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Background Information on Substitutes for Asbestos

Sponsored by:

The Environmental Protection Agency

The Consumer Product Safety Commission

The Interagency Regulatory Liason Group

PREFACE

This document presents background information on substitutes for asbestos, for use by attendees at the Workshop on Substitutes for Asbestos, sponsored by the Environmental Protection Agency, the Consumer Product Safety Commission, and the Interagency Regulatory Liasion Group. The information is the result of a preliminary study of substitutes for asbestos by EPA; data on the special qualities of asbestos-containing products, the available substitute materials, and cost comparisons between asbestos and the substitute materials are presented. This report is being distributed in order to form a basis for discussion of substitutes by participants at the workshop. Comments on the accuracy and validity of the report as well as any additional information are welcomed. Cost data were obtained from a variety of sources and though they are believed to portray 1979 values, the EPA cannot guarantee their accuracy.

CONTENTS

SECTION 1

INTRODUCTION

Asbestos is the common name for a group of fibrous silicates including chrysotile, amosite, anthophyllite, crocidolite, and tremolite-actinolite. Asbestos is used in many industrial and consumer products to provide strength, heat resistance, corrosion resistance, rot resistance, and fireproofing. The United States currently uses approximately 7 pounds of asbestos per person in products each year. An approximate breakdown for the major product categories is:

• Asbestos paper (including commercial roofing)	38 percent*
• Asbestos cement pipe	16 percent
• Floor tile	13 percent
• Friction products	7 percent
• Sealants	7 percent
• Asbestos cement sheet	6 percent
• Gaskets and packing	3 percent
• Plastics, textile, and miscellaneous	10 percent

This document summarizes the present information on the special qualities of asbestos-containing products, the available substitute materials, and cost comparisions between asbestos and the substitute materials.

*Percent of annual United States asbestos consumption. Clifton, R.A. Mineral Industry Survey, Asbestos Industry 1978. U.S. Bureau of Mines, August 22, 1979.

SECTION 2

PAPER PRODUCTS

Asbestos-containing paper can be used in products that serve many different functions. The performance and availability of substitute products will vary for each asbestos-paper product; therefore, this section presents the following subcategories of paper products:

- Beverage and Pharmaceutical Filters
- Millboard
- Commercial Papers
- Specialty Papers
- Roofing Felt
- Beater-Add Gaskets
- Electrical Insulation
- Flooring Felt
- Pipeline Wrap

Table 1 presents the estimated current annual consumption of asbestos fiber in paper products.

BEVERAGE AND PHARMACEUTICAL FILTERS

Asbestos is used in filters because of its large surface area per unit of weight and natural positive charge, which facilitates the removal of negatively charged particles from beverages.[1] Asbestos filter sheets are primarily used by the beer, wine, and liquor distilling industries to filter micro-organisms and very fine solids from liquids and to act as a clarifier removing haze from the liquid medium.

Substitute filters, composed of cellulose fibers, diatomaceous earth and a melamine resin, appear to be adequate alternatives to asbestos filters, although, instead of a natural positive charge, they must be chemically treated to produce a positive charge. Costs are comparable for both the asbestos and substitute filters.

MILLBOARD

Asbestos millboard resists rot and supplies protection from fire, heat, and corrosion. Asbestos millboard is used as a fire-resistant lining in floors, partitions, ceilings, and fire doors, and as an insulating barrier in stove ovens, and heating appliances. It has important uses in metal and chemical industries as well, due to the high temperature performance requirements.

TABLE 1. ESTIMATED CURRENT ANNUAL CONSUMPTION OF ASBESTOS FIBER IN PAPER PRODUCTS (IN TONS) [2,3,4]

Category	Consumption
Flooring felt	130,000
Roofing felt	90,000
Beater-add gaskets	30,000
Pipeline wrap	20,000
Millboard	8,000
Electrical insulation	1,000
Commercial paper	
General insulation	3,500
Muffler paper	NA
Corrugated paper	NA
Specialty papers	
Cooling tower fill	2,500
Transmission paper	1,000
Chlorine electrolytic diaphragms	3,500
Decorative laminates	NA
Beverage and pharmaceutical filters	100
Total paper products	286,100*

*Total should be increased slightly to include subcategories without figures.

NA - Not available but considered small.

Substitute millboard is primarily composed of an alumina-silicate refractory material. Substitute products generally have equal or superior insulating qualitites relative to asbestos board, but most have significantly higher costs (see Table 2).

TABLE 2. COST($) PER SQUARE FOOT FOR ASBESTOS MILLBOARD AND SUBSTITUTE PRODUCTS[5-7]

Thickness (inches)	Asbestos	Pars No. 9	Johns-Manville[a] Ceraform 102	Carborundum Fiberfrax		
				Duraboard	Hotboard[a]	GC Board[b]
1/8	$0.30	$0.85	$1.00	—	—	—
1/4	$0.60	$1.45	$1.20	—	—	$3.10
1/2	$1.15	$2.80	$1.65	$2.20	$1.30	—

[a]Price for 1,000 square feet or more.

[b]Price for 75 square foot lots.

COMMERCIAL PAPERS

Asbestos is used in commercial papers because of its strength, durability, and resistance to fire and corrosion. Commercial asbestos papers, including general insulation paper, muffler paper, and corrugated paper, provide maximum insulation against fire, heat, and corrosion with minimum product thickness.

Substitutes are made from ceramics, cellulose, or fiberglass. These materials display some advantages, such as the ability to withstand a greater temperature range, but they cost more and provide less dimensional stability.

SPECIALTY PAPERS

Asbestos is used in specialty papers, including cooling tower fill, electrolytic diaphragms, and decorative laminates, primarily because of its chemical and heat resistant properties.

Substitutes for cooling tower fill are polyvinyl and polypropylene plastics, cellulose, aluminum, and steel. An alternative to asbestos electrolytic diaphragms is a membrane-cell, consisting of a film of perfluoro-sulfuric acid resin and another monomer to which negative sulfuric acid groups are attached. Glass and ceramic substrates are available as substitutes for decorative laminates. Generally, costs for these substitute materials are higher than asbestos-containing papers.

