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AUTHENTICATION

I, Linda A. Travers, certify that I am the Director of the Information Management Division of the U.S. Environmental Protection Agency's Office of Toxic Substances and that the attached document is a true, correct and compared copy of a document in my official custody, consisting of:

> A draft Final Report prepared by the GCA Corporation (GCA-TR-82-53-G) entitled "ANALYSIS OF FIBER RELEASE FROM CERTAIN ASBESTOS PRODUCTS" dated December 1982, and contained in the docket for the EPA "Asbestos Ban and Phaseout Proposed Rule," docket No. OPTS 62036, consisting of 160 pages in all (pages 150 and 155 are missing).

Subscribed under penalty of perjury on 5/18, 1989.

Linda A. Travers

Linda A. Travers, Director
Information Management Division
(TS-793)

Certification

I, Gerald H. Yamada, certify that I am the Acting General Counsel of the U.S. Environmental Protection Agency, that I have duties throughout the United States and that the official whose signature appears above has legal custody pursuant to 40 C.F.R. §2.406 of the original document of which a copy is attached, as witnessed by my signature and the official seal of the Environmental Protection Agency which appear below.

Gerald H. Yamada

Gerald H. Yamada
Acting General Counsel

Date: 5/18/89

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Prepared by

Peter H. Anderson
Marc A. Grant
Robert G. McInnes
William J. Farino

GCA CORPORATION
GCA/TECHNOLOGY DIVISION
Bedford, Massachusetts

DISCLAIMER

This Draft Final Report was furnished to the Environmental Protection Agency by the GCA Corporation, GCA/Technology Division, Bedford, Massachusetts 01730, in fulfillment of Contract No. 68-01-5960, Technical Directive No. 15. The opinions, findings, and conclusions expressed are those of the authors and not necessarily those of the Environmental Protection Agency or the cooperating agencies. Mention of company or product names is not to be considered as an endorsement by the Environmental Protection Agency.

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SECTION 1

INTRODUCTION

OVERVIEW/PURPOSE

Over recent years, much has been written about the consequences of exposure to asbestos fibers during the manufacture and handling of asbestos-containing products. Governmental regulatory agencies such as the Occupational Safety and Health Administration (OSHA), Consumer Product Safety Commission (CPSC), and United States Environmental Protection Agency (EPA) have been entrusted with the responsibility of protecting workers, consumers, and the environment from exposure to asbestos fibers.

It is estimated that asbestos fibers have been used to manufacture 2,000 to 3,000 discrete commercial and industrial products.[1] Asbestos fibers may be released to the ambient air during product manufacturing, secondary processing, and end use. Persons may be exposed to asbestos fibers during the performance of these activities.

This study was undertaken to profile the activities routinely performed on asbestos-containing products during secondary processing and end use and to report, when data were available, airborne asbestos fiber concentrations associated with such activities. The data presented provide EPA with information on the likelihood of fiber release from selected asbestos products. EPA will distribute the data to other governmental regulatory agencies, OSHA and CPSC, and where the presence of risk is determined to be unacceptable, measures will be taken to reduce human exposure and environmental contamination.

REPORT ORGANIZATION

This report is organized by the asbestos product categories presented in Table 1. The categories profiled are asbestos-cement sheet products, flooring products, coatings and sealants, textiles, gaskets and packings, and paper products. The latter includes roofing felt, flooring felt, millboard and rollboard, beater-add paper, and electrical insulating paper. These categories were investigated to augment EPA's understanding of the fiber release potential from asbestos-containing products. Other products that contain asbestos include asbestos-cement pipe, friction materials, reinforced plastics, and under paper products, pipeline wrap, commercial paper, and specialty paper.

TABLE 1. ASBESTOS-CONTAINING PRODUCT CATEGORIES PROFILED

1. Asbestos-Cement Sheet Products
   - Flat Sheet
   - Corrugated Sheet
   - Roofing and Siding Shingles
2. Flooring Products
   - Vinyl-Asbestos Floor Tiles
   - Asphalt-Asbestos Floor Tiles
   - Sheet Vinyl Floor Covering (Backed with Asbestos Flooring Felt)
3. Coatings and Sealants
   - Petroleum-Based Compounds
   - Water Soluble Compounds
4. Textiles
   - Fire and Heat Resistant Materials
   - Thermal Insulation
   - Electrical Insulation
   - Gaskets and Packings
   - Friction Materials
5. Gaskets and Packings
   - Compressed Sheet Gaskets
   - Mechanical Packings (Asbestos Yarn)
6. Paper Products
   - Roofing Felt
   - Flooring Felt
   - Millboard and Rollboard
   - Beater-Add Gasket Paper
   - Electrical Insulating Paper

The information presented in this report was compiled from an extensive survey of publicly available data and telephone interviews with manufacturers, secondary processors, distributors, and end users of asbestos-containing products. A computerized literature search of eleven (11) data bases revealed that the amount and diversity of asbestos fiber monitoring data publicly available is limited. Various product-testing laboratories have monitored airborne fiber concentrations during simulated product use activities, but due to the preliminary nature of their findings or to proprietary agreements they are not willing to disclose publicly the results of their studies.

The product profiles presented herein include a brief description of product manufacturing operations and a more in-depth discussion of secondary processing and end use activities. Airborne fiber monitoring data are presented when available and fiber releasability is discussed. Secondary processing and end use activities include product fabrication and installation, in-service use, and removal, respectively. Due to the versatility of some products and the intermediate uses of others, there will be some overlap of products between categories. The overlap will be noted in the sections but not repeated.

QUALIFICATION OF ANALYTICAL TECHNIQUES AND AIRBORNE FIBER MONITORING DATA

Asbestos fiber concentrations presented in this report are based on the results of four different microscopic analytical techniques. The four techniques are phase contrast microscopy (PCM), polarized light microscopy (PLM), scanning electron microscopy (SEM), and transmission electron microscopy (TEM). PCM and PLM are optical microscopic analytical procedures. PCM, SEM, and TEM are commonly used to analyze air samples, whereas PLM is generally used to analyze bulk samples.

Phase contrast microscopy is an analytical technique for quantitative determination of airborne fibers. It is presently the recommended method of the National Institute for Occupational Safety and Health (NIOSH) for determining compliance with asbestos occupational exposure standards.[2] Fibers counted are those that are $\geq$5 microns (μm) in length and have a length-to-diameter aspect ratio of 3-to-1 or greater.[3] The principal disadvantages of PCM are that the technique cannot be used to differentiate asbestos fibers from nonasbestos fibers and it has a nominal magnification of 400 to 450X[3] with an image resolution of only 200 nm.[4]

Polarized light microscopy is generally used to identify and quantify asbestos in bulk samples of material. The technique takes advantage of specific optical properties each asbestiform mineral exhibits. With respect to analysis of air samples, PLM may be performed subsequent to PCM analysis to distinguish asbestos fibers from nonasbestos fibers, resulting in an actual asbestos fiber concentration measurement.

Scanning and transmission electron microscopes provide greater magnification (up to 100,000X and 250,000X, respectively) and image resolution (down to 20 nm and 0.4 nm, respectively) than optical microscopes.[4] Total fiber counts by electron microscopy ($\sim$25,000X) can exceed 100 times the number counted by optical microscopy (400X).[5] SEM used in conjunction with an

[illegible] energy dispersive x-ray (EDXR) spectrometer, which is almost always the case, provide qualitative results. EDXR is an electron beam microchemical analysis technique that provides semiquantitative elemental analysis of the fiber(s) under observation.[6,7] TEM with selected area electron diffraction (SAED) allows qualitative identification of fibrous minerals based on differences in crystalline structure. Transmission electron microscopes can also be equipped with an EDXR spectrometer.[4]

Discretion should be employed when interpreting and comparing the fiber concentration data presented in this report. Care should be taken not to compare optical microscopy results directly with SEM or TEM analyses. In addition, one should not mistakenly compare peak concentrations occurring during the performance of an activity with time weighted average (TWA) concentrations that have been scaled over an 8 hour period. To the extent possible, analytical methodologies are identified whenever fiber monitoring data are presented. Finally, some of the data presented may be out of date. Implementation of new control measures, changes in processing methods, and product reformulations should result in fiber concentrations lower than some of those reported. In all cases, the most recent airborne fiber concentration data are presented.

INTRODUCTION
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SECTION 2

ASBESTOS-CEMENT SHEET PRODUCTS

INTRODUCTION

Asbestos-cement (A/C) sheet refers to flat or corrugated cement board products that are primarily used in the construction, electrical insulation, glass, and metallurgical industries. Products within this category include flat sheets, corrugated sheets, and roofing and siding shingles. Shingles are cut from textured flat sheet and are usually painted, but also may be integrally colored. Asbestos fibers are incorporated into these products to provide strength, stiffness, and resistance to heat, rot, weathering, and attack by corrosive chemicals.

Specific formulations for A/C sheet products are dependent upon the method of curing used (ambient or autoclave) and end use specifications. If the sheet product is cured under ambient conditions (moist environment over several weeks), representative material formulations are 15 to 40 percent asbestos, with the majority of the balance consisting of cement.[1,2] For autoclave cured products, silica is added to speed the dehydration process. A general formulation for A/C sheet products cured by this method is asbestos (15 to 40 percent), cement (40 to 50 percent), and silica (30 to 40 percent).[3] In addition, other fillers, binders, and pigments may be added as necessary.[2]

A/C sheet products are manufactured by either a dry or wet process.[2] The dry process involves preparing a dry mixture of asbestos, cement, and silica (for autoclave cure). This mixture is metered onto a moving wet conveyor belt, then passes under steel rollers, is rewetted, and subsequently fully compressed under rolls. The sheet is then cut to uniform lengths and cured. After curing, the sheets are cut and trimmed to sizes ranging from the standard 1.2 x 2.4 meter (4 x 8 feet) size to the smaller size shingles. Flat siding shingles are manufactured in sizes ranging from 0.3 x 0.6 meters (12 x 24 inches) to 0.64 x 0.81 meters (25 x 32 inches). Roofing shingles are produced in surface dimensions ranging from 0.23 x 0.41 meters (9 x 16 inches) to 0.36 x 0.76 meters (14 x 30 inches). Thickness of the sheet products ranges from 0.32 to 10 cm (1/8 to 4 inches).[4]

Wet processing is the primary method used to produce both flat sheet and corrugated sheet. The predominant wet process, wet-mechanical, involves making a wet slurry of asbestos, cement, and silica (for autoclave cure) in a vat. The slurry is picked up by a screen cylinder mold and transferred to a felt conveyor belt. After dewatering by a vacuum the material is passed to a

mandrel which winds layers to the desired thickness. Width of the sheet is determined by the width of the vat; the length of the sheet is determined by the diameter of the accumulator mandrel. A cut is then made across the width of the sheet, and it is manually peeled off the rotating mandrel onto a transfer roll conveyor. The sheet may be partially dried by passing it over heaters before it is processed through embossing rollers and then trimming and cutting wheels. Corrugating is also done at this time, prior to curing.[2,5]

Another wet process involves making a slurry of ingredients as described above, and discharging it into a mold with a screen on the bottom through which water can pass. As the mold is closed, water is squeezed out of the slurry. Finally, when the sheet has the required density, it is ejected from the mold and is ready for curing.[2]

Primary manufacturers of A/C sheet may sell their products unfabricated directly to secondary processors or construction outfits or they may perform limited fabricating steps themselves before shipping the sheet as "complete" products ready for installation.[6,7] Fabricating activities performed by primary A/C sheet manufacturers are uncomplicated, large volume, repetitive operations. For example, pilot holes placed in roofing and siding shingles will normally be punched by the primary manufacturer.[6] The punch presses used to form the holes are integrated into the primary manufacturing process such that they are considered part of the production operation, not a secondary step.[6,7] Straight edge, dimensional sawing for large job orders is another fabricating operation performed by the primary manufacturer.[7]

Uses of A/C Sheet Product

Flat A/C sheet products are used in commercial, industrial, and residential applications. They are widely used by the construction industry in the following applications: soffit material (covering the underside of structural components), industrial partitions, fire-resistant walls, and interior and exterior decorative paneling. Sheet density, i.e., weight, generally determines a product's end use. Table 2 presents a partial listing of the many applications of one of the most commonly used flat A/C sheet products, Transite, a product manufactured by the Johns-Manville Corporation.

Flat sheets, impregnated with asphalt, are used as mounting panels for electrical switchboards, bus-bar supports and controller plates, and as insulating spacers in a wide variety of electrical apparatus.

Corrugated A/C sheets are used primarily in industrial and agricultural applications, serving as siding and roofing for factories, warehouses, and agricultural buildings. They are also used as linings for waterways, pilings for canal bulkheads, and as end paneling for cooling towers.[9]

Flat sheet is also textured and cut for exterior use as siding and roofing shingles. These shingles are extremely durable, and are available in a wide range of styles and colors.[6]

TABLE 2. PARTIAL LISTING OF THE MANY APPLICATIONS OF TRANSITE A/C SHEET[8]

Abattoirs
Animal hospitals
Air shafts
Air conditioning (housing)
Aerators (housing)
Air purification equipment
Animal stalls
Architectural panels
Arc barriers
Baffles
Boiler rooms
Bakery mixing stands
Baking ovens
Bulkheads
Blower ducts
Baseball dugouts
Bottom plates (foundries)
Burial vaults
Cell compartments (electrical)
Cell doors (electrical)
Cemetery markers
Incinerators
Canopies
Cooling towers
Chutes
Conveyor aprons
Conduits
Dental mfg. work tables
Dry kilns
Drying towers
Dust collectors
Drafting tables
Draft deflectors
Drying ovens
Ducts
Elevator linings
Exhaust vents and ducts
Fascia
Factory interior/exterior panels
Farm buildings
Floor underlayment
Fume hood liners/ducts
Fumigation chambers
Freezer lockers
Feed bins
Flumes
Furnace rooms
Fire barriers
Foundries
Flour mills
Freight houses
Fire lookouts
Fire stations
Freezer tunnels
Fuel hoppers
Foundry boxes
Fireplace screens
Grain bins
Grain elevators
Greenhouses
Hangers
Heat shields
Hothouses
Hoppers
Hoods (stove, ventilating)
Incubators
Welding table tops
Kennels
Kick plates
Laboratories
Linings for tanks
Louvers
Machine sheds
Milk houses
Meter boards
Mink warrens
Machine guards
Outdoor furniture (tables, benches)
Panels, partitions
Pizza ovens
Portable spray chutes
Poultry houses
Protective covering for marinite ovens
Press platens
Press plates
Pallets
Playhouses
Radiator covers
Refrigerators
Radiant panels
Sandblasted panels
Spray paint booths
Smoke houses
Septic tanks
Sluice boxes
Spacers
Storage bins
Stove shields
Sunscreens
Spaghetti dryers
Swings
Sand boxes
Table tops
Tank covers
Toilet partitions
Tanks (mixing/storage)
Vaults
Vats (exterior)
Wainscoting
Water tank screens
Water treating equipment
Walk-in coolers
Welding table tops

SECONDARY PROCESSING - FABRICATION

Fabrication of A/C sheet is normally required to transform unfinished material into a functional product ready for end use. As indicated above unspecialized material fabrication may be performed by the primary manufacturer. Asbestos-cement products requiring more specialized fabrication are usually handled by secondary processors, known as distributors, job shoppers, or cutters, who are located throughout the country. Secondary processing by job shoppers ranges from minor alteration of the sheet product to extensive fabricating operations involving sawing, drilling, sanding, routing, or beveling. Such operations, for example, are performed during the fabrication of A/C sheet to be used as laboratory table tops or mounting panels for electrical switches. In both cases, the A/C sheet must be finished to facilitate the insertion and attachment of plumbing or electrical components.

The most common fabricating operations performed by secondary processors are sawing and drilling, with sawing predominating. Operations such as sanding, routing or beveling occur less frequently. Overall duration of these activities varies, ranging from close to 8 hours per day at a large volume job shop using semiautomated equipment to 2 to 4 hours or less per day at smaller shops. The actual sawing of a 1.2 x 2.4 meter board, however, lasts only a few seconds. The same applies to drilling operations. Routing, sanding, and beveling operations tend to last longer but are not performed as often. Accumulated over an 8-hour workday the total time associated with actual performance of dust generating operations adds up to several minutes (est. 5 to 30). In general, A/C sheet products used in interior applications require more extensive fabrication than board products used for exterior applications.

Based on the chemical composition and physical structure of A/C sheet, asbestos fiber release is not expected during product handling except when the material is physically altered by mechanical disruption. A/C sheet is a hard, dense building product. The high percentage ($\geq$40%) of cement in the product produces a tightly bound matrix that is difficult to break apart. Only when an energy intensive abrasive force is applied to the material, such as sawing or drilling with a power tool, is a fine dust generated. The cutting energy supplied by the power tool pulverizes the asbestos-cement matrix, disintegrating the material to the point where it is easily entrained by the high speed rotating blade or bit. Because substantial dusting can occur during the fabrication of A/C sheet using power equipment, engineering control measures are usually implemented to minimize asbestos fiber release.

The tools used to fabricate A/C sheet products are similar to those used by the metal, masonry, and woodworking industries. These tools are stationary, heavily constructed pieces of equipment driven by electric motors.[10] Most of the time associated with their use is consumed in equipment setup and material layout and not in the actual performance of the cutting or grinding operation. The tools most commonly used are fixed table saws, drill presses, large surface grinders, and milling (lathe) machines. Hand tools, used to fabricate smaller pieces or assist in more detailed work, include electric sanders, routers, and drills. With respect to the tool's

cutting edge, masonry bits are often used to drill A/C sheeting, whereas diamond and carborundum blades or abrasive wheels are used with the sawing tools.[7,10]

A major difference existing between the tools used on A/C sheet products and those used on metal, masonry, and wood is the former's inclusion of a dust collection system. Most job shoppers use tools designed to prevent the release of fibrous dust into the workroom environment. The primary dust control system used by secondary processors is a simple dry vacuum exhaust system, with suction pickup points located as close as practicable to the site(s) of dust generation. This system is either of high air velocity, low air volume design such as those applied to stationary table saws and drill presses or a low air velocity, high air volume canopy hood design used for general area control. Another dust control measure commonly applied to table sawing operations is water spraying.[10,11] Under these conditions, the cutting blade and point of material contact are wetted by a constant spray or flow of water. Dust-laden water is captured and passed through a series of sedimentation tanks before being recycled.

Secondary processors of A/C sheet products are relatively small business concerns. Fabrication of A/C sheet is commonly performed in single story buildings. The workrooms within these buildings tend to be open with few internal walls and have high ceilings. Air circulation within the fabricating area results from infiltration through passageways and windows, with exfiltration by the dust collection vacuuming system.[11,12] No specialized filtering of the workroom air is carried out.

Secondary processors tend to deal with one or two industries or end use product applications. To illustrate this point, examples of two typical secondary processing operations are given below.

Laboratory Table Tops

A/C sheets make strong and chemically resistant workbench tops. A representative of the Brown-Morse Company of Muskegan Heights, MI, which deals almost exclusively in laboratory table tops and fume hood liners, referred to their fabricated materials as "complete" products, materials that do not require further processing.[12] Fabricating operations most frequently performed on these products are sawing and drilling. Final processing involves wipe cleaning the surface and edges, and painting if aesthetic qualities are desired.

Fabricating tools used by Brown-Morse include a table saw with a diamond blade and a standard industrial drill press; both are manually operated. Typically, during the course of an 8-hour workday, an employee is involved in sawing sheet for 4 hours and drilling for 2 to 3 hours. Sawing one straight edge takes 5 to 10 seconds, while drilling takes 3 to 5 seconds, depending on thickness of the sheet and diameter of the hole. The total daily time associated with the performance of each dust-generating activity is estimated to range from less than 5 to 30 minutes. All cutting tools are equipped with dust control devices; either water-spraying equipment or dry vacuum hookups venting exhaust air through a fabric filter. Workers in this shop also wear dust control face masks.

Fabricated Sheet Products for the Foundry Industry

The Hines Flask Company of Cleveland, Ohio, fabricates A/C sheet products for the foundry industry.[11] The company purchases Transite (core plate) from Johns-Manville and fabricates the material for use as jacket linings for "green sand" molds. Fabrication involves sawing the sheets to required dimensions, drilling a specified number of pilot rivet holes, and fastening the flat boards to a metal frame, making the jacket liner. Another product fabricated by the company is pallet car tops. These tops form the base of a foundry cast upon which a mold sits during pouring and cooling prior to shakeout. Sheets are cut to specified dimensions, but are not drilled. In use, the sheets lay flat on the pallet car top. In addition to being sturdy and noncombustible, Transite boards are true and flat at every point. This accounts for their use in the manufacture of brass, aluminum, gray iron, malleable iron, and steel castings.

During an 8-hour workday, board sawing accounts for approximately 4 hours of a worker's time and drilling for 2 to 3 hours.[11] As with Brown-Morse, the total sawing or drilling time is estimated to range from less than 5 to 30 minutes. The majority of the time is spent in equipment setup and material layout. Actual sawing and drilling operations last only a few seconds each. Large manually operated table saws and standard industrial drill presses are used to fabricate sheeting. All tools are equipped with high air velocity, low air volume vacuum exhaust dust collection systems to minimize fiber release to the workroom air. Operators are required to wear dust protection face masks and are also provided coveralls. Fabricating equipment is cleaned at the end of each workday with a portable vacuum unit. No special workroom air ventilation is employed. Dust control equipment is activated whenever operators are present in the workplace.

The sawing and drilling activities performed and the tools used by the two secondary processors described above are representative of the fabricating operations conducted on the A/C sheet products covered in this section. The tools and control measures employed are essentially the same whether electrical insulating boards or interior/exterior wall panels are being fabricated. The duration of the activities will vary, however, depending on the extent of product finishing required.

END USE ACTIVITIES

Field fabrication of A/C sheet products, which may be required prior to installation, is infrequently performed. Approximately 95 to 98 percent of the dust generating operations conducted are performed by the primary manufacturer or secondary processor before the product is sold to the end user.[6,7,10,13] The term "complete" product is often used to describe the item sold to the end user. It is apparent that a concerted effort is being made by the manufacturers of A/C sheet products to minimize field fabrication. However, when field fabrication is required, the extent of fabricating and the tools used vary greatly.

There exists an inconsistent approach by construction firms to provide adequate worker protection during field fabrication. This issue is compounded by the fact that the construction business is very competitive; awarding of a contract is directly related to cost bids. Given this rule of survival, many contractors bid at levels that would not allow them to purchase specialized dust control equipment or implement proper work practices to minimize employee exposure. Generally, only the very large firms or specialized outfits buy tools equipped to minimize fiber release. Many medium and small-size general contractors saw, drill, and sand asbestos-containing building materials using the same tools they use on wood, brick, metal or concrete-based materials.[10,14] As a minimum, facial dust masks may be worn by the workers. Also, onsite fabrication is normally performed outdoors whenever possible.

Field fabricating tools used to prepare A/C sheet for installation range from electric saws, drills, and sanders to manually operated handsaws, hand clippers, scoring knives, and rasps. Power tools, which are more likely to be used on the thicker and denser A/C sheet products, tend to pulverize the cement matrix releasing fine dust and possibly, free-form asbestos fibers. As a consequence, power-assisted field fabrication tools equipped to capture dust generated during operation have been developed and are commercially available.[10,15,16] These tools include hand-held power saws, sanders and drills with filter bags attached directly to them or stationary (fixed) saws or drills that are shrouded with an air exhaust line extending to a portable vacuum motor mounted to the top of a metal drum. In addition, manufacturers of A/C sheet products recommend that specific work practices be implemented during product installation to control dusting.[1] As with most work practice guidelines, however, the recommended procedures are widely publicized but not necessarily always followed as designed or intended.

Field fabrication of thinner A/C sheet products, those less than 0.64 cm (1/4 inch) thick, is typically accomplished using nonpower-assisted tools such as handsaws, hand clippers, scoring knives, and rasps. The slow cutting speed of the hand-operated tools generate coarse-size particles of asbestos-cement dust that tend to settle rapidly.[1] Local exhaust systems are not normally employed when these tools are used.

Handsawing and surface scoring are the two most widely used methods for cutting thin A/C sheet products in the field. A/C sheet cut by scoring involves placing the sheet on a flat surface (e.g., workbench or saw horses); clamping a guide bar along the cut line; and then scoring the material repeatedly after which the sheet is hand-snapped along the score line. This technique reportedly generates minimal dusting.[1]

In field fabrication situations where a rectangular hole has to be made in the A/C sheet to allow for access to electrical or plumbing fixtures, small holes are drilled (electric tool) into the board around the perimeter of the planned opening. The inside rectangle is then knocked out with a hammer. Any resultant rough edges are filed smooth or beveled using a metal file or rasp. The procedure just described also reportedly generates minimal dusting.[1]

During installation, A/C sheet products are secured by various means depending primarily on product weight (density) and end use. The methods employed include mechanical fastening using nails, screws, or bolts; gluing using epoxy or "liquid nail" adhesives; slide-in paneling using metal grooved framing; or simply laying the sheet flat under a heavy load. Installation by mechanical means or slide-in-place through metal guide channels is normally required for the denser, heavier utility and thermal insulation-type products, where the material is installed vertically.[7] Gluing is more often associated with the vertical installation of light-weight, flexible-type sheets and heavy sheets installed horizontally. Examples of these latter two installation methods are: the gluing of exterior or interior architectural wall panels to vertical surfaces, and the gluing of laboratory table tops horizontally to metal or wood support cabinets.[14,17]

Corrugated sheet is normally secured to a support structure using mechanical fasteners. Roofing and siding shingles are secured in a manner similar to that used for asphalt-felt or wood shingles using roofing nails.[6] The following presents a more detailed discussion of various A/C sheet product installations.

Utility Wall Panels

During installation of heavy, utility-type wall paneling, mechanical means such as fastening with nails, screws, or bolts are required to secure the sheets to a support surface. For most applications, whether exterior or interior, pilot holes are predrilled during secondary processing. Should field fabrication be required, standard construction sawing and drilling tools are used unless the contractor has purchased or has access to specialized dust controlled equipment.[7,10] In cases where cosmetic appearance is desired, the pilot holes are countersunk by the secondary processor. After erection, the recessed nail or screw head is patched over with a composite hardener that may or may not contain asbestos.[18] Following drying, the patched area is sanded flush with the paneling surface.

A representative of the Electro-Matic Products Company of Chicago, IL,[19] an end user of A/C sheet, stated that the majority of the electrical insulating mounting panels they purchase are processed as is, but a small number may require cutting or drilling for special applications. The contact estimated that the cutting operations would be performed once per month, lasting approximately 1 hour.

Architectural Panels

Architectural panels installed in both interior or exterior applications are secured using mechanical fasteners, such as bolts, screws, or nails, or an industrial strength adhesive (epoxy or "liquid nail"). Architectural paneling is flexible and fairly thin, 0.48 to 0.95 cm (3/16 to 3/8 inches) thick. Most panels are precut to size by a job shopper or purchased through a distributor in standard sizes. According to a representative of Erection Specialities, Inc. of Canton, MA,[10] the number of panels requiring field fabrication (e.g., the cutting of panels to fit around surface obstructions or end pieces) accounts for less than 5 percent of all sheets installed. Cutting equipment

used in the field ranges from hand held or table mounted power circular disc or sabre saws to hand operated saws or scoring knives. Power saws may or may not be equipped with dust collection exhaust hoods. Cutting time for the paneling lasts only a few seconds. In this case field fabrication normally takes place outdoors.

A/C sheet panels may also be installed using aluminum chanelling. In this system, the panels are slid into a grooved metal framework that holds the sheets in place.[7] Again, field fabrication may be required to get around surface obstructions, to cut end pieces, or to provide access holes for electrical and plumbing fixtures. The field fabricating tools and work practices employed are similar to those described above.

The representative of Erection Specialties, Inc., of Canton, MA, [10] stated that the company recently responded to a bid that included a clause stipulating "no field cutting of asbestos-containing products." To meet this requirement, Erection Specialties proposed cutting all A/C sheet products identified in the building specifications at their main office where they are equipped to fabricate such materials safely. Another source interviewed, Lampco, Inc. of Waltham, MA,[14] a distributor of A/C sheet products, indicated that for a job requiring the installation of 1,400 to 1,500 standard size A/C architectural cladding sheets, only 15 to 20 (< 2 percent) would require field cutting.

Laboratory Table Tops and Fume Hood Liners

Laboratory table tops and fume hood liners are prefabricated prior to shipment to the job site. A/C sheet products commonly used for these two applications are Colorlith* and Flexboard,* respectively. During the installation of laboratory table tops, an epoxy or some other type of strong industrial glue is used to secure the tops to wooden or metal support structures. Only during retrofits or special add-ons are abrasive power tools used on the material. Performance of these activities ranges from taking the sheeting outdoors and sawing or drilling it using tools equipped with dust controls to drilling the sheeting in place in the laboratory using uncontrolled equipment.[17] The frequency of these activities is unknown. A representative of Kewankee Scientific, of Statesville, NC,[17] a supplier of laboratory table tops and fume hood liners, stated that once they install the furniture according to design specifications the owner or operator of the laboratory can do whatever he wants to the furniture.

Laboratory fume hood liners (Flexboard) are also prefabricated by a secondary processor to facilitate easy assembly at the job site. Once erected, the fume hood may need to be secured to the table top (commonly A/C sheet) it rests on. This process involves drilling pilot holes into metal flanges of the hood chamber and table and screwing the flange to the bottom support. Set screws may also be used to secure the front edge of the hood chamber to the front lip of the table top. Installation of the set screws will not generate any dust.

*Manufactured by Johns-Manville Corporation.

Corrugated Sheet

Corrugated A/C sheets are generally used as exterior wall and roof coverings, bulkhead pilings, and window overhangs in industrial and commercial structures. Corrugated sheets are installed in a manner similar to other exterior cladding products in that overlapping pieces are nailed or screwed to the underlying support surface such as exterior grade plywood. Pilot holes are normally predrilled by a secondary processor to facilitate installation.

Roofing and Siding Shingles

Roofing and siding shingles, used primarily for residential construction, reportedly last from 30 to 50 years.[6] The most common method of securing shingles to a roof or building siding underlayment is with nails. Because the material is brittle, pilot holes are routinely predrilled or punched at the primary manufacturing plant.[6] A representative of the Supradur Manufacturing Corporation of New York, NY,[6] a major manufacturer of roofing and siding shingles, stated that abrasive power tools are not normally used during field fabrication. If the shingles require edge cutting to work around a surface obstruction, a specially designed guillotine cutting tool is used. Operation of the tool results in a clean edge cut, generating a minor amount of dust. This coupled with the slow cutting speed of the operation results in a low fiber release potential. Air monitoring during the performance of this activity has revealed that no measurable concentration of airborne asbestos fibers occurs near the breathing zone of the operator or in the general work area.[6] For a typical installation job, only a small percentage (less than five) of the shingles require field cutting.

The service life of A/C sheet products is relatively long, on the order of several years.[6,7,14] As used in the construction of buildings, A/C sheet products normally remain in place until the building is renovated or demolished. During renovation or demolition, A/C sheet products may be broken up into small pieces using a sledge hammer or other impact tools. If proper control measures (e.g. use of wetting agents) are not employed, asbestos fibers may be released into the ambient air (see following subsection). In some cases, the material may be dismantled intact and disposed of at a landfill in its nonfriable form or the material may be salvaged.

AIRBORNE FIBER MONITORING DATA

Asbestos fiber monitoring studies[20-23] covering simulated A/C sheet handling and actual field fabricating operations have been conducted. Fiber release tests on Transite have been performed in a glove box test chamber.[20] The A/C material was subjected to four routinely performed field fabricating and installation activities. The activities were hammering, hand scoring, and sawing and drilling using power tools (uncontrolled). The test results, which appear in Table 3 ranged from 1.1 f/cm^3 for scoring to 259 f/cm^3 during sawing. The fiber concentrations recorded are not representative of the levels expected under actual field conditions. Testing was performed in a confined, nonventilated air space that likely resulted in fiber accumulation, biasing the results high.

