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ASBESTOS SUBSTITUTE PERFORMANCE ANALYSIS

Final Report

Guimond

May 1981

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CONTENTS

Figures v
Tables. vi
Acknowledgments xi

1. Introduction 1
   References. 4
2. Paper Products 5
   Introduction. 5
   Flooring Felt 7
   Roofing Felt. 10
   Beater-Add Gaskets. 16
   Pipeline Wrap 20
   Millboard and Rollboard 23
   Commercial Papers 30
   Electrical Insulation 34
   Specialty Papers. 38
   Beverage and Pharmaceutical Filters 46
   Cost Comparison 50
   Current Trends. 53
   Conclusion. 57
   References. 60
3. Friction Materials 67
   Asbestos Product. 67
   Substitute Products 77
   Cost Comparison 93
   Current Trends. 94
   Conclusion. 96
   References. 99
4. Asbestos Cement Pipe 103
   Asbestos Product. 103
   Substitute Product. 110
   Cost Comparison 128
   Current Trends. 130
   Conclusion. 130
   References. 132
5. Asbestos-Cement Sheet. 135
   Asbestos Product. 135
   Substitute Products 138
   Cost Comparison 150
   Current Trends. 151
   Conclusion. 153
   References. 155

CONTENTS (continued)

6. Flooring Products 158
   Asbestos Product 158
   Substitute Product 162
   Cost Comparison. 165
   Current Trends 165
   Conclusion 165
   References 166
7. Gaskets and Packings 168
   Asbestos Product 168
   Substitute Product 173
   Cost Comparison. 192
   Current Trends 194
   Conclusion 195
   References 196
8. Paints, Coatings, and Sealants. 201
   Asbestos Product 201
   Substitute Products. 207
   Cost Comparison. 217
   Conclusion 219
   References 221
9. Reinforced Plastics 224
   Asbestos Product 224
   Substitute Product 226
   Cost Comparison. 234
   Current Trends 234
   Conclusion 238
   References 240
10. Textiles. 242
   Asbestos Product 242
   Substitute Product 247
   Cost Comparison. 257
   Current Trends 260
   Conclusion 260
   References 262
11. Miscellaneous Uses. 265
   Introduction 265
   Drilling Muds (Fluids) 265
   Cost Comparison. 271
   Current Trends 273
   Conclusion 274
   Shotgun Shell Base Wads. 274
   Asphalt/Asbestos Cement. 274
   Foundry Sands. 276
   Sprayed-On Insulation. 277
   Artificial Fireplace Ashes and Artificial Snows. 278
   References 279
12. Results, Discussion and Conclusion. 282
   Results and Discussion 282
   Conclusion 289

SECTION 3

FRICTION MATERIALS

ASBESTOS PRODUCT

Special Qualities

All products containing friction materials rely on the coefficient of friction between mating surfaces to transmit or stop motion. Brakes convert kinetic energy into heat, absorb the heat, and gradually dissipate it into the atmosphere. Brakes consist of two parts, the rotor which is connected to the wheel, and the stator on which the friction material is mounted. Clutches transfer kinetic energy from a rotating crankshaft to the transmission and wheels. Both brakes and clutches may operate wet or dry. In dry systems, the heat is conducted to the air and surrounding structure while wet systems operate within oil or another fluid which absorbs the heat to maintain temperatures below 200°C (392°F). The special qualities required by friction materials include:

- Possession of the appropriate coefficient of friction for the desired application
- Ability to withstand the high temperatures generated at friction interfaces
- Dimensional stability
- Strength
- Durability
- Lack of abrasive characteristics which could lead to scoring of mated surfaces.

Asbestos is used in friction materials because of the properties listed in Table 11. The most important properties are thermal stability, reinforcing abilities, and relatively high friction.

TABLE 11. UNIQUE PROPERTIES OF ASBESTOS APPLICABLE TO FRICTION MATER

Properties	Comments
Fibrous form	Flexibility contributes to forming characteri Fibers interlace and interlock, enhancing str Flexibility reduces wear at friction interfac
Fine fiber diameter	Provides strong reinforcing characteristics b of the large number of fibers per unit weight
High tensile strength	Provides strength and durability to friction products.
Temperature resistance	Unaffected by T < 500°C. Stable for short per of time at T around 1000°C. Able to withstan temperatures generated at friction interfaces.
Cost	Provides low cost/performance or cost/physical property ratio.

Product Composition

Friction materials for automotive brakes and clutches are complex c posites of three general types of ingredients:

- reinforcing fibers,
- property modifiers, and
- organic resin binders.

Historically, asbestos fibers have been the major constitutent of nearly organic friction materials, so chosen because of their thermal stability tion level, reinforcing properties, availability and relatively low cost. Small quantities of other fiber reinforcement may also be used. Because tos alone does not provide all of the properties required for friction m rials, property modifiers are added to provide various degrees of fricti wear, fade, recovery, noise, and rotor compatibility. A resin binder is to hold materials toegether and contributes to the friction characterist of the mixture. Table 12 lists common ingredients found in several pate formulae. Following is a more detailed description of the raw materials in organic friction material.

Binders--

In wet mix processing, a viscous material (usually a resole) is use dry-mix processing, a powdered material (usually a novolac) is used. Ph and cresylic reins (both synthetic) are the most commonly used binders a normally modified with drying oils, rubber, cardanal, or epoxy.

TABLE 12. TYPICAL INGREDIENTS USED FOR FRICTION MATERIALS (IN WEIGHT %)[9]

	Copolymers[a]	Asbestos[b]	Sulfur	Zinc oxide	Cardolite[c]	Resin	Barite	Rottenstone	Other additives
A	22	49	2	4			12	12	
B	11	63	1	2			12	12	
C	17	54	2	3			12	12	1[d]
D	15	58	2	3			12	12	
E	15	58		3			13	12	
F	15	79	1	3		2			
G	15	69	1	3	10	2			
H	15	69	1	5	10				
I	15	79	1	3					
J	15	69	1	3		2	10[e]		
K	13	55	1	2	9	2	17[f]		
L	13	64	1	3	10	6	1[g]		1[d]
M	15	15		6		5	40[h]		19[i]
N	15	69	1	3		2	10[e]		
O	15	69		4	10	2			
P	17	49		4	30				
Q	17	65		4	10		4[j]		
R	17	69		4	10				

[a]Acrylonitrile-butadiene copolymer

[b]Grade 5K chrysotile.

[c]Friction dust made from cashew-nut shell oil (3M tradename). 5

[d]Abundum (600 ×) - aluminum oxide.

[e]Unidentified friction particle.

[f]Zinc dust.

[g]Paraformaldehyde (curing agent).

[h]Steel wool.

[i]Iron oxide.

[j]Orlon fiber.

Fibrous Reinforcements--

The asbestos normally used in friction material is chrysotile. The size distribution of asbestos fiber consumed by the friction materials industry in 1978 consisted of chrysotile grades 3 through 8 (predominantly grades 7 and 5) and anthophyllite. A total of 73,800 megagrams (72,975 ~~metric tons)~~ worth $22,813,600 Canadian dollars was consumed. Of this, only 400 megatons was anthophyllite.[6,7] Long-fiber asbestos (grades 3, 4, and 5) ~~is used in~~ dry-mix processing and short-fiber asbestos (grades 6 and 7) is used for wet-mix processing. The longer fibers permit the bending of linings from flat to curved segments. Clutch materials contain additional continuous-strand reinforcements including cotton, asbestos, yarn, brass wire, and copper wire.

Property Modifiers--

Property modifiers can be classed as nonabrasive and abrasive. Table 13 lists property modifiers and their functions in organic friction materials.

Uses and Applications

The primary uses for friction materials are brakes for light- and heavy-duty vehicles, aircraft, railcars, and various types of heavy equipment. Clutch facings are another important friction material product. Minor uses include braking mechanisms for bicycles, presses, hoists, lift trucks, mining and drilling equipment, chain saws, tape recorders, spinning and knitting equipment, typewriters, snowblowers, and washing machines. In addition, many business machines require clutch mechanisms.

The primary uses for asbestos-containing friction materials are listed in Table 14.