ROOFING FELT

Roofing felt, primarily used for built-up roofing and as an underlayment for other roofing products, is manufactured with asbestos because of its dimensional stability and resistance to rot, fire, and heat. There are three substitutes for asbestos roofing felt: organic felt (cellulosic fibers), fiberglass felt, and a single-ply membrane system (a laminate of a modified bitumen or rubber and plastic or PVC). Organic felt is the most widely used roofing felt, followed by asbestos felt; fiberglass felt holds the smallest share of the roofing market.[8] Table 3 provides a cost comparison of roofing felts. The substitutes for asbestos containing roofing products are currently available and are fairly comparable in costs when installed, durability and performance.[8]

TABLE 3. ROOFING COSTS[9-13]

	Retail cost per roll ($)	Squares	Single square (one layer) ($)	Material cost per square ($)	Installed cost per square ($)	
					Range	Average
Organic felt	10.00	4	2.50	7.50 (three layers)	100-160	126.00
Asbestos felt	23.50	4	5.75	11.50 (two layers)	115-160	132.50
Fiberglass felt	28.50	5	5.60	16.80 (three layers)	110-160	140.00
Membrane single-ply	35.70	1	35.70	35.70 (one layer)	—	150.00

BEATER-ADD GASKETS

Gaskets are installed to provide tight, nonleaking connections in piping and other joints. They are used in the automotive industry, and also in industrial and commercial equipment of all varieties. Asbestos is used in gaskets because it is heat resistant, resilient, strong, and chemically inert.

Although alternative materials may be available for certain applications, there are no substitute products of the same effectiveness. In particular, no suitable substitutes have been found for applications requiring the chemical inertness and oil resistance of asbestos gasketing material.[8] The alternative materials that are sometimes employed are ceramic fibers, teflon, and metal. The costs of these substitute materials are generally higher than the asbestos containing materials.

ELECTRICAL INSULATION

The largest use of asbestos electrical paper is as insulation for dry transformers for layer insulation, layer barriers, core barrier tubes, general conductor wraps, lead insulation, and cross-over insulation. Asbestos is used in electrical paper insulation because of its high thermal and electrical resistance, which permits the paper to act effectively as an insulator and protects the conductor from fire.

Substitute materials currently available for electrical insulation are aromatic polymides, ceramic fibers, mica, and glass fiber. The costs of these substitutes are higher than the asbestos-containing materials.

FLOORING FELT

Most flooring felt is used commercially in residential applications. Asbestos is used in flooring felts to add dimensional stability, and high moisture, rot and heat resistance. There has been little success in substituting other fibers for asbestos fibers in this product.[8] Althernatively, various floor coverings can be used as substitutes for vinyl sheet flooring backed with asbestos felt. These coverings include everything from foam cushion-backed flooring and backless sheet flooring to wood flooring or carpeting and "place and push" vinyl tile squares. Costs of substitute products vary widely as the substitutes themselves differ greatly.

PIPELINE WRAP

Asbestos paper has been successful as pipeline wrap because asbestos can resist soil chemicals, rotting, and decay, while maintaining dimensional stability throughout its lifetime. Asbestos pipe wrap protects underground pipelines from corrosion. The largest user of asbestos pipe wraps is the oil and gas industry with their extensive underground piping networks.

Alternatives to asbestos pipewrap include saturated fiberglass, plastic tapes, extruded epoxy resins and extruded polyethylene wrapping, bound to undercoating.[14] Cost effectiveness still favors asbestos pipe wraps and, although competitive pipeline wraps are also used by the oil and gas industry, asbestos wraps are currently preferred because of cost and proven effectiveness.

SECTION 3

ASBESTOS-CEMENT PIPE

Asbestos-cement (A/C) pipe is most suitable for intermediate range pipe diameters (6 to 24 inches). A/C pipe is strong, resilient, flexible, durable, inert, and fire resistant. The majority of A/C pipe produced is used for water mains (pressure pipe) and sewer lines (nonpressure pipe).

A 1974 survey projected the total amount of water mains in use in the United States to be about 640,000 miles.[15] A/C pipe accounted for 84,000 miles or about 13 percent of this total. Table 4 lists the types of water main pipe in place as of 1975 and the national projections of mileage. Table 5 lists the type of sewer main pipe now in place and the national projections of mileage.

TABLE 4. TYPES OF WATER MAIN PIPE IN PLACE (1975) NATIONAL PROJECTIONS OF MILEAGE[15]

	Cast iron	Asbestos cement	Steel	Reinforced concrete	Plastic	Other	Total
Total Mileage	482,000	84,000	38,000	10,000	7,000	19,000	640,000
Percent of Total	75.3	13.1	5.9	1.6	1.1	3.0	100.8

NOTE: Cast iron is the predominate type of pipe now in place, accounting for three-fourths of the total. Asbestos cement has a 13 percent share with none of the other types having more than 6 percent.

TABLE 5. TYPE OF SEWER MAIN PIPE NOW IN PLACE-NATIONAL PROJECTIONS OF MILEAGE[15]

	Cost iron	Asbestos cement	Vitrified clay	Reinforced concrete	Plastic	Other	Total
Total Mileage	15,000	25,000	306,000	74,000	10,000	28,000	459,000
Percent of Total	3.3	5.4	66.8	16.2	2.1	6.2	100.0

NOTE: Vitrified clay is the predominate type of pipe now in place, accounting for two-thirds of the total. Reinforced concrete has a 16 percent share with none of the other types having more than 6 percent of the total. The majority of pipe within the "other" category is of the unreinforced concrete category.

The common pipe products available as substitutes for A/C pipe include:

- Ductile iron pipe
- Concrete pipe
- Glass-reinforced concrete pipe
- Plastic pipe
- Vitrified clay pipe

None of these products alone could substitute for all A/C pipe uses. However, as a group, they can meet all of the technical requirements placed on A/C pipe. A/C pipe used in water mains can be replaced by ductile iron, PVC, and reinforced concrete. In sewer mains, A/C pipe can be replaced with vitrified clay, concrete, PVC, and ductile iron. The only factor preventing the use of substitutes for A/C pipe in new construction or replacement service is economics. Table 6 lists pipe price estimates for asbestos cement and the substitute materials.

