventilation would reduce annual costs by up to three quarters for some model plants.

As might be expected, more stringent exposure levels have higher annualized costs on an industry-wide basis. For several individual models, however, costs were the same at two or even all three of the exposure levels.

Table 4-7. Comparison of Annualized Costs Across all Industry Segments for Models With & Without Local Exhaust Ventilation.

PEL f/cc	Model Costs Without LEV, $/worker	Model Costs With LEV, $/worker
0.5	229 - 1,602	659 - 6,254
0.2	320 - 4,597	751 - 6,346
0.1	435 - 4,711	865 - 6,460

Table 4-8. Comparison of Annualized Costs for Each Industry Segment for Models With & Without Local Exhaust Ventilation.

Industry Segment & PEL, f/cc	Model Costs Without LEV, $/worker	Model Costs With LEV, $/worker
PRIMARY		
0.5	229 - 284	659 - 6,254
0.2	320 - 375	751 - 6,346
0.1	435 - 490	865 - 6,460
SECONDARY		
0.5	1,602	-
0.2	1,276 - 4,597	1,744
0.1	1,391 - 4,711	2,590 - 3,593
AUTOMOTIVE		
0.5	1,464	-
0.2	1,406 - 1,523	798 - 1,263
0.1	1,393 - 1,523	1,072
SHIP REPAIR		
0.5	404 - 486	-
0.2	844 - 926	-
0.1	844 - 926	-

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5.0 INDICATORS OF ECONOMIC IMPACTS

This section outlines preliminary measures of the economic impact on the asbestos industry of three alternative exposure levels--0.5, 0.2, and 0.1 fibers/cc. The value of sales and new capital expenditures are estimated for 17 sectors. Control costs and capital outlays necessary for compliance with the three exposure levels are represented as percentages of total sales and capital investment for each sector. Aggregate percentages for the industry are also obtained.

5.1 SALES AND NEW CAPITAL EXPENDITURE ESTIMATES

For the 17 sectors examined (Table 5-1), workers are exposed to asbestos in an estimated 286,447 establishments (Table 5-2). This table summarizes the individual sector estimates developed in previous sections.

Estimates of average sales and new capital expenditures are presented in Table 5-3. Total value of shipments, total new capital expenditures, and numbers of establishments listed for 1977 for the SIC codes indicated in Table 5-4 were used to derive the estimates. These averages were converted to 1981 values using a GNP implicit price deflator.

Total sales and new capital expenditures for 1981 were estimated based on the calculated average values and the numbers of establishments given in Table 5-2. The results are presented in Table 5-5. Total industry sales are estimated at $237.5 billion in 1981, while new capital expenditures for the industry total $280 million.

5.2 TOTAL COMPLIANCE COSTS

The annual cost by sector necessary to attain each exposure level is presented in Table 5-6. The presence of a zero indicates that the sector already conforms to the exposure level. All costs are measured from current exposure levels, usually 2.0 fibers/cc except where lower standards are being met. The control costs were computed based on costs per model plant, and the number of each size model plant in the sector. Capital costs were annualized using a 10 percent cost of capital estimate and engineering estimates of equipment lifetimes.

The annual cost at 1981 rates is about $27 million to achieve an industry-wide 0.5 fibers/cc exposure level, and almost 16 times that to reduce exposures to the 0.2-0.1 fibers/cc range. The costs for the lower levels are $428 million and $438 million, respectively.

One indicator of the economic impact on the industry of the alternative exposure levels is the cost of compliance as a percentage of the total value of sales. These percentages were calculated by sector and are summarized in Table 5-7. There is a wide range of values across sectors, implying that impacts may be diverse. An accurate assessment of the actual impacts depends on the supply and demand conditions facing each sector. Thus, the industry averages of 0.01 percent for the 0.5 exposure level and 0.18 percent for the 0.2 and 0.1 exposure levels are inconclusive.

It is interesting to note that the percentages for the 0.2 and 0.1 levels are the same for the industry, as well as for several sectors. This is because measures required to achieve a level of 0.2 fibers/cc are sufficient to meet the 0.1 exposure level as well.

5.3 CAPITAL COSTS

The capital costs are estimated at the same exposure levels as annual compliance costs. The estimates were based on the capital cost per model plant, and the number of each size model plant in a sector. Capital costs by sector and exposure level are presented in Table 5-8.

