Investigation of Health Hazards in Brake Lining Repair and Maintenance Workers Occupationally Exposed to Asbestos

Task I

Description of Brake Materials, Work Practices and Exposure Levels During Brake Maintenance

Draft for comments

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I. BRAKE MATERIALS, PRODUCTS AND USAGE

A. Historical Development of Friction Products[1]

The requirements of early automobile friction materials were relatively minimal. Passenger cars were light and designed for low speed operations. Brakes were of an external contracting type and utilized a variety of materials. Leather and impregnated cotton products were commonly used along with wool and felt. In 1903 woven asbestos friction materials were first marketed in the United States by the Keasbey and Mattison Company of Ambler, Pennsylvania.[2] Because of its superior heat resistance and durability they rapidly increased in use and soon dominated the market. The Model T Ford provides an example of the changing use of materials. Initially, cotton bands, reinforced with zinc, copper, or brass wire and impregnated with oils and bitumenous material, were used for the brake bands. These were soon replaced by mixed cotton-asbestos materials and finally by woven asbestos products. The woven asbestos brakes continued to be the dominant product used in automobiles until about 1930. They typically contained 70% or more wire-inserted asbestos yarn, impregnated with drying oils, as linseed, and bituminous material.

Molded brake linings were developed in the early 1920's and gained increasing use with the introduction of internal shoe brakes in 1927. By 1940 virtually all automobiles were equipped with molded brake linings, although woven products continue to be used in trucks, heavy equipment and for specialized applications. The molded linings in use were cut to length, usually by the manufacturer, and mounted on brake shoes using rivets. Until the mid 1920's, brakes were only mounted on rear wheels. However, with the development of internal shoes, four wheel mountings soon became standard and by 1930 were

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generally operated hydraulically.

As automobiles were designed for use at even higher speeds, brake linings improved in both quality and performance. Various new materials were introduced as fillers, binders, and friction modifiers. In 1948 bonded brake linings were developed and soon accounted for approximately 40% of the original equipment brake market. Further, they rapidly dominated the replacement market because of the considerable savings in labor during installation. In 1965 the first disc brakes were introduced by American automobiles and rapidly increased in use. In 1975 virtually all original equipment front wheel brakes on cars were of this type. However, because of less stringent braking requirements and the difficulty of adapting mechanical parking brakes to the disc configuration, the rear wheel brakes on 95% of currently sold cars are still of the drum variety.

B. Requirements of Ideal Brake Linings

1. A constant or slightly decreasing coefficient of friction with temperature up to about 1,000°F. is required. Values of from 0.30 to 0.45 are normally sought. Lower values produce brakes requiring excess pedal pressure and those with higher values are too sensitive to pressure and develop excess wear. Ideally, the desired frictional qualities should be maintained throughout the life of the lining material. During braking, chemical and physical changes occur in the material at the braking surfaces. These changes may produce an increase in friction (build-up) or a decrease (fade). Satisfactory linings will fade slightly upon repeated applications, but will return to their initial state upon cooling (good recovery).

2. Low wear is obviously desirable for economical and practical considerations. However, high wear resistence can be associated with the tendency of the lining to glaze, with a concomitant reduction in the coefficient of friction. This

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can be overcome by allowing a slow alteration of the brake lining material to occur. Pyrolysis of the organic binders and thermal decomposition of the chrysotile fibers under braking provide the necessary continuing renewal of the lining surface.

3. The lining should be non-abrasive to the drum surface. In addition to causing rapid drum wear, abrasive linings score the drums, which, in turn, leads to a rapid wearing of the lining. Here, of course, the drum material is also important. Cast iron and steel are commonly used, with steel being the more susceptable to scoring. As brake drums have a hardness of from 3.5 to 4.0 on the MOH scale, virtually all lining material used have lower hardness values.

4. Other necessary or desirable properties include: physical strength, demensional stability, quiet operation, and safe and non-offensive degradation products. Of the various properties desired in brake linings, greatest attention is paid to build-up and fade and recovery characteristics. Wear problems are not as serious and can more readily be overcome with the materials available.