TABLE 6. PIPE PRICE ESTIMATES [16-21]

Material	Approximate price per foot ($)					
	Water			Sewer		
	8"	15"	24"	8"	15"	24"
Asbestos cement	5.50	16.00 (16")	—	3.00	10-14.00	25-30.00
Ductile iron	6.00	14.50 (16")	24.50	6.00	14.50 (16")	24.50
Vitrified clay	—	—	—	2.50	10.00	29.00
Reinforced concrete	—	—	15.50	—	6.00	11.50
Nonreinforced concrete	—	10.50	—	2.25	4.00	8.00
PVC	4.25	9.75 (12")	—	2.75	10.50	16.00 (18")
Fiber reinforced PVC*	6.25	12.25 (12")	—	—	—	—

*Johns-Manville - Permastrain

SECTION 4

FLOOR TILES AND SHEETING

Vinyl asbestos (V/A) flooring is installed in industrial, commercial, institutional, and residential buildings because it is extremely well suited to applications requiring:

- Toughness
- Dimensional stability
- Long life
- Economy
- Moisture resistance
- Smooth surface
- Cleanability

In 1975 asbestos flooring commanded a 91 percent share of the resilient floor covering market.[22] Of this total 38 percent was floor tile and 53 percent was sheet flooring. Only 9 percent of the resilient floor covering market was held by nonasbestos-containing products.

Major V/A flooring companies are actively pursuing or producing a substitute flooring product. Available alternate flooring products include vinyl-sheet roll goods, solid vinyl floor tiles, ceramic tile, carpeting, and wood.[8] However, these substitutes lack one or more of the above-mentioned characteristics of V/A flooring. The primary hindrances to a substitute product effectively competing with V/A flooring are higher cost and lack of toughness; i/e., durability, resilience, flexibility, and wear resistance.

SECTION 5

FRICTION MATERIALS

Asbestos is well suited for use in friction materials because of its thermal stability, reinforcing abilities, and relatively high ability to withstand friction. Asbestos-containing friction materials are used for brakes for light- and heavy-duty vehicles, aircraft, railcars, various types of heavy equipment and clutch facings.

Several manufacturers of friction materials have active research and testing programs to develop asbestos-free materials. Although industry's research and development activities are highly secretive, we know that among the materials proposed in the past as substitutes are: glass fiber, steel wool, mineral wool, carbon fiber, cermets (sintered metals), semimetallic materials, potassium titanate fibers, aramid fibers, vermiculite, and silicon nitrides. Some firms may have ceased research on one or more of these materials but others may still be under consideration.

Several manufacturers of friction materials have active research and testing programs to develop asbestos-free materials. Some of the materials proposed as substitutes are: glass fiber, steel wool, mineral wool, carbon fiber, cermets (sintered metals), semimetallic materials, potassium titanate fibers, aramid fibers, vermiculite, and silicon nitrides.

As friction applications vary, so do the materials most appropriate for each use. Semimetallic and cermet materials may all be used in direct asbestos substitute applications, semimetallic in disc brakes (it is projected that in 5 years nearly all original equipment disc brakes in passenger cars and light trucks will use semimetallics) and cermets for aircraft brakes (95 percent of all new commercial aircraft use cermets).[23,24] Nonasbestos drum brake linings for passenger cars are currently unavailable commercially.[23]

A cost comparison for various materials proposed as substitutes for asbestos in friction products is given in Table 7.

TABLE 7. COSTS OF MATERIALS PROPOSED AS SUBSTITUTES FOR ASBESTOS IN FRICTION MATERIALS [25]

Material	Price per pound ($)
Asbestos	0.05-0.15
Fibrous glass	0.05-0.75
Mineral wool	0.15
Potassium titanate fibers	1.00-1.25
Graphite and carbon fibers	10.00-12.00
Wollastonite	0.15
Cotton linters	0.15
Aramid fibers	6.00-8.00

Exact costs for semimetallic friction materials are not available, but they are comparable to organic friction materials. Cermets cost three to five times as much as asbestos friction materials.

SECTION 6

PAINTS, COATINGS, AND SEALANTS

Asbestos is used in asphalt and tar bases for products such as roof sealants, waterproof coatings, and automobile undercoatings. Previous uses of asbestos in texture paints, spackle, and joint compounds have been banned. The asbestos fiber serves as a filler and reinforcing agent in these diverse products.

An acceptable substitute must be:

- Noncombustible
- Resistant to decay, many acids, and vermin
- Made up of long, flexible fibers
- Strong enough to reinforce other binders
- Unaffected by temperatures up to 500°C (automobile undercoating)
- Cost effective

There are no substitutes available that possess all the above attributes, but for applications where several of the characteristics are not necessary, a substitute may be applicable.

There are no commercially available asbestos-free, asphalt-based roofing, undercoating, or linings and chemical resistant coatings products that provide the properties of asphalt-based products. However, several companies report the availability of products in the premarket or early commercial stages.[26,27] For nonasphalt asbestos-based linings and chemically resistant coatings, several mineral reinforcing materials are available as substitutes for asbestos. Although use of asbestos in texture paints was banned in 1977, no substitutes of comparable quality have been found.

Table 8 presents a cost comparison for substitute materials used in sealant products.

TABLE 8. COST OF SUBSTITUTE MATERIALS COMPARED WITH GRADE 7 CHRYSOTILE [22]

Substitute	Cost ($/pound)	Substitute	Cost ($/pound)
Chrysotile	0.06-0.12	Barite	-
Fiberglass	0.40-0.50	Diatomite	-
Polypropylene	0.35	Silica	-
Cellulose	0.60	Clay	0.04-0.08
Cotton	0.20	Mica	0.05
Talc	0.06	Carbonate	0.04-0.08
		Nylon	0.60

SECTION 7

ASBESTOS/CEMENT SHEET

Asbestos is used as a reinforcing material in cement sheet products because of its high tensile strength, flexibility, resistance to heat, chemical inertness, and large aspect ratio. Asbestos fiber in cement sheet adds to the stability, strength, stiffness, and toughness of the material, resulting in a product that is rigid; durable; noncombustible; and resistant to heat, weather, and attack by corrosive chemicals. A/C sheet may be broken down into four product categories: flat sheet, corrugated sheet, siding shingles, and roofing shingles.