Product Manufacturing Summary

Manufacturing Process--

Production methods and raw materials used in the manufacture of friction materials vary, depending on the intended application of the final product.

Organic linings, which must bend, require high resin contents and long fibers. Stiffer, heavy-duty materials with less resin require molding for shape and clutch materials require special fiber-forming methods. Major manufacturing methods are described below.

Linings--Most linings are produced from resin wet-mix by extrusion or in rolling processes. Asbestos and various property modifiers are mixed with liquid resin at 50°C (120°F), then binder solvent is added to yield a putty-like mass with good wet strength. In the extrusion process, the mix is heated to 90°C (195°F) and extruded as a flat, pliable sheet which is dried for 2 hours at 80°C (175°F). In the rolling process, the partially dried mix is fed between two rolls that align the fibers into flat, pliable "green lining." Linings are then cut to length, formed at 150°C (300°F), and molded for 4 to 8 hours at 180° to 250°C (360° to 480°F). The final product is ground to produce finished brake linings.

Brake Emissions
Emyls

TABLE 13. PROPERTY MODIFIERS IN FRICTION MATERIALS[5,8,9]

Modifier	Function
Nonabrasive	
Cardolite (cashew friction dust)	Noise, wear and abrasion control
Ground rubber	
Carbon black	
Petroleum coke flour	
Graphite	
Gilsonite	
Abrasive	
Brass chips	Scavengers, breakup surface films
Copper powder	
Rottenston (decomposed siliceous limestone)	
Quartz	
Wollastonite (Wo)	
~~Zinc~~	
Aluminum	
Zinc chips	Recovery of normal performance after fade
Limestone	Improve wear resistance
Clays	
Finely divided silicas	
Barite	
Alumina (-200 mesh)	increase friction level
Silicon carbide (-200 mesh)	
Kyanite	
Molybdenite	Lubricant
Calcium fluoride	
Lead and compounds	
Antimony compounds	Use not ~~available~~ defined
Calcium compounds	
Barium hydroxide	
Potassium dichronate	
Magnesium carbonate	
Iron oxide	
Cryolite	
Nickel	
Sulfur	

Guyclo-ms table

TABLE 14. USES OF ASBESTOS-CONTAINING FRICTION MATERIALS[8]

Product	Characteristics	Applications
Primary drum brake linings	High and stable friction at temperatures up to 250°C (480°F). Tensile strength of 4000 to 5000 PSI.	Automobiles, light trucks, ~~medium trucks~~, minor railcar.
Secondary drum brake linings	Stable friction, wear resistant, tensile strength of 4000 to 5000 PSI.	Automobiles, light trucks, ~~medium trucks~~, minor railcar.
Class A disk pads	Nonabrasive friction and wear, quiet, wear resistant up to 300°C (570°F), low coefficient of friction, tensile strength of 4000 to 5000 PSI, rotor compatibility.	Large United States-made automobiles.
Class B disk pads	Higher friction, wear resistant up to 350°C (660°F) but less wear resistant at lower temperatures, less quiet, tensile strength of 4000 to 5000 PSI.	European-made automobiles.
Class C blocks	High friction minimal face, wear resistance to 400°C (750°F) at the expense of other brake characteristics.	Heavy-duty trucks.
Clutch friction materials	Stable friction, good wear up to 250°C (480°F), quiet, very high tensile strength of 10,000 PSI.	Automobiles.

Non-servo lining

Truck segments

Linings for heavy-duty use are produced by a dry-mix process. Asbestos, modifiers, and resin are mixed and formed into 60 × 90 cm (24 × 35 inches) briquets that are pressed for 3 to 10 minutes at 140° to 160°C (340° to 375°F), and cured in molds for 4 to 8 hours at 220° to 280°C (425° to 540°F). The brake linings are finished after grinding.

Disk pads--A dry-mix is prepared as for heavy-duty linings. The mix is formed into briquets at room temperature and 27.6 to 41.4 MPa (4000 to 6000 psi). The briquets are pressed at 160° to 180°C (320° to 355°F) and 27.6 to 55.2 MPa (4000 to 8000 psi) for 5 to 15 minutes and are then cured at 220° to 300°C (430° to 570°F) for 4 to 8 hours. Grinding produces the final product.

Blocks--Asbestos reinforced brake blocks are prepared by a dry-mix process. Briquets are formed at 10.3 to 17.2 MPa (1500 to 2500 psi) and heated to 90°C (195°F) for 15 to 30 minutes to reduce blistering during hot processing. Blocks are formed at 130° to 150°C (265° to 300°F) and 13.5 to 20.7 MPa (2000 to 3000 psi) for 10 to 30 minutes. The blocks are then cut and ground to shape. Final curing takes place in confined or unconfined form. After grinding, drilling, and chamferring, the block is finished.

Clutch materials--The primary concern in the manufacturing of clutch materials is the placement of the wire reinforcement within the matrix. A dry-mix is used in molding without wire or molding around wire preforms. Another method is to prepare a wet mix and run a wire through the viscous material. This material can be woven after drying. The surface is ground to final shape after pressing and curing.

Woven bands--Woven bands for heavy-duty uses are produced by a process that begins with asbestos cord (which may be reinforced with wire) being passed through a wet-mix to pick up resin and modifiers. The saturated cord is then woven into tapes that pass through heated rolls to partially cure the resin. The material can be post-cured at 160°C (320°F) to remain as a flexible roll lining or post-cured at 280° to 230°C (355° to 445°F) to form rigid segments. Such materials are found in large band brakes used to control large machinery.

Name and Number of Manufacturers--

There are 27 major manufacturers of asbestos-bearing friction materials, listed in Table 15. Both large diversified companies such as Raybestos-Manhattan and small single product companies are included in this list. The first eight companies listed in this table accounted for 75 to 85 percent of the total estimated sales of asbestos-containing friction materials in 1975, a pattern consistent with the industry's historical trend. From 1954 to 1967, the eight larger companies together accounted for 86 to 91 percent of the industry's value of shipments.[1]

Production Volumes--

Table 16 gives the consumption of asbestos in friction products for the years 1969 to 1978. Figures for production volumes were not available, but a breakdown of the value of asbestos-bearing friction materials projected to 1979 from 1972 values given by Meylan is provided in Table 17.

in 1978 situation is diff in 1981

a 1981 or 82 report should have 1980 data and 1981 and 1982 projections.

why not project to 1981 to show the downturn

HWBUI0012936

what is criterion for ranking? Sales?

TABLE 15. U.S. MANUFACTURERS OF ASBESTOS-BEARING FRICTION MATERIALS[11-33,56]

Company	Plant location(s)	Products: Brakes: Automobile and light truck	Brakes: Heavy duty truck	Brakes: Railcar	Brakes: Industrial	Clutches: Vehicle	Clutches: Industrial	Comments	Estimated 1978 sales[3] ($ million)
Raybestos-Manhattan, Inc.[11] RM Friction Materials Co.	Stratford, CT Mannheim, PA Crawfordsville, IN Fullerton, CA	Drum, disk	Disk segment, block			✓	✓		165.0
Bendix Corporation[12] Automotive GRP	Troy, NY Cleveland, TN South Bend, IN	Drum, disk	Block			✓	✓	Brakes - machine tools, off-highway equipment.	94.5
Abex Corporation[12] Friction Products Group	Cleveland, OH Troy, MI Winchester, VA	Drum, disk	Block	✓					66.6
General Motors[12] Delco-Moraine Div., Inland Div.	Dayton, OH	Drum, disk							16.2
Carlisle → H. K. Porter Company[13] Thermoid Div.	Huntington, IN	Drum, disk			✓				26.5
Auto Fric → Chrysler Corporation[12] Cycleweld Div.	Tenton, MI	Drum, disk							-
Borg Warner Corporation	Bellwood, IL	Drum, disk				✓			-
Nuturn Company[15] (formerly World Bestos Co.) Maremont Corp., Grizzly Products, Div.	Nashville, TN Paulding, OH		Block						21.5
National Friction Products Corporation[16]	Logansport, IN				✓	✓	✓	Off-road vehicles, cranes, shovels, travel trailers, mobile homes, plant machinery, appliances.	12.0
Auto Specialties Manufacturing Company[17]	St. Joseph, MI	Drum, disk			✓		✓	Off-road vehicles, agricultural equipment.	0.66
Standco Industries[18]	Houston, TX				✓		✓	Off-road equipment, winches, cranes, drilling rigs.	8.7
Friction Products Company[19]	Medina, OH		Block		✓	✓	✓		4.0
Royal Industrial Brake Products Inc.[20]	Danville, KY	Drum, disk						Assembly of parts from Canadian manufacturers.	16.0
Reddaway Manufacturing Company[21]	Newark, NJ				✓	✓	✓		3.0
Molded Industrial Friction Corporation[22]	Prattville, AL		Block					Tractors and trailers.	3.6
Wheeling Brake Block Manufacturing Co.[23]	Wheeling, WV Bridgeport, OH		Block						4.0
Force Control Industries[24]	Fairfield, OH			✓	✓			Disk and plate brakes, railcar and diesel engine brakes, tramways, off-road vehicles.	-

(continued)

TABLE 15 (continued).