TABLE 3. FIBER[a] CONCENTRATIONS ASSOCIATED WITH ASBESTOS-CEMENT SHEET PRODUCT END USE ACTIVITIES[20]

Operation	Sampling Time (min)	PCM[b] (f/cm^3)	SEM[c] (f/cm^3)
Drill (power)	1	2.3	2.3
Score	4	3.2	1.1
Hammer[d]	1	12.7	16.5
Hammer[d]	4	6.4	10.2
Saw (power)	1	195.8	258.8

[a]Fibers as long as or longer than 5 µm having a length-to-diameter aspect ratio of 3-to-1 or greater were counted. This applies to analysis performed by both PCM and SEM.

[b]Phase contrast microscopy analysis.

[c]Scanning electron microscopy with energy dispersive x-ray (EDXR) analysis.

[d]Unclear whether this operation simulated installation with nails (fasteners).

An epidemiological study conducted by Rödelsperger et al.[21] showed that construction workers are exposed to fine dusts containing asbestos fibers during routine material handling activities. Monitoring of grinding operations performed on A/C sheet at approximately 40 building sites revealed that fiber concentrations (determined by PCM) ranged from 0.6 to 41 f/cm^3 at the breathing zone, with a mean of 20 f/cm^3.[21] Analysis by SEM showed mean values for fiber length ranging from 1 to 5 µm and fiber diameter from 0.1 to 0.4 µm. The ratio of fibers with a length of greater than 5 µm to the total number of free fibers ranged from 4 to 60 percent, with a median value of 25 percent. The authors state that when performed, grinding accounts for only 6 percent (approximately 30 minutes) of the daily working time. Grinding is not necessarily conducted every day A/C products are handled. As such, the daily mean value, calculated based on sixteen 30 minute periods per day, approaches 1.2 f/cm^3. It is presumed that the grinding tools used were not equipped with dust collection systems.

The study further explains that, based on a sampling of 61 roofers, the median frequency of roofing with corrugated sheets, shingles, and front plate asbestos-cement building products, where grinding is not performed, are 34, 30 and 25 days per year, respectively. It is noted that workers may handle more than one type of asbestos-cement product on any given day.

Nilfisk of America, of King of Prussia, PA, a manufacturer of HEPA* filtered industrial vacuum cleaners for toxic materials, conducted a study[22] demonstrating the effectiveness of their shielded power hand tools in controlling dusting during use. The tools demonstrated, an electric drill, a circular saw, and a sabre saw, were equipped with specially designed dust collecting enclosures (shrouding) connected by flexible hoses to a portable high efficiency vacuum cleaner. Airborne fiber concentrations were monitored during sawing and drilling of asbestos cement board. Only two sampling runs were conducted. The fiber concentration measured at the breathing zone of the operator during use of the circular saw was 0.04 f/cm^3. The breathing zone fiber concentration recorded during the combined operation of the circular saw, drill, and sabre saw was 0.15 f/cm^3. Sampling times for these two runs were 12 and 17 minutes, respectively. Both air samples were analyzed by phase contrast microscopy. Although it was not reported, it is presumed that the tool demonstration was conducted indoors. No visible emissions were observed from the cutting operation while the vacuum cleaner was activated.

Johns-Manville Corporation conducted a monitoring study[23] to determine the magnitude of airborne fiber concentrations generated during drilling and sawing flat A/C sheet. The electric drill and circular saw used to cut a 0.64 cm (0.25 in.) thick piece of flat A/C sheet were equipped with dust collection vacuum exhaust systems. Each cutting operation was monitored separately for 40 minutes. Air samples collected are presumed to have been analyzed by phase contrast microscopy. The test results presented in Table 4 show that airborne fiber concentrations of <0.1 f/cm^3 can be expected when A/C sheet fabricating activities are performed using tools equipped with dust control devices.

SUMMARY OF FINDINGS

The moderately high asbestos content (15 to 40 percent) of A/C sheet creates the distinct possibility for fiber release during physical alteration which can occur during material fabrication and removal. When in service, normally a static condition, the high percentage of cement in the product matrix strongly binds the asbestos material together making fiber release unlikely.

Secondary processing and field fabricating operations may be performed on A/C sheet products that result in asbestos fiber release. The magnitude of asbestos fiber release during these operations depends on the intensity of the mechanical energy applied. Power tools increase the likelihood of fiber release because of their pulverizing affect on the material. The high speed action of cutting blades also causes greater particle dispersal. Use of hand operated tools does generate dust, but the particles are coarser (tending to settle to the ground quickly) and the amount of physical energy applied is well controlled.

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*HEPA = High Efficiency Particulate Air Filter (99.97 percent retention at 0.3 microns).

TABLE 4. AIRBORNE MONITORING[a] RESULTS FROM USING A CIRCULAR SAW AND DRILL ON FLAT A/C SHEET[23]

Operation	Time (min)	Equipment	Fiber concentration[b] (f/cm^3)
Drilling holes (163 holes)	40	Drill with dust pick-up shroud operated at full speed	< 0.1
Sawing (18.3 meters)	40	Circular saw with dust pick-up shroud; totally enclosed masonry blade	0.0

[a]All tests conducted in an open room.

[b]NIOSH's phase contrast analysis assumed, counting fibers 5 μm long or longer with a length-to-diameter aspect ratio of 3 or greater.

Secondary processors performing fabricating operations primarily use power assisted tools. These tools are typically equipped with individual or centralized dust collection vacuum exhaust systems. Workroom air fiber concentrations are expected to be below current occupational exposure standards. Because secondary processors are in the business of fabricating A/C sheet products, they perform various sawing, drilling, and sanding operations more frequently and over a more extended period of time than any other product handling group. Material handling on any given day may last up to 4 hours, of which an estimated 5 to 30 minutes is actually involved in product machining. Fabrication of A/C sheet products by secondary processors is performed almost exclusively within the confines of a building. Rarely would the machining operations be performed outdoors.

Field fabricating operations, which are usually of short duration, are performed on only a small percentage (less than 5 percent) of the A/C material handled during installation. Depending on the activity performed and equipment available, dust control measures employed during field fabrication vary from no control to effective dust capture. Power assisted tools are more often used on the thicker, denser material whereas hand operated tools are used on thinner, flexible sheets. Airborne fiber monitoring data indicate that the use of power-assisted fabricating tools equipped with dust collection exhaust systems effectively control the release of asbestos fibers. Fiber concentrations of less than 0.2 f/cm^3 have been measured during the use of controlled power tools. Uncontrolled power tools, however, have caused fiber concentrations as high as 41 f/cm^3 near the breathing zone of construction workers.

Table 5 summarizes the data presented on A/C sheet products and identifies the principal activity of concern with respect to fiber release.

TABLE 5. SUMMARY OF A/C SHEET PRODUCTS SECONDARY PROCESSING AND END USE ACTIVITIES

Product: A/C sheet products	Secondary processing	End use
Activity:	Sawing, drilling, sanding	Sawing, drilling, sanding
Duration: Per Incident	<5 to 10 seconds	<5 to 10 seconds
Daily Total	5 to 30 minutes (est.)	5 minutes (est.)
Fiber Releasability:	High	High
Chemical Composition	Moderately high asbestos content (15 to 40%)	Same
Physical Composition	Hard, rigid material	Hard, rigid material
Disruptive Energy	Usually high intensity mechanical input	Varies from power tools to hand operated cutting devices
Control Measure(s):	Dust collection systems	Varies from portable dust collection systems to no control
Measured Fiber Concentrations (f/cm^3):	Less than 2 f/cm^3 expected in workroom, well documented values not available from literature	Less than 0.2 f/cm^3 when tools are equipped with dust collection devices; more than 2 f/cm^3 when tools are uncontrolled
Environmental Setting:	Fabricating operations are performed indoors	Whenever possible, field fabricating operations are conducted outdoors. Some will be performed indoors, however

Activity of Concern

Field fabrication of A/C sheet products using power hand tools that are not equipped with dust collection devices.

ASBESTOS-CEMENT SHEET PRODUCTS
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SECTION 3

FLOORING PRODUCTS

INTRODUCTION

Asbestos-containing floor products are classified as resilient floor coverings and include vinyl-asbestos floor tile, asphalt-asbestos floor tile, and sheet vinyl flooring backed with asbestos-containing felt. A discussion of the felt backing used for sheet vinyl flooring is presented in Section 7 under Paper Products.

Asbestos-containing floor tiles and sheet vinyl flooring backed with asbestos felt are installed in industrial, commercial, institutional, and residential buildings.[1,2] They may be installed on concrete or prepared wood floors, or over old tile floors, and are often specified for heavily trafficked areas such as kitchens, entry ways, restrooms, supermarkets, commercial plants, and offices.

Asbestos Floor Tiles

The production techniques for the two floor tile products, vinyl-asbestos and asphalt-asbestos, are similar. They differ only in product composition, with asphalt-based tiles serving some special applications and uses when darker shades are permissible.[3] Because vinyl-asbestos floor tile production accounts for most of the asbestos consumed by the floor tile industry[3], the following discussion relating to floor tiles will address only the vinyl product. This discussion, however, will apply directly to asphalt-asbestos floor tiles, as well.

Vinyl-asbestos floor tiles are composed of asbestos, binders, fillers, pigments, and chemical stabilizers.[1,2] The asbestos content of the tile usually ranges from 8 to 30 percent by weight, or up to 635 grams of asbestos per square meter (0.13 pounds per square foot) of tile.[1] Grades 5 and 7 chrysotile asbestos fibers are normally used. Polyvinyl chloride (PVC) resin serves as the binder and accounts for 15 to 25 percent of the tile composition. Limestone and other fillers represent 43 to 73 percent of the product weight. The pigment content usually averages about 5 percent, but may vary widely depending upon the materials required to produce the desired color.[1,2] Chemical stabilizers added to the product mix typically represent 1 percent of the total product formulation.

Floor tile production begins with dry mixing of the ingredients in a Banbury mixer to thoroughly blend all constituents. The mixture is then heated to 149°C (300°F) to flux the PVC resin and create a coherent plastic

mass. This material is fed to a mill where the tile is shaped, decorated, and cooled. Asbestos fibers contained in the floor tile product are tightly bound within the vinyl plastic matrix, thereby isolating them from the external environment during use.

Once cooled, the tile product is waxed, cut to size, inspected and packaged. Tiles are produced in sizes 23 cm (9 inches) square or 30 cm (12 inches) square, with thicknesses varying from 0.08 to 0.24 cm (1/32 to 3/32 inches). Asbestos floor tiles are very durable and may last for up to 30 years even in heavily trafficked areas.[1]

Sheet Vinyl Flooring

Asbestos felt-backed sheet vinyl flooring is a resilient floor covering that is applied to subfloor surfaces in roll or sheet form. The sheet backing or flooring felt is an asbestos-containing paper product that is manufactured separately and forms the underlayment of sheet vinyl flooring. Asbestos-containing flooring felts, which are produced on a conventional papermaking machine, are composed of approximately 85 percent asbestos (chrysotile) and 15 percent latex binder.[4] Once manufactured, flooring felt may be sold without further processing or may be used to produce sheet vinyl flooring.[5,6]

Asbestos flooring felt is manufactured into sheet vinyl flooring products by applying a resilient polyvinyl chloride coating to one side of the asbestos felt using various extrusion coating and laminating and spread-coating methods.[4] Once the coatings are applied, the sheet is passed through an oven where these layers are dried and gelled. The coated sheet is then decorated to enhance its appearance by passing it over one or more engraved cylinders and/or several printing stations. The printed sheet then goes to a fusion step where the sheet is coated with a "wearlayer." The wearlayer is a homogeneous polymer application that provides an impervious surface for the finished product.[2] The coated and printed sheet is next fed through an oven where the felt backing, the layers of latex and plastisol, and the wearlayer are fused into a single product. During fusion, the layer of plastisol foam may expand 2 to 6 times its original thickness, giving the sheet vinyl flooring its thickness and resilience. After fusion, these layers remain distinct, but are no longer chemically or mechanically separable.[2] The vinyl sheet is then cooled, cut to size, packaged and shipped.[1,5,6]

SECONDARY PROCESSING--FABRICATION

There is no secondary processing of the products within this category. Asbestos floor tiles and asbestos felt-backed sheet vinyl flooring are shipped directly from the factory to wholesalers and retailers who, in turn, sell directly to end users.[5,6]

END USE ACTIVITIES

As indicated above, vinyl-asbestos floor tiles and sheet vinyl flooring are used in industrial, commercial, institutional, and residential applications. Floor tiles can be installed either by professional floor

installers or home owners, while the sheet vinyl flooring is usually laid down only by professionals due to the difficulty involved in creating a perfect fit with the one-piece sheet.[7,8]

The installation of asbestos flooring products, like most floor coverings, requires preparation of a subfloor that is smooth and free of surface irregularities. Subfloor preparation may involve minor alteration of the existing floor covering or partial or total removal.

Subfloor Preparation and Removal

Subfloor preparation is considered by many installers to be the most difficult and time consuming as well as the most important part of the installation job if one is to get a smooth, long lasting new floor.[7,8] This activity also involves the greatest potential for asbestos fiber release if the existing subfloor is covered with an asbestos-containing floor product and the manufacturer's warnings against sanding are not heeded. Interviews with several flooring installers revealed that common subfloor preparation practices run the gamut from sanding or dry scraping without any personal protective equipment, to explicitly not sanding, to sanding while using a respirator.[7,8-13]

The majority of installers interviewed avoid sanding whenever it is economically or practicably possible. If the existing floor is not or cannot be sanded, it is either removed using flat-bladed putty knives or covered with plywood, fiberboard, or masonite. Sanding or removal of the subfloor covering takes approximately 4 to 8 hours for a standard 2.7 by 3.6 meter (9 foot by 12 foot) room, although this figure varies considerably depending on the size of the room and difficulties encountered in removing old tile.[8,11,12] Sanding and stripping machines, as well as flat-bladed putty knives, hammers, chisels, and scrapers are utilized in subfloor preparation.[8-13]

If the existing subfloor is covered with asbestos felt-backed sheet vinyl flooring, then the standard procedure is to "strip" the floor. This process involves removing the top two (wear and foam) layers of sheeting and splitting the bottom asbestos felt layer in half, along the horizontal plane. If the subfloor covering was glued over its entire area, then this procedure is relatively easy, since the felt has little vertical tensile strength and will split when pulled. During this process, the existing floor covering is cut into strips approximately 0.46 meters (1.5 feet) wide and each strip is pulled up and away from the subfloor.[6] This separation process, which may have a high fiber release potential, leaves half of the felt in place and offers a uniform subfloor for the new flooring product. Tarkett, Inc.* of Whitehall, PA,[6] a manufacturer of sheet vinyl flooring, recommends that the exposed felt be vacuumed immediately after each strip is removed to collect loose dirt that may contain asbestos fibers.

*Tarkett Inc. recently purchased the Whitehall, PA facility from GAF Corporation's Consumer Product Group.

If, instead of total surface gluing, the existing sheet vinyl flooring had only been pasted along its perimeter, then stripping will remove the entire covering, leaving only split asbestos felt around the perimeter. This felt is either scraped up after it has been wetted (recommended practice) or it is feathered to provide a smooth subfloor/felt interface. The former technique is favored since feathering involves sanding the felt, which can release asbestos fibers.[14-16] If (a third scenario) the existing sheet vinyl flooring is intact and relatively smooth, then its top layer will be used as the subfloor and be rough sanded to provide a better contacting surface for the adhesive. Sanding will disturb only the wear layer of the sheet flooring and not the asbestos felt.[14] The time it takes to remove or prepare a sheet vinyl flooring is similar to that for an asbestos tile floor, approximately 4 to 8 hours for the standard size room.

Installation

Vinyl-Asbestos Floor Tile--

The installation of vinyl-asbestos floor tile in a standard 2.7 by 3.6 meter (9 by 12 foot) room will take a professional installer from 2 to 4 hours.[8-13] Installation is typically begun in the center of the room and proceeds toward the walls. Tile adhesive is applied over one section of the floor at a time and full tiles are applied. If the floor tiles are prebacked with adhesive, the protective cover layer is removed and the tiles are pressed in place. Once all full tiles are in place, the perimeter and partial pieces are measured and cut out. This requires proportionately more time than laying full tiles; up to one half of the total installation time is devoted to this detailed work.[8,10-12] After partial pieces are marked, they are hand cut either by scoring the tile (cutting partially through) and snapping it or by simply cutting entirely through the tile in one operation. Whichever technique is used, the time spent in making each cut amounts to only 5 to 10 seconds. Total cutting time for an average 2.7 by 3.6 meter (9 by 12 foot) room is approximately 10 minutes. All cutting occurs in the room being tiled. Cutting tools include commercial tile cutters, utility knives, scissors, and razor knives.[7-13,17] The low energy input associated with the use of these hand tools and the binding properties of the tile matrix minimize fiber release during installation.

Sheet Vinyl Flooring--

The installation of asbestos felt-backed sheet vinyl flooring in a standard 2.7 by 3.6 meter (9 by 12 foot) room will take from 1 1/2 to 6 hours depending on the width of the vinyl roll (1.8, 2.7, 3.6 or 4.5 meters), the way in which it is glued, and whether or not a pattern has been used.[8,14-16] The narrower the flooring width, the greater the installation time since the patterns of adjoining sections must be matched. Gluing techniques, which were briefly described above, vary in three basic ways: fully pasted, whereby the entire felt backing is glued to the subfloor; perimeter pasted, in which only the perimeter of the flooring is glued; and the "Put Down Quick" (PDQ) technique, in which the flooring is layed without any glue.[16] A fully pasted floor will take the most time to install, but will last the longest. Perimeter pasting is used most often when the subfloor is concrete. This technique is quicker and saves time and money. A PDQ installation is more common to flooring which is solely vinyl than it is to the more expensive asbestos felt-backed product.

The use of a template for cutting sheet vinyl flooring is a widespread practice. The template is cut to match the exact perimeter details of the room. These details are then transferred onto the sheet vinyl product. Narrow strips of asbestos-containing flooring felt are often used as the template in sheet vinyl installations since it is readily available and is relatively inexpensive.[14,15]

Template preparation involves laying the template sheet along the perimeter of the room and transcribing onto it the perimeter outline. Each section of the template is cut on the spot and immediately refitted to the room perimeter to insure a perfect fit. Utility and razor knives are used for cutting the template, and this operation takes approximately 10 to 20 minutes of the total 1 1/2 to 6 hour sheet vinyl flooring installation time for a standard 2.7 by 3.6 meter (9 by 12 foot) room.[8,14-16] Installation time varies depending on the complexity of the perimeter details and the skill of the installer.

Once completed, the template pattern is transferred to the sheet vinyl flooring and the flooring is cut to shape and size. Razor knives and utility knives are also used for this purpose and the total cutting time is a fraction of the total installation time, usually lasting from 5 to 20 minutes, again for the standard size room.[8,14-16] Interviews with flooring retailers and professional installers alike indicated that preparation and installation of sheet vinyl flooring involves minor mechanical disturbance to the product, minimizing the potential for airborne asbestos fiber release. The only action during installation that disturbs the asbestos felt layer of the flooring is cutting, and this is short in duration and not energy intensive. During use, the asbestos felt layer is never directly exposed.

AIRBORNE FIBER MONITORING DATA

Monitoring of asbestos fiber release during floor tile installation and removal was performed by SRI International.[18,19] Results of this study are presented in Table 6. The results of a similar SRI study, done on the installation and removal of sheet vinyl flooring, are presented in Table 7. The reported fiber concentrations for both studies were determined by phase contrast microscopy. Fiber concentrations associated with the two asbestos floor tile end use activities ranged from 0.0 to 0.58 f/cm^3. The high end value was recorded when recommended practices were not followed during removal. Concentrations for the two sheet vinyl flooring activities were somewhat higher, especially those obtained during removal of the asbestos felt layer, up to 2.17 f/cm^3 for dry scraping of the felt layer. According to the Resilient Floor Covering Institute, dry scraping is not a recommended work practice. The higher fiber concentrations recorded for the asbestos felt-backed sheet vinyl flooring product is expected because the felt backing contains a much higher percentage of asbestos (85 percent) than the tile product (8 to 30 percent) and is not as structurally cohesive as the tile.

Monitoring of fiber release during floor tile use and maintenance has been performed by SRI and Sebastien et al.[18,22] SRI's results, presented in Table 6, show that fiber concentrations ranged from 0.00 to 0.195 f/cm^3 during in-service use, wet mopping, and machine buffing vinyl-asbestos floor tiles located in an office building's copy center and snack shop.

TABLE 6. FIBER RELEASE FROM VINYL-ASBESTOS FLOOR TILE INSTALLATION, USE, MAINTENANCE, AND REMOVAL[18,19]

Site description	Age of tile (years)	Operation	Sampling time (minutes)	Fiber concentration[a] range (f/cm^3)
Residential home	6	Old tile preparation for new installation	10	0.000
Residential home	New	Installation	113 to 114	0.092 to 0.184
Residential home	New	Installation	220 to 232	0.081 to 0.267
Residential home	New	Installation	65	0.048 to 0.189
Office building copy center	5	In-service use	411 to 419	0.002 to 0.011
Office building snack shop	5	In-service use	130 to 133	0.008 to 0.062
Office building copy center	5	Maintenance - mopping	15	0.135
Office building snack shop	5	Maintenance - mopping	21	0.195
Office building copy center	5	Maintenance - buffing	11 to 30	0.000 to 0.092
Office building snack shop	5	Maintenance - buffing	21	0.000
Residential home	NR	Removal	123 to 134	0.062 to 0.147
Residential home	6	Removal[b]	80	0.153 to 0.583

[a]Phase contrast microscopy analysis performed. Samples were taken at breathing zone of operators except for those taken in the office building copy center and snack shop, these were taken from 0.3 to 1.5 meters (1 to 5 feet) above the floor surface.

[b]Removal deviated from recommended procedures that include removal without sanding, use of a flat-bladed wall scraper instead of equipment that would unduly shatter the tile, and not breaking the tile by hand before placing in a disposal bag.

NR = Not reported.

TABLE 7. FIBER CONCENTRATIONS ASSOCIATED WITH THE INSTALLATION AND REMOVAL OF SHEET VINYL FLOORING BACKED WITH ASBESTOS FLOORING FELT[20,21]

Site description	Age of vinyl sheeting and method of attachment (years)	Operation	Sampling time (minutes)	Fiber concentration[a] range (f/cm^3)
Residential home - kitchen	New adhered	Installation	175 to 177	0.246 to 0.310
Residential home - kitchen	6-adhered	Installation	100	0.000
Residential home - kitchen	13-adhered	Installation	58 to 60	0.633 to 0.655
Residential home - foyer	2-adhered	Installation	177 to 179	0.075 to 0.554
Residential home - kitchen	8-adhered	Installation	44 to 45	0.325 to 1.016
Residential home - kitchen	13-adhered	Partial removal[b]	44 to 62	0.190 to 0.408
Residential home - foyer	2-adhered	Total removal[b]	121 to 123	0.368 to 0.402
Residential home - kitchen	8-unadhered	Total removal[b]	74 to 76	0.069 to 0.100
Residential home - kitchen	6-adhered	Wear layer removal	70 to 75	0.084 to 0.218
Residential home - kitchen	6-adhered	Wet scrape felt layer	55	0.484
Residential home - kitchen	6-adhered	Dry scrape felt layer	63	1.267 to 2.168
Residential home - kitchen	6-adhered	Dry scrape felt layer	40 to 45	1.004 to 1.126

[a]Phase contrast microscopy analysis performed. Samples were taken at breathing zone of operators.

[b]Operations were performed according to Resilient Floor Covering Institute practices that do not include sanding, sweeping, or dry-scraping.

Because the air samples obtained by SRI were analyzed by PCM, actual asbestos fiber concentrations were not determined. However, monitoring results obtained by Sebastien et al. indicate that asbestos fibers are released from vinyl-asbestos floor tiles during everyday use. Sebastien et al. performed air sampling at four locations within an office building containing 5,400 m^2 of vinyl-asbestos floor tile. Transmission electron microscopic analysis of air samples taken during periods of active building use revealed airborne asbestos concentrations of 8, 21, 25 and 170 ng/m^3* at the four locations, respectively. The locations sampled included three corridor sites and a fourth site located in a workshop where electronic machines are tested and part of a corridor. The highest concentration was recorded in the workshop, an area of greatest worker activity. No fibers longer than 3 µm were observed on the membrane filters analyzed.[22]

Fiber concentrations measured during the removal of old asbestos floor tile are presented in Table 6. As evident in the table, concentrations resulting from removal are significantly higher than those associated with the installation, use, and maintenance of this flooring product. This is consistent with the amount of energy expended in removing the tile. When an existing tile floor is removed, pieces of tile may remain affixed to the floor. To remove these pieces, a worker may use a hammer and a chisel to free the individual bits of tile from the adhesive binder. Alternatively, the worker may elect to use an electric sander to sand the tile down to the existing subfloor deck. In either case, substantial amounts of mechanical energy are applied to the floor tile to effect its removal. This action, particularly sanding, may expel asbestos fibers from the vinyl matrix, resulting in elevated (higher than background) airborne fiber concentrations.

Two monitoring studies on the release of asbestos fibers from vinyl-asbestos floor tile have also been conducted by GCA/Technology Division. One revealed asbestos fiber concentrations of 0.02 to 0.10 f/cm^3 during vinyl-asbestos floor tile removal.[24] Sampling occurred approximately 4.5 to 6.0 meters (15 to 20 feet) from an area where workers manually ripped up an asbestos tile floor. The ripping activity was monitored for 165 minutes. Air samples obtained were analyzed by SEM/EDXR. The other GCA study[25] involved measuring fiber concentrations during the reenactment of various end use activities on vinyl-asbestos tiles. The activities, which were performed in a laboratory glove box, included cutting, grinding, breaking, and drilling. Sampling periods ranged from 1 to 5 minutes. Initial analysis by phase contrast microscopy indicated no fiber release. When duplicate samples were analyzed by SEM (5000X) and EDXR, a fiber concentration of 0.5 f/cm^3 was recorded for the tile grinding operation only. No fibers were detected by SEM/EDXR analysis for the other activities monitored. It is noted that even though SEM/EDXR analysis was performed, only fibers $\geq$5 µm in length and having a length-to-diameter ratio of 3-to-1 or greater were counted.

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*EPA's factor for converting nanograms to fibers is 1 nanogram equals 30 fibers.[23]

Murphy et al. monitored fiber release during sanding of vinyl-asbestos floor tile.[26] The experiment was performed under laboratory conditions in a 3 x 3.7 x 2.1 meter (10 x 12 x 7 foot) walkin chamber. A belt sander was used to remove a section of old floor tile. The data indicate that sanding can result in airborne fiber concentrations of 1.2 to 1.3 f/cm.^{3} Air samples were analyzed by PCM.

SUMMARY OF FINDINGS

Airborne fiber concentrations measured during the installation of vinyl-asbestos floor tile and sheet vinyl flooring backed with asbestos flooring felt approach 1.0 f/cm^3, as determined by PCM. During product installation, the product matrix containing asbestos fibers is disturbed by a limited number of manual cuts, each of which lasts only 5 to 10 seconds. Total cutting time amounts to 10 to 20 minutes of the total 1 1/2 to 6 hour flooring installation time. The rooms in which this cutting activity occurs are typically well-ventilated.

Discarding sanding and dry scraping operations, fiber concentrations associated with floor tile removal (0.15 f/cm^3) are approximately the same as those associated with tile installation, (0.05 to 0.27 f/cm^3) while asbestos concentrations attributable to sheet vinyl flooring removal (up to 0.48 f/cm^3) are approximately half those recorded during installation (1.0 f/cm^3). When sanding or dry scraping are employed to remove vinyl-asbestos floor tile or sheet vinyl flooring during subfloor preparation, airborne fiber concentrations of 1.0 to 2.0 f/cm^3, as determined by PCM, can occur.

Table 8 summarizes the data presented on flooring products and identifies the activities of concern with respect to airborne asbestos fiber release.

TABLE 8. SUMMARY OF ASBESTOS FLOORING PRODUCTS SECONDARY PROCESSING AND END USE ACTIVITIES

Product: Flooring products: asbestos floor tile, sheet vinyl backed with asbestos felt	Secondary processing	End use	
		Floor tile	Sheet vinyl flooring
Activity:	No secondary processing for either product line	Subfloor preparation/ removal, installation	Subfloor preparation/ removal, installation
Duration of Activity:			
Per Incident	Subfloor preparation/ removal	NA	NA
Daily Total		4 to 8 hours	4 to 8 hours
Per Incident	Installation (cutting)	5 to 10 seconds	Somewhat continuous
Daily Total		10 minutes	10 to 20 minutes
Fiber Releasability:			
Chemical Composition		Low	Moderate
Physical Composition		8 to 30% asbestos, tightly bound in polymer resin	85% asbestos, bound by latex binder
		Moderately pliable, stiff, hard, very cohesive	Very pliable, not rigid
Disruptive Energy	Subfloor preparation/ removal	Hand chiseling and scraping, may use power tools (sander)	Hand scraping, may use power tools (sander)
	Installation (cutting)	Hand held scoring knife, tile cutter, scissors	Razor knives, scissors
Control Measure:	Subfloor preparation/ removal	Wetting, following recommended work practices	Wetting, following recommended work practices
	Installation	Following recommended work practices, no engineering controls	Following recommended work practices, no engineering controls

(continued)

TABLE 8 (continued)

Product: Flooring products: asbestos floor tile, sheet vinyl backed with asbestos felt	Secondary processing	End use: Floor tile	End use: Sheet vinyl flooring
Measured Fiber Concentration (f/cm^3):	Subfloor preparation/ removal	0 to 0.15[a]	0.07 to 0.48[a]
	Installation	0.05 to 0.27	0 to 1.0
	Use, maintenance	0.00 to 0.20 (8 to 170 ng/m^3[b])	ND
Environmental Setting:		Indoors, in room usually well ventilated	Indoors, in room usually well ventilated

Activity of Concern

Subfloor preparation involving removal of asbestos floor tile or sheet vinyl flooring backed with asbestos felt when recommended work practices are not followed.

[a]When following recommended work practices.

[b]EPA's factor for converting nanograms to fibers is 1 nanogram equals 30 fibers.[23]

NA = Not applicable.
ND = No data.

FLOORING PRODUCTS
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SECTION 4

COATINGS AND SEALANTS

INTRODUCTION

Asbestos fibers are used in the manufacture of coatings and sealants because of the strength, durability, thermal and corrosion resistance, sound deadening, and waterproofing characteristics they impart. Coatings are covering products used to rejuvenate and/or protect various types of surfaces. Sealants are liquid or semiliquid fillers used to fill gaps in building construction, vehicle components, and industrial equipment. Table 9 lists the applications of several coating and sealant products and the asbestos characteristics that make them desirable.

The products within this category can be divided into two subcategories based on their composition: those which are petroleum based and those which have a water soluble latex or gypsum base.

Petroleum-Based Products

Petroleum-based products primarily include asphalt and tar-based sealants. Product formulations vary widely depending on end use application. In general, petroleum sealants are comprised of 5 to 30 percent asbestos (primarily chrysotile) and 55 to 80 percent cut asphalt.[1] Other petroleum derivatives added to achieve the proper consistency required for the intended end use are naphtha, mineral spirits, and lighter-weight solvents. Other ingredients include rust proofing chemicals, pigments, heat reflecting powdered metals such as aluminum, emulsifiers, resins, and clay fillers.[1]

Sealants are produced in batches under a controlled production cycle. Initially, the fibers are fluffed prior to being charged to a batch blending tank where they are mixed with asphalt or tar and other additives, as required, for an even dispersion. After blending, the liquid product is pumped to dispersing operations and finally shipped out to market.