Asbestos can be replaced in A/C sheet by either a substitute reinforcing fiber or an entirely different sheet material. Glass-reinforced concrete (GRC) appears to be suitable for most corrosion and heat resistant applications where A/C sheet is currently used. [28] Cement/wood board, once it is actually under production, should be a cheaper material than A/C sheet for general construction purposes. [29] No substitute material is available that adequately matches A/C sheet's qualities as a laboratory table top; nor is there a material available that could replace ebonized A/C sheet in all electrical applications.

Table 9 presents the performance of possible fiber substitutes for asbestos in cement sheet.

TABLE 9. PERFORMANCE OF POSSIBLE FIBER SUBSTITUTES FOR ASBESTOS IN CEMENT SHEETS

Fiber	Performance and Comments	Reference
Alkali-resistant glass	Can be used in Portland cement; better impact resistance than asbestos; product loses strength with time; commercially feasible.	22,30
Mineralized wood	Lightweight; not as heat resistant as asbestos; superior impact resistance, abundant supply available; commercially competitive.	29
Steel fibers	Good enforcement; high impact strength; problems with processing and machining; problems with rust.	22
Mineral wool	Weak product; does not work well in cement.	22
Carbon fibers	Increases modular strength of cement sheet; is resistant to alkali attack; no increase in impact strength; very expensive.	22
Nylon	Provides impact strength; lacks reinforcement.	22
Ceramic fibers	No success to date; work is continuing.	22,31

A cost comparison of cement sheet products and siding products is presented in Tables 10 and 11, respectively.

TABLE 10. COMPARISON OF CEMENT SHEET PRODUCT PRICES[29-34]

Product	Cost ($) per square meter (square foot)	
	1/4"	1/2"
J-M Flexboard® (A/C)	5.90 (0.55)	14.00 (1.30)
J-M Transite® (A/C)	13.15 (1.20)	21.50 (2.00)
Cement/wood board	1.95 (0.20)	4.00 (0.40)
High density GRC	—	8.61 (0.80)
Low density GRC	—	less than 8.60 (0.80)
Alumina-Sheet®	161.40 (15.00)	—

TABLE 11. COMPARISON OF SIDING PRODUCT COSTS[29]

Product	Total cost ($) per square meter (square foot)
Wood siding, 5/8"	8.60 (0.80)
Wood shingle	15.60 (1.45)[a]
Asbestos-cement shingle	13.50 (1.25)[a]
Fiber board	10.80 (1.00)[a]
Brick or stone	61.75 (5.75)[a]
Stucco or concrete block	17.90 (1.65)[a]
Aluminum	13.40 (1.25)[a]

[a]Cost includes material price for plywood sheathing of $2.72/square meter ($0.253 square feet).

SECTION 8

GASKETS AND PACKINGS

Gaskets and packings, used to seal one fluid from another, are found in virtually every mechanical, chemical, and thermal operation or device where fluids are involved. Asbestos has been successful in both applications because it is heat resistant, resilient, strong and relatively chemically inert.

Two types of substitute products exist for asbestos gaskets and packings: (1) fiber-for-fiber replacements; and (b) an alternative material, such as Glyon® or Nu-Board. The fiber-for-fiber replacements include: silica, carbon, Kevlar,® ceramic and Teflon® fibers. Their characteristics are shown in Table 12.

TABLE 12. CHARACTERISTICS OF FIBERS

Fiber	Maximum tensile strength		Continuous-duty temperature limits (°C)		Chemical deterioration	References
	(10^6 kPa)	(10^3 psi)	Lower	Higher		
Silica	3,450	500	-73	990	Some molten metals, hydrofluoric acid, fluorides, oxides, hydroxides.	35-38
Ceramic	1,720	250	—	1,400	Hydrofluoric acid, phosphoric acid, hot concentrated alkalies.	39-41
Graphite	2,070	3,000	-200	3,000	Strong oxidizing compounds, chromium (VI) and permanganate solutions.	41, 42
Kevlar®	2,758	400	-46	200	Strong acids including: hydrochloric, hydrofluoric, nitric, and sulfuric.	43
Teflon®	359	52	-268	290	Certain perfluorinated organic liquids at temperatures above 299°C (570°F)	44
Asbestos	3,450	500	-273	540	Some molten metals, hydrofluoric acid, fluorides, oxides, hydroxides.	25

No single substitute fiber material possesses all desired qualities to the same degree as asbestos. However, for any particular application, a substitute fiber can often be employed to achieve the necessary combination of properties. Table 13 lists the raw materials identified as substitutes for asbestos-containing gaskets and packings.

For a fiber-for-fiber replacement, the cost of packings and gaskets is proportional to the cost of fibers used because the manufacturing processes are identical. A cost comparison of various fibers is presented in Table 14.

A cost comparison of asbestos gaskets and substitute gasket materials is shown in Table 15.