Company	Plant location(s)	Products: Brakes: Automobile and light truck	Brakes: Heavy duty truck	Brakes: Rail-car	Brakes: In-dus-trial	Clutches: Ve-hi-cle	Clutches: In-dus-trial	Comments	Estimated 1978 sales[3] ($ million)
Brassbestos Manufacturing Corporation[25]	Patterson, NJ	Drum, disk						Rebuilt	8.3
Auto Friction Corporation[26]	Lawrence, MA	Drum	Drum						26.5
Gatke Corporation[27]	Warsaw, IN				✓		✓	Custom manufacturing	12.0
Lasco Brake Products Company[28]	Oakland, CA	Drum, disk	Block						3.8
MGM Brakes, Incorporated[29]	Cloverdale, CA		Block	✓	✓			Off-road vehicles, buses, rail-cars, mining equipment, towing vehicles.	<1
Carlisle Corporation[30]	Ridgeway, PA		Block	✓				Buses, off-road vehicles.	28.2
Thiokol Chemical Corporation[31]	Trenton, NJ	Drum, disk						Rebuilt only.	9.7
P. T. Brake Lining Company Inc.[32]	Lawrence, MA	Drum	Block						-
Eaton Corporation[33]	Kenosha, WI		Block, disk						-
Scan-Pac Manufacturing Company[56]	Menomonee Falls, WI							Off-road nonautomotive brake linings	2.8

TABLE 16. ASBESTOS CONSUMPTION BY THE FRICTION MATERIALS INDUSTRY [34] (THOUSAND METRIC TONS)

1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	79*	80*	81*
64	60	62	66	72	73	60	58	83	82			

*Estimated

see AIA

TABLE 17. VALUE OF ASBESTOS FRICTION MATERIAL SHIPMENTS (IN MILLIONS OF 1979 DOLLARS)[a]

Final product	Total product shipments, including interplant transfers
Brake linings	
Woven, containing asbestos yarn, tape or cloth	$ 23.2
Molded, including all nonwoven types	257.0
Disk brake pads	32.3
Clutch facings	
Woven, containing asbestos yarn, tape or cloth	45.2
Molded, including all nonwoven types	110.2
Other	8.2
Total asbestos friction material	$476.1

[a]Projected from Meylan et al.[10] using January 1980 Engineering and Mining Journal cost index factors.

SUBSTITUTE PRODUCTS

Methodology

Search Strategy--

Twenty of the largest United States asbestos product manufacturers, as listed in Meylan,[10] were investigated to determine which friction materials are being produced. These manufacturers were questioned regarding both asbestos and substitute materials. Relevant trade associations were also contacted. Several sources in the literature were recommended by the above contacts. The section in the Encyclopedia of Chemical Technology entitled Brake Linings and Clutch Facings[8] was very useful in the writing of this section.

Summary of Contacts--

The following individuals and companies provided useful information concerning friction materials.

Robert A. Clifton
U.S. Bureau of Mines
2401 E St., NW
Washington, DC 20241

Robert Curran, Chief Engineer
Spring Division
Borg-Warner Corporation
700 South 25th Ave.
Bellwood, IL 60104

George Bason
Director of Advertising and
Public Relations
Abex Corporation
530 Fifth Avenue
New York, NH 10036

Jack Reynolds
Johns-Manville Corp.
Ken-Caryl Ranch
Denver, CO 80217

Leon Kopyt
Mass Transit Systems Corp.
Suite 1428
Suburban Station Building
Philadelphia, PA 19103

Walter Nichols
Sales Representative
Midland-Ross Corporation
55 Public Square
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Eugene Connor, National Sales Manager
Johns-Manville Corp.
Ken-Caryl Ranch
Denver, CO 80217

Joe Minsky
P.T. Brake Lining Co., Inc.
18 Shepard St.
Lawrence, MA 01842

Mr. Baltz, President
Baltz Co., Inc.
28 Robinson Rd.
Lexington, MA 02173

Raybestos-Manhattan, Inc.
100 Oakview Drive
Trumbull, CN 06611

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Asst. Dir. of Business Planning
Automotive Group
Bendix Corporation
40 North Bendix Dr.
P.O. Box 4001
South Bend, IN 46634

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Royal Industries, Inc.
Brake Products Division
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Edward W. Drislane
Executive Director
Friction Materials
Standard Institute
East 210, Route 4
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Bendix ~~Research Labs~~ Materials Center
Bendix Center
Southfield, MI 480~~76~~37

Mr. Gorney, Mr. Alek
Griffin Wheel Co. (Division
of Amsted Industries, Inc.)
200 W. Monroe St.
Chicago, IL 60606

Terry Blaine
Spring Division
Borg-Warner Corporation
700 South 25th Ave.
Bellwood, IL 60104

Paul Biondo
Auto Friction Corp.
652 Andover St.
Lawrence, MA 01842

Robert Randolf
Gatke Corp.
E. Winona Ave.
Warwaw, IN 46580

Lasco Brake Products Corp., LTD
26th & Magnolia Sts.
Oakland, CA 94607

Mr. Apollogene, Sales Representative
MGM Brakes
21800 Greenfield St.
Detroit, MI 48236

Carlisle Corporation
511 Watnut St.
Cincinnati, OH 45202

Thiokal Corporation/Chemical Div.
P.O. Box 1296
Trenton, NJ 08607

Jack Payton, Shop Superintendent
Friction Products Co.
922 Lake Rd.
Medina, OH 44256

Standco Industries, Inc.
P.O. Box 87
Houston, TX 77001

Bill Shine, Sales Administrator
Auto Specialties Mfg. Co.
P.O. Box 8
St. Joseph, MI 49085

Donna Craven, Customer Service
Scandura, Inc.
P.O. Box 949
1801 N. Tryon St.
Charlotte, NC 28231

Brassbestos Mfg. Corp.
45 E. 5th St.
Paterson, NJ 07524

Earl Fygert
Sales Manager
National Friction Products Corp.
1441 Holland St.
Logansport, IN 46947

Mr. Sleeth
H.K. Porter Co., Inc.
Thermold Division
315 Porter Bldg.
Pittsburgh, PA 15219

Mr. Montgomery, General Manager
Stanley Belting Co. (Distributors
for Reddaway Mfg. Co.)
28 Euclid Ave.
Neward, NJ 07105

Wheeling Brake Block Mfg. Co.
3602 Jacob St.
Wheeling, WV 26003

Reginald Kelley, General Sales Manager
Force Control Industries, Inc.
3656 Dixie Highway
Hamilton, OH 45014

While it is true that ~~many~~ evaluations are made on the basis of friction stability, wear, noise, etc., it should be emphasized that some companies (Bendix is one) are placing equal emphasis in the evaluation of potential health hazards.

often the product is noisy in use.