At 1981 rates, the capital cost of achieving the 0.5 exposure level industry-wide is about $31 million. Reaching the 0.2-0.1 range requires about

6.5 times more capital expenditure, at $201 million for the 0.2 level and $207 million for the 0.1 level.

Capital costs as a percentage of total new capital expenditures are summarized in Table 5-9. Where total expenditure data was not available, the percentage was not calculated. The differences across sectors in this table are noticeably large, with some sectors experiencing capital costs greater than 100 percent of their new capital expenditures. Averages for the industry are 10.88 percent for the 0.5 level, 21.98 percent for the 0.2 level, and 24.13 percent for the 0.1 level. Interpretation of the impact is difficult, since the various sectors face differing costs of acquiring capital, and have differing sources from which to draw investment funds.

For many sectors, capital costs are the same for at least the 0.2 and 0.1 exposure levels, and for some, they are the same for the 0.5 level, as well. For these sectors, once the equipment necessary to meet the higher levels is installed, achieving lower levels would not represent an excessive increase in capital expenditure, albeit those initial costs may be quite high.

Table 1. SECTOR DESCRIPTIONS

Code	Product or Service	Process
1	Asbestos-cement pipe	Primary manufacturing
2	Asbestos-cement sheet	Primary manufacturing
3	Asbestos friction materials	Primary manufacturing
4	Asbestos products	Primary manufacturing
5	Asbestos products	Primary manufacturing
6	Asbestos floor tiles	Primary manufacturing
7	Asbestos-reinforced plastics	Primary manufacturing
8	Asbestos packing and gaskets, and sealing devices	Primary manufacturing
9	Asbestos coatings, adhesives, and sealants	Primary manufacturing
10	Asbestos-cement sheet	Secondary fabrication
11	Asbestos friction products	Secondary fabrication
12	Asbestos textiles[a]	Secondary fabrication
13	Asbestos packing and gaskets	Secondary fabrication
14	Asbestos-reinforced plastics	Secondary fabrication
15	Brake and clutch remanufacturing	Automotive aftermarket
16	Retail service and repair	Automotive aftermarket
17	Shipbuilding and repair	Shipbuilding and repair

[a]Contains both heat and fire resistant textiles and electrical insulation.

Table 5-2. ESTIMATED NUMBER OF ESTABLISHMENTS BY SECTOR, 1981

Sector code	Number of establishments
1	5
2	6
3	44
4	3
5	22
6	3
7	4
8	21
9	78
10	23
11	38
12	51
13	289
14	245
15	250
16	285,188
17	179
Total	286,447

Table 5-3. AVERAGE SALES AND NEW CAPITAL EXPENDITURES, 1977 AND 1981 ($\$10^6$/establishment)[a]

Sector code	Average sales, 1977	Average sales, 1981[b]	Average new capital expenditures, 1977	Average new capital expenditures, 1981[b]
1	9.9	13.8	0.24	0.33
2	9.9	13.8	0.24	0.33
3	11.2	15.6	0.46	0.64
4	9.9	13.8	0.24	0.33
5	12.1	16.2	0.86	0.50
6	22.8	31.7	0.61	0.85
7	2.3	3.2	0.11	0.15
8	2.9	4.0	0.11	0.15
9	4.3	6.0	0.05	0.07
10	9.9	13.8	0.24	0.33
11	11.2	15.6	0.46	0.64
12	9.9	13.8	0.24	0.33
13	2.9	4.0	0.11	0.15
14	2.3	3.2	0.11	0.15
15	3.5	4.9	0.08	0.11
16[c]	0.6	0.8		
17	10.7	14.9	0.27	0.38

[a]Identical values appear for sectors classified by the same SIC code.

[b]GNP implicit price deflator of 1.39 used, 1972 = 100.

[c]Information on new capital expenditure was not available for this sector.

Table 5-4. SECTOR SIC CODES

Sector code	SIC code(s)
1	32929
2	32929
3	32922
4	32929
5	29521, 29523, 2661
6	32928, 3996
7	3079
8	3293
9	29522
10	32929
11	32922
12	32929
13	3293
14	3079
15	37143
16	7538, 551, 553, 554
17	3731

SOURCES: 1977 Census of Manufactures, 1977 Census of Retail Trade, and 1977 Census of Service Industries.