The batch sizes produced vary from several hundred gallons for small manufacturers with one production line to several thousand gallons for larger manufacturers with a wide product mix and several production lines.[2] The batch sizes also vary with company size, type of product, method of containerization, type of production equipment, and size of order. Sealant manufacturing is often not a full-time operation but rather run part-time. This is due to seasonal fluctuations in demand, a greater amount of sealants may be produced in certain months of the year than in others.[1]

TABLE 9. ASBESTOS-CONTAINING COATINGS AND SEALANTS

Use	Distinguishing characteristics of asbestos[a]
Roof coatings	A, E, G
Roof cements[b]	A, G
Flashing cements[b]	A, G
Chimney stack paints[b]	B, E, G
Automobile and truck undercoatings	A, B, E, F, G
Appliance insulating coatings	E, F
Corrosion-resistant coatings (resistant to salt solutions including seawater spray, organic acids, mineral acids, petroleum products)	B, G
Waterproof coatings for underground pipelines, concrete foundations, side walls, tanks, and other structures such as mobile homes and cooling towers in nuclear power plants	A, C, E, G
Anticondensation coatings for low temperature refrigeration services	B, G
Tile cements	A
Woodblock and concrete floor mastics	F, G
Speckle[b]	A, C, D
Dry wall joint compounds[b]	A, C, D
Caulking compounds	A, C, D
Texture paints[b]	A, C, D
Sprayed-on ceiling finishes[b]	A, C, D
Welding rod coatings[b]	B, E

[a]Letters correspond with the characteristics listed below. Stability, durability, and economy of asbestos are relevant to all uses listed above.

[b]No longer manufactured containing asbestos fibers.

Key:
A. Strength
B. Corrosion resistance
C. Decay resistance
D. Vermin resistance
E. Thermal resistance
F. Sound deadening
G. Waterproofing

Water Soluble Latex or Gypsum-Based Products

Products under this subcategory include joint compounds, patching plaster, spackle, and drywall taping and finishing compounds. Use of this class of compounds has decreased significantly since the issuance of a Consumer Product Safety Commission (CPSC) ban of consumer patching compounds containing respirable free-form asbestos in 1977.[3] The ban applies only to 'consumer' products, i.e., products that a consumer can purchase. The ban covers uses in residences, schools, hospitals, public buildings, or other areas where consumers have customary access.[3] Patching compounds which are labeled as, marketed, and sold solely for industrial use applications are not subject to the ban.

Two principal types of water soluble compounds have been produced. One used latex as the binder, which set by evaporation of the water. The other used dehydrated gypsum as the binder (and primary dry ingredient) and set by chemical reaction as the gypsum took up waters of hydration. The first type was mainly limestone with lesser amounts of mica and 3 to 5 percent asbestos. This type was used by about 80 percent of the market, and was mostly sold in the ready-mixed, wet form. The gypsum-based material, capturing roughly 20 percent of the market, also usually contained asbestos and was sold dry, requiring wetting just before use. The worker mixed the compound with water in the field. Wet-mix products were manufactured and packaged in a can for ready use.[2]

Manufacture of both these products involved the usual handling of raw asbestos fibers where bags were stored, transferred, split, dumped, and fluffed. After dry blending, the latex-based products were wet mixed, binding the fibers in the matrix. The dry mixed gypsum-based product, which was not wetted during manufacture, maintained the potential for fiber release throughout the manufacturing process, as well as during packaging, distribution, and end use.[2]

SECONDARY PROCESSING - FABRICATION

There is no secondary processing of the products within either subcategory. Once manufactured and containerized, the products are shipped to wholesalers and retailers who sell directly to end users.

END USE ACTIVITIES

Petroleum-Based Products

Petroleum-based compounds include roof and horizontal surface coatings, roof and flashing cements, automobile and truck undercoatings, waterproofing coatings, and floor mastics.[1] These products are applied by contractors, specialty coating professionals (undercoating, roofing), and homeowners who buy the product at local retail and hardware stores and lumberyards. The products may be applied by brush, spray gun, roller or trowel, depending on their consistency and intended use. The following discussion provides examples of some of the more common applications of petroleum-based sealants and coatings.

Asphalt and tar-based coatings and sealants are used primarily by the building and construction trades to protect exposed metal surfaces, waterproof exterior building walls, and to patch existing roofing and siding. Asbestos-containing coatings are used in highly corrosive environments, such as those found in paper mills, to protect structural metal surfaces from attack by chlorine, chlorine dioxide, and moisture.[4] The coating is shipped to the site in premix form and applied using a high pressure airless atomization spray gun.

Asphaltic-based asbestos sealants are widely used in the construction industry to waterproof foundations and other subgrade structures, as well as in "back-up" walls, which are exterior walls that are ultimately covered by an architectural covering such as brick.[5] Depending upon the amount of surface area to be coated and its location, the coating is applied either using brushes or spray equipment.

For roofing applications, the asbestos sealant is used primarily for installing flashing or the perimeter of a built-up roof.[5] It goes on after the roof covering material and is applied by a trowel. Asbestos sealants are also used in repair jobs, when, for example, a leaking chimney or roof must be patched. This operation is often performed by the homeowner and takes advantage of the ability of the asbestos product to bridge a crack without subsequently drying, contracting and cracking again. A brush is most often used for this purpose.

The activities just described occur predominantly outdoors or in large open areas within buildings. Application of the compounds may last from one half hour up to a full workday depending on the method of application and the size of area to be worked.

Another use of petroleum-based asbestos-containing compounds is for protective undercoatings and sound deadening on automobiles and trucks. Application of these materials is commonly carried out inside an automotive assembly factory or service shop using spraying equipment. Depending on the production schedule, material application may last from a few hours to a full 8-hour work shift. Spraying may occur in enclosed work booths or in an area open to the workroom environment.

Although the asbestos content of petroleum-based compounds is moderately high, the potential for fiber release during application and in-service use is low. Fibers contained within these products are thoroughly wetted and remain bound by the tacky asphalt or tar matrix. The petroleum compounds of the product mix effectively cover and bind the fibers together, minimizing the potential for free-form release during application.[2]

Most of the petroleum-based products are applied as exterior surface coatings, upon which no direct physical exertion is applied. Consequently, except for weathering, which is expected to have a minor effect on fiber release, the material remains unaltered after application.

Water Soluble Latex or Gypsum-Based Products

Water soluble asbestos-containing coatings and sealants include such products as spackling compounds and drywall patching and taping compounds. The latex sealing and coating products often come in premixed containers whereas the gypsum-based materials come dry and must be mixed by the user. Substantial fiber release can occur during dry product mixing, sanding, and clean-up, which, it is believed, contributed, in large measure, to the CPSC ban.

The dry joint compound powder, where still available, is normally purchased packaged in paper bags. The bag is slit open with a knife and the powder dumped into a container. Water is then added according to the manufacturer's directions and the compound is mixed by means of a portable electric drill equipped with a mud or paint mixer bit. Some joint compound is sold as a paste (referred to as "premix") and only a small amount of water is required. The prepared mixture, in its putty-like form after wetting, is referred to as mud. The time spent mixing in a working day is short. It usually takes 5 to 10 minutes to mix a batch and in most instances one to three batches are required daily.[6]

An initial or "embedding" coat of joint compound (mud) is spread across the joint by a 2-inch putty knife. This is immediately followed by the application of a 2-inch wide perforated paper tape which adheres to the mud; the mud passes through the perforations, insuring intimate tape/mud contact. The tape/mud layer is allowed to dry until it is thick and then is followed in succession by two additional mud coats. Each of these coats is feathered using putty knives until they blend with the wallboard surface.[7] For large jobs, a joint taping machine is available which puts down the first mud coat, the tape, and the second mud coat in one continuous operation. The final coats are applied by hand. A skilled worker can put down an 8-foot joint in 2 to 5 minutes.[7] A homeowner, however, may take up to 20 minutes for the same task. Sixty-five to 70 percent of the working day, or up to 5-1/2 hours, is spent performing this operation.[6]

After the mud has dried, it is sanded, as required, to leave a smooth connection between successive wallboards. Here again, the experience of the worker is evident, for if the final mud coat is feathered skillfully, no additional sanding is required.[7] When sanding is undertaken, a hand-held abrasive paper-covered sanding block is the most common tool employed. Electric sanders are not widely used since the mud, even after drying, is too soft for the high speed sander.[7] Pole sanders, in which the sanding block is attached to the end of a long pole, may be used for hard-to-reach areas. Workers employed in the sanding operation may use face masks for dust control, regardless of whether or not the joint compound contains asbestos.[7] It is estimated that 25 to 30 percent of the total joint application time is spent in sanding,[6] or up to 2-1/2 hours of every 8-hour workday. Almost all applications of the water soluble products occur indoors.

The debris and the dust accumulated on the floor resulting from the mixing, application, and sanding operations are generally cleaned up by dry sweeping. In many instances, especially in cases of commercial building and

large projects, this operation is carried out by nonskilled laborers. However, it was generally found to be part of the work responsibilities of skilled employees of small companies working on residential construction projects.[6]

AIRBORNE FIBER MONITORING DATA

Petroleum-Based Products

Airborne fiber concentrations measured during spray application and sand blasting removal of different types of asbestos-containing petroleum-based coatings are presented in Table 10. Operations monitored varied from spraying cutback asphalt containing 7.7 percent asbestos on a roof surface to sand blasting a 2.1 percent asbestos content high performance exterior resin coating from a steel tank. As shown in the table, airborne fiber concentrations did not exceed 0.6 f/cm^3. Another activity monitored involved sawing pipe coated with a polyester resin containing 2 to 3 percent asbestos. Measured fiber concentrations during this operation ranged from 0.04 to 0.1 f/cm^3.

Water Soluble Latex or Gypsum-Based Products

A summary of airborne fiber monitoring data obtained during the performance of the end use activities associated with gypsum-based drywall compounds is presented in Table 11. The table breaks down fiber concentrations into the various steps of product use and handling. Fiber concentrations measured during dry mixing ranged from 9.0 to 59 f/cm^3. During application, concentrations of 0.4 to 1.3 f/cm^3 were recorded. Fiber levels associated with sanding and sweeping operations ranged from 1.2 to 24.2 f/cm^3 and 4.0 to greater than 41.4 f/cm^3, respectively.

SUMMARY OF FINDINGS

From the discussion above, it is obvious that water soluble latex or gypsum-based coatings and sealants pose a far greater potential for fiber release during end use than petroleum-based products. Airborne fiber concentrations associated with dry mixing of such water soluble drywall patching compounds can approach 60 f/cm^3. Detection of such levels probably contributed, in part, to the 1977 decision by the Consumer Product Safety Commission to ban consumer patching compounds containing respirable free-form asbestos fibers. Because these materials are still used in industrial settings and may still be present in existing buildings, care must be taken during all phases of product handling to minimize asbestos fiber release.

Asbestos-containing petroleum-based coatings and sealants are applied in both exterior and interior settings by workers utilizing high pressure spray guns, brushes, or trowels. The asbestos fibers contained in these products are thoroughly wetted by the petroleum-based liquids, greatly reducing the potential for free-form fiber release during use. Monitoring tests conducted during product application and removal revealed airborne fiber concentrations

TABLE 10. FIBER CONCENTRATIONS ASSOCIATED WITH THE SPRAY APPLICATION OF ASBESTOS-CONTAINING PETROLEUM-BASED COATING PRODUCTS[8]

Asbestos-containing product	Activity performed	Measured fiber concentration (f/cm³)	Date of tests	Duration of activity/ sampling time (min)	Analytical method	Comments
Spray-applied asphaltic roof coating						
Cutback asphalt	Spraying	0.003 to 0.15	1974	342 to 432	Phase contrast[6] (assumed)	Percent weight of asbestos as sprayed ranged from 5.8 to 7.7, after curing 9.7 to 12.8
Asphalt-emulsion	Spraying	0.01 to 0.3	1974,1976	NR	Phase contrast (assumed)	Percent weight of asbestos as sprayed was 2.8, after curing 5.1
Built-up roofing	Tear-off	0.1 to 0.4	1974	NR	Phase contrast (assumed)	Monitoring performed in Indiana
	Tear-off and replace (spray)	0.0 to 0.3	1974,1976	NR	Phase contrast (assumed)	Monitoring performed in Pennsylvania and Indiana
	New application (spray)	0.0 to 0.6	1974,1975,1976	NR	Phase contrast (assumed)	Monitoring performed in Wisconsin, Colorado, and Indiana
Resin coatings	Ship coating by spray application	0.2	1974	8 to 33	Phase contrast (assumed)	Operator spraying outside and under a ship with asbestos-containing epoxy resin. Percent asbestos as sprayed 1.5
	Dry dock coating by spray application	0.0 to 0.2	1974	11 to 38	Phase contrast (assumed)	Operator spraying dock with an asbestos-containing epoxy and coal tar mixture. One percent asbestos as sprayed
	Coating pipe interior - spray application	0.1	1974	37	Phase contrast (assumed)	Operator spraying interior of 7.6, 15 and 30 cm diameter pipe with an asbestos-containing (1 percent) epoxy and coal tar mixture
	Fiber-glass pipe MFG (Mandrel coating)	0.1 to 0.4	1974	14 to 23	Phase contrast (assumed)	Operators monitored were involved in running automatic spray machine and wiping mandrel. A 1.4 percent asbestos chemical resistant resin was sprayed applied
	Ship coating below waterline (spray application)	0.0 to 0.4	1974	23 to 65	Phase contrast (assumed)	Chemical resistant resin containing 0.7 percent asbestos applied
	Painting building exterior (commercial)	0.0 to 0.06	1974,1977	5 to 16	Phase contrast (assumed)	Alkyd resin containing 6 percent asbestos or vinyl-acrylic latex containing 0.6 percent asbestos applied

(continued)

TABLE 10 (continued)

Asbestos-containing product	Activity performed	Measured fiber concentration (f/cm^3)	Date of tests	Duration of activity/ sampling time (min)	Analytical method	Comments
Resin coatings (continued)	Painting building interior (commercial)	0.03 to 0.06	1977	23	Phase contrast (assumed)	Vinyl-acrylic latex containing 0.6 percent asbestos applied
	Wall and roof spraying	0.0 to 0.2	1974	12 to 15	Phase contrast (assumed)	Operator spraying 2.8 to 3.7 percent asbestos vinyl latex on vertical wall panel
	Roof spraying	0.0	1974	14 to 28	Phase contrast (assumed)	Operator spraying 0.7 percent asbestos acrylic latex
	Boat MFG - spraying surface coatings	0.0 to 0.6	1972,1974,1975	4 to 55	Phase contrast (assumed)	Operator spraying 0.5 percent asbestos general purpose polyester resin
	Sawing pipe coated with polyester resin	0.04 to 0.1	1973	19 to 49	Phase contrast (assumed)	Operator sawing reinforced fiberglass pipe coated with polyester resin containing 2 to 3 percent asbestos
	Handsanding interior building panels	0.0 to 0.3	1977	1 to 16	1.5 asbestos Phase contrast (assumed)	Operator handsanding panel surfaces covered with vinyl latex paint containing 1.1 percent asbestos
	Sand blasting high performance exterior coating	0.2 to 0.3	1978	5 to 27	Phase contrast	Operators sandblasted 12 meter diameter by 7.6 meter high steel tank spray coated in 1973 with a 2.1 percent asbestos resin coating.

[a]Fibers 5 μm long or longer with a length-to-diameter aspect ratio of 3 or greater were counted by phase contrast microscopy.

NR - Not Reported

TABLE 11. SUMMARY OF AIRBORNE FIBER CONCENTRATIONS ENCOUNTERED IN THE DRYWALL TAPING PROCESS[6,9]

Asbestos-containing product	Activity performed	Measured fiber concentration (f/cm^3)	Date of tests	Duration of activity/ sampling time (min)	Analytical method	Comments
Water soluble gypsum-based drywall compound (Study A)	Application	0.4 to 1.3	1978	39 to 65	Phase contrast[a]	Commercial operation
	Mixing (dry powder)	9.0 to 12.4	1975 to 1977	10 to 12	Phase contrast	Residential setting
	Mixing (pre-mix)	1.2 to 3.2	1978	4 to 5	Phase contrast	Commercial operation
	Hand sanding	2.1 to 24.2	1975 to 1977	10 to 80	Phase contrast	Residential setting
	Pole sanding	1.2 to 10.1	1975 to 1977	10 to 38	Phase contrast	Residential setting
	Pole sanding	1.2 to 10.0	1978	4 to 21	Phase contrast	Commercial operation
	Sweeping	4.0 to 26.5	1975 to 1977	9 to 30	Phase contrast	Residential setting
	Sweeping	14.5 to 25.4	1978	10 to 20	Phase contrast	Commercial operation
Water soluble gypsum-based drywall compound (Study B)	Dry mixing (0.9 to 1.5 m)	35.4 to 59.0	1974	NR	Phase contrast	Commercial operation. Fiber range reported is not less background levels, which for the same room ranged from 0.5 to 13.1 f/cm^3
	Hand sanding (0.9 to 1.5 m)	1.3 to 16.9	1974	NR	Phase contrast	Commercial operation. Fiber range reported is not less background levels, which for the same room ranged from 2.1 to 2.5 f/cm^3
	Pole sanding (0.9 to 1.5 m)	1.2 to 19.3	1974	NR	Phase contrast	Commercial operation. Fiber range reported is not less background levels, which for the same room ranged from 3.5 to 19.8 f/cm^3
	Sweeping (3.0 to 15 m)	41.4 (mean)	1974	NR	Phase contrast	Due to heavy loading during sweeping, sampling occurred 15 minutes after sweeping stopped. After 35 minutes, the measured fiber level was [illegible] f/cm^3

[a]Fibers 5 μm long or longer with a length-to-diameter aspect ratio of 3 or greater were counted by phase contrast microscopy.

NR - Not Reported

ranging from 0.0 to 0.6 f/cm^3. Spray-applied petroleum-based coatings and sealants containing more than 1 percent asbestos are the only products not banned from building construction use by the asbestos NESHAP regulation.[10]

Table 12 summarizes the data presented on coatings and sealants and identifies the principal activities of concern with respect to fiber release.

TABLE 12. SUMMARY OF COATINGS AND SEALANTS SECONDARY PROCESSING AND END USE ACTIVITIES

Product: Coatings and sealants	Secondary processing	End use	
		Petroleum-based products	Water soluble products
Activity:	No secondary processing of either product line	Spray application, hand brushing and troweling, sand blasting removal	Dry mixing hand application troweling, sanding
Duration:			
Per Incident Daily Total		Continuous operation up to 8 hours per day	Mixing--5 to 10 minutes Application--up to 5 1/2 hours Sanding--up to 2 1/2 hours
Fiber Releasability:			
Chemical Composition		Low 5 to 30% asbestos, 55 to 80% asphalt	High 3 to 5% asbestos, majority gypsum or limestone
Physical Composition		Tacky material as applied, hard resinous finish when dry	Wet paste as applied, granular finish after drying
Disruptive Energy		Moderate to high, power sanding (sand blasting) of material off surfaces	Moderate, hand sanding
Measured Fiber Concentrations (f/cm^3):		0.0 to 0.6	Mixing--1.2 to 59 Application--0.4 to 1.3 Sanding--1.2 to 24.2 Sweeping--4.0 to >41.4
Environmental Setting:		Usually applied out of doors to exterior surfaces	Applied indoors to wall surfaces

Activity of Concern

Mixing, sanding, and cleanup sweeping of water soluble products that are still available and applied to interior wall surfaces.

COATINGS AND SEALANTS
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SECTION 5

TEXTILES

INTRODUCTION

Because asbestos fibers, after minimal conditioning, are processable on conventional textile manufacturing equipment, they are incorporated into all conventional textile forms, including: lap, roving, yarn, cord, thread, cloth, tape, tubing, wick, rope, and felt.[1] The special qualities afforded by asbestos fibers include fireproofing, chemical and dimensional stability, flexibility, and moisture, abrasion, and corrosion resistance.

Asbestos-containing textile products typically contain from 75 to 100 percent asbestos.[2] Small percentages of cotton, rayon, and other natural or synthetic fibers may be blended with asbestos to improve spinnability and to impart the desired serviceability to the end product.[3]

Primary manufacturing of asbestos textile products is performed by the established conventional process or by the wet process. Most textiles are made by the conventional process either by the dry or damp method.[2] Both methods are identical, except that during damp processing yarn is moistened to reduce fiber emissions.

In the conventional process, various size asbestos fibers are thoroughly blended prior to processing through a carding operation.[3] The carding operation combs the fibers creating a relatively parallel arrangement called a fiber mat. This mat is pressed and layered into a lap. The lap is separated into thin, continuous ribbons called roving. Cotton, rayon, or other material may be added at this stage to strengthen the roving.[2]

The more newly developed wet process yields a product that tends to hold asbestos fibers more tightly than those produced by the conventional process, thus reducing workplace fiber concentrations. In this process, asbestos fibers are mixed with hot, soapy water in a hydropulper.[4] The process yields a dense yarn by extruding the dispersion slurry and passing the material through spinnerettes. Wet processing eliminates the carding operation, the segment of the conventional process that generates a great deal of airborne fibrous dust.

Many of the asbestos-containing textiles manufactured are used as intermediate materials to produce other products, such as electrical and thermal insulation, gaskets and packings, fire and heat protective clothing,

woven clutch facings, and brake linings. Table 13 identifies the products made using the primary asbestos-containing textile materials described below. Product applications are also presented in the table.

Asbestos roving is loosely held together untwisted strands of lap. As shown in Figure 1, roving forms the building block for almost all the other asbestos textile products.

Asbestos yarn is roving that has been mechanically twisted and spun to give it tensile strength. This yarn may be twisted with other single yarns, wire, or other material to produce plied yarn which can be coated to produce thread or treated yarns. Asbestos wick is several strands of untwisted roving loosely twisted together.

Asbestos tubing is made by either braiding or weaving several strands of asbestos yarns. The braided style is supplied in many diameters and textures and in several wall thicknesses to meet a variety of end use applications.[3]

Asbestos tape is a narrow woven fabric manufactured from plied yarn containing selvage edges (the edge of the woven fabric finished to prevent raveling).[3]

Asbestos rope is made by twisting or braiding two or more strands of asbestos wick together tightly. Heavier ropes contain a binder to hold the twist. Braided asbestos rope is manufactured in three configurations: (1) by braiding one or more jackets of asbestos yarn over a base of asbestos rope or wick; (2) by braiding asbestos yarn braid over braid; and (3) by plaiting asbestos yarn into square cross section.[3]

Asbestos cord is usually twisted or braided asbestos yarn (a predetermined number of strands) which forms a cord of desired diameter and tensile strength. The yarns used may be sized or unsized, plain or metallic (wire inserted), or single or plied depending on the end use of the product.[3]

Cloth woven from asbestos yarn and thread is soft, flexible, and stitchable, enabling it to be fabricated into protective apparel, blankets, shields, and exterior jackets for fiberglass batts placed around boilers, columns, and heat exchangers.

In most cases, the asbestos textile materials identified above are surface treated with a resin or elastomer coating before shipment as a finished product.[8,9] The materials can also be aluminized to give a heat reflecting surface. The metallic layer can be sprayed or bonded to the cloth by a thermosetting resin. Treatment by either or both of these coating techniques effectively reduces the potential for asbestos fiber release during secondary processing and end use.

SECONDARY PROCESSING--FABRICATION

Depending on the product line, primary textile manufacturers may produce intermediate materials such as yarn and cloth that will be fabricated into a final product by a secondary processor or they may produce the final product themselves. Examples of the latter include tubing and tape used for thermal

TABLE 13. ASBESTOS-CONTAINING TEXTILES AND THEIR END USE APPLICATIONS[2,5,6,7]

Product application	Textile material	End use
Fire and heat resistant materials	cloth, thread, yarn, roving	Protective apparel (gloves, coats, hoods, and pants), blankets and draperies, conveyor belts, furnace shields, ironing board covers, hot metal splash guards, welding curtains, dryer felts and mats, hot pads
Thermal insulation	tape, tubing, cord, cloth, yarn	Marine and industrial pipe-wrap and sleeves (lagging), diesel exhaust line and manifold covers, tool insulation (glassware), braided wall liners in steam hoses, fuel line insulation, hydraulic line insulation
Electrical insulation	yarn, roving, tape, thread, felts, cord, lab, tubing	Electrical wire wrap and sheathing, multicore cable wrap and sheathing, motor winding insulation, heater cord insulation, core for electrical resistance wires, sleeving for electrical appliance leads
Gaskets and packings	rope, wick, cord, cloth, tape	All purpose shaft and valve stem packings, expansion joint gaskets, manhole and handhole boiler cover gaskets, oven and furnace door gaskets, chemical process vessel gaskets
Friction materials	roving, yarn, cloth	Industrial, truck, and marine clutch facings, heavy stress brake lining applications

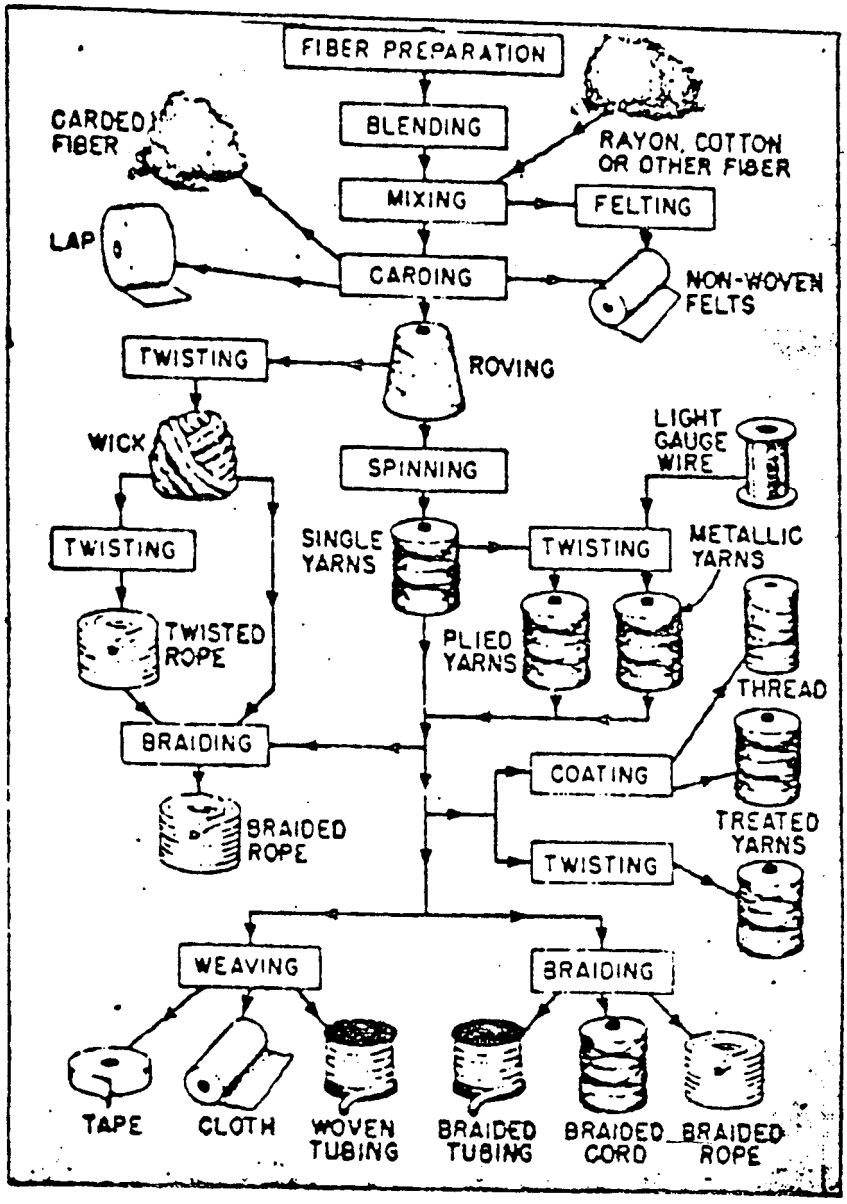

Figure 1. Flowsheet for asbestos textile manufacturing.[3]

insulation and rope used for boiler and furnace door gaskets. Except for major industrial customers, most of the primary manufacturers sell their products to distributors. The following discussion presents examples of common textile secondary processing operations.

Fire and Heat Resistant Materials

The asbestos cloth supplied to fabricators of fire and heat resistant materials is often surface-treated to minimize fiber release during secondary processing and end use.[8] Fabricators typically cut, sew, stitch, staple, weave, and grommet the "lint free" cloth into products ranging from space suits to welding curtains.[8,9] Secondary processing is usually performed indoors within enclosed factory rooms using electrically powered machinery. Material processing will occur over a normal 8-hour work shift.

The outside surface of woven textile products may be further treated by secondary processors to enhance certain product qualities. For example, asbestos-containing cloth may be aluminized to improve radiant heat characteristics or be given a polymeric coating to render it waterproof.[10] Other treatment methods include painting and plastering.[10] Each of these surface coating treatments reduces the potential for fiber release during subsequent processing and end use.

Thermal Insulation

Secondary processing of asbestos textile materials used as thermal insulation is required for certain product applications. Fabrication of these products, such as braided walls of steam hose lines and hydraulic fluid and fuel line sleeve covers, occurs at factories that either distribute these products or have direct use for them.[8,9] Secondary processing involves the use of electrically powered machinery over an 8-hour work shift. The use of engineering controls, such as total or partial enclosures which exhaust to a conventional particulate capture device like a fabric filter, will depend on whether the textile material has been surface-treated to minimize fiber release and the extent of dusting caused by the fabricating operation. Other dust control methods include dampening the material prior to processing and reducing machinery speeds.

Once the asbestos textile material is incorporated into a final product, such as a steam hose wall or fuel line cover, the potential for fiber release is extremely low. Under normal conditions, the asbestos textile is never exposed. Only during mishandling or when damaged whereby the textile material becomes exposed will fiber release become a potential problem.

Electrical Insulation

Asbestos yarn, thread, and tape are supplied to wire manufacturers for use as insulation material in the production of wire products.[8] Wire manufacturers wrap asbestos textile material around wire or cables using electrically powered wrapping machines capable of producing thousands of feet of wire per day. As a conductor covering, braided asbestos tubing or tape may be wrapped on wire (or cables), or plastic laminated and pressed onto wire.

Generally, asbestos-containing textiles are used to insulate wires and cables designed for low voltage, high current use under severe temperature conditions.[2]

Although asbestos textiles normally used for wire insulation and other forms of electrical insulation are surface-treated,[8] fiber release can be expected during product fabrication. During processing, the textile material is passed through various winding machinery that constantly bend and twist the material. Such handling will loosen the woven or twisted strands of the textile material, weakening its structural integrity. Continued agitation by the machinery can cause the release of fibers. Dust control methods implemented to minimize workroom contamination are similar to those described above for thermal insulation processing. Final processing involves applying a protective cover over the wound material. This encasing step greatly diminishes the potential for fiber release from the product during subsequent handling.

Gaskets and Packings

Untreated asbestos yarns are used by fabricators in the production of packings to prevent gumming-up of equipment. Untreated yarn is braided by machine to form the packing material. Then it is passed through a heated resin or petroleum-based liquid bath to saturate the strands with lubricant. Lubricants can include teflon, graphite, or molybdenum disulfide. The treatment process is performed to maintain product pliability while in service and to prevent the abrasive asbestos fibers from scoring machinery shafts and valve stems during use.[8,9,11] Unlubricated packing is used as gaskets.

Because the potential for fiber release during the braiding of the untreated yarn is high, engineering controls, personal protective equipment, and appropriate work practices, such as reducing machinery speeds, are generally employed. Engineering controls include enclosing the braiding machines in ventilated rooms or booths and installing exhaust hoods at key material handling stations. Personal protective gear may include a separate set of clean work clothes and dust control face masks, when necessary.

Friction Materials

Asbestos yarn or cord, that may be reinforced with wire, is used to make woven clutch facings and brake linings. These products are mainly found in industrial applications where long periods of heavy load conditions exist or where short bursts of resistance are required.[12] The asbestos textile is normally impregnated with phenolic resin or coated with asphalt prior to processing. After curing and drying, the treated yarn is then fed to mechanical winders, which are used to form the woven friction products. Because the yarn has been coated with the resin or asphalt-based compound, fiber release during winding is expected to be minimal.

END USE ACTIVITIES

Asbestos-containing textiles are used in a wide variety of applications ranging from industrial furnace shields and hot metal splash guards to laboratory gloves (see Table 13). The following describes the end use activities associated with the more common asbestos textile products.