TABLE 13. NONASBESTOS RAW MATERIALS FOR GASKETS AND PACKINGS [45]

Acropac
Acetate
Aluminum
Aluminum foil
Armaflex
Artus shim
Asphalt-saturated sheathing felt

Backcheck felt
Bakelite
Binders board
Black fibre
Blotting paper
Bond paper
Bucar
Bucote
Buna N-rubber
Buna S-rubber

Cambric
Canvas
Canvas-based bakelite
Canvas-based phenolic
Cardboard
Celluloid
Cellulose materials
Cerafelt
Cerakote
Celcon
Chipboard
Chipboard-treated
Clear cellulose acetate
Cloth
Cloth-inserted rubber
Copper
Cork
Cork-rubber compositions
Cork-synthetic compositions
Crepe barrier paper

Deadening felt
Delrin
Duck
Duracel
Durocork
Duroid

EPDM
EPT
Embossed chipboard
Emery cloth
Ethafoam

Fabric supported rubber
Fairprene materials
Felt
Fibre, vulcanized
Fireboard
Fibreflex
Fiberglass
Fiberglass, neoprene coated
Fiberglass, silicone-coated
Fiberglass, teflon-coated
Fibre-kork
Filter felt
Firm pad felt
Fishpaper (armite)
Flexible fibre
Fluorglass
Fluorosilicone
Foam

Gasket felt
Graphite-coated materials
Graphited rubber
Gum rubber
Gummed kraft paper

Hemp
Hycar (GR-N) rubber

Jute
Jute-lined chipboard
Jute paper

K-grey paper
Kapton
Klingerit
Kraft paper
Koroseal

Leather
Leatherboard
Lexide
Lexan
Linen-base bakelite
Linen-base phenolic

Manila paper
Melamine
Metal finishing felt
Mold-resistant sheathing felt
Molybdenum filled materials
Monocast nylon
Mylar
Mystik tape

Natural rubber
Neoprene-asbestos, compressed
Neoprene-coated materials
Neoprene-cork compositions
Neoprene (GR-M) rubber
Nomex
Nylatron
Nylon

O ring cord
Oil-resistant material
Onion-skin paper

P.V.C.
Packtite
Paper
Paper-base bakelite
Paper-base phenolic
Panelyte
Parchment paper
Phenolics
Plastics
Polyamid
Polyethylene, linear
Polypropylene
Pressboard
Pure gum rubber

Red rope paper
Royal grey paper
Rubber-synthetic compounds

SBR rubber
Saran screen
Sheathing felt
Shim stock
Showcase felt
Silicone
Soft pad felt
Spauldite
Spauldo
Sponge rubber
Stencil board
Supercork
Superpak

Teflon
Teflon-coated fibreglass
Thio-flex
Thiokol-coated materials
Thiokol-impregnated leather
Transformer board
Treated leather
Trimming felt

Upholstery felt
Urethane, homogeneous
Urethane, foam polyester
Urethane, foam polyether
Urethane, foam scott felt
Urethane, liquid cast
Urethane, millable gum

Varnished cambric
Velbestos
Vellumoid
Vinyl
Vinylite
Viton
Viton sponge
Vulcanized fibre

Waterproofed chipboards
Wax-impregnated materials

TABLE 14. COST COMPARISON BETWEEN ASBESTOS FIBERS AND SUBSTITUTES FOR USE IN TEXTILES (IN 1976 DOLLARS)[3, 46]

Fiber	Approximate cost per pound ($)
Asbestos fiber	1.00
Glass fiber	0.75
Nomex® — fiber	5.00-5.50
— continuous filament	6.50-10.00
Kevlar®	5.50-6.00
Teflon®	7.00-10.00
Kynol®	3.60
Carbon	2.00
Ceramics — 3M	30.00-32.00
— refrasil fibers	9.00
— refrasil strands	28.00

TABLE 15. COSTS OF ASBESTOS AND ASBESTOS SUBSTITUTE GASKETING [47, 48]

Material	Cost per square foot 1/16" diameter
Asbestos Sheet Garlock 900	1.95
Asbestos Sheet Garlock 7006	1.20
Gylon® Fawn	8.60
Vegetable Garlock 681	0.50
Cork	0.55
Red Rubber	0.40
Nu-Board 1800	0.90

SECTION 9

REINFORCED PLASTICS

Asbestos-reinforced plastic molding compounds are used in many industries, including the electrical, electronics, automotive, and printing industries. Asbestos fibers, when added to polymeric materials, modify the physical and chemical characteristics of the composite. The fibers serve as both fillers and reinforcing agents. Phenolic molding compounds (thermosetting polymers) are the major users of asbestos in reinforced plastic applications outside of floor coverings. In phenolic molding compounds, asbestos provides good surface finish, toughness, resistance to heat and fire, and less shrinking and warping than other fibers. Asbestos also improves the handling qualities of the product during processing.

Not all products require all of the physical properties supplied by asbestos, consequently substitutes that lack some physical properties of asbestos but meet product specifications can be used. In addition, new fiber technology has been developed which has improved physical properties of substitutes so that they are comparable to asbestos. Table 16 lists the substitute materials, their price compared to asbestos, and performance information and comments. Examination of the table shows a trend towards the replacement of asbestos in reinforced plastics.

TABLE 16. COST COMPARISON OF ASBESTOS AND SUBSTITUTE PRODUCTS FOR REINFORCED PLASTICS[22]

Substitute material	Price compared to asbestos	Performance and comments
Fibrous glass	75¢/lb vs 55¢/lb long fiber asbestos; 50¢/lb vs 10¢/lb short fiber asbestos	May be used for higher temperature applications; new glass fiber technology improves the physical properties of the material; problems with abrasiveness of glass wearing out processing equipment; process change probable.
Clay	Same	Used as filler, no reinforcement; new clay base compositions are reported to maintain the acceptable balance between heat resistance and impact strength.
Talc	6¢/lb vs 5-10¢/lb asbestos	Loss of strength but can compensate by making thicker walled product; presently used as an asbestos substitute; limited to 450°F applications.
Mica	5¢/lb vs 12-25¢/lb for asbestos	Adds dimensional stability and increases strength of plastics; mica's high aspect-ratio is purported to provide cost performance somewhere in-between that of inorganic particulate fillers and fiber reinforcement; it is blended with higher priced substitute materials.
Carbon fibers	$10-$12/lb vs 13-25¢/lb asbestos	For high strength applications; increases acid resistance in phenolics; also used as filler for thermoset plastics; high heat resistance; specialty applications only.
Aramid fibers	$6-$8/lb vs 13¢-25¢/lb for asbestos	Use in specialty plastic reinforcements; too expensive for asbestos replacement in phenolic molding compounds; can be blended with less expensive materials.
Polyethylene fibers	No data	Still in development stage; high modulus of elasticity (10^6 psi) but poor heat resistance properties.
Calcium sulfate	2¢-3¢/lb vs 13¢-25¢/lb for asbestos	Provides improved output rates, allows high loadings, and results in low densities; high heat resistance; no reinforcing properties.