Table 5-5. ESTIMATED TOTAL SALES AND NEW CAPITAL EXPENDITURES, 1981 ($\$10^6$)

Sector code	Total sales	Total new capital expenditures
1	69.0	1.65
2	82.8	1.98
3	686.4	28.16
4	41.4	0.99
5	356.4	11.00
6	95.1	2.55
7	12.8	0.60
8	84.0	3.15
9	468.0	5.46
10	317.4	7.59
11	592.8	24.32
12	703.8	16.83
13	1,156.0	43.35
14	784.0	36.75
15	1,225.0	27.50
16[a]	228,150.4	
17	2,667.1	68.02
Total	237,492.4	279.90

[a]Information on new capital expenditure was not available for this sector.

Table 5-6. CONTROL COST BY SECTOR AND EXPOSURE LEVEL, 1981 (10^6 \$/yr)

Sector code	Exposure level (fibers/cc)		
	0.5	0.2	0.1
1	0.17	0.24	0.32
2	0.51	0.60	0.60
3	17.58	18.03	18.60
4	0.87	1.11	1.11
5	0.00	1.89	1.89
6	0.10	0.14	0.18
7	0.16	0.93	0.93
8	0.71	0.90	0.90
9	0.52	0.58	0.66
10	0.00	0.00	1.17
11	0.68	0.68	0.68
12	0.68	0.61	1.30
13	0.00	18.94	25.47
14	1.17	5.86	5.86
15	0.91	4.96	5.92
16	0.00	365.33	365.33
17	3.31	6.91	6.91
Total	27.37	427.71	437.83

Table 5-7. CONTROL COST AS A PERCENTAGE OF TOTAL SALES, 1981

Sector code	Exposure level (fibers/cc)		
	0.5	0.2	0.1
1	0.25	0.35	0.46
2	0.62	0.72	0.72
3	2.56	2.63	2.71
4	0.21	2.68	2.68
5	0.00	0.53	0.53
6	0.11	0.15	0.19
7	1.25	7.27	7.27
8	0.85	1.07	1.07
9	0.11	0.12	0.14
10	0.00	0.00	0.37
11	0.11	0.11	0.11
12	0.10	0.09	0.18
13	0.00	1.64	2.20
14	0.15	0.75	0.75
15	0.07	0.40	0.48
16	0.00	0.16	0.16
17	0.12	0.26	0.26
Average	0.01	0.18	0.18

Table 5-8. CAPITAL COST BY SECTOR AND EXPOSURE LEVEL, 1981 ($\$10^6$)

Sector code	Exposure level (fibers/cc)		
	0.5	0.2	0.1
1	0.03	0.03	0.03
2	0.74	0.75	0.75
3	25.66	25.66	25.66
4	1.37	1.40	1.40
5	0.00	2.41	2.41
6	0.01	0.01	0.01
7	0.02	0.76	0.76
8	1.14	1.15	1.15
9	0.68	0.68	0.68
10	0.00	0.00	1.78
11	0.06	0.06	0.06
12	0.20	0.20	1.25
13	0.00	20.27	24.50
14	0.17	1.99	1.99
15	0.30	5.73	4.70
16[a]	0.00	139.44	139.44
17	0.33	0.41	0.41
Total	30.77	200.95	206.98

[a]Capital costs for this sector are deleted from totals for determination of industry average capital cost as a percentage of new capital expenditures.

Table 5-9. CAPITAL COST AS A PERCENTAGE OF NEW CAPITAL EXPENDITURE, 1981

	Exposure level (fibers/cc)		
Sector code	0.5	0.2	0.1
1	1.82	1.82	1.82
2	37.37	37.88	37.88
3	91.12	91.12	91.12
4	138.38	141.41	141.41
5	0.00	21.91	21.91
6	0.39	0.39	0.39
7	3.33	126.67	126.67
8	36.19	36.51	36.51
9	12.45	12.45	12.45
10	0.00	0.00	23.45
11	0.25	0.25	0.25
12	1.19	1.19	7.43
13	0.00	1.75	56.53
14	0.46	5.41	5.41
15	1.09	20.84	17.09
16[a]			
17	0.49	0.60	0.60
Average	10.88	21.98	24.13

[a]Not calculated for this sector. Data on new capital expenditure not available.

Appendix A

Establishment Listings

Table A-1. PRIMARY MANUFACTURERS OF ASBESTOS-CEMENT PIPE

Company	Plant Location
Capco Pipe Co. (ASARCO, Inc.)	Van Buren, AR
Certain-Teed Corp.	Riverside, CA Hillsboro, TX
JM A/C Pipe Company	Stocton, CA Denison, TX

SOURCE: RTI