Fire and Heat Resistant Materials

Applications for fire and heat resistant asbestos cloth include welding curtains, draperies, blankets, protective clothing, hot conveyor belts, furnace shields, and molten metal splash protection aprons.[3,8,9] Many of these applications generally do not involve the performance of any activity that would cause airborne fiber release. All of the necessary stitching, sewing, and grommeting work is performed by the primary manufacturer or secondary processor. To install these products one simply hangs the material on support structures, as in the case of heat shields and curtains, or puts the clothing on, as with personal protective apparel. Material installation for static applications is estimated to last only a few minutes. Wearing protective clothing may last from a few minutes as in the case of gloves to several hours for heat resistant suits worn in industrial plants or when fighting fires.

Airborne asbestos fiber release is likely to occur with product wear. The life span of these various products ranges from many months to several years depending on the application and severity of wear. Most applications are industrial, where harsh and strenuous conditions exist. As the material wears, the structural integrity of the woven fabric begins to fail allowing pieces of the material to unravel or become frayed.

Thermal Insulation

Asbestos textiles, such as cloth, tubing, and tape, are used as thermal insulation. Applications include pipe wraps for safety protection, stress relieving pads in welding operations, protective coverings for hot glassware utensils, coverings for hydraulic and fuel lines, and braided walls in the construction of steam hoses.[2,8,9]

Thermal insulating materials are generally used in static applications. Their woven and surface-treated construction minimizes the possibility of fiber release due to product degradation. The greatest potential for fiber release occurs during removal. Removal typically takes longer than installation and requires more cuts to extract the worn and sometimes encrusted material from the surface it was covering.

A specific example of a thermal application involves the use of asbestos-containing textile tapes to insulate pipelines that transport hot liquids and gases. During installation, the tape is normally applied as a secondary insulator over a primary insulating coating of calcium silicate. Shears or knives are used to cut the textile tape. The number of cuts required depends on the surface complexity and the number of start and stop points. Cutting takes only seconds and accounts for only a few minutes of the total installation time. After the tape has been wrapped around the primary insulator, with edges overlapping, it is covered with paint or other sealant. Initial installation of the textile tape is almost exclusively performed by professional insulation contractors, whereas maintenance personnel will make repairs or renovations when they are required. The length of time for installation varies depending on the size of the job, lasting anywhere from less than one hour to a full work day.[9]

When the time comes to remove the pipeline covering, it is common practice to thoroughly wet the insulation, which serves as a general dust control measure and facilitates handling. After wetting, the insulation wrap is slit lengthwise using a utility knife or razor. The material is then peeled off the pipe and discarded in drums or plastic bags.[9]

Another application, somewhat unique, involves the use of asbestos tape as a thermal insulator of process lines in a steel mill. A maintenance crew at a mill reportedly had to replace asbestos-containing insulating wrap around hoses carrying cooling water to the doors of an open hearth furnace every 3 to 4 weeks.[13] The frequent need for replacement resulted from hot metal spills on the hoses. Specifics about the removal of the damaged wrapping and the application of new tape were not provided in the referenced citation. The high frequency of replacement associated with this operation is related to the extreme working conditions. Under less harsh conditions, thermal insulation applications using tape and tubing wraps are expected to last several years before replacement is required.

Asbestos textile materials used as thermal insulation in static applications are not likely to release fibers to the ambient air under normal conditions. Generally, no abrasive force is applied to surface of the material that would disturb its structural cohesiveness. However, fiber release is likely during product removal if not properly controlled (e.g., thoroughly wetting material). Exposure to extreme temperature fluctuations, corrosive gases, or hot fumes over many years can physically age the asbestos material. The aging process weakens the structural cohesiveness of the textile material such that fiber release during removal is likely.

Textile materials used in dynamic (moving) applications, such as steam hoses and hydraulic lines are likely to release fibers if jacket walls or sleeve covers are cut or otherwise damaged such that the asbestos-containing material is exposed. Continuation under these conditions will increase the potential for fiber release due to repeated agitation of the damaged or exposed material.

Electrical Insulation

Asbestos-containing textiles used for electrical insulation are normally incorporated into the internal workings of an electrical appliance or component. Rarely is the material exposed. In use, the textile material is usually held in a stationary position not subject to direct wear or abrasion.

With proper use, asbestos fibers are not expected to be released from electrical products containing asbestos textile insulating materials. However, if mistreated, the cloth covering of electrical appliance cords, for example, may become frayed exposing the inside insulating material. Continued misuse and abrasion to the exposed asbestos material may release airborne fibers.

With respect to removal at the end of its service life, the entire electrical appliance is discarded or the component containing the asbestos insulation is simply replaced. When damaged electrical components containing asbestos textile insulation need repairing, the whole unit, similar to above,

will be entirely replaced to maintain system continuity. However, for small repairs, such as replacement of damaged wire, splicing new wire into the system may be all that is required. Splicing initially involves cutting the old and new wire to expose the enclosed metal filament. The low energy input involved in cutting the wire and removing part of the insulating sleeve is expected to minimize fiber release from the asbestos material. Cutting of the asbestos textile using wire snips or scissors will take only a few seconds and result in a clean edge cut. After the new wire has been spliced with the existing wire, electrical tape is wrapped around the splice point(s) to insulate the wire. This step covers all exposed asbestos textile surfaces.

Gaskets and Packings

The following paragraphs focus on the end use of asbestos textiles as gasketing material, with a brief discussion on packings. A more detailed analysis of packings made from asbestos textiles is presented in Section 6 under Gaskets and Packings.

Various asbestos-containing textile products are used as gaskets to seal expansion joints, boiler manhole and handhole (inspection) covers, commercial and residential oven doors, industrial furnace openings, and chemical process vessels.[2,9,11,14] The textile forms most often used are rope, cord, wick, cloth, and tape.[5,6,7,11] These products are purchased from distributors in specified precut lengths, or if larger quantities are needed, wound on spools or coiled in boxes. Distributors of the textile gasket material cut desired lengths and punch pilot holes required for mechanical fastening at their outlet stores.[11,14] Cutting is done using shears or a knife; hole punching may be accomplished using a power-assisted or manually operated press machine. Other than possibly wearing a surgical-type face mask, no dust control measures are employed.[14]

Installation of the gasketing product ranges from setting the rope into grooved tracks to bolting the tape to the mating surface. Cementing the gasketing to the mating surface using a furnace adhesive may also be performed.[11] The gasket material selected for use may or may not be surface-treated. Rope used for this purpose tends to be untreated whereas the tape is usually treated.[11,14] Rope will likely have a cotton fiber carrier to add structural integrity.

When installing the new gasketing material, required lengths are first measured, then the rope or tape is cut using a knife, scissors, or tin snips.[11,14] If the gasketing material is untreated, fiber release may occur when the material is pulled from the carrying spool or box.[11]

In use, the gasket material is not subject to any mechanical disturbance. However, changes in temperature, moisture, or chemical conditions will affect the material. These environmental conditions can break down and 'cook out' the binders in the rope or tape causing them to degrade between the two mating surfaces. When manhole covers are opened, or pipe flanges separated, the inner portion of the gasketing will tear apart while the outer surfaces that were in contact with the mating surfaces may be baked on. Before installing new replacement gasketing, the old encrusted material

must be removed leaving a smooth, clean surface. Flat edge putty knives or wire brushes are used to remove the old material. Because asbestos textiles have a high asbestos content (low binder content) and that the binders present may have reacted with various gases or been 'cooked-out', fiber release is expected during gasket removal. No monitoring data are available, however, to document this assumption.

The length of time required to replace gasket material depends on the size of the pipe flange or manhole cover to be disassembled. The actual time involved in cutting new strips and removal of old material accounts for only a small percentage of the total job. Cutting is expected to last only seconds while material removal and surface cleaning are estimated to last several minutes (15 to 30 minutes). The frequency of gasket replacement also varies. Replacement may be required more frequently than actually needed due to the opening and closing of manholes or handholes as part of a routine maintenance program.

Friction Materials

Woven asbestos brake linings are found mainly in industrial brakes contained in cranes, lifts, excavators, winches, concrete mixers, and mine equipment. Woven friction products are also used as clutch facings for industrial band, plate and cone clutches in cranes, lifts, excavators, and winches.[2] Additionally, automotive brake pads may be manufactured from woven asbestos cloth which may be reinforced with brass wire or impregnated with phenolic resin.[15] However, molded automotive asbestos-containing brake materials, developed in the 1950's, are replacing woven textile products because they offer superior frictional properties.[16]

Asbestos fiber release is not expected during the installation of woven friction products. The asphalt or resinous coating applied to the asbestos yarn prior to winding effectively prevents the release of asbestos fibers from an unused product during installation. Fiber release to the outdoor air during material wear is also not expected because woven friction products are usually contained within a metal casing, such as a transmission housing. The wear of a clutch facing, for example, depends on the amount of slippage that occurs since the clutch is basically a static friction couple that momentarily slides during gear shifts. Once the clutch cannot hold a continuous couple, it must be replaced.

During product replacement asbestos fibers may be released to the ambient air when the friction material housing is opened and the worn out textile product is removed. Specific asbestos fiber monitoring studies have not been reported for woven friction product repair or replacement work.

AIRBORNE FIBER MONITORING DATA

Although monitoring to determine airborne asbestos fiber concentrations during secondary processing is routinely performed by asbestos textile fabricators, the results of these studies are not readily available nor well documented in the open literature. Therefore, only a small amount of data is presented.

Workplace fiber concentrations ranging from 2.0 to 6.0 f/[illegible] (determined by PCM) were reported in the literature in 1978 for operations involving secondary processing of asbestos textiles.[17] These fiber levels are not likely to be representative of current workplace concentrations. The institution of process modifications and improved control techniques since these data were collected has resulted in lower work place concentrations. For example, the manufacturing modification involving wet-processing of asbestos textiles has resulted in lower airborne fiber concentrations during primary manufacturing and secondary processing.[18] Fiber concentrations in the general workroom area and near an operator during the processing of asbestos cloth made by the wet-process were 0.46 and 0.90 f/cm^3, respectively. General area and breathing zone fiber concentrations recorded during cloth unrolling, measuring, cutting with scissors, and folding were 0.33 and 0.68 f/cm^3, respectively. Fiber analysis of all four air samples was performed using phase contrast microscopy.[18]

Airborne fiber monitoring data associated with asbestos textile end use activities are scant. Only a few studies have been performed covering a limited number of textile products. The following presents the monitoring results that have been obtained from the literature.

Tests to determine fiber release during the wearing of asbestos garments were performed at a blast furnace and a phosphorous plant where asbestos coats, hoods, and mittens are worn. Personal monitors were used to measure the concentration of airborne fibers at the breathing zone level. Fiber concentrations of 0.3 to 5.0 f/cm^3 were recorded for a blast furnace worker with an 8-hour TWA concentration of 0.1 to 1.1 f/cm^3.[19] At the phosphorous plant, fiber concentrations were considerably higher; 9.9 to 26.2 f/cm^3, with an 8-hour TWA concentration of 4.7 f/cm^3.[19] No reason was given for the difference in concentrations recorded at the two plants. Airborne fiber concentrations were determined by phase contrast microscopy.

The garments tested were made of an untreated fabric. Hoods, however, were aluminized on the outside. The age of the garments was also examined in the study. Generally, asbestos fiber release increased with product age, however, no firm correlation could be developed.

Measurements of fiber release from asbestos-containing fire-fighting helmets during use have been made.[20] Products tested included a new helmet with an unlined surface, an identical older helmet, and a helmet with an aluminized covering on the inside and outside surfaces. Monitoring results revealed breathing zone fiber concentrations of 2.30, 1.38, and 0.0 f/cm^3 for the three helmets, respectively. Results of the samples analyzed by phase contrast microscopy clearly indicate that aluminization of asbestos cloth garments effectively controls fiber release during use of these products.

Another study[21] has similarly shown that woven asbestos textile gloves can release fibers during use. Asbestos textile gloves contain from 80 to 85 percent asbestos and 15 to 20 percent rayon. The gloves tested were surface treated with an acrylate-based compound, which enables the manufacturer (unknown) to market them as "lint free."

Three tests were performed as part of the referenced study. [illegible] release monitoring experiments included: testing in a ventless isolation chamber (glove box); a well-ventilated (five air changes per hour) biology preparation room; and in university laboratories under conditions of actual glove use. The researchers examined the potential differences in fiber release from new and worn gloves, the latter varying from clean to heavily soiled.

The glove use activities included the following: (1) picking the gloves up from a table top and putting them on; (2) opening an autoclave or oven door; (3) removing a tray containing laboratory growth media or glassware and setting the tray on a table top; (4) closing the door; and (5) taking the gloves off and tossing them onto a table top. The results of the three test cases are summarized in Table 14.

In all cases, fiber release was found to be directly related to the condition of the gloves. Under the nonventilated isolation chamber conditions, the well-worn/clean gloves emitted almost three times as many fibers as did the new gloves, although the number of fibers released from the well-worn gloves decreased with increased surface soiling.

TWA values calculated for the well-ventilated biology preparation room were considerably lower than those obtained in the ventless isolation chamber. The authors postulate that these levels result from dispersion of fibers within the room by the ventilation system. The findings of the biology preparation room testing concur with those of the ventless isolation chamber whereby the well-worn/clean gloves released a significantly higher number of asbestos fibers into the atmosphere than the new gloves did. Fiber concentrations also increased with work load, as one would expect.

Monitoring tests conducted in various university laboratories revealed a wide range of fiber concentrations. The researchers state that airborne concentrations depended more on the particular laboratory than on glove condition or usage (work load). The range in values reported are thought to be attributed to differences in room size and configuration, efficiency of the ventilation system, and amount of moisture on the gloves.

In another study[22] relating to thermal insulation application, Raybestos Manhattan Corporation of Charleston, SC, a manufacturer of asbestos textiles, measured airborne fiber concentrations of 0.01 to 0.05 f/cm^3 during the cutting of untreated lagging cloth and counts of 0.0 to 0.04 f/cm^3 during material application. Specifics about the activities performed and sampling and analysis procedures employed were not reported.

SUMMARY OF FINDINGS

A limited amount of airborne fiber monitoring of asbestos textile - secondary processing and end use activities has been performed and reported in the literature. The majority of the available data relate to fire and heat resistant garments. Fiber concentrations reported for the breathing zone of workers wearing hooded fire protective clothing made from untreated woven asbestos fabric ranged from 0.03 to 26.2 f/cm^3. Other studies have shown

TABLE 14. AIRBORNE FIBER CONCENTRATIONS[a] RESULTING FROM THE USE OF ASBESTOS-CONTAINING GLOVES[21]

Sampling environment	Condition of gloves and work load	Fiber concentration Mean TWA ± SD (f/cm^3)
Isolation chamber (nonventilated)	New	2.25 ± 0.57
	Well-worn/clean	7.97 ± 3.14
	Well-worn/lightly soiled	5.08 ± 1.27
	Well-worn/heavily soiled	0.95 ± 0.16
Biology preparation room (well ventilated)		
Breathing zone	New - normal[b]	0.07 ± 0.02
	Well-worn/clean-normal	0.49 ± 0.11
	New - heavy[c]	0.51 ± 0.21
	Well-worn/clean-heavy	0.99 ± 0.22
Work area	New - normal	0.06 ± 0.02
	Well-worn/clean-normal	0.40 ± 0.09
	New - heavy	0.26 ± 0.08
	Well-worn/clean-heavy	0.60 ± 0.12
University Laboratories		
Breathing zone	Well-worn/clean	0.07 to 2.93[d]
	Well-worn/lightly soiled	0.10 to 0.71
Work area	Well-worn/clean	0.04
	Well-worn/lightly soiled	0.30 to 0.74

[a]Fibers counted were 5 μm long or longer with a length-to-diameter aspect ratio of 3-to-1 or greater. Phase contrast microscopy analysis was performed.

[b]Normal usage of gloves, two times per hour.

[c]Heavy usage of gloves, six times per hour.

[d]Values reported are not means; ranges are from tests performed at five different laboratories.

that treated cloth, particularly aluminization of the cloth surface, greatly reduces fiber release. Monitoring conducted during the use of aluminized fire-fighting helmets revealed no fiber release.

Studies performed on laboratory gloves made from woven asbestos cloth have shown that fiber release increases as the textile material begins to wear. Airborne fiber monitoring has demonstrated that well-worn, clean gloves release a comparatively higher concentration (0.49 f/cm^3) of fibers into the ambient air than do new gloves (0.07 f/cm^3) subjected to the same use.

With respect to other textile products, monitoring during the cutting and installation of untreated asbestos-containing lagging cloth for thermal insulation revealed fiber concentrations of 0.01 to 0.05 f/cm^3 and 0.0 to 0.04 f/cm^3, respectively.

The majority of the textile materials manufactured today are surface-treated with various chemical coatings to minimize fiber release during use. Textile manufacturers and others have developed processes whereby the surface of the material is impregnated with a proprietary compound during manufacture. This technique reportedly reduces the release of airborne fibers by more than 75 percent when compared to untreated materials.[7] Surface treatment also reduces unraveling after the material is cut or fabricated. Fiber release from asbestos textiles is likely, however, during mishandling or product abuse. Fiber release appears to be greatest from unsoiled, well-worn products.

Table 15 summarizes the data presented for asbestos-containing textiles and identifies the principal activities of concern with respect to fiber release.

TABLE 15. SUMMARY OF ASBESTOS TEXTILE PRODUCTS SECONDARY PROCESSING AND END USE ACTIVITIES

Product: Fire and heat resistant materials	Secondary processing	End use
Activity:	Sewing, stitching, stapling, cutting, or grommeting woven textile fabric	Installing material in place for worker protection or putting on, wearing, and taking off apparel.
Duration:		
Per Incident Daily Total	Fabricating operations will occur for up to 8 hours per day at factory.	Continuous use throughout day or wearing for short durations (e.g., gloves)
Fiber Releasability:	Low to moderate	Low
Chemical Composition	Asbestos woven fabric 75 to 100% asbestos, usually surface treated	Asbestos woven fabric 75 to 100% asbestos, usually surface treated
Physical Composition	Woven fabric, pliable	Woven fabric, pliable
Disruptive Energy	Low torque machinery	Hand applied
Control Measure(s):	Engineering controls, personal protective clothing, workroom ventilation	None, surface of material usually treated
Measured Fiber Concentrations (f/cm^3):	Assumed to be less than 2 f/cm^3 within workroom environment	0.1 to 5.0 (TWA) for wearing heat protective clothing 0.1 to 3.0 (TWA) for using asbestos laboratory gloves
Environmental Setting:	Indoors, open room of factory	Indoors or outdoors, industrial or laboratory setting
Activity of Concern		
Handling or wearing worn, unsoiled material		

(continued)

TABLE 15 (continued)

Product: Thermal insulation	Secondary processing	End use
Activity:	In general, no secondary processing	Cutting, wrapping, removal
Duration:		
Per Incident Daily Total		Cutting - few seconds, totaling minutes Wrapping - minutes to hours Removal - minutes to hours
Fiber Releasability:		
Chemical Composition		Low during cutting - may be high during removal 75 to 100% asbestos content, usually surface treated
Physical Composition		Twisted, woven, or braided; pliable
Disruptive Energy		Hand cutting, ripping
Control Measure(s):		Wetting possibly during removal ('rip-out')
Measured Fiber Concentrations (f/cm^3):		0.0 to 0.05 for cutting and installation
Environmental Setting:		Mostly industrial applications occurring indoors
Activity of Concern		
Removal of worn out material		

(continued)

TABLE 15 (continued)

Product: Electrical insulation	Secondary processing	End use
Activity:	Winding or sheathing of wire, cables, cords, other electrical components	Intended use of electrical appliance/component
Duration:		
Per Incident Daily Total	Up to 8 hours per shift	Continuous use whenever electrical appliance/component is activated
Fiber Releasability:	Low to moderate	Low
Chemical Composition	75 to 100% asbestos,	Same
Physical Composition	Pliable, asbestos textile contained in finished product is not usually exposed	Same
Disruptive Energy	Winding machines	Static end use application
Control Measure(s):	Engineering controls, personal protective clothing, work practices	None
Measured Fiber Concentrations (f/cm^3):	Assumed to be less than 2 f/cm^3 within workroom environment	No data reported
Environmental Setting:	Indoors, open room of factory	Indoors or outdoors

Activity of Concern

Mishandling, abuse of electrical appliance/component such that insulation becomes exposed and frayed.

(continued)

TABLE 15 (continued)

Product: Gaskets and packings*	Secondary processing	End use
Activity:	No secondary processing	Cutting, removal
Duration:		
Per Incident		Few seconds per cut
Daily Total		totaling 5 minutes, 15 to 30 minutes for removal
Fiber Releasability:		Moderate
Chemical Composition		75 to 100% asbestos-many gasket applications will use untreated rope
Physical Composition		Pliable, woven or unwoven
Disruptive Energy		Hand cutting, scraping during removal
Control Measure(s):		None
Measured Fiber Concentrations (f/cm^3):		No data reported
Environmental Setting:		Industrial applications, mostly indoors

Activity of Concern

Removal of worn gasket and cleaning of adhering material from mating surfaces.

*Gaskets only presented, summary of packings is presented in Section 6.

(continued)

TABLE 15 (continued)

Product: Friction materials	Secondary processing	End use
Activity:	Coating asbestos yarn with asphalt or other compound, followed by winding coated yarn to form woven product	Installation, wear, removal
Duration:		
Per Incident	Secondary processing activities will occur up to 8 hours per shift	Installation (estimated 1/2 hour to 4 hours)
Daily Total		Wear intermittent - product lasts days, years Removal (estimated 1/2 hour to 4 hours)
Fiber Releasability:	Low to moderate	Low
Chemical Composition	75 to 100% asbestos yarn coated with asphalt	Same
Physical Composition	Rigid structure with tacky surface	Same
Disruptive Energy	Moderate, pulling of asbestos yarn through asphalt bath	Stressful, shearing of product surface when in use
Control Measure(s):	Engineering controls, personal protective clothing, work practices	None
Measured Fiber Concentrations (f/cm^3):	Assumed to be less than 2 f/cm^3 within workroom environment	No data presented, beyond scope of study
Environmental Setting:	Indoors, open room of factory	Material enclosed in machinery housing. Installation or removal may occur indoors or outdoors.

Activity of Concern

Removal of worn friction material.

TEXTILES
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SECTION 6

GASKETS AND PACKINGS

INTRODUCTION

Gaskets and packings are found in virtually every mechanical, chemical, and thermal piece of process equipment where fluids are involved.[1] Gaskets and packings are primarily used to prevent leakage between two bearing surfaces: gaskets for static applications and packings for dynamic uses. Gaskets are needed to obtain tight nonleaking connections between pipe flanges and other joints such as the covers and openings on all types of industrial and commercial equipment. Packing is used as a dynamic seal for revolving or moving parts, preventing leakage of the contained fluid along the bearing surface.

Asbestos fibers have been used successfully in both product types because of their unique combination of qualities. In addition to providing heat resistance, resilience, and strength, the mineral fibers are also relatively chemically inert, which is an important factor for many of the gasket and packing applications.

Gaskets

Asbestos-containing gaskets are made from either compressed sheet, beater-add paper, or millboard. Beater-add paper and millboard gaskets are discussed in Section 7 of this report under Paper Products. Gaskets made from compressed sheet are used in pumps, compressors, valves, pipe flanges, industrial and marine engines, gear and axle housings, sheet metal covers, shim gaskets, industrial transmissions, and transformers.[1-3] Because of the strength, chemical inertness, and heat resistance properties of asbestos fibers, the gasket material is used in applications where temperature, pressure, and fluid environments are extremely destructive. Compressed sheet has a higher density and lower polymer-content than beater-add paper and millboard, hence it is used in more severe environments.

The compressed sheet used to make gaskets is formed in a sheeting machine by rolling out a mixture of asbestos, binder, and solvent. The calendered sheet is then cut to size and packaged for shipment. Sheet manufacturing may be a wet or dry process depending on product requirements. Compressed sheet formulations vary with manufacturer and product grade. A commercial grade gasket sheet, used in applications up to 204°C (400°F), contains 75 to 80 percent asbestos, normally chrysotile, whereas specialty grade gasket sheet, used in higher temperature applications, may contain as much as 100 percent asbestos, including chrysotile and crocidolite fibers.[1,4]

Compressed sheet may be fabricated into gaskets at the primary manufacturing plant or more commonly sold to secondary processors or distributors who supply the industrial equipment maintenance market.

Packings

Asbestos packing is a braided product manufactured from untreated asbestos yarn. The yarn is purchased from a primary manufacturer and made into the sealant material by a packing fabricator. The asbestos content in packing varies considerably, and may be as high as 100 percent for high temperature applications such as sealing furnace doors.[5] Braiding is performed using a flat belt common shaft electric driven machine or other similar equipment. The yarn used is untreated because resin impregnated or similarly coated yarn will not pass freely through the braiding machines.[6,7]

After the yarn has been braided, the newly formed packing material may be packaged as is, uncoated, or, more commonly, saturated with a lubricant. Dry, unlubricated asbestos packings are used to seal furnace doors, rotary kilns, and high-temperature refractory equipment.[5] Lubricated asbestos packings are employed in a variety of industrial, commercial, and residential equipment applications, as well as in motor vehicles. Saturation of the braided material is accomplished by passing the packing through a heated liquid bath that contains the lubricant. Some of the more common lubricants used in packing manufacture are:[5,7]

- petroleum based oils and waxes,
- high grade animal fats and waxes,
- Teflon,
- mineral oil,
- natural rubber,
- Buna-S rubber,
- vegetable oil,
- glycerine,
- graphite, and
- molybdenum disulfide.

This treatment process is performed to maintain product pliability while in service, to retard material desiccation, and to prevent the abrasive asbestos fibers from scoring machinery shafts and valve stems during use.[7,8] Final processing before packaging for sale, involves calendering the packing material into specific sizes and cross-sectional shapes.[1,7] Common cross-sectional shapes are round and square. Square packings are preferred because they provide a good seal, creating no gaps along the packing/shaft or valve stem interface.[8]

SECONDARY PROCESSING--FABRICATION

Gaskets

Secondary processing, which involves transforming the compressed sheet into a useable gasket product, is performed by an independent fabricator or the maintenance user. Fabricators, such as gasket cutters, generally form

gaskets from compressed sheets by die-cutting, while the maintenance user cuts the sheet manually (see End Use Activities subsection below). Independent fabricators, who cut the sheet to customer specifications, also supply uncut sheets to the maintenance user who will field fabricate the material to their own specifications. One secondary processor contacted, B and D Supply, Inc. of Yeadon, PA,[9] estimated that marketing uncut gasket sheet accounted for less than 10 percent of their annual sheet sales.

Gasket cutting by the secondary processor is normally performed by forcing a metal die through the compressed sheet using automatic or semiautomatic pressing machinery, which sometimes requires manual gasket sheet feeding.[9-11] The actual cutting process, when the die is forced through the gasket sheet, lasts only about 1 second, compared to up to a minute for product handling time. Because of the clean edge cut made and that asbestos fibers are firmly bound by the gasket matrix, the potential for fiber release during secondary processing is low. This explains, in part, why engineering dust control devices are not normally employed for the cutting operation and the press equipment is open to the workroom environment.[12,13] Operators may wear gloves during material handling, which includes sheet feeding, product separation (hand-picking), and packaging.[9]

Packings

Packing distributors[14-16] report that, in contrast to gaskets, packing is infrequently cut before being supplied to the end user. This is due to the simplicity of the packing/cutting procedure, as well as to the variations of end use application. A representative of Janos Industrial Insulation Corporation of Moonachie, NJ[15] did indicate, however, that packings may be cut to length by a secondary processor for a specific type of application using automatic machinery equipped with a wet dust suppression system.

Also, some distributors may mold packing, which does not involve material abrasion or severing, to a customer's specifications using an automatic press.[14-16] For most applications, however, direct distribution of the standard square or round cross-section material is sufficient to perform job requirements.

END USE ACTIVITIES

Gaskets

Compressed sheet gasket end use activities include installation, in-service use, and removal during equipment maintenance or gasket replacement. Gasket installation normally involves temporarily securing (holding) the precut material to one bearing surface while carefully aligning the other surface over the gasket. When the gasket is in place between the two rigid surfaces, the joint is sealed by torquing down bolts or clamps at regular intervals along the perimeter of the joint. In service, the gasket faces are isolated from fluids on either side of the joint by the pressure of the bearing surfaces. Gasket edges, however, may be exposed on the internal or external side of the joint. For special applications, field fabrication may be required to obtain the correct gasket size and shape. Gasket shaping can be performed with a sharp knife or scissors.[9]

After installation, the gasket's service life depends on the severity of work conditions and the frequency of equipment maintenance. A common cause for gasket replacement results from disassembly of the joint for routine maintenance. The gasket may be damaged during disassembly or its sealing capability may be in doubt due to low compression. Rather than risk a leak by reinstallation of the used gasket, a new one will be installed in most cases.[9,12] In 1978 it was estimated[4] that 15 percent of the asbestos-containing gasket materials* produced are used in new installations, 25 percent for replacement of gaskets failed within 1 year, and 60 percent for maintenance and long-time replacement.

During removal, portions of a gasket may adhere to the bearing surfaces if high temperatures or penetration of working fluids alters the elastomeric binder in the gasket matrix. The adhering material is typically removed manually using a flat-edged scraping tool (e.g., putty knife, paint scraper, or screwdriver) or a stiff wire brush.[10] In many cases the energy input must be well controlled to avoid damaging the joint surfaces, which must be smooth and level for a proper fit. The removal process lasts several minutes, whereas the overall maintenance task typically requires a half-hour or more. Penetration of the working fluid into the gasket material is expected to suppress fiber release during removal. To facilitate gasket release from bearing surfaces, some compressed sheet manufacturers offer materials covered with an anti-stick film.[17-19]

Packings

Similar to gaskets, the end use activities associated with packing applications include installation, in-service use, and removal. Packing installation varies depending on whether the process equipment to be serviced requires a dynamic or static seal. Pump and agitator shafts, hydraulic cylinders, and valve stems require a dynamic seal and are packed in a somewhat similar manner. These devices have a shaft that is in contact with process fluids in the interior of the pump, valve, or vessel. Where the shaft exits the device it must be sealed to prevent or control leakage of process fluids. The shaft exits these devices through a cylindrical cavity commonly referred to as a "stuffing box."[8] The annular space between the shaft and stuffing box is filled with packing material to control leakage. The packing is sized to fill this cavity by forming it into rings. Rings are formed by wrapping the packing around the shaft and cutting with a knife.[8,20,21] Packing rings may be coated with oil or grease before pushing them along the shaft and into the stuffing box. Most applications require from 4 to 10 rings seated back-to-back in the stuffing box.[20,21] When in place, the packings bear against the inner (static) surface of the stuffing box and the outer (dynamic) surface of the shaft. Packings are held in place in the stuffing box by the "gland," a metal cylinder with a lip that is tightened against the stuffing box. In a pump or agitator, the gland is tightened (pressing against the

*Meylan's estimate includes compressed sheet, beater-add paper, and millboard gaskets. The latter two are addressed in Section 7.

packing material in the stuffing box) only enough to control leakage of process fluid between the packing and the rotating shaft. Some leakage is required to provide lubrication to the packing.[20,21]

Packings used in static applications to seal process equipment doors or covers typically include twisted, braided, and plaited ropes as well as square or rectangular composites.[21,22] These materials are held in place by pressing them into a performed, milled groove or recess in the door or cover plate. The packing is usually cut to length using a sharp knife. In a door or cover static application, the packing functions in a manner similar to a gasket in that adjoining surfaces are stationary. Door and cover packings are usually unlubricated, although a rubber cement or elastomer may be used to help hold the material in place during installation.[21]

In service, dynamic packings may fail for a number of reasons. Failures are frequently related to improper size selection (thickness or cross-sectional shape) or installation (cut length), worn or misaligned shaft or stuffing box, insufficient lubrication, or improper gland tightening. Packing failure may also result from loss of flexibility, chemical attack, or lubricant boil-off.[20,21] The service life of dynamic packing material has been estimated to be less than 1 year for 90 percent of the packing applications, while the rest wear out much more rapidly.[4]

Failure of process equipment door or cover packings is usually related to alignment or compaction, since there is little wear on the material surface (no movement) and these materials contain a high percentage of asbestos, capable of withstanding temperature and chemical extremes. When properly installed, the service life of static packings generally depends on two factors: (1) material reaction with the fluid or gases being contained by the packing, and (2) frequency of process equipment maintenance.[1,7] Chemical reactions with process fluids or gases may degrade the packing material causing failure of the seal and leakage. Maintenance, whether scheduled or nonscheduled, prematurely shortens the service life of the packing by requiring replacement of the material that has been damaged when the seal is broken.[1,7]

Removal of worn out packing from a pump, valve, or hydraulic piston requires equipment disassembly, followed by removal of the 'gland' (when present) and extraction of the material from the stuffing box using screw-tipped or pointed rods.[8,20,21] Depending on how well lodged they are in the stuffing box, the packing rings may be torn during removal.[8] Removal of a static packing from a door or cover is somewhat easier because of better access. Under these conditions the material is easily peeled off the door or cover plate or pried out of a retaining groove with a sharp object.