C. Compounding Ingredients of Brake Linings 4,5,6,7

To achieve the desired friction properties, a wide variety of ingredients are commonly used in the manufacturer of automobile brake linings. These include:

1. Asbestos is used for fiber reinforcement of the friction product. Chrysotile is used almost exclusively and comprises from 40 to 50 percent of the brake lining. Fiber grades 4 through 7 are used, and occasionally, several sizes are admixed or even calcined to improve performance characteristics. Amosite, crocidolite or other amphibole asbestos varities are not used because they are too harsh and tend to score the brake drums.

2. Organic binders are primarily phenolic type resins selected for high

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binding strength. Unmodified phenolic resins, when subjected to heat usually become hard and brittle. To prevent this, linseed, cashew nut or China wood oils or cresols are added. Rubber also finds use as a binder; it imparts desirable friction qualities and improves the flexibility of the lining material.

3. Friction modifiers are added to achieve a desirable coefficient of friction over all operating conditions. They may do this by producing a more homogeneous lining surface as well as by directly altering the coefficient of friction. Included among these materials are lead, zinc and brass material, cashew nut oil, graphite and oxides of iron and copper

4. Fillers as rubber scrap, barites, clays, silica, coke, coal and other minerals are used. These also have utility in achieving desired friction properties, in some cases through action as abrasives to recondition braking surfaces. It is important to note that one major purpose of the reconditioning agents is to retard the formation of forsterite (a mineral not originally present in the brake material, but created by dehydroxylation and recrystallization of chrysotile asbestos at high temperatures) which may accumulate on the surface of the brake lining. The hardness of the forsterite (hardness 6.5-7.0) is such that it tends to score and gouge brake drums and discs (hardness 3.5), degrading them prematurely. Therefore, recrystallization of chrysotile to forsterite is an unwanted effect, hindered insofar as possible by the modifiers present in the matrix.

5. Curing agents and/or accelerators are use to assure that appropriate chemical reactions occur to produce the desired brake quality.

D. Types of Brake Linings and Manufacturing Processes

1. Wired Backed. These are made by calendering process in which putty-like stock is formed into a ribbon about a wire backing. The wire reinforcing serves to maintain strength during the curing process. Further, as linings of

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this type are invariably rivetted, the wire reinforcing provides long term structural strength and prevents shearing of the lining at the rivets during braking. Linings of this type were extensively produced prior to World War II. They are in little use today.

2. Extruded Linings. These are manufactured by exuding the soft plastic stock through an appropriate sized rectangular oriface. To minimize structural weakness in this lining, curing agents are added which, however, result in a hard inflexible finished product.

3. Sheet Linings. These are laminated structures formed by winding a 0.001 inch to 0.002 inch film of stock about a hot roller. As the fabrication process is a relatively expensive one linings of this type are not commonly produced for general use.

4. Dry Mixed types. This process is a basically simple one of dry mixing various ingredients capable of passing a 200 mesh screen and molding the lining under pressures of from 1,000 to 3,000 pounds per sq. inch pressure. The resulting lining is among the most heat stable of friction materials in use today and obtains wide use in the manufacture of brake blocks for heavy duty service.

5. Millboard Type. The manufacture of this type of brake lining material is by a process similiar to that utilized in the paper industry. Wet stock is formed and passed over rollers with various drying and baking operations producing sheets of uniform lining material. The equipment for producing such materials is expensive, but the volume of production leads to an economically produced molded lining.

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II. BRAKE LINING REPAIR AND MAINTENANCE PRACTICES

To a large extent the changing character of brake lining materials has led to changing work practices and differing asbestos exposures over the years. From 1920 until about 1930, when braking was done through the use of external brake bands and woven materials were utilized, the prodominant exposure to asbestos would have come from the cutting and fitting of the woven lining material. It would be expected that air concentrations here would be considerably less than those developed in later years when machining of molded materials was common.