Roy Huckabee, Sales Representative
Nuturn Co. (formerly World
  Bestos Co.)
1112 S. 25th St.
New Castle, IN 47362

Fiber Substitutes

Most companies have pursued the development of both fiber and product substitutes to insure asbestos-free products at the earliest possible date. Both naturally occurring and synthetic materials have been evaluated as substitutes to asbestos in friction products. Evaluations are made on the basis of friction stability, wear, effect on opposing surfaces and noise. In many cases, direct substitution of the alternatives mentioned here has resulted in poor friction levels, friction instability, roughness, structural failure, increased noise, mating surface deterioration and/or front to rear brake imbalance, such that complete reformulation is necessary as a further course of action.[36] Using nonasbestos fibers [illegible] is difficult as most fibers ~~are~~ very brittle, have little ~~or~~ no surface adsorptivity, ~~are often more noisy in use~~ and are difficult to handle. Whereas asbestos ~~fiber~~ bundles open during mixing to entrap the friction modifiers and resin, giving a consistent mix, nonasbestos fibers often spring back and their low tack leads to weak greater structures. Asbestos has a high, stable friction level, good adsorptivity for strength and wear resistance and does not contribute significantly to noise; substitute fibers generally show greater frictional instability, little or no surface adsorptivity, and/or a significant contribution both to the noise factor and to mating-surface degradation.[36] ~~Substituting an organic for a semimetallic~~, for example, ~~results in greater~~ wear (especially in ~~compact cars with solid rotors)~~; ~~this can also cause brake lock-up on slippery surfaces~~. Many factors such as these influence the special quality attributes of asbestos versus substitute materials in this area.

EPA/CPSC paper

X

Special Qualities and Product Composition--

These are given for the following materials, which have been proposed as substitutes for asbestos in various friction materials. Some have been successful in replacing organic friction materials for some applications. Table 18 summarizes the advantages and potential problems with these materials as compared to asbestos.

Glass fiber--The overall strength of glass fiber is lower than that of asbestos but strong enough for friction material applications. However, it is not a viable substitute because it melts at the temperatures reached at braking interfaces even in depths below the operating surface, causing fade. It also looses its fibrous form in high shear mixing, has low wear resistance, and wears aggressively.

Steel wool[8,24]--Compared to asbestos, the overall strength of steel is lower and its cost is higher. The material hardness of steel wool can result in scoring ~~of the mating~~ surface. Wear debris can cause severe damage to the counterface. Brakes using steel fibers are more noisy than asbestos-containing brakes.

not true

this ref did not say this

Class B organics are more aggressive and noisier than semimetallics

TABLE 18. REINFORCING FIBERS FOR FRICTION MATERIALS[a]

Fiber	Advantages	Potential problems
Asbestos	High strength and modulus Thermal stability Infusible Good wear Also acts as filler	Linked to health problems due to its fibril sizes. some of
Aramid (Kevlar®)	High strength and modulus Thermal stability Non-aggressive wear characteristics	Needs special attention in mixing
Steel Wool	Adequate strength and modulus Thermal stability	Noisy, high density Corrosion Low cold friction Costly
Glass	Adequate strength and modulus Controllable fiber diameter	Melts at very high temperatures causing fade Loses fiber form in high shear mixing Molding spring back Low wear resistance Aggressive wear characteristics
Cermets-Sintered Materials	High thermal stability	High cost, insufficient wear resistance, high thermal conductivity
Silicon Nitride	Long service life, high thermal conductivity	Expensive, heavy
Noroloid Fibers	Highly insulating, flame-retardant, nonmelting	
Carbon Fibers	High strength, very high modulus Infusible High thermal stability Low density	Loses fiber form in mixing Costly Low temperature and impact strengths
Mineral Wool	Inexpensive	Low strength, brittle
Semi-metallic Materials	Thermal stability Excellent wear resistance	Expensive
Vermiculite	High temperature strength	

[a]Halvar Y. Loken, Industrial Fibers Div., E.I. duPont de Nemours & Co., Inc., Wilmington, DE,[40] in combination with GCA literature reviews.

not fibers

Ceramets and Semimets are asb-free friction materials both of which usually contain steel fiber see paper by Halberstadt

Mineral wool[24]--The overall strength of mineral wool is very low and brittle to the extent of limiting mixing processes.

Potassium titanate fibers[7]--The National Aeronautical and Space Administration (NASA) has investigated new friction materials and their applications outside the space program. As part of this effort an improved friction material was developed that utilized potassium titanate fibers with the DuPont tradename FYBEX for lightweight cars and trucks. However, unfavorable toxicological effects and other market considerations caused DuPont to withdraw FYBEX from the market.

Silicon nitride[37]--This material was used for the brake pads in prototypes of the Concorde. It has a longer service life than asbestos and higher thermal conductivity (desirable in this application) but is more expensive and heavier than the carbon composites eventually adopted.

Noroloid fibers[38]--Noroloid fibers were invented by the Carborundum Company in the late 1960s. Made from novolac (phenol-formaldehyde) resin, the fibers are compatible with many resin and rubber matrices. The manufacturer claims the highly insulating, flame-retardant and nonmelting fibers are finding increased acceptance as a replacement for asbestos in, among other applications, friction materials.

Carbon fiber[8,24]--The main properties of carbon fibers are good but still somewhat inferior to asbestos. A major consideration is cost, which is a ~~great deal higher than for~~ asbestos. It is more efficient than asbestos under high service temperature conditions, but heat flow is uneven and the tensile and impact strengths are relatively low. It has high thermal stability and low density, making it especially attractive for aircraft brakes. Abex Corporation of New York, NY took out a patent for a nearly pure carbon article for replacement of brakes or clutch disks in 1971. Abex makes tiger composition brake shoes containing fiber, rubber, resinous material and fillers.[12]

not true for carbon brakes

error?

Vermiculite--A British patent was recently issued for a vermiculite-based brake lining. The composition of this product is given in Table 19. Although not produced in volume, it serves as an example of continuing research and development activity aimed at replacing asbestos in brake linings.

TABLE 19. VERMICULITE-BASED BRAKE LINING FORMULATION[39]

Material	% Composition
4% solution of rubber	40
Calcium carbonate	15
Barium sulphate	15
Synthetic rubbers	20
Iron oxide, zinc oxide, chromium oxide	10

DuPont has indicated in a recent meeting that they do not know of any company that is using their fiber (Kevlar) in brake pads or linings.

Delaminated vermiculite is used in friction materials commercially available throughout Europe. They maintain strength at high temperatures, are compatible with phenolic resins, require little attention in manufacturing methods, and may be used with asbestos to help reduce asbestos content.[37]

Aramid fibers--Kevlar® aramid fiber is made of an infusible aromatic polyamide polymer. Inert fillers are then selected on the basis of thermal and wear characteristics, with less concern about other properties due to Kevlar's efficient strengthening. One brake mix tested consisted of: 50 percent wollastonite, 20 percent barium sulfate, 15 percent dry phenolic resin, 15 percent cashew friction particles, strengthened with different forms of Kevlar at the 5 percent level. Kevlar can be bought as cut fiber, which can be processed in a mixer to any length. Kevlar can also come as a continuous filament whch gives the highest strength conversion, or as a pulp which is more fibrillated and shorter than cut fiber and can be readily processed into friction paper.[40]

Aramid fibers are being researched for use in high performance dry clutch facings, automatic transmissions and asbestos-free brakes. Kevlar, for example, has high tensile strength and is reported to be five times stronger than steel on a weight basis.[40] Composites have good resistance to external abrasion, high frictional stability, excellent durability, and much better high temperature properties than common organic fibers. They are used in disk brake pads with wear levels between asbestos and semimetallics, and are now in experimental use in drum brake linings and wet friction papers. They do not score mating surfaces and can presently be found in manual transmissions for Mercedes, Audi and Porsche.[51] However, the fibers are not easily dispersed in mixing as they tend to clump together. E.I. duPont de Nemours & Co., Inc.

edv. ~~of Wilmington, DE produces Kevlar aramid fiber.~~ This appears to be a promising candidate for reinforcement of friction materials.

Other[37]--Various other fibers have been used in phenolic binders, such as aluminosilicates (wollastonite). However, all have drawbacks and none is yet as good as asbestos, especially for higher-temperature applications such as disk brake pads.

Product Substitutes

Special Qualities and Product Composition--

The following materials are currently under development and/or production as direct substitutes for asbestos friction products. Some of these presently occupy a significant share of the friction materials market for some applications.