SECTION 10

TEXTILES

Asbestos textiles are used in the six product categories that follow.

FIRE-RESISTANT MATERIALS

Asbestos is used to manufacture fire-resistant materials because it is fireproof, acid-resistant and strong enough to be processed into textiles using looms and other equipment commonly employed in the textile industry. For example, asbestos cloth, yarn and thread are used to produce welding curtains, draperies, blankets, protective clothing, hot conveyer belts, furnace shields and molten metal splash protection aprons.

THERMAL INSULATION

Asbestos is used in thermal insulation because of its temperature resistance, high tensile strength, abrasion resistance, corrosion resistance and durability. Asbestos tubing, tape, rope, card, cloth and yarn are used for safety protection in pipe wraps, stress relieving pads in welding operations, protective coverings for hot glassware utensils, coverings for diesel engine exhaust lines, flue sleeves, and braided walls in steam hose construction.

ELECTRICAL INSULATION

Asbestos yarn, roving, tape, thread, felts, cord, lap, and tubing are used for the insulation of wires and cables, arcing barriers in switches, circuit breakers, heater cords, and motor winding.

Asbestos textiles are employed in electrical insulation because of their high dielectric strength, temperature resistance, flexibility, abrasion resistance and high tensile strength.

PACKINGS AND GASKETS

Asbestos is also used in packings and gaskets in the textile industry. It provides these products with low thermal conductivity, resilience, chemical stability, immunity to thermal shock, compressibility, and abrasion resistance. For example, asbestos yarn, rope, wick, cord, cloth, and tape are used for pump packings, all purpose shaft and valve stem packings, expansion joints, manhole gaskets, seals for boilers, ovens and furnaces, flange gaskets and gaskets for storage tanks, coolers and dryers.

FRICTION MATERIALS

Asbestos textiles, usually in the form of woven yarn, are used in friction materials for brake linings, clutch facings, and brake pads, primarily because of their friction and wear characteristics.

SPECIALTY TEXTILES

Asbestos carded fiber is the main form of asbestos textiles that can be used in specialty products, such as liquid filters, electrolytic diaphragms, wiping pads and stuffing box packing. Asbestos carded fiber is well suited for these uses because of its filter medium qualities, chemical resistance and natural positive charge.

SUBSTITUTE MATERIALS

There is a large variety of fiber materials which can substitute for asbestos fibers. The physical properties of these substitutes for asbestos fibers in textile applications are presented in Table 17. Cost comparisons between asbestos fibers and substitute materials are presented in Table 18.

TABLE 17. PROPERTIES OF SUBSTITUTE FIBERS FOR ASBESTOS TEXTILE APPLICATIONS

Substitute material (manufacturer)	Product application	Properties: Temperature resistance[a] up to °C (°F)	Properties: Tensile strength[b] kPa (psi)	Comments	References
ASBESTOS:	All applications requiring an incombustible high temperature fabric.	649[c] (1200)[c]	5.68×10^6 (824,000)	Low thermal conductivity; excellent radiation stability; good flexibility; excellent resistance to moisture and corrosion; excellent spinnability; contains a minimum of magnetic or conductive fibers.	49
GLASS:	All applications requiring an incombustible high temperature fabric.	538 (1000)	2.17×10^6 (315,000)	Density similar to asbestos; excellent handling characteristics; high dielectric strength; not as durable as asbestos; may produce some skin irritation; fiber diameter 0.066 mm (0.0026 inch).	3, 49
Refrasil® (Hitco Materials)	Fire-resistant materials; thermal and electricl insulation; packings and gaskets.	982 (1800)	5.17×10^5 (75,000)	Good acid resistance; good dielectric properties; excellent resistant to thermal shock; high capacity to absorb moisture; lacks abrasion resistance, fiber diameter 8-12 microns.	50, 51
Thermo-Sil™ (Garlock, Inc.)	Fire-resistant materials; thermal and electrical insulation; packing and gaskets.	538 (1000)	2.17×10^6 (315,000)	Resists organic solvents and most acids and alkalies; resists abrasion and wear; moisture and weather resistant; dimensionally stable; high dielectric strength; low dielectric constant; soft and flexible.	52, 53
Zetex™ (Newtex Industries, Inc.)	Fire-resistant materials; thermal and electrical insulation; packings and gaskets.	1538 (2800)	3.44×10^6 (500,000)	Excellent strength and durability; excellent dielectric strength; dimensional stability; excellent cutting, sewing and handling; abrasion resistant; fiber size ~9 microns.	54, 55
CERAMICS:	All applications requiring an incombustible high temperature fabric.	1427 (2600)	high	A high tensile strength silica - alumina fiber; flexible; abrasion-resistant.	3
Nextel® 312 (3M Company)	Fire-resistant materials; thermal and electrical insulation, packings and gaskets.	1427 (2600)	1.72×10^5 (250,000)	High strength retention; low shrinkage; abrasion-resistant (after 4 hours at 816°C (1500°F), it retained 100% of its strength); good flexibility; some skin irritation; fiber size 10-12 microns in diameter.	56, 57
Thermo-Ceram™ (Garlock, Inc.)	Fire-resistant materials; thermal and electrical insulation; packings and gaskets.	1260 (2300)	1.72×10^6 (250,000)	Excellent resistance to mechanical vibration and stress; resists attack from most chemicals; no loss of strength due to water evaporation at high temperatures; low thermal conductivity and excellent electrical resistance.	52, 67
Fiberfrax® (Carborundum Co.)	Fire-resistance materials; thermal and electrical insulation; packings and gaskets.	1260 (2300)	1.72×10^6 (250,000)	Chemical resistant; low thermal conductivity; resists oxidation and reduction; excellent resistance to thermal shock.	68, 69

TABLE 17 (continued).