From 1927 when internal brake shoes were developed using molded linings until 1948 when bonded brake linings were introduced all internal brake linings were attached to shoes using rivets. The lining material for use in the replacement market would be precut to appropriate size for various brakes or obtained from rolls of indeterminate length. The precut segments would usually be predrilled at the factory for rapid mounting on shoes. In some circumstances, however, drilling for the rivets and bevelling would be done by the mechanic installing them. The use of rolled linings required cutting the friction material to shape, drilling holes for rivets, and bevelling the edges appropriately. In this latter circumstance, asbestos exposure to workers could be considerable. (See Section III for dust counts) Even when shoes with pre-drilled and beveled linings were installed, the processes of punching out the rivets on the old shoes and riveting on of the new shoes gave rise to greater exposures than that accompanying the use of bonded linings.

With the introduction of bonded linings, the need for drilling, facing or grinding operations during installation decreased significantly. However, for a short period of time, in the mid-1950's when automobile shoes were first

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installed with a fixed anchor, some tapering was necessary on uniform thickness bonded linings to achieve a proper fit. Previously, the end of the shoe opposite to that of the hydraulic cylinder could be mechanically adjusted. Shortly, however, tapered bonded linings were available from the factory. Subsequent to 1960 considerably fewer bevelling or grinding operations would be done by an automobile mechanic replacing brake linings.

During replacement of internal shoe brakes it was common practice to remove the brake wear dust from the housing by air blowing or brushing. As shown in Section III, this produces asbestos air concentrations of considerable magnitude, albeit for short periods of time. After 1970 increasing awareness of the hazards of asbestos and its presence in brakelining dust led to wet wiping or vacuming in some shops or by some individuals. However, even today such improvements in work practices are not universal. Table 1 lists the use of different practices over the years by a group of workers employed in various shops. While the sample is limited it does illustrate the universality of the air blowing or brushing in the decades prior to 1970.

In the 1930's and 1940's most automotive shops were relatively small and most mechanics performed all automobile maintenance and repair activities. In recent years, however, there has been an increasing tendency towards specialization, with shops designed for brake and front end work exclusively. Here, while asbestos exposures doing brake work may be less than those of previous years, some workers are exposed for considerably longer periods of time.

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III. ASBESTOS FIBER CONCENTRATIONS DURING BRAKE REPAIR AND MAINTENANCE

A. Brake Lining Degradation Products

The degradation products of brake linings reflect the surface temperature at the drum-lining interface during braking operations.[4,8,9,10] Chrysotile has a major dehydroxylation peak at between 650° - 680° C and recrystallizes to fosterite at about 810° - 820° C.[11,12] but variations about these temperatures occur depending upon fiber size and heating conditions. Some changes occur, albeit slowly, at much lower temperatures.

Generally, during light braking average temperatures of 350° C or less are maintained. However, during moderate braking action, average temperatures as high as 500° C may occur.[4,9] In very localized "hot spots" temperatures of from 800° to 1000° C have been reported.[4] Under these conditions it has been suggested that, in addition to binder pyrolysis, chrysotile dehydroxylates and "reduces to powder" when it is swept off the brake facing. However, others have pointed out that, in addition to thermal wear, abrasive and shearing degradation occur[9,10] and that brake lining disintegration can occur at temperatures well below those which alter chrysotile fibers. Thus, both altered and unaltered chrysotile fibers may be present in brake dust.

Rohl et al analyzed 10 samples of brake drum dust using optical microscopy, X-ray diffraction, and transmission and scanning electron microscopy techniques. (A) X-ray difraction analysis, including step-scanning, demonstrated the presence of chrysotile in all samples. The proportion ranged from 2% to 15% with an average of about 4%. The presence of small amounts of fosterite was suggested, but could not be demonstrated conclusively. The

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presence of chrysotile was also found by transmission electron microscopy. The amount determined by this procedure was less than that of X-ray diffraction, as fibers present in clumps of binder material could not be unequivocally identified.