The removal and subsequent installation of dynamic or static packing material may last from one-half hour to more than an hour depending on the size of the equipment and ease of access.[8] The majority of the time spent during servicing is in disassembly and reassembly of the equipment. Material cutting will last only a few seconds and actual packing installation and removal will each require only a few minutes.[8] Packing installation and removal operations are performed indoors or outdoors, wherever the equipment being serviced is located.

Fiber release from the handling and use of lubricated packings is expected to be very low. Packings, used in pumps, valves, and pistons, are impregnated or coated with a lubricant that suppresses dusting. Cutting operations performed during installation should cause minor or no dusting. Cuts must produce a clean, smooth edge in order to ensure good end closure when the packing is in place. In service and during removal asbestos fiber release is also expected to be low due to material saturation.

Concerning fiber releasability from unlubricated packings used in static applications, Johns-Manville reports[23] that where a door or cover is periodically opened or closed, the packing is decompressed and compressed, but without much abrasion. The potential for fiber release to the atmosphere is expected to be highest during removal of the unlubricated packing. The door/cover packings are generally twisted or woven to promote easy release from the sealing surface during use,[21] but prolonged compaction in a retaining groove, for example, may necessitate scraping when replacement is required. The packing material will be physically altered during this process, possibly releasing asbestos fibers.

AIRBORNE FIBER MONITORING DATA

Gaskets

Secondary Processing - Fabrication--

Airborne fiber monitoring data collected during the fabrication of compressed sheet into gaskets are presented in Table 16. Fiber concentrations for the processes monitored, which included machine cutting, hand shaping, and various materials handling operations, ranged from less than 0.01 to 1.3 f/cm^3, with the exception of hand and machine punching operations that were performed without dust controls. Fiber concentrations measured for the uncontrolled hand and machine punching operations were 3.0 and 5.0 f/cm^3, respectively. When control measures were applied to these two operations, fiber concentrations of less than or equal to 0.15 f/cm^3 were recorded.

End Use Activities--

Fiber monitoring data collected during the installation and removal of compressed sheet gaskets are also presented in Table 16. Fiber concentrations measured during the performance of these end use activities were less than 0.4 f/cm^3. The highest concentration recorded (0.39 f/cm^3) occurred during gasket removal, which involved cleaning (hand scraping) adhering residue from a bearing surface. Airborne asbestos fiber release is not expected during gasket wear because the bearing surfaces are stationary during use.

Packings

Secondary Processing - Fabrication--

Because there is virtually no secondary processing of packings, no airborne fiber monitoring data were obtained.

End Use Activities--

In April 1979, Johns-Manville conducted an airborne fiber monitoring study of routine packing installation, in-service use, and removal activities at their Manville, NJ plant.[23] The simulated field operations were

TABLE 16. FIBER CONCENTRATIONS ASSOCIATED WITH VARIOUS COMPRESSED ASBESTOS SHEET GASKET HANDLING ACTIVITIES[10,11,24]

Study	Activity performed	Measured fiber concentrations (f/cm^3)	Date of tests	Duration of activity/ sample time (min)	Analytical method	Comments
A	Punch press operation	0.04 to 0.67	1980	80 to 211	Fibers were counted by PCM[a] with PLM[b] verification	Monitoring performed at a major gasket fabricator located in Wisconsin
	Power shear operation	0.17	1980	188	Fibers were counted by PCM with PLM verification	Monitoring performed at a major gasket fabricator located in Wisconsin
	Shear press operation	0.23 to 0.81	1980	50 to 76	Fibers were counted by PCM with PLM verification	Monitoring performed at a major gasket fabricator located in Wisconsin
	Roussel press	0.04 to 0.08	1980	100 to 192	Fibers were counted by PCM with PLM verification	Monitoring performed at a major gasket fabricator located in Wisconsin
	Picking operation	0.10 to 0.31	1980	93 to 206	Fibers were counted by PCM with PLM verification	Monitoring performed at a major gasket fabricator located in Wisconsin
	Tumbling operation	0.42 to 0.60	1980	77 to 141	Fibers were counted by PCM with PLM verification	Monitoring performed at a major gasket fabricator located in Wisconsin
	Materials handling	0.11 to 0.34	1980	91 to 216	Fibers were counted by PCM with PLM verification	Monitoring performed at a major gasket fabricator located in Wisconsin
	Platen press operation	0.05 to 0.29	1980	52 to 256	Fibers were counted by PCM with PLM verification	Monitoring performed at a major gasket fabricator located in Wisconsin
B	Platen press operation	0.03 to 0.15	1980	63 to 238	PCM	Monitoring performed at an asbestos-using gasket operation in Wisconsin

(continued)

TABLE 16 (continued)

Study	Activity performed	Measured fiber concentrations (f/cm^3)	Date of tests	Duration of activity/ sample time (min)	Analytical method	Comments
	Hydraulic beam press	0.02 to 0.05	1980	61 to 178	PCM	Monitoring performed at an asbestos-using gasket operation in Wisconsin
	Hand picking and packaging	0.06 to 0.20	1980	45 to 176	PCM	Monitoring performed at an asbestos-using gasket operation in Wisconsin
	Platen press picking operator	0.09 to 0.12	1980	67 to 140	PCM	Monitoring performed at an asbestos-using gasket operation in Wisconsin
	Reeves punch press operator	0.12	1980	124	PCM	Monitoring performed at an asbestos-using gasket operation in Wisconsin
C	Storage for receipt and issue	< 0.01 to 0.05	1978	60 to 132	PCM	Housekeeping[c] performed, monitoring conducted under actual work conditions
	Storage for use	< 0.01 to 0.12	1978	97 to 122	PCM	No control,[d] monitoring conducted under actual conditions
	Hand punching	3.00	1978	NR	PCM	No control, monitoring conducted under actual conditions
	Hand punching	< 0.05 to 0.15	1978	28 to 31	PCM	Housekeeping performed, monitoring conducted under actual work conditions
	Hand operated mechanical punching	< 0.05	1978	30	PCM	No control, monitoring conducted under actual work conditions

(continued)

TABLE 16 (continued)

Study	Activity performed	Measured fiber concentrations (f/cm^3)	Date of tests	Duration of activity/ sample time (min)	Analytical method	Comments
	Machine punching	5.0	1978	NR	PCM	No control, monitoring conducted under actual work conditions
	Machine punching	< 0.03 to 0.7	1978	20 to 30	PCM	Housekeeping performed, monitoring conducted under actual work conditions
	Machine punching	< 0.05 to 0.06	1978	23 to 31	PCM	Housekeeping and ventilation,[a] monitoring conducted under actual work conditions
	Hand shaping	< 0.03 to 0.3	1978	7 to 31	PCM	No control, monitoring conducted under actual work conditions
	Machine shearing	0.5 to 1.3	1978	6	PCM	No control, monitoring conducted under actual work conditions
	Machine shearing	0.05 to 0.15	1978	31 to 38	PCM	Housekeeping performed, monitoring conducted under actual work conditions
	Machine nibbling	< 0.08 to 0.46	1978	8	PCM	No control, monitoring conducted under actual work conditions
	Machine nibbling	0.08 to 0.8	1978	24 to 31	PCM	Housekeeping performed, monitoring conducted under actual work conditions
	Installation of flange gasket	< 0.03	1978	30	PCM	No control, monitoring conducted under actual work conditions

(continued)

TABLE 16 (continued)

Study	Activity performed	Measured fiber concentrations (f/cm^3)	Date of tests	Duration of activity/ sample time (min)	Analytical method	Comments
	Removal and concurrent installation (boiler header gaskets)	0.02 to 0.3	1978	21 to 95	PCM	Housekeeping performed, monitoring conducted under actual work conditions
	Clean-up following removal by hand scraping	< 0.05	1978	33 to 37	PCM	No control, monitoring conducted under actual work conditions
	Removal and hand scraping	< 0.06 to 0.39	1978	15 to 28	PCM	No control, monitoring conducted under actual work conditions
	Removal and wire brushing	< 0.03 to 0.18	1978	25 to 33	PCM	Housekeeping performed, monitoring conducted under actual work conditions

[a]Phase contrast microscopy.

[b]Polarized light microscopy, thus reported fiber concentrations are all assumed to asbestos fibers.

[c]Housekeeping - high efficiency vacuum cleaners were used to clean areas (area kept clean and free of debris accumulation), waste material placed in sealed containers.

[d]No control - no specific controls were used; i.e., no wetting, enclosing, or ventilation.

[e]Ventilation - filtered local exhaust ventilation provided to operation.

NR - Not Reported

performed on two water circulating side-by-side pumps. An area air sample between the pumps and a simultaneously collected personal sample were obtained. Both ends of each pump was packed with five rings of material, therefore 20 sections of packing were used per test. Six different dynamic packings were tested over a 4-day period. The duration of each test period was not reported. A minimum of four separate samples were taken for each packing tested: two (one area, one personal) during installation and use, and two during removal. The installation and removal operations performed were similar to those described above in the End Use Activities subsection.

Four of the packings tested were impregnated with petroleum-based lubricants, one was impregnated with a corrosion inhibitor and treated with a graphite surface finish, and one was rubber-coated and treated with graphite. No unlubricated or uncoated packings (e.g., used in static door/cover applications) were tested.

Of the 28 samples collected, 5 had a fiber concentration* of 0.0 f/cm^3, 10 had a concentration of "less than 0.1" f/cm^3, 12 had a concentration of 0.1 f/cm^3 and one sample, an area sample taken during the removal of the rubber-coated packing, had a measured concentration of 0.2 f/cm^3. In general, the personal samples revealed slightly higher fiber concentrations than the area samples, and the installation/use activity samples showed slightly higher concentrations than the removal activity samples.

SUMMARY OF FINDINGS

Gaskets

Secondary processing of compressed sheet into gaskets can result in comparatively high workroom fiber concentrations, on the order of 3.0 to 5.0 f/cm^3 during hand and machine punching, if control measures are not employed. When dust control procedures are implemented, which is usually the case, fiber concentrations resulting from various hand and machine processing steps and materials handling operations range from less than 0.01 to 1.3 f/cm^3.

Measured airborne fiber concentrations resulting from the installation of compressed sheet gaskets were less than 0.03 f/cm^3 as reported by one study. Removal of these materials, however, can result in higher concentrations, up to 0.4 f/cm^3 during hand scraping of worn material adhering to a bearing surface. In this latter case, fiber release is related to the physical exertion required to remove the material and to the high asbestos content (equal to or greater than 75 percent) of compressed sheet gasket. Table 17 summarizes the data presented in this section on compressed sheet gaskets and identifies the principal activities of concern with respect to asbestos fiber release.

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*Phase contrast microscopy analysis assumed.

TABLE 17. SUMMARY OF COMPRESSED SHEET GASKET SECONDARY PROCESSING AND END USE ACTIVITIES

Product: Gaskets	Secondary processing	End use
Activity:	Die-cutting, packaging	Installation; in-service use; removal
Duration:		
Per Incident	Cutting: less than 1 second Packaging: up to 1 minute	Installation; 1-2 minutes Use: weeks to years, depending on application Removal: 5 to 20 minutes, equipment disassembly will require several minutes to more than an hour
Daily total	Cutting: several minutes. Packaging: total production time over 8 hour work shift	Same as above
Fiber Releasability:	Moderate	Moderate
Chemical Composition	Asbestos fiber content 75 to 80% in commercial grades, up to 100% for high temperature applications	Same
Physical Composition	Pliable, may have anti-stick coating, usually "oily" surface texture	Same
Disruptive Energy	Hydraulic press die-cutting; sorting and packaging by hand	Removal; hand scraping, hand or power tool brushing to clean bearing surface
Control Measure(s):	Other than general housekeeping involving vacuuming the process areas, no engineering controls are used.	Generally none, though during removal operation gasket may be saturated with process fluids. Further wetting of worn material prior to removal may also be performed.
Measured Fiber Concentrations (f/cm^3):	0.1 to 1.3 with general housekeeping 0.1 to 5.0 without controls	0.02 to 0.4 during installation, in-service use and removal
Environmental Setting:	Open room, indoors	Open room, indoors or outside
Activities of Concern		
Secondary fabrication, especially die-cutting gaskets. End use, removal of worn gaskets, particularly the cleaning of adhering material from bearing surfaces.		

Packings

Secondary processing of asbestos-containing packings is generally limited to molding operations, in which the material is pressed without material abrasion or severing. Any cutting of the packing is routinely performed by the end user during installation, using hand tools. Installation of dynamic packings results in fiber releases on the order of 0.1 f/cm^3. Dynamic packings are prelubricated and/or coated with friction reducers before use and further lubricated by process fluids during use. When dynamic packing material removal is required, the material is usually saturated with process fluid or still contains residual amounts of lubricant, both of which act to suppress fiber release. Removal is performed using hand tools requiring low energy inputs. Some material disintegration can be expected during the removal of severely worn packing. Airborne fiber concentrations equal to or less than 0.2 f/cm^3 have been recorded during the removal of packing from a mechanical pump.

Fiber monitoring studies documenting asbestos fiber release from unlubricated packings used for static applications have not been reported in the literature. Asbestos fiber release is expected from these types of packings during cutting, installation, and removal because they contain a high asbestos content, have a low binder content, and are not normally treated or coated with any type of lubricant that would suppress fiber release. Table 18 summarizes the data presented on packings and identifies the principal activity of concern with respect to asbestos fiber release.

TABLE 18. SUMMARY OF PACKING SECONDARY PROCESSING AND END USE ACTIVITIES

Product: Packings	Secondary processing	End use
Activity:	Rarely performed, but may be cut to length or molded	Installation (including cutting); in-service use; removal
Duration:		
Per Incident	Cutting: less than 1 second actual cutting. Molding: several minutes (est.)	Installation: 10-30 minutes (Cutting: up to 1 minute actual). Use: weeks to years, depending on application Removal: 10 to 30 minutes
Daily total	Cutting: several min. actual cutting Molding: totalling more than 1 hour (est.)	Same as above
Fiber Releasability:	Moderate	Low
Chemical Composition	Fiber content up to 100% (rare); wide variation in type and amount of lubricant/ coating, depending on intended use.	Same; but dynamic packing may be coated with lubricant during installation, and may be saturated with process fluid during removal. Static packings will be unlubricated.
Physical Composition	Flexible, oily or waxy surface when lubricated	Same
Disruptive Energy	Cutting with a knife or press machine, molding in press machines	Knife or sheers for cutting during installation; pointed or screw-tip extractor to remove dynamic packing from stuffing box. Flat-bladed knives to remove static packings.
Control Measure(s):	Wet suppression dust control during automated cutting. No control during molding	None
Measured Fiber Concentrations (f/cm^3):	No data reported, work-room concentration assumed to be less than 2 f/cm^3	0.0 to 0.2 during the installation, in-service use and removal of lubricated and/or coated dynamic packings. No data reported for unlubricated packings.
Environmental Setting:	Open room, indoors	Open room indoors or outdoors

Activity of Concern

Removal of worn packings, especially unlubricated materials used in static applications.

GASKETS AND PACKINGS
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SECTION 7

ASBESTOS PAPER PRODUCTS

OVERVIEW

Products within this category include those that contain asbestos fibers and are manufactured on a fourdrinier or cylinder papermaking machine. Several subcategories have been identified for Paper Products.[1,2] For this report, the following subcategories were investigated; roofing felt, flooring felt, millboard and rollboard, beater-add paper used for gaskets, and electrical insulating paper. Paper product subcategories not profiled include commercial paper, specialty paper, and pipeline wrap.

The manufacture of all asbestos-containing paper products is similar. Raw materials are blended together with water in a pulp beater or hollander. This base stock is then processed through a series of material build-up and dewatering steps followed by drying. Product differentiation results from the addition of a manufacturing step, such as the saturation of paper with asphalt to produce roofing felts, or from using different forming equipment, as with millboard production. Paper products are also differentiated by varying asbestos content and grades, as well as binders and fillers.[3]

ROOFING FELT

Introduction

Asbestos roofing felt is a paper product that is converted to a weather resistant roofing material by saturation of the paper with asphalt or tar. Asbestos fibers are used in the manufacture of roofing felts because they provide dimensional stability and resistance to rot, fire, and heat buildup. Rot resistance is particularly important due to roofing felt's use on flat or nearly flat surfaces having poor drainage.

Asbestos roofing felts are typically composed of 85 to 87 percent asbestos (primarily chrysotile) with differing amounts of cellulose fibers and starch binders. Sheets of roofing paper are made in either single or multilayered grades and may have fiberglass filaments or wire strands embedded between the felt layers for reinforcement.

Following formation on the papermaking machines, the paper-like product is either drawn through a bath of hot asphalt or coal tar to provide a weather resistant coating or wound into rolls for future processing. The process of

saturating the felt with asphalt is a distinct operation, often performed by the felt manufacturer at a different plant from where the felt itself is made.[1]

Secondary Processing--Fabrication

There is no secondary processing of asbestos-containing roofing felts. These materials are supplied in roll form by the roofing felt manufacturer to local distributors who market roofing products to construction firms.

End Use Activities

Roofing felts are primarily used as one component of "built-up" horizontal roofing systems and less frequently as an underlay for inclined roofs covered by conventional shingles or sheet roofing materials. Both applications require cutting the asbestos felt to size prior to attaching it to the roof deck using adhesives or nails. If removal of the roofing material is required, the methods used depend largely on the materials of construction and amounts installed.

Built-up roofs are constructed by building up successive layers of roofing felt (asbestos or nonasbestos) and asphalt or an asphaltic-type coating. The felts used may be composed of asbestos fibers, fiberglass, or organic fibers, all saturated with asphalt.[4,5] With respect to asphaltic roof coatings and cements, a wide range of product types are available. These include both asbestos-containing and nonasbestos-containing materials.[6,7]

Three basic types of built-up roof systems are currently in use. They are smooth surface, gravel surface, and mineral surface. Each type includes a number of variations which allow for the use of different felt compositions, number of felt plies, and type of roofing substrate (nailable deck without insulation, insulated nailable or nonnailable deck, or light weight loosefill insulating material). The smooth-surface roof type consists of alternating layers of asphalt and roofing felt topped with a light application of heated asphalt or a cold-apply asphaltic coating. The gravel-surface roof type has a similar built-up layer configuration but the top coat is a heavy application of heated asphalt, over which a mineral aggregate is distributed and embedded. The mineral surface roof type has the same built-up layer construction as the other two but the top covering consists of a preformed inorganic "cap sheet" mat that is embedded in a layer of asphalt. The cap sheet is manufactured in different colors and is installed to add a cosmetic finish to the roof.

During installation roofing felts are cut to length using a knife whereas width cuts, when necessary, are made using a knife or a "felt slitter" cutting tool.[4,8] Felts, which are laid down with adjacent edges overlapping, are attached to the roof deck and to underlying felts using nails or asphalt, depending on the deck composition and the roof slope. Asphalt may be mopped on and the felt manually unrolled and pushed into the asphalt, or a specially designed machine can be used that automatically dispenses the asphalt and

applies the felt. In order to achieve a uniform membrane (referring to the total built-up layer) thickness along the edges of the roof deck, a single felt is ordinarily cut lengthwise to obtain two felt strips of the required widths to build up the perimeter thickness. These strips are generally 30, 46, and 61 cm (12, 18, and 24 inches) wide. When the felt is used as underlayment for a shingle or sheet roof, the felt is generally nailed to the deck and no asphalt coatings are used.[5]

Asbestos roofing felts have been in use for over 100 years.[9] Built-up roofs comprised of these felts are reported to have an expected service life of at least 20 years, with some lasting up to 40 years.[9,10]

Product deterioration results principally from climatic exposure. During weathering asphalt coatings and asphaltic felts become brittle and crack.[4] Where isolated leaks occur due to excessive wear, the roof may be repaired simply by application of heated asphalt or a cold-apply roof coating to the affected area. If the deterioration is widespread, the entire roof must be recovered or replaced. Since the roof membrane derives much of its integrity from the structure of overlapping felts, a number of localized repairs is much less effective than total recovering or replacement.[7]

Industry representatives report that more than 60 percent of the asbestos roofing felt produced is applied during reroofing, with the remainder used in new construction.[1] Johns-Manville representatives report that the smooth-surface type of roof is the easiest to recover and replace, owing to the smooth surface and overall light weight.[4,8] A gravel-surface roof requires at least power-brooming to prepare the surface for recovering, and frequently the top layer of gravel/asphalt must be removed entirely to provide a smooth surface.[4,8] Additionally, the gravel-surface roof is the heaviest of the three built-up roof types, and careful attention must be paid to the structural capacity of the underlying roof deck if the existing asphalt flood coat and gravel are to be left intact. Recovering tends to be preferred over reroofing because of lower costs.[8]

Roof removal generally requires chopping or sawing the existing roof membrane into pieces which can be pried or scraped off the roof deck. Any number of roof layers may be removed depending on the scope of the roofing job, from the top layer of asphalt down to the insulation or the roof deck itself. Cutting tools commonly used are an axe or circular saw (mounted on wheels), the latter being faster and generally used on large jobs.[4,11] The circular saw is preferred for removal of top layers of a membrane because it cuts to a controlled depth. After cutting, the cut-up blocks of roof are pried off of the deck or underlying layers with a shovel or crow bar.[4,11] In large job operations, the waste material is carted to the edge of the roof in wheelbarrows and is dropped down enclosed chutes leading to a ground-level dumpster. Less sophisticated disposal methods are used for smaller jobs.

A series of several scraping routines and a final sweep of the roof area may be necessary to prepare the deck for application of a new roof.[11] A Johns-Manville representative stated that it is impossible to characterize

the number of workers and time required for a reroofing job, as the work and even the tools used vary widely with the roof type.[4] Removal of a 10.5 x 18 meter (35 x 60 foot) section of fiberglass-insulated asphalt roofing membrane, which was monitored by GCA/Technology Division personnel in December 1979, required about 2 hours.[11] Built-up roof installation is estimated to take a similar length of time or longer to apply the multilayered membrane.

Airborne asbestos fiber release during roofing felt installation is expected to be low. Asbestos-containing roofing felts, which are coated with asphalt, are quite pliable and normally carefully handled during built-up roof construction to ensure the integrity of the finished membrane.[7,12] During installation, the only mechanical disruption applied to the felt is cutting with a sharp bladed tool. Liberation of asbestos fibers from such a low energy activity is expected to be minimal.

In use, asbestos-containing felt is isolated from the atmosphere by layers of asphalt and/or other roof coating materials. Although these coatings may eventually wear off, wind and water erosion is believed to be a very gradual process whereby minimal fiber release is expected. By the time the felt becomes exposed, a membrane leak is likely and repairs would be performed on the affected area. Roofing materials tend to wear nonuniformly, therefore the felt is not likely to be exposed over the whole roof at one time.

Of all the roofing felt end use activities, felt removal poses the greatest potential for fiber release. During this operation the top membrane coating and the asphalt in the felt have weathered to a hard, stiff material. During removal, when surface layers are sawed and scraped, the felt matrix is likely to be physically altered, releasing free-form asbestos fibers. The membrane top coat and asphalt coats between the felt layers, however, do tend to bind the cut felts together, minimizing felt fracture during prying and waste disposal.

Airborne Fiber Monitoring Data

Several monitoring studies have been conducted to determine airborne asbestos fiber concentrations encountered during roofing felt installation and removal. Results of these studies, conducted by the Johns-Manville Corporation and GCA/Technology Division, are presented in Table 19. Airborne fiber concentrations in and around the work sites were generally found to be equal to or less than 0.6 f/cm^3.

The Johns-Manville studies were initiated through requests by internal marketing staff or roofing representatives and spanned a period from October 1972 to August 1976. Air samples collected were analyzed in Waukegan, IL, Manville, NJ, and Denver, CO by Johns-Manville technicians using the PCM analytical method.[6] The GCA samples were obtained on December 11, 1979 and were analyzed by Eastern Analytical Laboratories of Burlington, MA using SEM (5000x) and EDXR techniques.

The data presented in Table 19 do not indicate any trends as to which roofing operation has the greatest potential for airborne asbestos fiber release. Although reported fiber concentrations for any given study

TABLE 19. FIBER MONITORING DATA FROM ASBESTOS ROOFING FELT STUDIES[11,13]

Test conditions[a]	Sample No.[b] Man	Sample No.[b] Area	Specific operation or area sampled	Tools/materials	Fiber level (f/cm³)[c]
10-10-72 (5-10 mph) Univ. of Wisconsin (MD) by Nelson Roofing Co. (1)—Johns-Manville (Waukegan)	1		Majority of cutting felt; also spread asphalt	Centurion base, No. 15 finishing felts	0.3
	2		Assisted cutting and laying felt	Same as above	0.2
	3		Carried felts to operation; some cutting	Same as above	0.2
		1	Upwind of operation	—	0.1
		2	Along side operation	—	0.1
		3	Downwind of operation	—	0.1
		4	Six ft above operation	—	0.1
5-18-73 (MD) School at Hobart, IN (MD) by Mario Roofing Co. (1)—Johns-Manville (Waukegan)	1		Mopping hot asphalt	MD	0.1
	2		Laying and cutting felt	MD	0.1
	3		Hot asphalt tank operator	MD	0.2
		1	Downwind of operation	—	0.1
		2	Downwind of operation (near man shoveling scrap off roof to truck)	—	0.4
		3	Downwind of operation	—	0.1
3-14-74 (9-10 mph) at Racine, WI (2,000 sq ft) by unidentified contractor (1)—Johns-Manville (Denver)		1	Ground level 500 ft from school building (75 ft below roof)	—	0.4
		2	15 ft upwind of operation, 4 ft above roof	—	0.4
		3	Same as No. 2 area	—	0.2
		4	15 ft downwind of operation, 2 ft above roof	—	0.3
		5	30-15 ft downwind of operation, 2 ft above roof	—	0.3
	6		Mopping hot asphalt; some felt cutting and laying	Knife to cut felt/Centurion base, perforated finishing felts	0.6
	7		Cutting and laying felt	Same as above	0.5

(continued)

TABLE 19 (continued)

Test conditions[a]	Sample No.[b] Man	Sample No.[b] Area	Specific operation or area sampled	Tools/materials	Fiber level (f/cm³)[c]
4-11-74 (10 mph) School at Indianapolis, IN (1,350 sq ft) by Sink & Edwards Roofing CO. (R)—Johns-Manville (Waukegan)		1	525 ft upwind of building at ground level	—	0.1
		2	10-25 ft downwind of operation, 4-5 ft above roof	—	0.1
		3	Same as No. 2 area	—	0.2
		4	40 ft upwind of operation 4-5 ft above roof	—	0.4
	5		All phases of roof removal	Axe cutting, pry bars and shovels to remove surface; sweep clean with brooms	0.1
	6		Same as No. 5 man	Same as above	0.3
5-21-74 ("slight-moderate") Dept. Store at Allentown, PA (1,500 sq ft) by Hill Metal and Roofing Co. (R,I)—Johns-Manville (Manville)	1		Power sawing and removing sections of old roofing	Power saw, pry bar	0.1
			Tacking down new felt	Nailing Centurion base felt	0.0
	2		Prying off old roofing	Pry bar	0.0
			Laying new felt (unrolling)	Centurion base felt	0.1
	3		Removing old roofing	Wheelbarrow	0.1
			Tacking down new felt	Nailing Centurion base felt	0.2
		4	Upwind corner of work area—removal	—	0.1
			- Installation	—	0.1
		5	25 ft downwind of work area—removal	—	0.1
			- Installation	—	0.1
		6	15 ft downwind of ground-level truck receiving waste roofing—removal	—	0.2
			- Installation	—	0.1
		7	150 ft downwind of work area and at ground level—removal	—	0.1
			- Installation	—	0.1

(continued)

TABLE 19 (continued)

Test conditions[a]	Sample No.[b] Man	Sample No.[b] Area	Specific operation or area sampled	Tools/materials	Fiber level (f/cm³)[c]
5-21-74 (continued)		6	25 ft upwind of ground-level truck receiving waste roofing—removal	—	0.0
			- Installation	—	0.0
7-25-74 (0-2 mph) School at Gary, IN (3,500 sq ft) by Marie Roofing Co. (R,I)—Johns-Manville (Waukegan)	1		Roof removal by sawing, prying; installation by nailing base felt and hot mopping other layers	Power saw, shovel, wheelbarrow, broom; nailing felts, mopping hot asphalt	0.2
	2		Same as No. 1 man	Same as above	0.3
		3	15 ft downwind of work area	—	0.1
		4	15 ft upwind of work area	—	0.2
11-20-74 (10-8 mph) School at Cherry Creek, no state given (5,800 sq ft) by United Materials Roofing Co. (I)—Johns-Manville (Waukegan)		1	Upwind edge of work area	—	0.1
		2	Downwind edge of work area	—	0.1
	3		Felt laying machine operator	Machine lays felt in hot tar	0.2
	4		Broom felt into hot asphalt	Push broom	0.1
	5		Hot asphalt tank operator	Pouring hot asphalt	0.1
	6		Felt "fitting" (probable cutting)	ND	0.2
12-15-75 (variable) Industrial building on location given (7,700 sq ft) by unknown contractor (I)—Johns-Manville (Waukegan)	1		Felt laying machine operator	Machine lays felt in hot tar	<0.1
	2		Replace felt rolls on laying machine, broom felt into tar	Push broom	<0.1
		3	North edge of work area, generally upwind	—	<0.1
		4	South edge of work area, generally downwind	—	0.0
		5	East edge of work area	—	<0.1
8-76 (MD) School at Anderson, IN (1,500 sq ft) by Adams Roofing (R,I)—Johns-Manville (Waukegan)		1	2 ft downwind of work area, 5 ft above roof—removal	—	0.0
			- Installation	—	0.0
		2	Same as No. 1 area—removal	—	0.0

(continued)

TABLE 19 (continued)

Test conditions[a]	Sample No.[b] Man	Area	Specific operation or area sampled	Tools/materials	Fiber level (f/cc)[c]
8-76 (continued)		2	- Installation (continued)	—	0.0
		3	Upwind edge of work area, 5 ft above roof—removal	—	0.0
			- Installation	—	0.0
	4		"Tear-off man" (probably cutting and prying off old roofing)	HD	0.0
	5		"Scrap removal man" (probably shoveling and wheelbarrowing old roof material)	HD	0.0
	6		"Asphalt applicator" (probably mopping hot tar)	HD	0.0
	7		"Asbestos paper application" (probably cutting and laying felt)	HD	0.0
8-76 (HD) School at Chesterfield, IN (1,500 sq ft) by Adams Roofing (I)—Johns Manville (Waukegan)		1	2 ft downwind of work area, 5 ft above roof	—	0.0
		2	Same as No. 1 area	—	0.0
		3	Upwind edge of work area, 5 ft above roof	—	0.0
	4		"Asphalt applicator" (probably mopping hot tar)	HD	0.0
	5		"Asbestos paper applicator" (probably cutting and laying felt)	HD	0.0
12-11-79 (15 mph) Office building at Bedford, MA (31,000 sq ft) by unidentified contractor (R, I)—OCA/Technology Division (Eastern Analytical)		1	Corner of roof 25 ft downwind of work area	—	0.00
		2	Edge of roof 25 ft downwind of work area	—	NA
		3	Edge of roof 25 ft downwind of work area	—	0.03
		4	100 ft upwind of work area	—	0.05

(continued)

TABLE 19 (continued)

Test conditions[a]	Sample No.[b] Man	Area	Specific operation or area sampled	Tools/materials	Fiber level (f/cm³)[c]
12-11-79 (continued)		5	Same as No. 4 area	—	0.01
	5		Cutting, scraping, and shoveling old roof off of deck; sweeping; laying fiberglass insulation and roofing felts, layered with hot asphalt	Removal: circular saw, shovels, wheelbarrows, brooms Installation : ND	0.00

[a]Test conditions include date of sampling (reported wind speed); location (area of work site); roofer (type of operation—R = removal, I = installation); sampling personnel (analysis lab).