Substitute material (manufacturer)	Product application	Properties: Temperature resistance[a] up to °C (°F)	Properties: Tensile strength[b] kPa (psi)	Comments	References
POLYMERS:					
Nomex® (Dupont Co.)	Fire-resistant materials; thermal and electrical insulation; packings and gaskets.	371 (700)	6.89×10^5 (100,000)	Abrasion resistant, flexible, radiation resistant; chemical resistant; washable; low shrinkage.	3, 58, 59
Kevlar® (DuPont Co.)	Fire-resistant materials; friction materials; cables.	204 (400)	2.76×10^6 (400,000)	High thermal stability; excellent chemical resistance; excellent cut resistance; low thermal conductivity.	3, 58, 60
Teflon® (DuPont Co.)	Fire-resistant materials; thermal and electrical insulation; packings and gaskets.	316 (600)	3.62×10^5 (52,500)	High chemical resistance; low friction and adhesion; low shrinkage; great flex-abrasion resistance; radiation resistant.	3, 58, 61
Kynol™ (American Kynol, Inc.)	Fire-resistant materials; packings and gaskets.	704[d] (1300)[d]	1.86×10^5 (27,000)	Low moisture absorption; acid resistant; low toxic off gases; low shrinkage; is a carbon precursor; low abrasion.	62, 63
Durette® (Fire Safe Products, Inc.)	Fire-resistant materials.	593 (1100)	4.83×10^5 (70,000)	Better heat stability than Nomex®; high abrasion resistance; good acid resistance; high tear resistance; excellent dimensional stability.	3, 64
P.B.I.™ (Celanese Plastics and Specialties Co.)	Fire-resistant materials.	500 (932)	2.07×10^6 (300,000)	Polybenzimidazole; nonflammable in air; little or no emittance of toxic off gases; acid resistant; readily processed on conventional textile equipment; comfortable; good cryogenic characteristics; high moisture regain.	65, 66
Norfab® (AMATEX Corp.)	Fire-resistant material; thermal and electrical insulation; packings and gaskets.	343 (650)	Moderate	Is a combination of synthetics; excellent workability; lightweight; high abrasion resistance; flexible; good chemical resistance.	76, 77
CARBON:	Fire-resistant materials; packings and gaskets; friction materials.	1427 (2600)	Over 3.10×10^6 (450,000)	High flexibility, lightweight, good retention of fiber properties at high temperatures.	3, 70, 71
Celion® (Celanese Plastics and Specialties Co.)	Friction materials; packings and gaskets.	5432 (3000) (no oxygen)	3.24×10^6 (470,000)	Flexible, low shrinkage; excellent oxidative stability; excellent adhesion to organics; excellent electrical/thermal conductivity.	70, 71

TABLE 17 (continued)

Substitute material (manufacturer)	Product application	Properties: Temperature resistance[a] up to °C (°F)	Tensile strength[b] kPa (psi)	Comments	References
Celiox™ (Celanese Plastics and Specialties Co.)	Fire-resistant materials.	760 (1400)	2.10×10^5 (30,500)	Lightweight, flexible, high moisture regain, low density, readily converted into carbon.	70, 72
QUARTZ:					
Alphaquartz® (Alpha Associates)	Fire-resistant materials; thermal and electrical insulation; packings and gaskets.	Over 1204 (2200)	8.69×10^5 (126,000)	Thermal stability; elastic; excellent resistance to thermal shock; easily impregnated; excellent ablative characteristics; high purity; transparent to electromagnetic and radio waves.	73, 74, 75
NATURAL FIBER.					
Cotton (Westex, Inc.)	Fire-resistant materials	232 (450)	8.62×10^5 (125,000)	Flame resistant; is coated and treated; washable; fiber diameter 0.020 to 0.030 mm (0.0008 to 0.0011 inches.	49, 78

[a]Temperatures depend upon product application.

[b]Figures are for fibers only, and are not necessarily related to fabric strength.

[c]Wire inserted asbestos textiles.

[d]Carbonizing temperature range.

TABLE 18. COST COMPARISON BETWEEN ASBESTOS FIBERS AND SUBSTITUTES USED IN TEXTILES[a]

Product	Approximate cost ($) per kilogram (pound)	Reference
Asbestos	0.45-0.50 (1.00-1.10)	3
Fiberglass	0.50 (1.10)	3
Kevlar®	2.50-2.70 (5.50-6.00)	58
Nomex®	2.70-2.95 (6.00-6.50)	58
Teflon®	3.15-4.50 (7.00-10.00)	58
Refrasil®	3.15-5.40 (7.00-12.00)	50
Durette®	3.60 (8.00)	64
Nextel® 312	13.50 (30.00)	56
Kynol™	2.00-2.25 (4.50-5.00)	62
Celiox™	4.50 (10.00)	70
Celion®	11.25 (25.00)	70

[a]Prices vary with product style and quantity.

SECTION 11

MISCELLANEOUS

DRILLING MUDS

Drilling muds or drilling fluids are used when wells are drilled by the rotary method. Asbestos increases the carrying capacity of the mud (the ability of the mud to bring up cuttings) without significantly increasing the mud viscosity and acts as a loss-circulation material in helping to plug passages in the drill hole. No single substitute except possibly bentonite or attapulgite clays serves both of these functions, but several substitutes can be used as viscosifiers and many additional materials can be used as loss-circulation materials.

A list of both commonly substituted drilling mud viscosifiers and loss-circulation materials as well as a cost comparison with asbestos is in Tables 19 and 20.