Carbon composites[8]--These materials are made of carbon fiber - reinforced carbon matrix composites. The fibers are produced by graphitization of organic or pitch fibers by techniques resulting in parallel alignment of carbon chains with fiber length providing maximum tensile strength. In one description, the article is wound up from one or more filaments, resin soaked, and then the whole ~~part is~~ ultimately carbonized by sintering. The carbonized reinforcing filaments have a greater strength than the carbonized resin binder. These filaments can be used for strength alone and to back an all-carbon friction facing which has no filaments.[36]

X

misquote

This statement is true for some semimetallics
For most semimetalls it is more correct
to say:

Semimetallics--The major constituent of nearly all semimetallics is iron ~~powder in conjunction with a small amount of steel fiber~~. Property modifiers are added to provide desired performance characteristics and a resin binder is added to hold the materials together. Nonabrasive modifiers including cardolite, ground rubber, carbon black, petroleum coke flour, and natural and synthetic graphite are added to control friction, improve wear, and reduce noise. Abrasive modifiers such as alumina, silicon carbide, and kyanite are also used to control friction. A typical semimetallic friction formula may include metallic powder, sponge iron particles, ceramic powder, steel fiber, rubber particles, graphite powder, and phenolic resin. Because of the ferrous nature of the product, rust inhibitors may be added.

which may be in the form of iron particles, steel fiber, or a mixture of both

Semimetallics were first introduced in the 1960s, primarily to meet heavy-duty disk brake and extreme duty truck block applications, although they operate satisfactorily against the ventilated cast-iron rotors in the smaller brakes of downsized cars and against the solid rotors found in the lighter brakes of new front wheel drive vehicles. They rely on steel fiber and powder metallurgy techniques for reinforcement without asbestos. Semimetallics are stable to temperatures of 400°C (750°F) and exhibit excellent wear resistance.[8]

particles

Cermets[8,24]--Cermet friction materials are composed of metal bonded ceramic. The metal matrix may be copper or iron. Typical formulae are presented in Table 20.

Cermets have extremely high thermal stability. ~~Wear resistance~~ Friction is not sufficient for automobile use and cost is high. They are used extensively in aircraft and high-speed train brakes. Both carbon fiber and cermet materials are stable to 700°C (1290°F). One problem is high thermal conductivity, which can excessively heat hydraulic brake fluid causing erratic performance.[41] This problem may be avoided by proper design.[49]

Other--Raybestos-Manhattan Inc. manufactures RAYFLEX, a nonasbestos friction material for use in oil-cooled transmissions and brake applications in large, off-the-road vehicles.[48]

Uses and Applications--

Semimetallic, cermet, and carbon composite materials are used in the friction materials industry as substitutes for asbestos based friction materials for the B applications.

The Friction Materials Standards Institute polled its membership early in 1980 to obtain information on the use of nonasbestos ~~disk brakes~~ friction materials.[43] Results of this survey are presented in Tables 21 and 22. However, the data does not specify the exact type of nonasbestos lining used nor the actual prevalence of the asbestos substitute.* In other cases, such as for police cars and taxis, nonasbestos brake linings were a buyer option, with actual usage depending on the number of orders placed.

*In some years, semimetallics were being phased in and were not included on all models.

TABLE 20. CERMET FRICTION MATERIALS, WT %[42]

Material	1	2	3	4	5	6	7	8	9	10
Matrix										
copper	47.1	49.6	44.6	44.7	44.9	46.2	52.4	43.6	18.6	46.2
zinc										5.5
tin								7.4		3.3
nickel	7.1	7.1	7.1			7.0	6.6	6.6	7.1	
titanium	3.6	3.6	3.6			3.5	3.3	3.3	3.6	
brass chips									28.6	
iron				15.0	15.0					8.8
Total	57.8	60.3	55.3	59.7	59.9	56.7	62.3	60.9	57.9	63.8
Friction Material										
calcined kyanite	26.1	26.1	26.1	24.9	19.9	25.6	24.0	24.2	26.1	22.0
silica	4.8	4.8	4.8	4.6	4.6	4.8	4.4	4.5	4.8	4.4
Total	30.9	30.9	30.9	29.5	24.5	30.4	28.4	28.7	30.9	26.4
Lubricant										
graphite	1.2	1.2	1.2	1.1	6.1	1.1	1.1	1.1	1.2	8.8
lead						2.0	3.7			
Total	1.2	1.2	1.2	1.1	6.1	3.1	4.8	1.1	1.2	8.8
Antioxidant										
molybdenum	10.0	7.5	12.5	9.5	9.5	9.8	4.6	9.3	10.0	1.0
Total	10.0	7.5	12.5	9.5	9.5	9.8	4.6	9.3	10.0	1.0

22

TABLE 21. PASSENGER CAR AND LIGHT TRUCK USAGE OF NONASBESTOS DISK BRAKE ~~LININGS~~ PADS[43] (See Table AL for Police/Taxi option usage)

Vehicle type	Nonasbestos lining (with asbestos back)		Nonasbestos lining only
American Motors			
1980, Spirit, Concord 4's	Outer only		
1980, Spirit, Concord, Eagle 6's	Outer only		
1979, AMX	Outer only		
Buick			
1980, Buick Electra			I & O
1979-80, Riviera	I & O		
1980, Regal, Century	I & O	or	I & O
1980, Skylark (Power brakes)			I & O
1980, Skylark (Manual brakes)			Inner only
1976-80, Skyhawk	I & O		
1978-79, Regal, Century (Power brakes)			I & O
1978-79, Regal, Century (Manual brakes)			Outer only
1976-79, Skylark			Outer only
1976-77, Century (Manual brakes)	Outer only		
1973-75, Apollo (Manual brakes)			Outer only
Cadillac			
1979-80, Eldorado (Diesel)	I & O		
1979-80, Seville (Diesel)	I & O		
1968-80, Commercial	I & O		
Chevrolet			
1980, Monte Carlo, Malibu	I & O	or	I & O
1980, Citation (Power brakes)			I & O
1980, Citation (Manual brakes)			Inner only
1976-80, Monza	I & O		
1980, Chevette			Outer only
1976-80, Camaro			Outer only
1978-79, Monte Carlo, Malibu (Power brakes)			I & O
1978-79, Monte Carlo, Malibu (Manual brakes)			Outer only
1976-79, Nova			Outer only
1976-77, Malibu (Manual brakes)	Outer only		
1976-77, Vega	I & O		
1973-75, Nova (Manual brakes)			Outer only

(continued)

TABLE 21 (continued).

Vehicle type	Nonasbestos lining (with asbestos back)		Nonasbestos lining only
Chevrolet Truck			
1978-80, El Camino			I & O
1979-80, C-, K-, P-20	I & O	or	I & O
1979-80, C-, P-30	I & O	or	I & O
1979-80, K-30	I & O		
1979-80, P-30 (JF-9) (Front & Rear)	I & O		
1979-80, G-30			I & O
1976-78, C-, K-, P-20	I & O	or	I & O
1976-78, C-, G-, P-30	I & O	or	I & O
Dodge			
1978-80, Omni	I & O		
Dodge Truck			
1976-78, Mini Bus	I & O		
1976, W-300	I & O		
Ford			
1979-80, Fairmont V8	I & O		
1980, Thunderbird	I & O		
1979-80, Mustang V8, Turbo 4	I & O		
1979-80, Fiesta	Outer only		
1980, Mustang V6	I & O		
Ford Truck			
1976-80, F-100 (4 × 4)	I & O		
1977-80, F-150 (4 × 4)			
1976-80, Bronco	I & O		
1976-78, F-250 (Lt)	I & O		
1976-80, E-250, F-250 (HD), E-350, F-350	Inner only		
1980, E-350 School Bus	I & O		
GMC Truck			
1978-80, Caballero			I & O
1979-80, C-, K-, P-2500	I & O	or	I & O
1979-80, C-, P-3500	I & O	or	I & O
1979-80, K-3500	I & O		
1979-80, P-3500 (JF-9) (Front & Rear)	I & O		

(continued)

TABLE 21 (continued).