[b]Sample No. generally corresponds to sampler's reported data, and two columns indicate whether sampling was performed on a worker (moving) or in a general area (stationary).

[c]Johns-Manville data based on PCM. GCA data based on SEM/EDXR analysis.

ND = No data

NA = Not analyzed

generally follow a logical pattern, with highest concentrations reported for cutting, scraping, and sawing operations as compared to spreading asphalt or unrolling felts, the differences in fiber levels within a given study are less than the differences between studies (generally less than 0.2 f/cm^3). The variations in reported concentrations between studies in which similar materials and operations were used seem to suggest some contribution from the work practices of individual roofers' or from background fiber concentrations. A confusing factor in 4 of the 11 studies was that upwind fiber concentrations were higher than downwind concentrations, and in 3 of the 4 studies they were higher than work site levels. No explanation is given for these unexpected results.

Summary of Findings

There is no secondary processing of asbestos-containing roofing felt. The manufactured material is sold directly or through distributors to the roofing contractor. Asbestos-containing felts are used predominantly in "built-up" roof systems which combine the felts between layers of asphalt or other coatings. These systems are rarely used for residential roofing. The flat or gently sloping "built-up" roof is widely employed on commercial and industrial buildings. Asbestos-containing felts are occasionally used as an underlay for shingle or sheet roofing materials on inclined surfaces.

Felt handling practices employed by roofing contractors tend to be fairly standardized, although a wide range of combinations with asphalt, roof deck insulation, and other felts occur. Felt installation is generally a low energy intensity process, requiring only felt unrolling, "brooming" (removal of underlying air pockets), and mopping with hot asphalt. Only a minor amount of cutting (with a sharp-bladed hand tool) is required. Removal of existing roof material requires greater energy input. Power saws or axes are used to cut the substrate into 0.6 meter (two foot) square or larger blocks, which are then pried off and scraped from the underlying deck using crow bars and shovels.

Despite the variety of cutting and scraping operations that are performed, roofing felts appear to have a low fiber release potential. This probably results from the encapsulation of the fibers during the asphalt saturation step of manufacturing. Also, during installation, as the felts are successively layered with hot asphalt and/or cold coatings, the asbestos fibers are further isolated. In addition, roof weathering is very gradual and fiber release resulting from wind or rain erosion is expected to be minimal. The greatest potential for fiber release exists during roof removal when high-energy mechanical disruption is required to remove sections of felt from the roof deck. Fiber monitoring studies indicate that asbestos roofing felt installation and removal operations result in airborne fiber concentrations that are equal to or less than 0.6 f/cm^3. Table 20 provides a summary of the data presented on asbestos roofing felts and identifies the principal activity of concern with respect to airborne asbestos fiber release.

TABLE 20. SUMMARY OF ASBESTOS ROOFING FELT SECONDARY PROCESSING AND END USE ACTIVITIES

Product: Roofing Felt	Secondary processing	End use
Activity:	No secondary processing performed	Installation; in-service use; and removal
Duration--per incident Daily total		Site-specific; Installation and removal highly variable with roof size and number of felt layers. Actual felt cutting time is estimated to last less than one hour.
Fiber releasability: Chemical composition		Low Before asphalt saturation: 85 to 87% asbestos fiber content, remainder filler(s) and binder(s)
Physical composition		Pliable, with a tacky surface
Disruptive energy		Knife or slitting machine during installation; axes, power saws, and hand scraping tools during removal
Control measure(s):		None
Measured fiber concentrations (f/cm^3):		0.0 to 0.6 (ranging from installation to removal)
Environmental setting:		Outdoors

Activity of Concern

Removal (power sawing and scraping) of wornout, brittle felts from roof deck.

FLOORING FELT

Introduction

Flooring felts are used to provide a cushioning effect under floor coverings and to aid in subflooring moisture control. Asbestos fibers are used in the manufacture of flooring felts to provide dimensional stability and resistance to heat and rot due to moisture. Asbestos-containing floor felts may be installed separately as an underlay for various floor coverings or more commonly fused to the back of sheet vinyl flooring. The vinyl sheet flooring product backed with asbestos-containing felt was discussed previously (see Section 3).

Asbestos-containing flooring felts, which are formed on conventional papermaking machines, are composed of approximately 85 percent asbestos and 15 percent latex binder. Chrysotile asbestos fibers are used, with grades 5 and 7 predominating. Currently, a styrene-butadiene latex binder is used in the manufacture of these felts. Asbestos-containing flooring felts sold separately are most often used in residential applications.

Asbestos flooring felts are used as underlay for floor coverings that include vinyl tiles, sheet vinyl, and carpeting, or on concrete subfloors where moisture problems may occur. The asbestos paper product helps to absorb the moisture and transfer the water to the walls. Use of the flooring felt by itself presently accounts for only a small percentage of all asbestos felt produced, as most of the material is combined with sheet vinyl flooring. It is reported, however, that this product distribution is shifting towards an increase in the use of the unfinished felt as a floor general covering underlayment.[14]

Secondary Processing--Fabrication

As mentioned above, asbestos-containing flooring felts may be sold as an unfinished product that is used as a floor covering underlayment or it can be fused to the back of sheet vinyl flooring. No secondary processing is performed on the unfinished felt product. Rolls of the material are distributed directly from the primary manufacturer to wholesale outlets and retailers.

End Use Activities

Although asbestos flooring felt is used primarily in residential settings, the installation and removal of the underlayment is usually performed by professional contractors. Work practices are implemented to minimize fiber release. Felt end use activities include subfloor preparation, installation, in-service use, and removal.

To insure proper installation, a clean, smooth and level subfloor surface is required. Subfloor preparation is similar to that described in Section 3 for Flooring Products and will not be repeated here.

Before the flooring felt is laid down, the dimensions of the room and perimeter wall configurations are measured and recorded. Next the measurements and wall irregularities are transferred to the flooring felt, followed by cutting the specified size and edge shapes using scissors or razors. Flooring felt installation is similar to sheet vinyl installation whereby the entire contacting surface will be pasted to the subfloor, only the perimeter of the felt will be pasted, or no adhesive will be used such as in the put-down-quick (PDQ) method.

In use, the felt is completely covered by a flooring product such that it is isolated from direct wear. Minimal fiber release is expected during the felt's service life.

The process of removing flooring felt is very similar to that for sheet vinyl flooring backed with asbestos felt. For a description of the removal process refer to the discussion presented in Section 3 on sheet vinyl flooring.

Airborne Fiber Monitoring Data

No fiber monitoring data associated with the installation, use, and removal of asbestos flooring felt have been reported in the literature. Fiber concentrations resulting from these end use activities are expected to be very similar to those recorded for the installation, use, and removal of sheet vinyl flooring backed with asbestos felt. Fiber concentrations measured during the installation and removal of sheet vinyl flooring backed with asbestos felt were on the order of 1.0 f/cm^3 and 0.48 f/cm^3, respectively (see Section 3). When recommended work practices are not followed (dry scraping) during the removal of worn out sheet vinyl flooring, workroom fiber concentrations of 1.0 to 2.2 f/cm^3 may result.

Summary of Findings

There is no secondary processing of asbestos-containing flooring felts. Most of the flooring felt manufactured today is incorporated into a sheet vinyl flooring product, although the popularity of using the felt separately as a floor covering underlayment is on the rise.

End use activities associated with felt applications that may result in asbestos fiber release include subfloor preparation, cutting during installation, and material removal. No fiber monitoring data have been reported to document fiber release during the performance of such activities. Fiber release data are available, however, for sheet vinyl flooring backed with asbestos felt, which is handled and applied under conditions that are very similar to those of the unfinished flooring felt. Fiber concentrations up to 1.0 and 0.48 f/cm^3 were measured during the installation and removal of asbestos felt-backed sheet vinyl flooring, respectively. Table 21 summarizes the end use activities associated with asbestos flooring felts and identifies the principal activity of concern with respect to airborne asbestos fiber release.

TABLE 21. SUMMARY OF FLOORING FELT SECONDARY PROCESSING AND END USE ACTIVITIES

Product: Flooring Felt	Secondary processing	End use
Activity:	No secondary processing	Installation; in-service use; and removal
Duration--per incident Daily total		Cutting during installation is somewhat continuous lasting from 10 to 20 minutes. Removal and subfloor preparation is estimated to last 4 to 8 hours.
Fiber releasability:		Moderate
Chemical composition		85% asbestos fiber content, remainder being latex
Physical composition		Pliable, soft
Disruptive energy		Binders, hand shears, scissors, or a knife during installation, sanding or scraping during removal
Control measure(s):		Wetting during removal*
Measured fiber concentrations (f/cm^3):		No data, but expected to be similar to fiber release from asbestos felt-backed sheet vinyl flooring during installation and removal, (1.0 and 0.48 f/cm^3, respectively)*
Environmental setting:		Indoors, closed room

Activity of Concern

Removal of residual felt adhering to subfloor when recommended work practices are not followed.

*When following recommended work practices.

MILLBOARD AND ROLLBOARD

Introduction

Asbestos-containing millboard and rollboard are considered paper products because they are manufactured by a process similar to that used to make paper. In structure and texture, millboard and rollboard products resemble cardboard, with millboard more closely allied with the heavier paper grades.

Millboard is manufactured in individual sheets, this being the only difference from the continuous sheet production of other asbestos-containing paper products. The individual sheets are formed on conventional papermaking equipment employing a technique whereby the desired sheet thickness is obtained by building up layers of fibers on a rotating cylinder mold. When the desired thickness is obtained, the cylinder is then momentarily stopped as workers cut the built-up layer of material lengthwise, removing one thick sheet of damp millboard. The wet millboard sheet, containing about 50 percent water, is then air-dried or placed in an autoclave or oven for rapid curing. Finished millboard usually contains 5 to 6 percent water.[15]

Although rollboard differs from millboard in that it is thin enough to be rolled, both are usually sold in flat sheets. Millboard manufactured in the United States is produced in a standard 1.0 by 1.2 meter (42 x 48 inches) size sheet with thicknesses ranging from 0.79 mm to 1.9 cm (1/32 to 3/4 inch). Thicker sheets are produced by laminating sheets together. Rollboard is a lamination of two 0.4 cm (1/6 inch) thick or thinner sheets.[1]

Asbestos-containing millboard (and rollboard) is composed of asbestos fibers (68 to 95 percent), binders (3 to 25 percent), and fillers.[1,15] Chrysotile asbestos is the most common fiber type used, with grade 5 preferred.[16] The binders may include starches, elastomers, or silicates. Millboard may also contain 5 to 40 percent portland cement and starch as the binder.[3] Mineral wool, fiberglass, and cellulose are commonly used as fillers.[1]

Millboard is one of the most versatile asbestos-containing products. Its numerous applications are listed in Table 22. A principal attribute that makes it so adaptable to varied uses is the way in which it can be manipulated during installation: millboard is easy to cut, can be punched into shape, can be wet molded, and is compressible. Unfabricated millboard may be purchased by a number of secondary processors who install it or incorporate it into other products; wholesale distributors who supply the molten metals and glass industry; and construction contractors for use as a building material[16]. Rollboard may also be used in similar applications, but is generally less suited to industrial settings where structural rigidity is a desirable feature.

In both the molten metals and glass industries, transfer rollers comprised of asbestos-containing millboard are used to convey annealed or pickled steel or flat glass from one point in the manufacturing process to another. Millboard is also used as slip planes to insulate the silica furnace linings of induction furnaces. Other industrial uses include mats to place hot products on, sealings for holes and flues in roofs of furnaces, thermal

TABLE 22. INDUSTRIAL, COMMERCIAL AND RESIDENTIAL USES OF ASBESTOS-CONTAINING MILLBOARD AND SPECIFIC APPLICATIONS[1]

User	Application
Industrial	
General	In boilers, as gaskets, which may be metal reinforced, as flame and heat barriers, as slip-planes for furnace linings, in transfer rollers that convey hot material from one point in a manufacturing process to another.
Electrical	Thermal protection in large circuit breakers
Appliance	Fire-proofing agent for commercial and home security boxes, safes, and files
Aluminum	Pouring trough cover and trough liner
Marine, shipyard, aircraft	Liner for container that catches hot metal from cutting operations
Foundry	Trough liner and iron trough cover
Steel	Backup insulation for furnace lining
Metallurgical	Used between the hot mandrel and the bearing shell in molten babbitt operation
Ceramic	Low mass kiln cars
Glass	As insulation in glass tank crowns, melter, refiner, sidewalls, etc.
Commercial	
Metal-clad doors	Between outside metal and wood core
Office partitions	Between metal sheets, valued as a fireproofing and sound deadening material. Very large potential market
Soldering fixtures and soldering blocks	
Spark and glare shields in welding shops	
Fireproof wallboard	
Washers in electrical apparatus	
Linings for safes, dry-cleaning machines, incinerators, heater rooms	
Garage paneling	
Residential	
Linings for home safes, stoves, heaters and electric switch boxes	
Tent shields	
Stove pipe rings	
Stove mats, table pads	
Perfume rings for oil lamps	

door gaskets, and heat protection walls. Millboard is also used as gaskets for joining pipes at industrial plants and for a variety of boiler applications.

Commercial applications include heat or flame barrier shields for welding and soldering operations, office partitions, and fireproof wallboards. Millboard is also used as a filler for metal reinforced gaskets that are frequently used on small air-cooled engines such as lawnmowers.

In residential settings, millboard is used as a flame or heat barrier in wood and coal burning stove installations. It is also used in the manufacture of prefabricated fireplaces. Residential uses extend to the linings of safes, stoves, heaters, and electrical switch boxes; stove pipe rings; stove mats; and table pads.

Secondary Processing--Fabrication

Most millboard and rollboard manufacturers market their unfinished products through one or more distributors. These distributors will either sell directly to the end user or to secondary processors who fabricate the millboard for specific end use applications.[17-19]

Fabricating operations performed during secondary processing range from die-cutting gaskets and rings to drilling, sawing, and shearing the millboard to produce various dimension construction materials. The following discussion pertains to the more common secondary processing operations performed by millboard and rollboard fabricators and gives specific examples.

In the molten metals and glass industries, asbestos-containing millboard is fabricated into rings that are slid along the circumferential axis of steel mandrels to make heat-resistant rollers used in conveyor lines.[17] The millboard rings are assembled with the steel mandrel, such that the entire outer surface of the roller is comprised of the edges of the millboard discs. Manufacture of the transfer roller is performed in two steps by separate fabricators. The steps involved are: (1) die-cutting the millboard rings followed by (2) mounting them onto a steel mandrel.

During die-cutting, the millboard sheets are fed by hand to an automatic punch press which forms the rings from the sheet using a metal die. The actual cutting action only lasts about one second but it is repeated hundreds of times throughout an 8-hour work shift.

After the rings have been formed, they are packaged and distributed to a second fabricator who assembles the transfer rollers. The millboard rings are slipped onto the steel mandrel and press-fitted together between two end flanges. Transfer rollers range in length from 4 to 7 meters (13 to 24 feet) and may contain from 800 to 1000 rings each. To provide a smooth outer rolling surface contour, 0.64 cm (1/4 inch)of the assembled roller's outer diameter is ground off using a surface grinding operation. Depending on production demand, grinding will vary from a few hours per day to an entire work shift.

The potential for fiber release and subsequent dispersal during die-cutting is expected to be low given the somewhat rigid composition of the gasket material and that the operation results in a clean edge cut and has virtually no dust propellant forces associated with it. However, a greater fiber release potential is expected during surface grinding due to material shearing. Also, the high speed rotation of the grinding wheel will propel dust generated by the operation into the workplace air if not properly controlled. Grinding machinery is commonly equipped with high air velocity, low air volume capture hoods that vent to a baghouse dust collection device. Workers may also wear dust control face masks as they desire and building doors and windows may be left open to provide natural ventilation in the workplace.[20,21]

In general, the fabrication of millboard or rollboard into a final flame or heat barrier product is no longer routinely performed by a secondary processor but by the end user.[17,18,22] Janos Industrial Insulation of Moonachie, NJ,[23] a major fabricator of insulating materials, has discontinued millboard and rollboard operations because of the increasing cost of insurance for workers handling hazardous substances. B and D Supply, Inc. of Yeadon, PA[19] discontinued their fabricating operations citing the complications of operating and maintaining dust control equipment, and J and S Supply Corporation, of Long Island City, NY,[24] estimates that only 1 percent of their millboard throughput is cut to size, while the majority of it is marketed unprocessed to retail outlets (lumberyards, hardware stores).

When they do fabricate, J and S Supply[24] cut their millboard products to customer specification using a bench-mounted electric circular saw equipped with a vacuum exhaust dust collection device. The saw is located in an enclosed room having no special ventilation system. Saw operators routinely wear surgical-type face masks when cutting the millboard. Actual sawing time lasts only a few seconds per cut; accumulated over the course of the workday, sawing totals several minutes.

Due to the abrasive shearing and propellant forces associated with drilling and sawing operations, fiber release into the workplace is expected. The pulverizing action of these power tools breaks down the cohesive structure of the millboard, producing fine-size particles that can be expelled into the air by the high speed cutting bits and blades. Consequently, the fabricating operations need to be controlled, and generally are, to minimize fiber release into the workplace.

End Use Activities

The end use activities associated with millboard and rollboard products include field fabrication, product installation, in-service use, and product removal. In industrial environments, field fabricating operations primarily include cutting, drilling, and wet molding. Cutting can be performed using a handsaw. However, considering the dimensions of a standard size sheet 1.0 by 1.2 meters (42 x 48 inches), it is much faster to use an electric circular saw or to score the material with a knife, breaking it by hand. Scoring followed by snapping, whereby the board matrix is more cleanly sheared apart, has a comparatively low dust release potential. Power-operated saws create higher

dust release potentials, but may be used in conjunction with dust control equipment and protective clothing, particularly if the user is a large industrial plant with other safety concerns (e.g., steel, glass, and ceramic manufacturers). Drilling tools used on millboard are generally power-operated, hand-held devices that may or may not be equipped with dust collection devices.[19,24]

Field fabrication of millboard for use in commercial or residential settings is similar to that for the industrial sector. However, fabricating tools equipped with dust collection systems are not likely to be employed considering the small scale size and infrequent occurrence of fabrication at the commercial/residential level. Handling of asbestos millboard may occur from once or twice a week for commercial operations to once in a lifetime for the homeowner.[25,26] Duration of the finishing operations will depend on the quantity of material to be worked. Commercial and residential operations may last up to 8 hours or only one hour or fraction thereof.

Under either setting, workers will use conventional tools readily available to them. Cutting and drilling operations are performed using hand operated or power-assisted tools.[25,26] The actual time required to perform each activity varies from a few seconds to drill a single hole to several seconds to cut a staight or curved line using a power saw or longer with a hand saw. Because millboard is fairly easy to cut, hand tools, such as scoring knives can be used to fabricate the material. The potential for fiber release from the use of such hand operated tools is expected to be low due to the minor surface abrasion imparted by these tools and the absence of strong propellant forces. Any dust that is generated tends to fall directly to the ground, not upwardly dispersed as can occur with the use of uncontrolled power saws. As a minimum, protective clothing, particularly surgical-type face masks, are likely to be worn by the safety-conscious user.[25,26]

Asbestos millboard used as a heat or flame retardant barrier is commonly secured to support surfaces and frames using adhesives or mechanical fasteners, such as screws, bolts, and nails.[27] In addition, sections of millboard may be set in place unsecured, between metal support frames as in the case of slip planes.[16] Adhesive bonding is unlikely where a board is to be removed regularly, as in a foundry trough or catch basin liners where no fasteners are used. Also, because of its low tensile strength and easily abraided surface, millboard is not installed in situations where it could come in contact with moving parts. In situations where the millboard surface is left exposed, beveling or sanding with subsequent surface coating is not expected given the low aesthetic concerns in an industrial setting.

Millboard installation time will range from days for new installations and renovations to a few hours for small material replacement jobs.[23-26] If the millboard has been prefabricated, fiber release during installation is not expected. If field fabrication is required, the finishing operations would be similar to those described above. This latter situation occurs when mechanical fastening is required. Pilot holes will be drilled to avoid fracturing the millboard during installation. The potential for airborne fiber release and extent of dispersion during cutting will depend on the type

of drilling tool used. As discussed above, power-assisted tools are more likely to introduce fibrous dust into the workplace than hand operated tools. Under industrial settings, where these activities are most common, power-assisted tools are generally used.

Millboard and rollboard can also be molded to nonplanar surfaces by dipping in water prior to application. Because the millboard serves no structural purpose (only insulating), mechanical attachment to a surface or frame is unnecessary as long as the surface covering or frame restricts board movement. The time required to apply the millboard by this process varies depending on the amount of surface area to be covered. Installation times of a few hours are likely.

The potential for fiber release during application is greatly diminished by wetting of the board prior to installation. Once installed fiber release is not expected under normal conditions given that this is a static application and no surface abrasion should occur. During removal, the potential for fiber release will be considerable unless adequate control techniques (e.g., use of a wetting agent) are employed. In dry form, cutting of this material to remove it has the potential to generate substantial dusting.

Millboard rings used in the rollers of conveyor lines in the molten metals and glass industries are subjected to repeated contact with very hot surfaces. A representative of Guardian Industries of Northville, MI,[21] a glass manufacturer, reports that there is no visible wear of the roller surface on a day-to-day basis, but that the edges of the glass slab eventually score the roller surface through repeated contact. When a production line is shut down for several weeks for routine maintenance, about every 5 to 7 years, the most worn rollers (typically one-third of the total of 220) are removed and sent to the roller assembler for replacement of the millboard rings.[28]

Gaskets made from millboard and rollboard are carefully installed to ensure proper sealing during use. Gasket wear resulting in fiber release is normally not a concern since the bearing surfaces are isolated and immoveable while in-service. During routine maintenance or scheduled gasket replacement, however, portions of a gasket may adhere to bearing surfaces if the binder component of the gasket is decomposed by high temperatures or penetration of working fluids. The adhering material can be removed manually using a flat-edged scraping tool or a stiff wire brush. The removal process for any gasket generally lasts only minutes, while the maintenance task which necessitates gasket removal may range from several minutes to several hours.

The potential for fiber release during material scraping or brushing will depend on the dryness of the gasket and the intensity of the physical energy applied to remove the material. The dryer the remaining material is and the greater the force applied to remove it, the greater the potential for fiber release. Gaskets penetrated by working fluids tend to be pliable allowing them to be more easily removed and are less likely to disintegrate than dried-out material during removal.

Airborne Fiber Monitoring Data

Secondary Processing Fabrication--

Fiber monitoring data associated with millboard secondary processing operations have not been reported in the literature. A representative of Nicolet Industries of Ambler, PA,[18] a fabricator of asbestos millboard, reported that the capture efficiency of a baghouse serving their punch press operation is high enough that workers do not have to wear respirators to comply with the 2 f/cm^3 8-hour TWA occupational exposure standard.

With respect to assembling industrial transfer rollers, a representative of New Hudson Corporation, Verticarb Division, of New Hudson, MI,[20] reported that fiber concentrations in the workroom air where millboard rings are placed on steel mandrels approached 0.2 f/cm^3. Details about the sampling location, specific activities performed, and analytical techniques used were not provided.

End Use Activities--

Actual field fabrication monitoring data for millboard gasket use activities are scarce. In a controlled laboratory glove box test,[11] scoring and sawing of millboard resulted in measured fiber levels of 8.4 and 6.2 f/cm^3, respectively, as determined by SEM (5000x)/EDXR analysis. To simulate material fastening, a piece of millboard was subjected to hammering for 10 minutes in the laboratory glove box.[11] The recorded fiber concentration was 1.4 f/cm.^{3} The glove box results are likely to be higher than those expected under actual field conditions. Fiber accumulation in the nonventilated air space of the glove box chamber could account for the relatively high fiber concentrations recorded. In an industrial setting, field fabrication would be performed in a large open workspace with good ventilation or out of doors. In a commercial or residential setting, onsite fabrication would take place in a relatively small room, normally 3 by 4.5 meter (10 by 15 feet) or larger, in a garage, or out of doors. Greater fiber dispersion, resulting in lower airborne asbestos concentrations, is expected under actual conditions.

Summary of Findings

Millboard and rollboard are used in a wide range of industrial, commercial, and residential applications. These board products are used primarily to insulate equipment or building structures from high heat or direct flame contact. They generally function in a static mode where they are not physically abraided while in service.

Millboard and rollboard have comparatively high asbestos fiber contents and low binder contents, suggesting high fiber release when mechanically disturbed. Although millboard tends to be somewhat rigid in the greater thicknesses, it is not strong enough to be used in load bearing applications. When impacted with only a moderate force, millboard will fracture.

Fabricating operations performed by secondary processors, particularly sawing and grinding using power tools, generate substantial dust emissions. Because of this, processing equipment are well controlled, employing engineering practices to minimize fiber release. Field fabricating operations performed by millboard and rollboard end users are generally not as well controlled. However, the tools used by the general consumer are not as energy intensive. Many of the tools used, such as hand saws and scoring knives, are manually operated. Power tools not equipped with dust collection systems will occasionally be used. Millboard retail suppliers may warn their customers of the hazards associated with dust generated by board fabrication, but this is not standard practice.

Representative fiber monitoring data documenting the release of asbestos fibers during millboard and rollboard field fabrication, installation, and removal are not available. A laboratory study simulating these activities has been conducted, but the measured fiber concentrations, ranging from 1.4 to 8.4 f/cm^3 for hammering, sawing, and scoring, are not likely to be representative of concentrations under actual field conditions. Table 23 summarizes the information presented on millboard and rollboard products and identifies the principal activities of concern that are likely to result in airborne asbestos fiber release.

BEATER-ADD GASKETS

Introduction

Another asbestos-containing paper product used to make commercial and industrial gaskets is beater-add paper. Beater-add paper is named after its manufacturing process, in which an elastomeric binder and asbestos fibers are added to the product mix during the beater step of papermaking.[1] The binder, which may include latex, natural rubber, synthetic rubber, or neoprene, accounts for 20 to 40 percent of the paper product. Selection of the binder depends on the end use application for the gasket paper. The remaining 60 to 80 percent of the paper composition is asbestos fiber, normally chrysotile asbestos. Beater-add paper is produced in sheet or sheet-roll form with thicknesses ranging from a few hundred micrometers up to about 1 cm.[16,29]

Gasket products are routinely installed to obtain tight, nonleaking connections in piping and other joints. Beater-add gaskets are used as sealing members in applications where chemical inertness, heat resistance, and resilient strength are important. The major user of this type of gasket is the automotive industry.[16,30-32] Beater-add gaskets are used in sealing oil pans and pumps, gear case covers, cylinder head covers, and intake and exhaust manifolds. Metal-sheathed beater-add paper is used in cylinder head and exhaust manifold gaskets.[29,31] In addition, beater-add paper is used in other transportation applications in a similar role, as engine and drivetrain gaskets. Further, it is used in a variety of industrial and commercial equipment, including heat exchangers, boilers, furnaces, and pipe connections. The chemical industry uses the asbestos gaskets extensively for equipment connections because of the chemical inertness of asbestos.[1]

TABLE 23. SUMMARY OF MILLBOARD AND ROLLBOARD SECONDARY PROCESSING AND END USE ACTIVITIES

Product: Millboard and Rollboard	Secondary processing	End use
Activity:	Die-cutting, power sawing, surface grinding, some drilling	Power or hand sawing, scoring and snapping, drilling, nailing or screwing, wet molding
Duration—per incident	Die-cutting: less than 1 sec. Sawing, grinding, and drilling: Several seconds.	Sawing, scoring, or drilling: a few seconds; Nailing or screwing: 1 to 2 minutes; Wet molding: several minutes (estimated).
daily total	5 to 30 minutes actual cutting (estimated)	1 to 10 minutes total cutting time (estimated)
Fiber releasability:	High	High
Chemical composition	Asbestos content 68-95%; binders include starches, elastomers, silicates.	Same
Physical composition	Millboard: generally inflexible, friable Rollboard: generally semi-rigid, pliable, friable	Same
Disruptive energy	Electric and hydraulic-powered blades for cutting; electric power sawing, grinding, and drilling tools	Same; also hand scoring with knife, hand sawing, hand hammering and screwing, hand molding
Control measure(s):	Baghouses on automated equipment; vacuum exhaust systems on some portable power tools	Vacuum exhaust collection systems on some portable power tools. Field fabricating operations mostly performed uncontrolled.
Measured fiber concentrations (f/cm^3):	Data not readily available, assume workroom concentrations to be less than 2 f/cm^3	Representative data not available.
Environmental setting:	Indoors: open space or closed rooms	Indoors: open and closed rooms, (basements, garages) Outdoors.

Activity of Concern

End use: field fabrication involving power sawing, sanding and drilling operations without the use of dust collection devices. Hand sawing and scoring also.

Secondary Processing--Fabrication

Although some primary manufacturers transform their paper sheet into final product form, most beater-add paper producers usually market their product uncut to secondary processors. Gasket fabricators cut the paper to customer specifications using a metal die in stamping or pressing machinery. Some gaskets are modified by adding wire insert reinforcements or sheathing the paper with metal foils, plastics, or cloth.[16]

The cutting machinery used is automatic or semi-automatic, the latter requiring manual paper sheet feeding. Workers use gloves to facilitate product handling. The actual cutting process in which the die is forced through the gasket paper lasts only about 1 second, compared to up to a minute of product handling time (including separation and packaging).[33] Total accumulated cutting time over an 8-hour workday is estimated to be approximately one hour. Cutting operations are performed indoors in a typical machine shop setting.

Because beater-add paper used to make gasket products is not brittle, but somewhat pliable, the potential for fiber release during die-cutting is expected to be low. Die-cutting using powerful press machines makes a clean edge cut, purposefully preventing unnecessary ripping and tearing of the beater-add paper. In addition, die-cutting is not a vigorous operation, one that would propel dust into the workroom air. Consequently special dust control devices or work practices are not normally employed for the die-cutting operation.[30,33]

End Use Activities

End use activities include installation, in-service use, and gasket removal. Some job site fabrication may be required for special applications. When this occurs, material alteration will be performed using a sharp knife or scissors and require only a few seconds of cutting.

Beater-add gasket installation is very similar to the installation process described for compressed sheet gasket in Section 6. The procedure normally requires placing the precut gasket on one bearing surface and placing the other bearing surface over the gasket carefully to ensure proper alignment. When the gasket is in place between the two surfaces, the joint is sealed by torquing down bolts located at regular intervals along the perimeter of the joint.

In service, the gasket faces are isolated from fluids on either side of the joint by contact with the bearing surfaces. The gasket edge may be exposed on either side of the joint. Again similar to compressed sheet gaskets, the functional life span of a beater-add gasket depends on the severity of wear, chemical conditions of the work environment, and maintenance practices. Since the joint is typically immoveable, material wear is normally not a concern. A common cause for replacement is disassembly of the joint for

routine maintenance. If the gasket is damaged during disassembly or if it is compressed to the point where its sealing capability for future use is in doubt, the gasket will be replaced.

With respect to removal, portions of a beater-add gasket may adhere to a bearing surface if high temperatures or penetration of working fluids alter the elastomeric binder of the gasket matrix. Adhering material will be removed manually using a flat-edged scraping tool or a stiff wire brush. The removal process lasts only several minutes, while the overall maintenance task often requires an hour or more (as in automotive applications). Beater-add paper manufacturers do offer a line of materials covered with an anti-stick film to facilitate gasket release from the bearing surfaces.[29,34]

Abestos fibers are not expected to be released to the air during the installation of properly selected pre-cut gaskets. However, fibers may be released during field fabrication of material requiring alteration to fit special applications. The potential for fiber release will be minimized by the use of hand tools such as scissors and knives. These tools make clean edge cuts, generating only a small quantity of loose particles.