TABLE 19. COST COMPARISON OF DRILLING MUD VISCOSIFIERS

Material	Cost ($/pound)	Amount used/ barrel (pounds)	Cost ($/barrel)	Reference
Asbestos	0.40 - 1.00	2 - 5	0.80 - 5.00	79, 80
Bentonite	0.05 - 0.10	20 - 40	1.60 - 4.00	79
Attapulgite	0.15 - 0.20	15 - 20	2.40 - 4.00	79
Sepiolite	0.20 - 0.25	5 - 10	1.00 - 2.50	79
Xanthan (XC) polymer	7.00 - 9.00	0.5 - 2	3.50 - 18.00	79
Carboxymethyl cellulose	3.60	0.25 - 2	0.90 - 7.20	80
Polysaccharides polymer (DF-VIS)	5.00	1 - 2	5.00 - 10.00	81
Hydroxyethyl cellulose	1.00	8 - 9	8.00 - 9.00	82

TABLE 20. COSTS OF COMMON LOSS-CIRCULATION MATERIALS[81]

Material	Cost ($/pound)
Asbestos	0.45
Cellophane flakes	0.40
Mica	0.35
Nutshells	0.30
Bentonite	0.10

OTHER PRODUCTS

Other minor uses of asbestos fibers include:

- Shotgun shell base wads
- Asphalt/asbestos cement
- Foundry sands
- Sprayed on insulation
- Artificial fireplace ashes and artificial snows.

The present use of asbestos in shotgun shell base wads appears to be negligible; one-piece polyethylene shells may serve as alternatives. While there is some indication that asbestos may improve the quality of asphalt cement, the prevailing opinion appears to be that if there is actually anything to be gained by adding asbestos, it is not enough to make it worthwhile.[83] In foundry sands, asbestos is actually an undesirable material because it lowers the refractory point of the sand mold.[84] Substitutes used in insulating sleeves on risers for foundry sand castings can be any inert mineral material that (a) withstands high heat, (b) insulates, and (c) will not crystallize with water at high temperatures.*

The use of asbestos in sprayed-on insulation was regulated in 1973,[Δ] effectively eliminating further use of asbestos in this product. Substitute materials include both cellulose fibers and rock wool, both of which are made to be fire retardant, cost-effective, and, at present, have demonstrated no adverse health effects. Artificial fireplace ashes containing asbestos were banned in 1977[85]; vermiculite, rock wool, mica, and synthetic fibers have since replaced asbestos in this use. Health considerations have also nearly halted the use of asbestos in artificial snows.

*To date, materials developed are proprietary.

[Δ]National Emissions Standard for Asbestos (40 CFR 61).

SECTION 12

CONCLUSIONS

With the exception of a few specific applications, each product category has commercially available alternatives. Characteristics of asbestos product substitutes for each category are summarized in Table 21.

Products such as specialty papers, roofing felts, A/C pipe, and aircraft brakes are, to some extent, being displaced by products that have been available for several years. Many of the available substitute products fulfill some but not all of the requirements placed on asbestos fibers. Asbestos still provides the most complete haze removal of any beverage filter; it is currently the preferred pipeline wrap because of the length of time it has been on the market; it is the single best component of tough vinyl floor tile; railcar brakes appear to be reverting to asbestos at this time; it is unique in high-temperature A/C sheet applications such as lab table tops; and it is a low cost viscosifier in drilling muds.

Substitutes are available for asphalt-based sealants, many A/C sheet products, gaskets and packings, reinforced plastics, and textiles, but often the cost is higher, the product lacks the durability attributed to asbestos, or certain applications may not be filled by the nonasbestos product. Products still in the development stage include flooring felts, various types of brakes and clutches, and asphalt-based sealants.

In no case is there a fiber or material alternative that can completely replace the special qualities of asbestos in all uses. Instead, many alternatives are available, each fitting only a small niche in the range of applications for which asbestos is currently used.

TABLE 21. SUBSTITUTE PRODUCT CHARACTERISTICS

Asbestos product category	Availability	Performance characteristics	Costs	Comments
1. Paper Products				
a. Beverage filters	Commercially available	Meets most requirements	Higher	For haze removal, asbestos still superior.
b. Millboard	Commercially available	Meets many requirements	Higher	Substitutes not available for all applications.
c. Commercial papers	Commercially available	Meets some requirements	Much higher	Substitutes not available for all applications.
d. Specialty papers	Commercially available	Meets all requirements	Comparable	Durability may not equal asbestos.
e. Roofing felt	Commercially available	Meets all requirements	Comparable	Some substitutes pre-date asbestos, best covering varies with roof
f. Heater-add gaskets	Limited availability	Not resilient	Higher	Substitutes only available for limited application.
g. Electrical insulation	Commercially available	Meets all requirements	Higher	Extensive substitute products available.
h. Flooring felt	Under development			Material substitutes such as carpet readily available; fiber felt substitute still under development.
i. Pipeline wrap	Commercially available	May be less durable	Higher	Asbestos pipeline wrap presently preferred.
2. A/C Pipe	Commercially available	Meets all requirements	Comparable	Several available substitutes.
3. Floor Tiles	Commercially available	Less durable	Higher	Currently, no substitutes comparable to asbestos.
4. Friction Products				
a. Automobile brakes	Commercially available	Meets all requirements	Comparable	Proprietary composition.
b. Heavy-duty truck brakes	Commercially available			—
c. Railcar brakes	Commercially available	—	-	—
d. Aircraft brakes	Commercially available	Meets all requirements	Higher	All new brakes cermet; some asbestos still in use
e. Industrial brakes	Under development		—	Many diversive uses.
f. Vehicle clutches	Under development			-
g. Industrial clutches	Under development		-	-
5. Sealants				
a. Asphalt-based	Under development	Expected to be less durable	Comparable	Specially treated cellulose fibers.
b. Non-asphalt based	Commercially available	Meets some requirements	Generally higher	Asbestos banned in some products.
6. A/C Sheet	Commercially available	Meets most requirements	Some higher	Substitutes for high temperature applications more costly.
7. Gaskets and Packings	Commercially available	Meets most requirements	Variable	Equipment redesign required in certain cases
8. Reinforced Plastics	Commercially available	Meets most requirements	Variable	Many manufacturers have already switched to substitutes.
9. Textiles	Commercially available	Meets most requirements	Higher	Substitutes available for most applications.
10. Miscellaneous	Commercially available	Meets most requirements	Some higher	Some asbestos products banned; drilling mud substitutes may be much more expensive.

SECTION 13
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