Vehicle type		Nonasbestos lining (with asbestos back)		Nonasbestos lining only
1979-80,	G-3500			I & O
1976-78,	C-,K-,P-2500	I & O	or	I & O
1976-78,	C-,G-,P-3500	I & O	or	I & O
Mercury				
1979-80,	Zephyr V8	I & O		
1980,	Cougar	I & O		
1979-80,	Capri V8, Turbo 4	I & O		
1980,	Capri V6	I & O		
Oldsmobile				
1980,	Oldsmobile 98			I & O
1979-80,	Toronado	I & O		
1980,	Cutlass	I & O	or	I & O
1980,	Omega (Power brakes)			I & O
1980,	Omega (Manual brakes)			Inner only
1976-80,	Starfire	I & O		
1978-79,	Cutlass (Power brakes)			I & O
1978-79,	Cutlass (Manual brakes)			Outer only
1976-79,	Omega			Outer only
1976-78,	Toronado	Outer only		
1976-77,	Cutlass (Manual brakes)	Outer only		
1969-75,	Oldsmobile Commercial	I & O		
1974-75,	Toronado	I & O		
1973-75,	Omega (Manual brakes)			Outer only
Plymouth				
1978-80,	Horizon	I & O		
Pontiac				
1980,	LeMans, Grand Prix	I & O	or	I & O
1980,	Phoenix (Power brakes)			I & O
1980,	Phoenix (Manual brakes)			Inner only
1976-80,	Sunbird	I & O		
1976-80,	Firebird (drum rears)			Outer only
1979-80,	Firebird (organic disc rears)	I & O		
1978-79,	LeMans, Grand Prix (Power brakes)			I & O
1978-79,	LeMans, Grand Prix (Manual brakes)			Outer only

(continued)

TABLE 21 (continued).

Vehicle type		Nonasbestos lining (with asbestos back)	Nonasbestos lining only
1978-79,	Phoenix		Outer only
1976-77,	Ventura		Outer only
1976-77,	LeMans (Manual brakes)	Outer only	
1976-77,	Astre	I & O	
1973-75,	Ventura (Manual brakes)		Outer only
Toyota			
1980,	Corolla Coupe	I & O	

Key: I = Inner Lining
O = Outer Lining

TABLE 22. POLICE AND TAXI USAGE OF NONASBESTOS DISK BRAKE LINING ON FRONTS[a 43]

Vehicle type		Nonasbestos lining (with asbestos backing)
<u>American Motors</u>		
1978,	Concord Police, Taxi	Outer only
1975-78,	Matador Police	Both I & O
<u>Buick</u>		
1971-80	Buick Police, Taxi	Both I & O
1979-80	Century Police	Both I & O
<u>Chevrolet</u>		
1971-80,	Chevrolet Police, Taxi	Both I & O
1977-79,	Nova Police	Both I & O
1979-80,	Malibu Police	Both I & O
<u>Chrysler</u>		
1976-80,	Chrysler Police, Taxi	Both I & O
1978-80,	Cordoba Police	Both I & O
1977-80,	LeBaron Police, Taxi	Both I & O
<u>Dodge</u>		
1977-80,	Aspen Police, Taxi	Both I & O
1979-80,	St. Regis Police, Taxi	Both I & O
1977-80	Diplomat Police, Taxi	Both I & O
1977-78,	Monaco Police, Taxi	Both I & O
1977,	Royal Monaco Police, Taxi	Both I & O
<u>Ford</u>		
1978-80,	Fairmont Police, Taxi	Both I & O
1976-80	Ford Police, Taxi	Both I & O
1976-80,	Granada Police, Taxi	Both I & O
1978-79,	LTD II Police, Taxi	Both I & O
<u>Mercury</u>		
1978-80,	Zephyr Police, Taxi	Both I & O
1976-80,	Mercury Police, Taxi	Both I & O
1976-80,	Monarch Police, Taxi	Both I & O

(continued)

TABLE 22 (continued).

Vehicle type		Nonasbestos lining (with asbestos backing)
Oldsmobile		
1971-80,	Oldsmobile Police	Both I & O
1979-80,	Cutlass Police	Both I & O
Plymouth		
1977-80,	Volare Police, Taxi	Both I & O
1977-80,	Gran Fury Police, Taxi	Both I & O
1978,	Fury Police, Taxi	Both I & O
Pontiac		
1971-80,	Pontiac Police, Taxi	Both I & O
1979-80,	Phoenix Police	Both I & O

[a]Police and Taxi usage of nonasbestos disk brake linings was as a Police/Taxi option — actual usage depended on customers ordering that option. Ford-Mercury in 1976-78 also had non-asbestos disk rears for the Police/Taxi option.

Key: I = Inner Lining
O = Outer Lining

mandated the use of semimetallics
as Class A organics gave poor
performance and Class B organics
were noisy and scored rotors.

Ref 1 is in error. Fuel efficient vehicles and
front wheel drive has increased the need for
heavier-duty small brakes that need the
improved performance that semimetallics offer.

friction materials

Semimetallic or resin bonded metallic ~~brakes~~ are presently used in heavy-duty automotive applications such as police cars and taxis. Semimetallic disk pads ~~developed~~ were able to attain overall excellent properties at both low and high temperatures which ordinary Class A or Class B organics could not accomplish. Downsizing of vehic~~les, resulting in smaller front brakes and~~ higher operating temperatures has helped semimetallics gain a foothold here. Semimetallic drum ~~linings,~~ blocks first used in air brakes in heavy-duty trucks used in the logging industry (an extremely severe application), have been attempted to be scaled down to small drum brakes, but the basic nature of semimetallics has not lent itself to the accurate segment configuration required in this application. Here, semimetallics do not possess the necessary green strength, are difficult to bend into the proper shape, and are more brittle in cured form and therefore subject to cracking. Modifications to date have generally resulted in a product that cannot achieve commercially-acceptable performance characteristics. Work in this area therefore continues. The first generation of asbestos-free drum linings is currently under evaluation by vehicle manufacturers.[36] While their performance may be superior to asbestos ~~brake~~ linings, semimetallic conductive brake linings tend to perform erratically in different temperatures, fade, ~~and produce~~ more noise than asbestos linings. They are more aggressive than asbestos ~~brakes~~ based linings; that is, ~~they have~~ higher friction levels and cause more wear. Currently, semimetallics are 50 to 60 percent more expensive than asbestos ~~linings~~ compounds but with increased production it is estimated that costs would drop to within 25 percent of asbestos brake linings.[1] Approximately 20 percent of passenger cars using disk brakes in 1979 and 65% in 1981 ~~are~~ were equipped with semimetallic disk brakes as original equipment,[44] and it is estimated that in ~~5 to 10~~ 1985 years, most original equipment disk brakes in passenger cars and light trucks will be equipped with semimetallics.[36]

As Table 21 shows, General Motors, in the past, has used a hybrid brake consisting of one semimetallic and one organic asbestos ~~lining~~ disc pad in some mass-produced passenger cars. Here the asbestos ~~lining~~ backing plate insulates the brake fluids from heat ~~generated~~ conducted ~~by the~~ semimetallic surface during braking, but never actually touches the rotor surface. In effect, the asbestos content of the brakes is reduced. Compared to asbestos-lined disk brakes, the hybrid brakes have a higher coefficient of friction, higher heat resistance, and wear longer but ~~are more noisy and more expensive~~. While some industry ~~sources feel that hybrid brakes will capture the market because of~~ superior performance, others believe that trends to lower speed limits and lighter weight cars will reduce the need for high performance brakes.[1] This uncertainty is reflected in Table 21 where, for example, American Motors reports using a nonasbestos brake lining with an asbestos back on outer brake positions only on their 1980 Spirits while Chrysler uses nonasbestos linings with an asbestos back on both inner and outer brake positions on their 1980 Dodge Omnis.

Check over statement in 8th draft

a compromise in cost vs full semimet or Class B.