In service, beater-add gaskets are held in stationary positions by two bearing surfaces. Under such conditions no fibers are expected to be released to the air. During removal of the beater-add material, fibers may be released to the air if the gasket has dried out and the force applied to remove the material is excessive and vigorous. Gasket material adhering to bearing surfaces may easily disintegrate during removal if the binders within the material have decomposed or been structural altered with use. Under these conditions the cohesiveness of the beater-add paper matrix has been substantially reduced to the point where fibers can be readily released with only minor disturbance.

Airborne Fiber Monitoring Data

No airborne fiber monitoring data have been reported for beater-add gasket secondary processing or end use activities. Beater-add gasket manufacturers[30,31] and secondary processors[33,35,36] interviewed report that fiber release during fabrication activities is expected to be low due to the relatively high (20 to 40%) percentage of binder in the beater-add paper and the type of machining (die-cutting) performed. Rogers Corporation of Rogers, CT,[31] claims that there are fewer exposed fibers on the surface of beater-add paper than there are on compressed sheet gasket material (see Section 6). Also, die-cutting, which is the most common operation performed during secondary processing, is less likely to produce fiber release than, for example a sawing type of cut, because the material is sheared rather than ripped apart.[33,35]

With respect to gasket end use activities, particularly automotive applications in which beater-add paper is most often used, the gasket is frequently coated with or surrounded by oil or petroleum sealants, or sheathed in metal. These conditions impart a dust suppression effect such that fiber release during installation and removal should be effectively reduced. Fiber

release can be expected, however, during the initial stages of gasket handling when the uncoated material is cut for special applications, and during the removal and cleaning of bearing surfaces of dried out residual gasket material.

Summary of Findings

No monitoring data are available to document airborne asbestos fiber concentrations associated with secondary processing and end use activities performed on beater-add paper gaskets. During beater-add paper fabricating and gasket handling, installation, and use, the potential for fiber release is expected to be low as long as the elastomeric binder in which the asbestos fibers are contained remains undisturbed and functional. Once the binder dries out or is 'cooked out' the potential for fiber release increases during product handling. Fiber release is expected during removal if the material adhering to the supporting surfaces is dried out and sanding or dry scraping is performed. Table 24 summarizes the data presented on beater-add gaskets and identifies the principal activity of concern with respect to asbestos fiber release.

ELECTRICAL INSULATING PAPER

Introduction

Asbestos-containing paper used for electrical insulation is formed on conventional papermaking machines. Electrical insulating paper is produced in rolls, tapes, tubes, and sheets. Asbestos is used in the manufacture of electrical insulating papers because it exhibits excellent thermal and electrical resistance properties. Paper composition varies with intended application, but generally contains chrysotile asbestos and cellulose bound with latex polymers.[1]

Electrical insulating paper manufacturers use automatic slitters (for thin paper) and saws (for thicker materials) to cut the paper to specified product use sizes.[37,38] Most of the paper produced tends to be a composite of asbestos paper laminated with a structural fiber.[39,40] The laminate offers greater strength and rigidity than the asbestos paper alone, and the presence of the backing material and thermosetting resin or adhesive tends to reduce the potential for fiber release during primary finishing and subsequent processing and handling.

Secondary Processing—Fabrication

Asbestos-containing paper used for electrical insulating purposes is fabricated into tapes, spacers or washers, and electrical component boards by the primary manufacturer or secondary processors.[1,39,40] Prior to being fabricated into a final product, electrical insulating paper is cut to required sizes using slitting and die-cutting machinery. Actual cutting time for these two operations will last only seconds per cut, but over the course of a day, accumulate to several minutes or even hours for large volume, well-automated production operations.

TABLE 24. SUMMARY OF BEATER-ADD GASKET SECONDARY PROCESSING AND END USE ACTIVITIES

Product: Beater-add Gaskets	Secondary processing	End use
Activity:	Die-cutting	Installation (involving limited cutting); in service use, removal
Duration--Per incident Daily total	Few seconds Several minutes up to more than one hour (est.) for an 8-hour workday	Installation--several minutes (5-10). In service--days to years depending on application. Removal--15-20 minutes
Fiber releasability:		
Chemical composition	Asbestos content (60-80%), binder content (20 to 40%).	Same
Physical composition	Pliable material	Same, with possible coating of petroleum-based compounds collected during in-service use
Disruptive energy (tools)	Shear cutting with press machinery	Hand operated tools, scissors
Control measure(s):	None reported	Possibly wetting during removal, otherwise none
Measured fiber concentrations (f/cm^3):	No data reported, assume workroom airborne asbestos concentrations to be less than 2 f/cm^3.	No data reported
Environmental setting:	Indoors, open room, machine shop conditions	Indoors, in open room or outdoors

Activity of Concern

Removal of wornout, dry, brittle material adhering to joint surface by sanding or dry scraping. Also, field cutting of uncoated gasket material prior to installation.

Product fabrication using the insulating paper includes, for example, tape winding and electrical component board assembling. Asbestos insulating tape is wound over wires and wire windings (e.g., transformer coils) to provide a heat resistant covering.[37,40] This process is normally performed by machines, but may be done by hand for special applications. In cable manufacture, the asbestos tape winding is covered with a plastic or rubber sheath to provide waterproofing and abrasion resistance. Board assembling activities include attaching electrical components using screws and adhesives, and installing the board itself in an appliance or fixture.[39]

All of the secondary processing activities occur in typical factory environments. Depending on production demand, processing of the electrical insulation paper and its intermediates will run from a few hours per day up to full time production.

The potential for fiber release during slitting and die-cutting is expected to be low. Both of these operations result in clean edge cuts that generate small amounts of loose particles. When an asbestos-containing laminate is fabricated, the slitter operation is controlled by vacuum hooding that vents to a fabric filter for dust collection. Spacers and washers are die-cut from asbestos papers and laminates. Board mounting details required to carry electrical components in small appliances may be die-cut from heavy papers or laminates. It could not be positively determined whether these die-cutting operations employ dust control equipment, though a representative of the Facile-Division of the Sun Chemical Corporation of Patterson, N.J.[40] indicated that some type of controls are used.

The potential for fiber release during the processing of insulating paper into electrical components is expected to be low considering that a majority of paper is laminated with a structural fiber. The addition of the structural fiber will increase the cohesiveness of the paper making it less susceptible to tearing or cracking during processing. Fiber release from insulating paper that has not been strengthen may occur when it is wound around wires or cables. Bending of the paper, causing internal tearing can result in cracks that could release fibers.

End Use Activities

There are essentially no end use activities performed on electrical insulating paper that would cause the release of asbestos fibers to the air. Asbestos-containing electrical insulating paper is incorporated into products that require very little handling or manipulation during end use. Many of these products are used in stationary applications. Under such conditions, there is no physical disturbance to the paper that would cause the release of asbestos fibers.

Only when the electrical component is damaged or needs repair is there a potential for fiber release. The following conditions provide reasons why only a minimal amount of or no fiber release is expected from the use of eletrical cables, transformers, electrical appliances, and other products that contain asbestos insulating paper:

1. The paper products are typically isolated behind covers to provide structural protection.

2. The electrical components containing the paper tend to be fragile; breakage or abrasion of the attached paper product is not encouraged in normal use.

3. If minor structural or electrical failure occurs, repair, for example of a wire or cable, would involve exposing only a small amount of the insulation. The repair of a wire or cable containing asbestos paper is similar to the repair of a wire or cable containing asbestos textile tape (see Section 5 for discussion).

4. If major structural or electrical failure occurs, the whole electrical component or device is usually replaced rather than repaired.

5. Electric appliances with repairable components are typically designed for easy removal of these components without damage to insulating washers or boards.

Airborne Fiber Monitoring Data

Quin-T Corporation of Tilton, N.H.,[37] a manufacturer of asbestos electrical insulating paper products, has conducted fiber monitoring studies at a number of their own as well as other plants which fabricate electrical insulating paper products. Relevant results from these studies are presented in Table 25. It is not known whether dust control equipment or special work practices were instituted during monitoring of these activities. The operations monitored, including cutting mounting board, die-cutting, tape winding, board assembly, and packaging and shipping, were found to generate workplace fiber concentrations of less than 0.1 f/cm^3. Paper slitting appears to present the greatest potential for airborne fiber release, with fiber concentrations of 0.53 f/cm^3 measured in the vicinity of this process.

One other concentration recorded by Quin-T that may have significance, but is not presented in Table 25, concerns a concentration of 12.3 f/cm^3 measured during the use of a band saw machine.[37] This datum is not presented because a description of the type of material being cut was not provided and the sawing equipment used is not typically employed for product fabrication.

Summary of Findings

The end use applications of asbestos-containing electrical insulating paper are confined to the applications of the products manufactured by secondary processors. There are virtually no product applications that require field fabrication or even removal of the asbestos-containing insulating paper itself. Fabrication by secondary processors generally results in fiber concentrations of less than 0.1 f/cm^3 in the workplace

TABLE 25. AIRBORNE FIBER CONCENTRATIONS RESULTING FROM ASBESTOS ELECTRICAL INSULATING PAPER AND BOARD FABRICATION AND INSTALLATION PROCESSES.[37]

Activity performed	Measured fiber[a] concentration (f/cm^3)	Date of tests	Duration of activity (min)
Slitting paper	0.53	7-12-78	42
	0.14	7-10-78	120
	0.031	NR	90
	< 0.033	6-01-80	21
	< 0.008	NR	90
Cutting electrical mounting board	<0.005	NR	141
Die-cutting board	0.097	NR	298
Packaging & shipping	<0.028	6-01-80	25
	<0.009	NR	156
Tape winding	0.075	NR	74
	0.038	7-10-78	180
	< 0.008	NR	90
	0.008	NR	90
	<0.007	11-14-79	103
	<0.006	12-17-79	108
Board assembling .	0.008	NR	165

[a]As determined by phase contrast microscopy.

NR - No Reported.

environment. The manufacture and fabrication of these products appears to be limited to a handful of companies, and usage has declined dramatically since the promulgation of standards identifying the health concerns associated with asbestos exposure. Table 26 summarizes the secondary processing and end use activities performed on electrical insulating paper and identifies the principal activity of concern with respect to airborne asbestos fiber release.

TABLE 26. SUMMARY OF ELECTRICAL INSULATING PAPER SECONDARY PROCESSING AND END USE ACTIVITIES

Product: Electrical insulating paper	Secondary processing	End use
Activity:	Slitting; die-cutting; sawing; assembling or winding	Installation; in-service use; removal
Duration—per incident	Slitting—intermittent to continuous for automated operations Die-cutting—less than 1 second Assembling—seconds up to minutes Winding—continuous	Installation—(no direct handling of asbestos paper) In service—months to years, depending on application Removal—less than one hour (est.) for electrical component
daily total	Slitting—total production time (up to 8-hour shift) Die-cutting—several minutes up to hours depending production volume Assembling—several hours Winding—total production time (up to 8 hour shift)	
Fiber releasability: Chemical composition	Moderate Asbestos fibers and cellulose with latex binder	Low Same, but laminates have epoxy coatings
Physical composition	Ranging from fairly stiff to pliable	Same, but laminates are less pliable
Disruptive energy	Die-cutting press, sawing, slitter machine, screw fastening	Screw fastening (installation)
Control measure(s):	Vacuum exhaust to fabric filter control device on slitting and sawing machinery	None
Measured fiber concentrations (f/cm^3):	Slitting—0.01 to 0.53 Die-cutting—0.01 to 0.10 Assembling—0.01 Winding—0.01 to 0.08	No data reported
Environmental setting:	Indoors, open workroom of factory	Indoors or outdoors, closed room or open air space.

Activity of Concern

Secondary processing, tape slitting operation.

ASBESTOS PAPER PRODUCTS
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SECTION 8

CONCLUSION AND RECOMMENDATIONS

CONCLUSION

This study was conducted to profile secondary processing and end use activities routinely performed on certain asbestos-containing products and to provide an analysis of the potential for asbestos fiber release during the performance of such activities. Product category profiles presented were developed to provide information necessary to identify candidate products to be tested under future monitoring programs sponsored by EPA. Products to be tested are those for which airborne asbestos fiber monitoring data are insufficient or nonexistent.

Fiber concentration data presented were obtained from technical reports, trade journals, and interviews with government agencies and industry representatives. Table 27 lists each product category investigated and presents all monitoring data compiled for the products. Table 28 summarizes, by asbestos product type, the number of monitoring studies cited in this report. Many of the studies have been performed on products that are suspected to release high fiber concentrations based on their chemical and physical composition and how they are acted upon, or on products having widespread use.

The quantity and quality of the monitoring data presented vary greatly between product categories and products within each category. Measured fiber concentrations also vary among tests performed on similar products. These latter variances are attributable to monitoring in a laboratory glove box versus monitoring in a well-ventilated room or out of doors; employing dust control measures during some tests but not during others; differences in sampling location and analytical techniques; and differences in product composition. Consequently, meaningful comparative analysis of the test results is restricted.

Based on the data compiled, a combination of the following three factors will affect fiber release from asbestos-containing products: chemical composition (asbestos and binder content), physical composition (structural integrity), and intensity of mechanical disruption applied during handling (field fabrication, installation, and removal). Dispersal of dust generated during product handling depends on the magnitude of the propellant force created by the tools or method of operation used. Actual fiber release to the ambient air, however, is governed by the presence or absence of control equipment or recommended work practices and their effectiveness in minimizing fiber release at the point of contact during mechanical disruption.

TABLE 27. MEASURED AIRBORNE FIBER CONCENTRATIONS RESULTING FROM SECONDARY PROCESSING AND END USE PRODUCT TESTING ACTIVITIES

Asbestos product category	Asbestos product	Activity performed	Measured fiber concentration (f/cm^3)	Date of tests	Duration of activity/ sampling time (min)	Analytical method	Comments	Ref.
Asbestos-cement sheet	Flat sheet	Drill	2.3 (2.3)	1981	5	NIOSH Method[a] (SEM/EDXR)[b]	Testing performed in glove box. Only fibers ≥5 μm in length counted, even when analyzed using SEM.	1
		Score	3.2 (1.1)	1981	4	NIOSH Method (SEM/EDXR)	Testing performed in glove box. Only fibers ≥5 μm in length counted, even when analyzed using SEM.	1
		Hammer	6.4-12.7 (10.2-16.5)	1981	4.1	NIOSH Method (SEM/EDXR)	Based on two repetitions in glove box. Only fibers ≥5 μm in length counted, even when analyzed using SEM.	1
		Saw	195.8 (258.8)	1981	1	NIOSH Method (SEM/EDXR)	Testing performed in glove box. Only fibers ≥5 μm in length counted, even when analyzed using SEM.	1
	0.64 cm (0.25 in.) thick flat sheet	Drilling holes (163)	0.1	1979-1980	40	Phase contrast (assumed)	Drill was equipped with dust pickup shroud.	2
		Sawing (18.3 meters)	0.0	1979-1980	40	Phase contrast (assumed)	Saw was equipped with dust pickup shroud that totally enclosed masonry blade.	2
	Asbestos-cement board (flat sheet)	Sawing with a circular saw (carbide blade)	0.04	1979	12	Phase contrast	Saw was equipped with dust pickup shroud that vented to a Nilfisk HEPA filtered vacuum cleaner.	3
		Sawing, drilling, and scrolling (sabre saw)	0.15	1979	17	Phase contrast	Power tools were equipped with dust pickup shrouds that vented to a Nilfisk HEPA filtered vacuum cleaner.	3

(continued)

TABLE 27 (continued)

Asbestos product category	Asbestos product	Activity performed	Measured fiber concentration (f/cm³)	Date of tests	Duration of activity/ sampling time (min)	Analytical method	Comments	Ref.
Asbestos-cement sheet (continued)	Corrugated sheet	Grinding to cut stack of sheeting in open air Grinding to cut sheeting while on roof	0.6 to 41	1980	ND	Phase contrast	Testing performed outdoors on job site. Assumed no dust controls used.	4
Flooring products (excluding flooring felts which are covered under paper)	Vinyl-asbestos floor tile	Cut	0	1981	5	NIOSH Method	Testing performed in glove box.	1
		Grind	0 (0.5)	1981	3	NIOSH Method (SEM/EDXR)	Testing performed in glove box. Only fibers ≥5 µm in length counted, even when analyzed using SEM.	1
		Break	0	1981	3	NIOSH Method	Testing performed in glove box.	1
		Drill	0	1981	1	NIOSH Method	Testing performed in glove box.	1
		Flooring removal, ripping up tiles	0.02-0.1	1980	165	SEM/EDXR	Monitoring performed during actual flooring removal. Results are more indicative of levels nearby the workplace than those actually experienced by the worker.	5
		Flooring removal by sanding rough surfaces remaining	1.2-1.3	1970-1971	29	Phase contrast	Simulated testing in laboratory chamber 3x3.7x2.1 meters with four air changes/hr. Belt sander with coarse paper used.	6
		Pedestrian traffic on floor tile	0.002 to 0.062	1979	130 to 419	Phase contrast	Monitoring occurred in an office setting; the areas examined were a photocopying room and a snack shop.	7

(continued)

TABLE 27 (continued)

Asbestos product category	Asbestos product	Activity performed	Measured fiber concentration (f/cm^3)	Date of tests	Duration of activity/ sampling time (min)	Analytical method	Comments	Ref.
Flooring products (continued)	Vinyl-asbestos floor tile	Floor covering maintenance; Mopping	0.135 to 0.195	1979	15 to 21	Phase contrast	Activity was performed on floor tiles located in photocopying room and snack shop.	7
		Buffing	0.00 to 0.092	1979	11 to 30	Phase contrast	Activity was performed on floor tiles located in photocopying room and snack shop.	7
		Complete removal by recommended procedures[c]	0.062 to 0.147	1979	123 to 134	Phase contrast	Testing was performed in laundry room, powder room, closet, and hallway of a private home.	7
		Installation by recommended procedures	0.081 to 0.267	1979	220 to 232	Phase contrast	Tiles, precoated with adhesive, were installed in laundry room, powder room, closet, and hallway of a private home.	7
		Installation by recommended procedures	0.092 to 0.184	1979	113 to 114	Phase contrast	Testing was performed in basement and small utility room of private home.	7
		Old tile preparation for new installation	0.0	1979	10	Phase contrast	Preparation include stripping and dry mopping of old tile surface.	8
		Complete removal by a method that deviates from recommended procedures	0.153 to 0.583	1979	80	Phase contrast	Dry scraping and sweeping occurred during removal.	8
		Installation by recommended procedures	0.048 to 0.189	1979	65	Phase contrast	Self-adhering tiles were installed following standard work procedures. Authors postulate that fiber levels recorded resulted from fiber release during preceding removal operation.	8

(continued)

TABLE 27 (continued)

Asbestos product category	Asbestos product	Activity performed	Measured fiber concentration (f/cm^3)	Date of tests	Duration of activity/ sampling time (min)	Analytical method	Comments	Ref.
Flooring products (continued)	Vinyl-asbestos floor tile	Normal building traffic	8 to 170[d] (ng/m^3)	1980	NR	Transmission electron microscopy (TEM)	Sampling occured at four sites in office building containing 5,400 m^2 of vinyl-asbestos (chyrostile) floor tile. No asbestos fibers >3 μm in length were observed.	9
	Sheet vinyl flooring backed with asbestos flooring felt	Installation	0.0 to 1.02	1978-1979	44 to 179	Phase contrast	Installation covered four adhering and one nonadhering applications.	11
		Partial removal by recommended procedures[e]	0.190 to 0.408	1979	44 to 62	Phase contrast	Material removed had been adhered to subflooring.	11
		Complete removal by recommended procedures	0.368 to 0.402	1979	121 to 123	Phase contrast	Material removed had been adhered to subflooring.	11
		Complete removal by recommended procedures	0.069 to 0.100	1979	74 to 76	Phase contrast	Material removed had not been adhered to subflooring.	11
		Complete removal	0.084 to 0.218	1979	70 to 75	Phase contrast	Material removed had been adhered to subflooring.	12
		Wear layer removal						
		Dry scraping of flooring felt	1.00 to 2.17	1979	40 to 63	Phase contrast	Material removed had been adhered to subflooring.	12
		Wet scraping of flooring felt	0.484	1979	55	Phase contrast	Material removed had been adhered to subflooring.	12
Coatings and sealants	Spray-applied asphaltic roof coatings							
	Cutback asphalt	Spraying	0.003 to 0.15	1974	342 to 432	Phase contrast (assumed)	Percent weight of asbestos as sprayed ranged from 5.8 to 7.7, after curing 9.7 to 12.8 percent asbestos.	11

(continued)

TABLE 27 (continued)

Asbestos product category	Asbestos product	Activity performed	Measured fiber concentration (f/cm³)	Date of tests	Duration of activity/ sampling time (min)	Analytical method	Comments	Ref.
Coatings and sealants (continued)	Asphalt-emulsion	Spraying	0.01 to 0.3	1974,1976	NR	Phase contrast (assumed)	Percent weight of asbestos as sprayed was 2.8, after curing 5.1 percent asbestos.	13
	Built-up roofing	Tear-off	0.1 to 0.4	1976	NR	Phase contrast (assumed)	Monitoring performed in Indiana.	13
		Tear-off and replace (spray)	0.0 to 0.3	1974,1976	NR	Phase contrast (assumed)	Monitoring performed in Pennsylvania and Indiana.	13
		New application (spray)	0.0 to 0.6	1974,1975, 1976	NR	Phase contrast (assumed)	Monitoring performed in Wisconsin, Colorado, and Indiana.	13
	Resin coatings	Ship coating by spray application	0.2	1974	8 to 33	Phase contrast (assumed)	Operator spraying outside and under a ship with asbestos-containing epoxy resin. Percent asbestos as sprayed 1.5.	13
		Dry dock coating by spray applications	0.0 to 0.2	1974	11 to 38	Phase contrast (assumed)	Operator spraying dock with an asbestos-containing epoxy and coal tar mixture. One percent asbestos as sprayed.	13
		Coating pipe interiors - spray application	0.1	1974	37	Phase contrast (assumed)	Operator spraying interior of 7.6, 15, and 30 cm diameter pipes with an asbestos-containing (1 percent) epoxy and coal tar mixture.	13
		Fiber glass pipe MFG (mandrel coating)	0.1 to 0.4	1974	14 to 23	Phase contrast (assumed)	Operators monitored were involved in running automatic spray machine and wiping mandrel. A 1.4 percent asbestos chemical resistant resin was spray-applied.	13

(continued)

TABLE 27 (continued)

Asbestos product category	Asbestos product	Activity performed	Measured fiber concentration (f/cm^3)	Date of tests	Duration of activity/ sampling time (min)	Analytical method	Comments	Ref.
Coatings and sealants (continued)	Resin coatings	Ship coating below waterline (spray application)	0.0 to 0.4	1974	23 to 65	Phase contrast (assumed)	Chemical resistant resin containing 0.7 percent asbestos applied.	13
		Painting building exterior (commercial)	0.0 to 0.06	1974,1977	5 to 16	Phase contrast (assumed)	Alkyd resin containing 6 percent asbestos or vinyl-acrylic latex containing 0.6 percent asbestos applied.	13
		Painting building interior (commercial)	0.03 to 0.06	1977	23	Phase contrast (assumed)	Vinyl-acrylic latex containing 0.6 percent asbestos applied.	13
		Wall and roof spraying	0.0 to 0.2	1974	12 to 15	Phase contrast (assumed)	Operator spraying 2.8 to 3.7 percent asbestos vinyl latex on vertical wall panel.	13
		Roof spraying	0.0	1974	14 to 28	Phase contrast (assumed)	Operator spraying 0.7 percent asbestos acrylic latex.	13
		Boat MFG - spraying surface coatings	0.0 to 0.6	1972,1974, 1975	4 to 55	Phase contrast (assumed)	Operator spraying 0.5 percent asbestos general purpose polyester resin.	13
		Sawing pipe coated with polyester resin	0.04 to 0.1	1973	19 to 49	Phase contrast (assumed)	Operator sawing reinforced fiber glass pipe coated with polyester resin containing 2 to 3 percent asbestos.	13
		Handsanding interior building panels	0.0 to 0.3	1977	11 to 16	Phase contrast (assumed)	Operator handsanding panel surfaces covered with vinyl latex paint containing 1.1 percent asbestos.	13

(continued)

TABLE 27 (continued)

Asbestos product category	Asbestos product	Activity performed	Measured fiber concentration (f/cm³)	Date of tests	Duration of activity/ sampling time (min)	Analytical method	Comments	Ref.
Coatings and sealants (continued)	Resin coatings	Sand blasting high performance exterior coating	0.2 to 0.3	1978	5 to 27	Phase contrast (assumed)	Operators sandblasted 12 meter diameter by 7.6 meter high steel tank spray coated in 1973 with a 2.1 percent asbestos resin coating.	13
	Water soluble gypsum-based drywall compound (Study A)	Application	0.4 to 1.3	1978	39 to 65	Phase contrast	Commercial operation.	14
		Mixing (dry powder)	9.0 to 12.4	1975-1977	10 to 12	Phase contrast	Residential setting.	14
		Mixing (pre-mix)	1.2 to 3.2	1978	4 to 5	Phase contrast	Commercial operation.	14
		Hand sanding	2.1 to 24.2	1975-1977	10 to 80	Phase contrast	Residential setting.	14
		Pole sanding	1.2 to 10.1	1975-1977	10 to 38	Phase contrast	Residential setting.	14
		Pole sanding	1.2 to 10.0	1978	4 to 21	Phase contrast	Commercial operation.	14
		Sweeping	4.0 to 26.5	1975-1977	9 to 30	Phase contrast	Residential setting.	14
		Sweeping	14.5 to 25.4	1978	10 to 20	Phase contrast	Commercial operation.	14
	Water soluble gypsum-based drywall compound (Study B)	Dry mixing (0.9 to 1.5 m)	35.4 to 59.0	1974	NR	Phase contrast	Commercial operation. Fiber range reported is not less background levels, which for the same room ranged from 0.5 to 13.1 f/cm³.	15
		Hand sanding (0.9 to 1.5 m)	1.3 to 16.9	1974	NR	Phase contrast	Commercial operation. Fiber range reported is not less background levels, which for the same room ranged from 2.1 to 2.5 f/cm³.	15

(continued)

TABLE 27 (continued)

Asbestos product category	Asbestos product	Activity performed	Measured fiber concentration (f/cm^3)	Date of tests	Duration of activity/ sampling time (min)	Analytical method	Comments	Ref.
Coatings and sealants (continued)	Water soluble gypsum-based drywall compound (Study B)	Pole sanding (0.9 to 1.5 m)	1.2 to 19.3	1974	NR	Phase contrast	Commercial operation. Fiber range reported is not less background levels, which for the same room ranged from 3.5 to 19.8 f/cm^3.	15
		Sweeping floor (3.0 to 15 m)	41.4 (mean)	1974	NR	Phase contrast	Due to heavy loading during sweeping, sampling occurred 15 minutes after sweeping stopped. After 35 minutes, the measured fiber level was 26.4 f/cm^3.	15
Textiles	Asbestos cloth made by wet-processing technique	Secondary processing of cloth	0.46, 0.90	1972	NR	Phase contrast microscopy analysis	Values reported are for an area and personal sample, respectively. Specifics about activities performed not reported	16
	Asbestos cloth made by wet-processing technique	Unrolling, measuring, cutting with scissors and folding of cloth	0.33, 0.68	1972	NR	Phase contrast microscopy analysis	Values reported are for an area and personal sample, respectively.	16
	Fireproof clothing	Wearing asbestos fireproofing clothing: (untreated material)						
		Steel mill-Blast furnace workers	0.3-5.0 (TWA 0.1 to 1.1)	1975	52 (average)	Phase contrast	Actual sampling in plant.	17
		Phosphorus plant-Reduction furnace	9.9-26.2 (TWA 4.7)	1975	35 (average)	Phase contrast	Actual sampling in plant.	17

(continued)

TABLE 27 (continued)

Asbestos product category	Asbestos product	Activity performed	Measured fiber concentration (f/cm^3)	Date of tests	Duration of activity/ sampling time (min)	Analytical method	Comments	Ref.
Textiles (continued)	Firefighting helmets:							
	New helmet with unlined asbestos cloth cover	Naval firefighting personnel wearing helmets	2.3	1971	22.4	Phase contrast		18
	Old helmet with unlined asbestos cloth cover	Naval firefighting personnel wearing helmets	1.38	1971	20.6	Phase contrast		18
	Helmet with aluminized asbestos cover	Naval firefighting personnel wearing helmets	0	1971	20.5	Phase contrast		18
	Asbestos gloves	Putting on, handling hot tray, taking off	0.95 to 7.97	1981	<10	NIOSH Method	Range of fiber levels monitored in ventless isolation chamber (glove box).	19
		Putting on, handling hot tray, taking off	0.07 to 0.99	1981	10	NIOSH Method	Range of fiber levels monitored in well ventilated biology preparation room. Range encompasses breathing zone and work area.	19
		Using gloves in laboratory	0.04 to 2.93	1981	10	NIOSH Method	Range of fiber levels monitored during normal use in university laboratories. Range encompasses breathing zone and work area.	19
	Untreated lagging cloth	Hand cutting	0.01 to 0.05	NR	NR	Phase contrast microscopy (assumed)	Specifics about monitoring not provided.	20
		Application/installation	0.00 to 0.04	NR	NR	Phase contrast microscopy (assumed)	Specifics about monitoring not provided.	20
Gaskets and packings	Compressed asbestos sheet gaskets	Storage for receipt and issue	<0.01 to 0.05	1978	60 to 132	Phase contrast	Housekeeping[f] performed, monitoring conducted under actual work conditions.	21

(continued)

TABLE 27 (continued)

Asbestos product category	Asbestos product	Activity performed	Measured fiber concentration (f/cm^3)	Date of tests	Duration of activity/ sampling time (min)	Analytical method	Comments	Ref.
Gaskets and packings (continued)	Compressed asbestos sheet gaskets	Storage for use	<0.01 to 0.12	1978	97 to 122	Phase contrast	No control.[g] Monitoring conducted under actual work conditions.	21
		Hand punching	3.00	1978	NR	Phase contrast	No control. Monitoring conducted under actual work conditions.	21
		Hand punching	<0.05 to 0.15	1978	28 to 31	Phase contrast	Housekeeping. Monitoring conducted under actual work conditions.	21
		Hand operated mechanical punching	<0.05	1978	30	Phase contrast	No control. Monitoring conducted under actual work conditions.	21
		Machine punching	5.0	1978	NR	Phase contrast	No control. Monitoring conducted under actual work conditions.	21
		Machine punching	<0.03 to 0.7	1978	20 to 30	Phase contrast	Housekeeping. Monitoring conducted under actual work conditions.	21
		Machine punching	<0.05 to 0.06	1978	23 to 31	Phase contrast	Housekeeping and ventilation.[h] Monitoring conducted under actual work conditions.	21
		Hand shaping	<0.03 to 0.3	1978	7 to 31	Phase contrast	No control. Monitoring conducted under actual work conditions.	21
		Machine shearing	0.5 to 1.3	1978	6	Phase contrast	No control. Monitoring conducted under actual work conditions.	21
		Machine shearing	0.05 to 0.15	1978	31 to 38	Phase contrast	Housekeeping. Monitoring conducted under actual work conditions.	21

(continued)

TABLE 27 (continued)

Asbestos product category	Asbestos product	Activity performed	Measured fiber concentration (f/cm^3)	Date of tests	Duration of activity/ sampling time (min)	Analytical method	Comments	Ref.
Gaskets and packings (continued)	Compressed asbestos sheet gaskets	Machine nibbling	<0.08 to 0.46	1978	8	Phase contrast	No control. Monitoring conducted under actual work conditions.	21
		Machine nibbling	0.08 to 0.8	1978	24 to 31	Phase contrast	Housekeeping. Monitoring conducted under actual work conditions.	21
		Installation of flange gasket	<0.03	1978	30	Phase contrast	No control. Monitoring conducted under actual work conditions.	21
		Removal and concurrent installation (boiler header gaskets)	0.02 to 0.3	1978	21 to 95	Phase contrast	Housekeeping. Monitoring conducted under actual work conditions.	21
		Clean-up following removal by hand scraping	<0.05	1978	33 to 37	Phase contrast	No control. Monitoring conducted under actual work conditions.	21
		Removal and hand scraping	<0.06 to 0.39	1978	15 to 28	Phase contrast	No control. Monitoring conducted under actual work conditions.	21
		Removal and wire brushing	<0.03 to 0.18	1978	25 to 33	Phase contrast	Housekeeping. Monitoring conducted under actual work conditions.	21
	Compressed asbestos sheet gaskets	Punch press operation	0.04 to 0.67	1980	80 to 211	Fibers were counted by phase contrast with PLM[1] verification	Monitoring performed at major gasket fabricator located in Wisconsin.	22
		Power shear operation	0.17	1980	188	Fibers were counted by phase contrast with PLM verification	Monitoring performed at major gasket fabricator located in Wisconsin.	22