~~The he~~avy weights and high landing speeds of modern aircraft and high-speed trains require friction materials with high thermal stability. Cermet ~~materials~~ possess this property and, for this ~~reason,~~ their share of the aircraft brake market continues to grow. Currently, 95 percent of all new commercial aircraft use cermet brakes. The remaining 5 percent are carbon composite.[45]

do trains fly and land

mistake?

get info from a carbon brake person like N.A. Hooton

HWBUI0012958

last paragraph P 92

Abex also makes fiberglas ~~[illegible]~~ reinforced disc brake friction materials! However on P 79, Para 3 it is stated that glass fiber is not a viable substitute.

Cermet materials have also been used for railcar brakes, but, in the last several years, nearly ~~all railcar br~~akes have been made of rubber polymeric binders with various frictionizers and friction modifiers.[46] In general, asbestos and lead are not pre~~sent in the~~se brakes.[47]

Substitute Product Manufacturing Summary--

usually not true

Manufacturing process--Semimetallic disk pads are made using a dry-mix process. Ingredients are blended, then formed into briquets at room temperature and 27.6 to 41.4 MPa (4000 to 6000 psi). The briquets are then hot-pressed at 160° to 180°C (320° to 360°F) for 5 to 15 minutes at 27.6 to 55.2 MPa (4000 to 8000 psi). The pads are then cured at 220° to 300°C (430° ~~to 570°F) for 4 to 8 hours.~~ Final grinding produces the finished disk pads. Semimetallic blocks are produced from the same dry-mix as semimetallic disk pads. Briquets are ~~formed at 10~~.3 to 17.2 MPa (1500 to 2500 psi). Briquets may be heated to 90°C (195°F) for 15 to 30 minutes to reduce blistering during hot pressing. Blocks are formed by heating at 130°C to 150°C (265° to 300°F) at 13.8 to 20.7 MPa (2000 to 3000 psi) for 10 to 30 minutes. After cutting to size, blocks are ground to the appropriate size, followed by curing [unconfined for 15 hours at 180°C (355°F) or confined for 6 hours at 280°C (535°F)]. The final block requires grinding, drilling and chamferring.

Cermet materials are manufactured using the powder metallurgy technique. Desired amounts of individual ingredients are weighed, mixed, compacted, sintered, and coined (or recompacted). The sintering is performed in a reducing or neutral atmosphere, and the sintering temperature has to be high enough so that the metal ingredients will adhere to each other.

In carbon composites, carbon or graphite fibers are embedded in a carbon or graphite matrix. The matrix can be formed by two methods: chemical vapor deposition and coking. In the case of chemical vapor deposition, a hydrocarbon gas is introduced into a reaction chamber in which carbon formed from the decomposition of the gas condenses on the surface of carbon fibers. An alternative method is to mold a carbon fiber-resin mixture into shape and coke the resin precursor at high temperatures. In both of the methods the process has to be repeated until a desired density is obtained.

Name and number ~~of manufacturers~~--Table 23 lists nonasbestos brake manufacturers, their locations, and the substitute materials they use. Semimetallic disk brakes (pads and blocks) were originally designed and produced by Bendix Corporation. Bendix has reported that new equipment was required for their manufacture. Abex Corporation ~~and Raybestos~~-Manhattan, Inc. also make semimetallic disk brakes pro

Cermet materials are manufactured ~~by Bendix~~ Corporation and ~~Abex Corporation~~. Abex also makes fiberglass disk brakes. Carbon composite brakes are manufactured by Dunlop. American ~~Filler and~~ Abrasives has been marketing an asbestos substitute called Kay-O-Cel, made primarily of cellulose and clay wastes, which is being tested in brake linings.[42] Kevlar® aramid fiber products are made by E.I. DuPont de Nemours and Co., Inc. of Wilmington, DE. Raybestos-Manhattan makes Rayflex for brakes in off-the-road vehicles.

(Bendix, Goodrich, and Goodyear.

While DuPont may be expanding production facilities for its aramid fiber, there is no reason at present to believe this is due to finding an asbestos substitute for use in friction materials.

TABLE 23. NONASBESTOS BRAKE MANUFACTURERS

Manufacturer	Location	Substitute material
Bendix Corp.	Southfield, MI* Troy, NY Cleveland, TN	Semimetallics Cermets
Abex Corp.	Cleveland, OH Troy, MI Winchester, VA	Semimetallics Cermets Fiberglass
Raybestos-Manhattan, Inc.	Stratford, CT Trumbull, CT	Semimetallics
Dunlop	Δ	Carbon composite
American Filler & Abrasives	Bangor, MI	Kay-O-Cel (cellulose and clay)
Delco-Moraine Div., General Motors Corporation	Dayton, OH	Semimetallics
E.I. DuPont deNemours and Company	Wilmington, DE	Kevlar (aramid)

*Designed at this location

$^{\Delta}$Location unknown – why (England)

Production volumes--Although production figures for individual firms are not available, it is known that semimetallic materials in 1980 were ~~are~~ used ~~for~~ in 40 percent of all front disk brakes.[54] Cermet materials are used almost exclusively for aircraft brakes and cont~~rol~~ 95 percent of the current market. Carbon composite brakes are used for the remaining 5 percent of the aircraft brake market.[45] Kevlar® products are available from a commercial production facility wh~~ich is~~ being expanded to 20 million kg/yr capacity.[40]

COST COMPARISON

The basic cost of the substitute friction products involves many complex factors, including the amount and types of materials used and the basic raw materials cost. The fixed and variable costs of manufacturing can differ greatly, based on the type of process and its complexity as well as production volumes, labor costs, energy costs, and process yield. Administrative costs and handling/distribution costs are also significant variables as are implementation costs. Here, it appears that timing of test programs will be important as expenses could be minimized by converting to asbestos-free materials as part of the scheduled new vehicle ~~design programs, where significant~~ brake system testing ~~is already~~ necessary. Life cycle costs are also a necessary consideration; semimetallics have higher life cycle costs than organics, yet they are smaller and lighter and therefore result in better fuel economy.[50]

Although exact costs for semimetallic friction materials are not available, their improved performance compensates for their higher costs due to more expensive ingredients, higher specific gravity, and more costly processing requirements. Currently, they are good candidates ~~to~~ and have replaced organic friction materials in disk brakes. Preliminary cost estimates indicate that asbestos-free brake lining may cost 20 to 25 percent more than current linings with disk brakes at 20 to 100 percent greater cost. These preliminary estimates are highly dependent on the characteristics of semimetallics making them extremely difficult and costly to process as drum lining segments. Consequently a new class of friction materials is currently under development to suit this application.[36] X

Cermets cost three to five times as much as asbestos friction materials. Costs for carbon composites are not available but they are considerably more expensive than cermets. Kevlar® (aramid) fiber is available in a short pulp form at $3.75/lb ($8.25/kg). Only small amounts of this fiber are reported to be required with deep filler materials, making the cost between 20 and 40 percent greater than for asbestos, with lifetime costs approaching those of asbestos.[51] Table 24 lists the costs of various fibers proposed as substitutes for asbestos in friction material.

TABLE 24. COSTS OF MATERIALS PROPOSED AS SUBSTITUTES FOR ASBESTOS IN FRICTION MATERIALS[1]

Material	Price - $/lb ($/kg)
Asbestos	0.05 - 0.15 (0.11 - 0.33)
Fibrous glass	? 0.05 - 0.75 (0.11 - 1.65) 0.50-0.75
Mineral wool	0.15 (0.33)
Potassium titanate fibers	1.00 - 1.25 (2.20 - 2.75)
Graphite and carbon fibers	10.00 - 12.00 (22.00 - 26.50)
Wollastonite	~~0.15~~ (0.33)
Aramid fibers	6.00 - 8.00 (13.25 - 17.65)

CURRENT TRENDS

The need for more energy-efficient automobiles and trucks has put an increased demand on friction materials. Major trends are towards smaller, lighter, more efficient vehicles with manual transmissions and smaller brakes. Although organic friction materials will continue to serve the drum brake industry, more and more vehicles are being equipped with ventilated disk brakes. Ventilated brakes may be replaced by solid disk brakes to save weight. As brakes become smaller, braking temperatures become higher. Class B organic and semimetallic friction materials will replace Class A organics because they have higher thermal stability. Heavy vehicles are using more and more efficient disk brakes. More cermet friction materials will be used in heavy-duty clutches. The trend in aircraft brakes may be toward lighter carbon composite materials.

Rockwell does not manufacture friction materials.
They may have requested that their suppliers
provide asb-free fm's.

with the remaining role being in the braking stage.

Because of present and future health standards, some automobile manufacturers are in favor of removal of asbestos and lead from brakes.[52] U.S. automakers have cut the average asbestos content of disk brake linings from 0.45 kg to about 28 grams. Both General Motors and Ford have asked their suppliers to seek ways to totally eliminate asbestos from disk brakes. Because of the curved shape required for drum brakes, no suitable substitute for asbestos is readily available. However, Rockwell International Corporation, manufacturer of about 60 percent of the brakes used in heavy trucks, has a major development effort aimed at producing nonasbestos brakes underway.[52] ?

Semimetallics are the best available substitute and ~~now~~ in 1980 constituted approximately 40 percent of original equipment front disk brakes. One problem with new heavy-duty friction materials is high noise levels. To prevent noise pollution, noise-free organic friction materials will continue to be used for trucks and buses.

Borg-Warner Corporation[53], Bendix[36], and Abex Corporation[35] (among others) have developed proprietary substitutes for automobile brake friction materials. Some are in the consumer testing stage, but no additional information is available at this time. A company such as Bendix is not aggressively pursuing licensing policies but does have many license agreements for the international market which usually include territorial exclusions. Significant company funds ~~by Bendix~~ have been expended by Bendix to develop this new technology. Borg-Warner has spent several million dollars to develop asbestos-free friction materials for employee safety and may enter license agreements or manufacture in Brazil.[50] Although Raybestos-Manhattan, Inc. stated publicly in May 1979 that the company would "halt" the manufacture of brake linings and other parts that contain asbestos by using a blend of 10 to 15 components (40 percent fiber, 20 percent resin binder, and 40 percent friction modifiers), discussions with company representatives revealed that this was not strictly true.[54] The company has developed some nonasbestos substitute products for certain applications and has committed itself to a search for nonasbestos substitutes, but the complete removal of asbestos from their friction materials is not expected in the foreseeable future. Small brake manufacturers have a real problem with capital equipment and financing of nonasbestos friction products.[50]

mis quote of 46?

Part of the problem in designing new brake systems is simply that it takes time. Both the materials used and their properties are a result of optimization procedures, with extensive testing programs both by the material supplier and by the customer to ensure suitability, quality, and regulatory conformance. For evolutionary changes, an example of which would be an improved organic disk pad utilizing the same basic components (asbestos, resin, and modifers) but with better wear, improved fade resistance and the same friction and noise properties, years are required. In this case, asbestos organic linings are essentially the product of 40 years of evolutionary changes. Supplier development and validation testing requires 18 to 24 months, consumer application testing 12 to 18 months, and 6 months manufacturing lead-time, or, a total of 3 to 4 years for one evolutionary change. In addition, there are revolutionary changes, which actually advance the state-of-the-art, that are more difficult to come by, and are even longer in the developmental phases. It is unrealistic to apply a timetable to inventions, but for establishing the feasibility of a new concept, 12 to 18 months is a reasonable time period to be expected. Reducing that concept to a product with some or most of the basic characteristics can take another 12 to 24 months. Formulation development for commercial application and validation of properties adds 24 to 36 months. An additional 12 to 18 months is required for customer application testing plus 6 months manufacturing lead-time, or a total change-over requiring 5½ to 8½ years. Eliminating asbestos from automotive friction materials is considered a revolutionary change. As ideas on substitute products came into being around 1975 and later, the first evolutionary changes are now underway to help develop a second generation of materials which have improved properties and the multiple types and assortment of formulations necessary for different applications.[36]

As indicated, semimetallic disk brake ~~linings~~ pads without asbestos in either the friction material or the backing layer are currently in use, but cannot be used in all vehicle applications. An orderly transition is expected to occur, approaching 100 percent utilization by 1985. Development of asbestos-free organic disk-brake ~~linings~~ pads and semimetallic drum brake linings is continuing at Bendix with production implementation not yet able to be predicted. In addition, Bendix ~~is~~ and others are in the final development stage of work on first generation asbestos-free organic drum-brake linings and some asbestos-free blocks are available commercially for heavy-duty applications, with the first significant production release expected in 1982. All of these new developments show continued effort from industry to move towards a dominance of asbestos-free products in the friction materials area.

RR blocks in Europe

CONCLUSION

Semimetallic disk brakes, originally ~~designed~~ and produced by Bendix Corporation and now also manufactured by ~~Trist, Draper, Ltd.~~, are expected to increase market share relative to asbestos ~~disk brakes~~. In fact, it is projected[44] that in ~~5 years~~ 1985 nearly all original equipment disk brakes made for passenger cars and light trucks will be ~~made with~~ equipped with semimetallic ~~disc pads~~ friction materials.

Delco Abex

At the present time a nonasbestos product for drum brake linings for passenger cars is not available commercially. However, intense research in this area is underway, with specifics still proprietary at this time. The first commercially-available nonasbestos drum lining may contain some combination of steel fibers, synthetics, cotton, ceramic, carbon, natural materials, glass, and mineral fibers. For the model year 1980, commercial nonasbestos linings were not available[44] for drum brakes; however, Bendix Corporation is apparently very close to marketing this kind of product. Performance characteristics of the nonasbestos lining versus the asbestos lining are not available.[36]

As for cermet brake linings, once the problem of their interaction with hydraulic brake fluid can be solved, their use may grow. With all of the current research into brake lining substitutes, a nonasbestos product for more universal use should become available in the future.

Delco Moraine and Abex

Clearly, the design of the entire braking system has a great influence on the types of friction material that can be used. The lack of readily available nonasbestos drum brakes linings contrasted with the progress toward totally asbestos-free disk brakes pads underscores this point. Redesign of motor shafts or the stator on which the friction material is mounted could conceivably contribute to the elimination of asbestos from brake linings. However, redesign appears to be given less consideration than the search for a material to replace asbestos for the following reasons:

- Brake systems in use have been time tested and proven effective. Changes in the existing systems would require that the system and the asbestos replacement both be tested intensively. Problems could result if replacements are not made of materials similar to those of the original equipment, as the entire brake system is designed as a unit. Without careful study, substitution may cause safety or wear problems. Time is often needed to heal these faults. Testing requirements are significantly reduced if only the asbestos substitute is to be evaluated.

- Any new brake system must be suitable to be maintained by automobile dealers and service stations. Any complex new system or radical changes in brake system construction that would be difficult to maintain properly would be unacceptable.

- Equipment designed to produce brake systems currently in use would either have to be replaced or modified to produce a new brake system, possibly necessitating large capital expenditures at a time the automotive industry is feeling financial constraints.

- The many manufacturers of brake linings must respond to the needs of their customers. Until the automobile manufacturers supply different product specifications, as for the friction material component of a new braking system, the brake lining manufacturers will continue to supply a traditional product. Brake system changes must be initiated by original equipment manufacturers.

It is much easier, more readily acceptable and much less risky for brake lining manufacturers to attempt to find a substitute for asbestos rather than effect a complete redesign of braking systems. Consequently, most research is focussed on the search for substitutes.

The outlook for the use of asbestos in friction material is, at best, mixed. The majority of the industry's products are used in passenger automobiles and, as such, are influenced by the vagaries of the buying public: if a lot of new cars are being sold, a lot of new brakes will be required. Conversely, if fewer new cars are sold, more used cars in the marketplace friction materials.

will result in more sales of replacement brakes. Further uncertainty is introduced by the American automobile manufacturers' avowed intentions to eliminate asbestos from original equipment brakes by the 1985* model year. If a successful substitute is found, asbestos consumption in friction materials will drop precipitously. Yet it is unclear whether the target date represents the culmination of a carefully thought-out phased production introduction or is merely the consequence of wishful thinking. Whichever situation holds will provide the key to any projections of the use of asbestos in friction materials.

better to use plural.

Not wishful thinking ref 36

*Raybestos Manhattan plans to eliminate asbestos from its friction material products by 1982.[55]

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