(continued)

TABLE 27 (continued)

Asbestos product category	Asbestos product	Activity performed	Measured fiber concentration (f/cm^3)	Date of tests	Duration of activity/ sampling time (min)	Analytical method	Comments	Ref.
Gaskets and packings (continued)	Compressed asbestos sheet gaskets	Shear press operation	0.23 to 0.81	1980	50 to 76	Fibers were counted by phase contrast with PLM verification	Monitoring performed at major gasket fabricator located in Wisconsin.	22
		Roussel press	0.04 to 0.08	1980	100 to 192	Fibers were counted by phase contrast with PLM verification	Monitoring performed at major gasket fabricator located in Wisconsin.	22
		Picking operation	0.10 to 0.31	1980	93 to 206	Fibers were counted by phase contrast with PLM verification	Monitoring performed at major gasket fabricator located in Wisconsin.	22
		Tumbling operation	0.42 to 0.60	1980	77 to 141	Fibers were counted by phase contrast with PLM verification	Monitoring performed at major gasket fabricator located in Wisconsin.	22
		Materials handling	0.11 to 0.34	1980	91 to 216	Fibers were counted by phase contrast with PLM verification	Monitoring performed at major gasket fabricator located in Wisconsin.	22
		Platen press operation	0.05 to 0.29	1980	52 to 256	Fibers were counted by phase contrast with PLM verification	Monitoring performed at major gasket fabricator located in Wisconsin.	22
	Compressed asbestos sheet gaskets	Platen press operation	0.03 to 0.15	1980	63 to 238	Phase contrast	Monitoring performed at an asbestos-using gasket operation in Wisconsin.	23
		Hydraulic beam press	0.02 to 0.05	1980	61 to 178	Phase contrast	Monitoring performed at an asbestos-using gasket operation in Wisconsin.	23

(continued)

TABLE 27 (continued)

Asbestos product category	Asbestos product	Activity performed	Measured fiber concentration (f/cm³)	Date of tests	Duration of activity/ sampling time (min)	Analytical method	Comments	Ref.
Gaskets and packings (continued)	Compressed asbestos sheet gaskets	Hand picking and packaging	0.06 to 0.20	1980	45 to 176	Phase contrast	Monitoring performed at an asbestos-using gasket operation in Wisconsin.	23
		Platen press picking operator	0.09 to 0.12	1980	67 to 140	Phase contrast	Monitoring performed at an asbestos-using gasket operation in Wisconsin.	23
		Reeves punch press operator	0.12	1980	124	Phase contrast	Monitoring performed at an asbestos-using gasket operation in Wisconsin	23
	Packing - mechanical packings for pumps	Simulated field installation	<0.1 to 0.1	1979	NR	Phase contrast (assumed)	Simulated activity was performed in open building and involved unrolling, wrapping, cutting, flattening with a hammer and pushing the material into a pump.	24
		Simulated removal of packing from pump	<0.1 to 0.1	1979	NR	Phase contrast (assumed)	Simulated removal occurred in open building, details of removal not reported.	24
	Gaskets and packings (in general)	Cutting/packaging	0.1 to 0.5 (TWA)	NR	NR	Phase contrast (assumed)	General fiber ranges are reported, specifics about the activities monitored not available from reference.	25
Asbestos paper	Roofing felt	Sawing, scraping, sweeping old roof material. Cutting and laying new felts	0.00 to 0.05	1979	135	SEM/EDXR	Fiber concentration range includes area and personal samples taken during roof removal and felt installation.	5

(continued)

TABLE 27 (continued)

Asbestos product category	Asbestos product	Activity performed	Measured fiber concentration (f/cm^3)	Date of tests	Duration of activity/ sampling time (min)	Analytical method	Comments	Ref.
Asbestos paper (continued)	Roofing felt	Cutting and laying felts	0.0	1976	ND	Phase contrast	Fiber concentration of 0.0 f/cm^3 reported for 3 area and 2 personal samples taken during felt installation.	26
		Cutting, scraping, sweeping old roof material. Cutting and laying new felts	0.0	1976	ND	Phase contrast	Fiber concentration of 0.0 f/cm^3 reported for 6 area and 4 personal samples taken during roof removal and felt installation.	26
		Cutting and laying felts	<0.1	1975	180	Phase contrast	Area and personal samples taken during felt installation.	26
		Cutting and laying felts	0.1 to 0.2	1974	180	Phase contrast	Fiber concentration range includes area and personal samples taken during felt installation.	26
		Sawing, scraping, sweeping old roof material. Cutting and laying new felts	0.1 to 0.3	1974	75-120	Phase contrast	Fiber concentration range includes area and personal samples taken during roof removal and felt installation.	26
		Sawing, scraping, sweeping old roof material. Cutting and laying new felts	0.0 to 0.2	1974	ND	Phase contrast	Fiber concentration range includes area and personal samples taken during roof removal and felt installation.	26
		Axe chopping, prying and scraping, sweeping old roof	0.1 to 0.4	1974	60-82	Phase contrast	Fiber concentration range includes area and personal samples taken during roof removal.	26

(continued)

TABLE 27 (continued)

Asbestos product category	Asbestos product	Activity performed	Measured fiber concentration (f/cm^3)	Date of tests	Duration of activity/ sampling time (min)	Analytical method	Comments	Ref.
Asbestos paper (continued)	Roofing felt	Cutting and laying felt	0.2 to 0.6	1974	83-107	Phase contrast	Fiber concentration range includes area and personal samples taken during felt installation.	26
		Cutting and laying felt	0.1 to 0.4	1973	ND	Phase contrast	Fiber concentration range includes area and personal samples taken during felt installation.	26
		Cutting and laying felt	0.1 to 0.3	1972	ND	Phase contrast	Fiber concentration range includes area and personal samples taken during felt installation.	26
	Millboard	Score	8.4	1980	10	SEM/EDXR	Testing performed in glove box.	5
		Hammer	1.4	1980	10	SEM/EDXR	Testing performed in glove box.	5
		Saw	6.2	1980	10	SEM/EDXR	Testing performed in glove box.	5
		Secondary processing	0.2	NR	NR	Phase contrast assumed	Assembly involving placement of punched millboard rings on steel mandrels to form transfer rollers.	27
	Electrical insulating paper and boards	Sterling magna ply package operator	<0.016	1980	43	Phase contrast	Results from monitoring electrical insulating paper products manufactured by Quin-T Corporation.	28
		Paper machine rewind operator, 0.008 cm thick paper	<0.004	1980	178	Phase contrast	Results from monitoring electrical insulating paper products manufactured by Quin-T Corporation.	28

(continued)

TABLE 27 (continued)

Asbestos product category	Asbestos product	Activity performed	Measured fiber concentration (f/cm³)	Date of tests	Duration of activity/ sampling time (min)	Analytical method	Comments	Ref.
Asbestos paper (continued)	Electrical insulating paper and boards	Paper machine rewind operator, 0.04 cm thick paper	<0.006	1980	112	Phase contrast	Results from monitoring electrical insulating paper products manufactured by Quin-T Corporation.	28
		Millboard cutter operator 0.08 cm thick paper	<0.005	1980	141	Phase contrast	Results from monitoring electrical insulating paper products manufactured by Quin-T Corporation.	28
		Winding operator, 0.03 cm thick paper	<0.008	1980	90	Phase contrast	Results from monitoring electrical insulating paper products manufactured by Quin-T Corporation.	28
		Slitting operator, 0.03 cm thick paper	<0.008	1980	90	Phase contrast	Results from monitoring electrical insulating paper products manufactured by Quin-T Corporation.	28
		Highlander, band saw operator	12.3	1978	30	Phase contrast	Reference cites release as excessive.	28
		Highlander, slitter operator	0.53	1978	42	Phase contrast	Results from monitoring electrical insulating paper products manufactured by Quin-T Corporation.	28
		Coil cutter operator	0.094	ND	118	Phase contrast	Results from monitoring electrical insulating paper products manufactured by Quin-T Corporation.	28

(continued)

TABLE 27 (continued)

Asbestos product category	Asbestos product	Activity performed	Measured fiber concentration (f/cm^3)	Date of tests	Duration of activity/ sampling time (min)	Analytical method	Comments	Ref.
Asbestos paper (continued)	Electrical insulating paper and boards	Coil cutter operator	0.015	ND	94	Phase contrast	Results from monitoring electrical insulating paper products manufactured by Quin-T Corporation.	28
		Acme paper cutter	<0.008	1979	91	Phase contrast	Results from monitoring electrical insulating paper products manufactured by Quin-T Corporation.	28
		Acme coil cutter	<0.013	1979	53	Phase contrast	Results from monitoring electrical insulating paper products manufactured by Quin-T Corporation.	28
		Acme conv. winding	<0.008	1979	87	Phase contrast	Results from monitoring electrical insulating paper products manufactured by Quin-T Corporation.	28
		Winding operator, 0.008 cm thick paper	<0.008	1980	90	Phase contrast	Results from monitoring electrical insulating paper products manufactured by Quin-T Corporation.	28
		Slitting operator, 0.008 cm thick paper	0.031	1980	90	Phase contrast	Results from monitoring electrical insulating paper products manufactured by Quin-T Corporation.	28

(continued)

TABLE 27 (continued)

Asbestos product category	Asbestos product	Activity performed	Measured fiber concentration (f/cm³)	Date of tests	Duration of activity/ sampling time (min)	Analytical method	Comments	Ref.
Asbestos paper (continued)	Electrical insulating paper and boards	Electrical insulating paper—punch press operator (TV BOARD)	0.097	ND	298	Phase contrast	Results from monitoring electrical insulating paper products manufactured by Quin-T Corporation.	28
		Electrical insulating paper—shear operator (TV BOARD)	0.064	ND	153	Phase contrast	Results from monitoring electrical insulating paper products manufactured by Quin-T Corporation.	28
		Electrical insulating paper—assembly dept. operator (TV BOARD)	0.008	ND	165	Phase contrast	Results from monitoring electrical insulating paper products manufactured by Quin-T Corporation.	28
		MICO, shear machine operator	0.033	1978	120	Phase contrast	Results from monitoring electrical insulating paper products manufactured by Quin-T Corporation.	28
		MICO, winding area operator	0.038	1978	180	Phase contrast	Results from monitoring electrical insulating paper products manufactured by Quin-T Corporation.	28
		Acme heavy handwinding	<0.006	1979	108	Phase contrast	Results from monitoring electrical insulating paper products manufactured by Quin-T Corporation.	28

(continued)

TABLE 27 (continued)

Asbestos product category	Asbestos product	Activity performed	Measured fiber concentration (f/cm³)	Date of tests	Duration of activity/ sampling time (min)	Analytical method	Comments	Ref.
Asbestos paper (continued)	Electrical insulating paper and boards[j]	Acme coil pulling	<0.008	1979	87	Phase contrast	Results from monitoring electrical insulating paper products manufactured by Quin-T Corporation.	28
		Acme compound pourer	<0.012	1979	60	Phase contrast	Results from monitoring electrical insulating paper products manufactured by Quin-T Corporation.	28
		Resinite band saw operator	0.034	ND	372	Phase contrast	Results from monitoring electrical insulating paper products manufactured by Quin-T Corporation.	28
		Square D saw operator	0.062	1980	111	Phase contrast	Results from monitoring electrical insulating paper products manufactured by Quin-T Corporation.	28

[a]NIOSH Method is phase contrast microscopy counting fibers 5 μm long or longer having a length-to-diameter aspect ratio of 3-to-1 or greater.
[b]Analysis performed by scanning electron microscopy with energy dispersive x-ray (EDXR) analysis.
[c]Recommended procedures involve preparation, installation, and removal without sanding, use of a flat-bladed wall scraper instead of equipment that would unduly shatter the tile and not breaking the tile by hand before placing in a disposal bag.
[d]EPA's factor for converting nanograms to fibers is 1 nanogram equals 30 fibers.[10]
[e]Recommended procedures involve preparation, installation, and removal without sanding the existing floor covering or the residual felt, and wet-scraping the residual felt instead of dry-scraping or sweeping.
[f]Housekeeping - high efficiency vacuum cleaners were used to clean areas; processing areas were kept clean and free of debris accumulation; and waste material was placed in sealed containers.
[g]No control - no specific controls were used; i.e., no wetting, enclosing, or ventilation.
[h]Ventilation - filtered local exhaust ventilation provided to operation.
[i]Analysis performed by polarized light microscopy.
[j]Many of the concentrations recorded were found to be no more than ambient levels.

ND - No data.
TWA - Time-Weighted-Average (8-hour).
NR - Not reported.

TABLE 28. NUMERICAL SUMMARY OF MONITORING STUDIES PERFORMED ON ASBESTOS-CONTAINING PRODUCTS[a]

Asbestos product category	Asbestos product	Number of studies[b] performed on product (as presented in this report)
Asbestos-cement sheet	Flat sheet	3
	Corrugated sheet	1
	Roofing shingles	0
	Siding shingles	0
Flooring products	Vinyl-asbestos tiles	6
	Asphalt-asbestos tiles	0
	Sheet vinyl floor covering	2
Coatings and sealants	Asphalt or tar-based products	1
	Latex or gypsum-based products	2
Textiles	Fire and Heat Resistant Materials	
	Firefighting helmets	1
	Outer garments	1
	Gloves	1
	Thermal Insulation	2
	Electrical Insulation	0
	Gaskets and Packings	0
	Friction Materials	0
Gaskets and packings	Compressed sheet gaskets	4
	Asbestos yarn packings	2
Asbestos paper	Roofing felt	2
	Flooring felt	0[c]
	Millboard and rollboard	1
	Beater-add gaskets	0
	Electrical insulating paper	1

[a]Some studies investigated fiber release from more than one product.

[b]Some studies may incorporate several test runs.

[c]Comparison monitoring covered under sheet vinyl floor covering.

In general, the asbestos content of an asbestos-containing product does not change appreciably during its service life, although its binder content may. A product's physical configuration and structural integrity may also be altered during use, particularly in the case of textile products and materials used as gaskets and packings. Disintegration of a product's physical cohesiveness increases the likelihood of fiber release. This factor becomes especially important when these types of materials are removed from service after the expenditure of their normal life span.

Mechanical disruption which physically alters asbestos-containing products can occur during secondary processing, field fabrication, installation, in-service use, and removal. Secondary processing involves the operation of power equipment such as stationary table saws, surface grinders, drill presses, die-cutting and punch press machines, and hand held sanders and routers. These operations have the potential to release a substantial number of asbestos fibers. However, to comply with occupational asbestos exposure standards, these processing machines and tools are normally equipped with engineering controls to minimize workroom contamination. Further worker protection is accomplished by the operator's use of a respirator and personal protective clothing.

Manually operated tools, such as scissors, scoring knives, and hand saws, may also be used during secondary processing of asbestos products. However, the slow cutting speed associated with the use of these types of tools minimizes dust generation, and just as important, imparts a low propellant force which minimizes particle dispersal. Scissors and scoring knives make clean edge cuts generating only small quantities of loose particles. Cutting using hand saws produces coarse-size particles that settle rapidly to the ground.

Mechanical disruption of asbestos products can also occur prior to and during installation when total field fabrication or partial alteration of a prefabricated product is required. Tools used range from hand held power saws and drills to knives for scoring and scissors. Dust control practices, which may or may not be employed to minimize fiber release from these activities, include using power tools equipped with vacuum exhaust collection systems, moving the fabricating operation from indoors to outdoors where greater air dispersion and dilution lower fiber concentrations, thoroughly wetting the point of physical contact where the tool and material meet, and controlling the exertion applied when operating hand tools to minimize pulverization of the product matrix and subsequent fine dust entrainment.

In many cases asbestos fiber release is generally the lowest if not nonexistent during product installation. Asbestos-containing products are usually purchased clean and prefabricated, ready for use. Installation of the material usually requires only simple mechanical dexterity and common sense. Once installed, many asbestos products will not release fibers. Due to their rigid physical structure, most asbestos products are used in stationary or static applications. In use, the material is subjected to little or no direct physical force or abrasion. Only fire and heat resistant protective clothing, dynamic packings, and millboard used in hot material transfer rollers are involved in active or mechanical applications.

Removal of worn out asbestos products at the end of their service life is normally performed by hand. Control practices described above under field fabrication and installation, may be similarly instituted during product removal. Material wetting followed by controlled energy input can effectively minimize fiber release. Many examples of this are presented in the report but one in particular serves as a good illustration. Dry scraping of residual flooring felt during subfloor preparation resulted in airborne fiber concentrations ranging from 1.0 to 2.17 f/cm^3, whereas wet scraping of the same material resulted in a measured airborne concentration of 0.48 f/cm^3.

Whenever possible, asbestos-containing products should be fabricated, when required, using hand operated tools instead of power tools. Power tools such as circular and sabre saws, drills, sanders, and routers pulverize the product matrix, creating a fine dust. During mechanical disruption the physical cohesiveness of the product matrix is disintegrated to the point where free-form asbestos fibers may be released. Additionally, the size of the fibers released may be altered (decreased) from their original dimensions. The fine dust generated is easily entrained by the high speed cutting implement of power tools and can remain suspended in the ambient air for long periods of time.

Differences in airborne fiber concentrations are also expected between various power tools. For example, material drilling will pulverize the product matrix, generating a fine dust, but the particle propellant force is somewhat restrained compared to that of a circular saw. Dust generated during drilling tends to accumulate near the drill bit and is not dispersed to any great extent. The cutting action of a circular saw, however, is much more vigorous, providing enough energy input to propel the fine dust generated quite a distance from the point of contact. Because of these factors, asbestos product manufacturers and equipment designers recommend the use of power tools equipped with vacuum exhaust dust collection systems.

With respect to hand operated tools, engineering controls are not normally used because these types of tools do not generate fine dust nor do they propel the particles into the ambient air with the same force as power tools. Dust particles generated during the use of hand operated tools are coarser than those generated by power tools. These coarse, comparatively large particles tend to settle rapidly near the operation, minimizing ambient dispersion and residence time.

In summary, easily implemented and uncomplicated control practices have been developed by asbestos product manufacturers, industrial trade associations, and product distributors. These practices have been well publicized and documented in training manuals and product brochures. However, due to a myriad of reasons, they are not always followed. Many times, simply for convenience, dust control equipment, work practices, and protective equipment will be ignored during asbestos product handling and processing or if established control measures are used, they frequently will be improperly implemented.

RECOMMENDATIONS FOR FUTURE PRODUCT TESTING

Airborne asbestos fiber concentrations resulting from secondary processing and end use activities routinely or most frequently performed on certain asbestos-containing products have been presented in this report. These data will be used inconjunction with population exposure data (both occupational and nonoccupational) and product usage information to prioritize candidate products for testing under future EPA monitoring programs. Following prioritization based these criteria, products selected for initial testing can be further classified according to the following:

- Product testing to create a data base where one does not exist, or
- Product testing to expand an existing data base. Testing would be performed to validate results of previous studies or to monitor other product handling activities that have not been examined.

Asbestos-containing products not profiled in this report, which include asbestos-cement pipe, friction materials, reinforced plastics, paper pipeline wrap, commercial paper, and specialty paper are also potential sources of airborne asbestos fibers. These products and those that were investigated but are not recommended for initial testing (see below) may be evaluated under subsequent monitoring programs.

Based on the information compiled and the prioritization scheme described above, Table 29 identifies the asbestos-containing products profiled in this report that require first time testing or further investigation. These products are listed below in descending order of testing preference. Product handling activity, tools, and duration of activity to be performed, used, and monitored during testing are identified, respectively.

	Product	Activity	Tools	Duration
1.	Millboard (paper product)	Sawing, drilling, hammering, and/or scoring	Uncontrolled power tools and hand tools	1 to 10 minutes per operation
2.	Flat A/C sheet	Sawing, drilling	Uncontrolled power tools	1 to 15 minutes per operation
3.	Gaskets (textile-untreated rope)	Cutting, hand manipulation, removal	Scissors, razor, or utility knife; flat-bladed knife or wire brush for removal	<1 to 10 minutes for cutting and handling, 15 to 30 minutes for removal
4.	Packings (unlubricated braided yarn)	Cutting, hand manipulation, removal	Scissors, razor, or utility knife; flat-bladed knife or wire brush for removal	<1 to 10 minutes for cutting and handling, 10 to 30 minutes for removal

TABLE 29. ASBESTOS-CONTAINING PRODUCTS AND ACTIVITIES OF CONCERN RECOMMENDED FOR INITIAL FIBER MONITORING STUDY

Product category	Product	Activity of concern	Tool(s)	Location of activity	Duration	Expected fiber concentrations from activity[a]	Asbestos content of product (%)	Existing fiber monitoring data[b]	Reason for testing
Asbestos-cement sheet products	Flat sheet	End use involving field fabrication	Uncontrolled power hand tools (circular saws, drills, sanders)	Indoors or outdoors	Totaling several minutes over course of day	High	15 to 40	2.3 to 195.8 f/cm^3 (PCM analysis) testing performed under laboratory conditions in nonventilated glove box chamber	To generate data representative of actual field conditions.
Textiles	Fire and heat resistant garments (untreated, uncoated inner surfaces) and worn clothing	Wearing of clothing	NA	Indoors or outdoors	Up to 4 hours at a time for wearing clothing	Moderate to high	75 to 100	0.3 to 26.2 f/cm^3 (PCM analysis)	Validation of fiber concentrations measured.
	Thermal Insulation (tape, cloth)	Cutting during installation and removal of material from process equipment or transfer pipes	Knives, utility razor blades	Indoors primarily, but also outdoors	Cutting totalling a few minutes. Removal lasting several minutes to hours depending on extent of material application	Moderate to high	75 to 100	0.0 to 0.05 f/cm^3 (PCM analysis assumed). Monitoring occurred during cutting and installation of untreated lagging cloth.	Validate and generate data.
	Gaskets[c] (untreated rope)	Cutting during installation and removal of wornout material and cleaning of joint surfaces	Scissors, knives for cutting. Flat-bladed putty knife, wire brush, possibly hand sanding during removal.	Indoors primarily but also outdoors	Cutting totalling a few minutes. 15 to 30 minutes (est.) for removal.	Moderate to high	75 to 100	No data reported	Generate data.

(continued)

TABLE 29 (continued)

Product category	Product	Activity of concern	Tool(s)	Location of activity	Duration	Expected fiber concentrations from activity[a]	Asbestos content of product (%)	Existing fiber monitoring data[b]	Reason for testing
Gaskets and Packings	Packings (unlubricated braided asbestos yarn)	Cutting during installation and removal of wornout packing material used in static door or cover applications	Scissors, knives for cutting. Flat-bladed putty knife, hand scraping using wire brush during removal.	Indoors primarily but also outdoors	Cutting totalling a few minutes. 10 to 30 minutes (est.) for removal.	Moderate to high	75 to 100	No data reported	Generate data
Asbestos Paper Products	Millboard	Field fabrication involving sawing and drilling	Power hand tools that are not equipped with dust collection systems	Indoors or outdoors	1 to 10 minutes over course of day	High	68 to 95	1.4 to 8.4 f/cm^3 (SEM/EDXR analysis) hammering, sawing, and scoring monitored in nonventilated glove box chamber	To generate data representative of actual conditions
—	Baster-Add Gasket	Cutting or shaping of material during installation and removal of worn, dried-out gasket material and cleaning of joint surfaces	Knives, scissors for cutting, shaping. Flat-bladed putty knife, hand scraping with a wire brush during removal	Indoors primarily also outdoors	Cutting, shaping totalling a few minutes. 15 to 20 minutes for removal	Moderate to high	60 to 80	No data reported	Generate data.

[a]Qualitative determination made by CCA/Technology Division based on chemical and physical composition of material and mechanical disruption applied at time of activity. For discussion purposes, 'moderate' refers to expected fiber concentrations of up to 1.0 f/cm^3, whereas 'high' is an expected fiber concentration of greater than 1.0 f/cm^3.

[b]Refers to data reported in the open literature or supplied to CCA/Technology Division from telephone requests.

[c]Textile gaskets only, textile packings will be presented under the gaskets and packings product category.

NA - Not Applicable

		Activity	Tools	Duration
5.	Beater-add gaskets (paper product)	Cutting, hand manipulation, removal	Scissors, razor, or utility knife; flat-bladed knife or wire brush for removal	<1 to 10 minutes for cutting and handling, 15 to 20 minutes for removal
6.	Fire and heat resistant garment (textile-clothing, hoods)	Wearing, hand manipulation	Not applicable	5 to 15 minutes total
7.	Thermal insulation (textile)	Cutting, tearing, ripping, hand manipulation	Scissors or utility knife	5 to 15 minutes total

Product handling activities to be monitored are those that are routinely performed. For example, during field fabrication of A/C sheet products, recommended work practices include the use of engineering controls to minimize fiber release during sawing with power tools. Monitoring data show that under these conditions resulting airborne fiber concentrations are less than 0.2 f/cm^3. However, it has been reported (see Section 2) that field fabricating of A/C sheet products is also performed using power tools that are not equipped with dust control devices. Although not well documented, this latter practice is suspected to be fairly common. Consequently, because this situation does exist and fiber release from the cited activity is expected to be high, product testing of flat A/C sheet using uncontrolled power tools is recommended. In summary, the products listed in Table 29 have been selected because fiber monitoring data are insufficient or nonexistent and fiber release from product handling activities associated with the products is expected to be high.

Asbestos products not listed in Table 29 were excluded from recommendation for initial testing based on a combination of the following factors investigated under this study:

- Airborne fiber release from the product's end use activities has been well documented.
- The products have a low asbestos content.
- Product handling activities result in minor disturbance to product matrix and last for short periods of time.
- The products have a strong structural cohesiveness whereby the asbestos fibers are tightly bound within the material matrix.
- Well designed and implemented engineering controls and work practices are almost always instituted when product handling activities are performed.

Following is a list of the products profiled and a statement regarding recommendation for initial testing. Where a product is not recommended for testing, appropriate reasons are given based on the criteria outlined above.

Asbestos-Cement Sheet Products (Section 2)

Flat Sheet:	Recommended for testing (see Table 29).
Corrugated Sheet:	Not recommended for testing. The product composition is the same as flat sheet, testing results from flat sheet will be directly applicable. Testing of flat sheet is recommended over corrugated sheet because of the latter's limited use.
Roofing and Siding Shingles:	Not recommended for testing. Limited field fabrication is performed, most shingles are prefabricated by the primary manufacturer for direct installation. Fabricating tool (guillotine cutter) used in field causes only minor dusting.

Flooring Products (Section 3)

Vinyl-Asbestos Floor Tile:	Not recommended for testing. Fiber release from end use activities associated with floor tiles has been well documented. The product's polymer matrix binds asbestos fibers, minimizing release. Low-energy mechanical disturbance is applied during installation. Comparatively high fiber concentrations may result during removal and subfloor preparation if recommended work practices are not followed, which is not normally the case.
Asphalt-Asbestos Floor Tile:	Not recommended for testing. Same as above—except not well examined with respect to monitoring studies. Fiber release from asphalt-asbestos floor tiles is expected to be similar to vinyl-asbestos tiles.
Sheet Vinyl Floor Covering: (backed with asbestos felt)	Not recommended for testing. Fiber release from end use activities associated with this product has been well documented. Low-energy mechanical disturbance is applied during installation. High fiber concentrations may result during removal and subfloor preparation if recommended work practices are not followed, which is not normally the case.

Coatings and Sealants (Section 4)

Not recommended for testing.
The asbestos content of these products is comparatively low (5 to 30 percent). With respect to petroleum-based products, asbestos fibers are tightly bound in the tacky product matrix. Airborne monitoring studies reveal comparatively low concentrations of fibers during the application and removal of petroleum-based coatings and sealants. Use of water soluble products is limited strictly to industrial applications. Fiber release from these products has been well documented precluding the need for additional testing.

Textiles (Section 5)

Fire and Heat Resistant Materials: Apparel recommended for testing (see Table 29). Other materials not recommended for testing. Heat shields, splash curtains, and blankets are normally surface-treated to minimize fiber release. Also, they are mostly installed in static applications and therefore are not recommended for testing.

Thermal Insulation: Recommended for testing (see Table 29).

Electrical Insulation: Not recommended for testing. These textile materials are usually concealed or incorporated into internal parts of appliances or electrical wire. Only minor mechanical disturbance is applied to textile material during secondary processing and end use.

Gaskets and Packings:

Gaskets - Certain gaskets (untreated rope) recommended for testing (see Table 29). Fiber release from surface-treated textile gasket material is expected to be low and only minor mechanical disturbance occurs during performance of end use activities. Therefore testing of treated gasket material is not recommended.

Packings - See discussion below under Gaskets and Packings.

recommended for testing.
paper is often laminated with structural fiber and adhesive by a secondary processor before it is incorporated into an electrical appliance. Only minor mechanical disturbance will occur to the paper during end use.

Exposure product testing studies should include an analytical technique which provides results that are fiber specific and consistent. The technique must be capable of distinguishing asbestos fibers from nonasbestos fibers and identifying fibers over a wide size range. Of the analytical methodologies most commonly used to determine airborne asbestos fiber concentrations, phase contrast microscopy (PCM), scanning electron microscopy (SEM), and transmission electron microscopy (TEM), only the electron microscopy techniques are capable of meeting the analytical criteria requisite for a meaningful product testing program. Phase contrast microscopy is not capable of differentiating asbestos fibers from nonasbestos fibers nor is it capable of identifying fibers less than 5 μm in length with an acceptable degree of reliability.[29]

Scanning electron microscopy and transmission electron microscopy offer separate advantages. Upper end magnification and image resolution for scanning and transmission electron microscopes are 100,000X and 250,000X, and 20 nm and 0.4 nm, respectively. Scanning electron microscopes provide better observation of surface topography and enable viewing of a relatively large number of fields in a short period of time. Transmission electron microscopes offer superior image resolution and morphological characterization.[30,31]

Transmission electron microscopes, with selected area electron diffraction (SAED), are capable of distinguishing asbestos fibers from nonasbestos fibers, and chrysotile asbestos fibers from other (amphibole*) asbestos fibers based on differences in crystalline structure. However, because amphibole asbestos fibers exhibit similar diffaction patterns, TEM/SAED analysis is not capable of differentiating amphibole asbestos minerals from each other.[32,33]

Fiber identification using a scanning electron microscope is limited because electron diffraction studies are not possible.[30] However, a scanning electron microscope equipped with an energy dispersive x-ray (EDXR) spectrometer can be used for qualitative analysis. EDXR is an electron beam microchemical analytical technique that provides semiquantitative elemental analysis of the fiber(s) under observation.[33-35] Because the fibrous minerals exhibit characteristic x-ray spectrums, qualitative identifications can be made. Transmission electron microscopes can also be equipped with an EDXR spectrometer.[30,31]

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*Amphibole asbestos minerals are amosite, crocidolite, and the fibrous forms of actinolite, anthophyllite, and tremolite.

It is important to note that some fibrous minerals produce similar elemental x-ray spectrums, thus prohibiting individual identification. Unless the mineralogy of the fiber source is well known, the results of SEM/EDXR analysis should be interpreted with discretion.[33,36] In cases where the fiber source is not well known, the use of TEM with SAED and an EDXR spectrometer can provide accurate qualitative results. The SAED capability of TEM enables differentiation of fibers exhibiting similar x-ray spectrums based on characteristic crystalline diffraction patterns. A transmission electron microscope with SAED and EDXR capabilities is one of the most powerful analytical tools available for airborne particulate and fiber studies.[30,37]

CONCLUSION AND RECOMMENDATIONS
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