An earlier estimate of brake lining decomposition products is that of Lynch[13] who analyzed 15 brake drum samples by transmission electron microscopy. (B) He found that under extreme braking activities up to 15% of the debris could be free chrysotile asbestos fibers. On the other hand the vast majority of samples, which were taken during light or normal braking conditions, showed less than 1% of free fiber to be present in the decomposition products. Hickish and Knight[14] also reported chrysotile to be present in brake dust in quantities of less than 1%, compared with original lining contents from 40-60%.

The most definitive study of brake degradation products and their fate is that of Jacko et al,[9] who estimated that 99.7% of eroded asbestos in brake lining is converted to other products. (C) This followed from the analysis of over 100 samples of brake drum dust in which the percentage of asbestos ranged from 0.003% to 1.65%. It should be noted that 89% of this unconverted asbestos, comprising about 140,000 pounds of chrysotile, is released to the environment annually from brake and clutch degradation.

Limited data exist on other degradation products. Some are tabulated by Jacko et al[8] and Anderson et al[15] on wear debris materials from brake drums. These data are listed in Tables 2 and 3.

The vast majority of the chrysotile fibers released from brake degradation are shorter than 5μ, Limited data of Rohl et al[7] on the analysis of ten drum samples indicated that 83% of the fibers were shorter 0.37μ (Table 4).

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Optical microscopic data of Hatch[16] suggested that of fibers longer 2μ 94% were shorter than 5μ in length. Combining these two data would suggest that over 99% of the asbestos fibers from brake lining erosion would be less than 5μ in length. (E) However, no direct data exist that would establish this point.

The finding that the vast majority of fibers in an asbestos aerosol are shorter than 5μ is not uncommon. In other work circumstances where chrysotile is released into the air, size distribution measurements have indicated that between 95% and 99.5% of the fibers released are shorter than 5μ.[17] Thus, the size distribution of brake lining dust aerosols may not be too different from those produced by other uses of asbestos products.

B. Fiber Concentrations During Brake Repair and Maintenance Work

A variety of measurements have been made of asbestos air concentrations during brake lining repair and maintenance activities in the United States and Great Britain. These include both long-term sampling over a working day to obtain information on time weighted average exposures to workers, and short-term sampling to document the concentrations during various work practices.

The largest set of samples of brake maintenance work is that obtained by NIOSH during the years 1975 through 1976 where 283 samples were taken in five brake repair facilities, including 152 over a one week period in one facility, documenting both long-term, time weighted average (TWA) exposures and asbestos concentrations in specific brake repair activities[18]. Unfortunately, no documentation exists as to the number of brake jobs performed in a facility or by workmen during sampling periods or on the work practices utilized during the repair and maintenance work. The limited information available

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on the average number of jobs per shop and the personnel employed therein is listed in Table 5. Table 6 summarizes the data on time weighted exposures, over a sampling period, for men changing lining material, punching out rivets, riveting linings to shoes, and working in the parts department. The samples taken during lining change work were, in general, over a 6-8 hour period of time. Thus, the sampling strategy appears more designed to determine if the asbestos exposures of workers in a particular shop are in excess of the TWA concentrations specified by the asbestos standard than to document air concentrations during specific work activities or over the course of a single brake job. In some shops it would appear that only one brake job would have been done during the day and, thus, the long-term samples would reflect work activities other than brake repair. Table 7 lists general area samples taken during the course of a day and Table 8 documents peak exposures that occurred during cleaning of the drum housing by an air hose or other means. These data amply demonstrate that, in general, the long-term asbestos exposures of garage employees are below 0.5 f/ml. However, during the air blowing of drums, punching out of rivets and riveting asbestos concentrations can be considerably higher. Further, area samples taken distant from the location of brake repair show widespread dissemination of airborne asbestos with concentrations up to 1.3 f/ml found to be present.

More limited data are available from industry sources. In Great Britain Knight and Hickish[14, 19] of the Ford Motor Company have provided information on both long and short term sampling during different brake repair activities. Similiar data are provided by the Raybestos Manhattan Corporation[20] on sampling undertaken by that organization during different circumstances. These are

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shown in Tables 9, 10 and 11. The work practices sampled by Hickish and Knight[14] appeared typical of those of past years with the drum dust being removed by air blowing. During the full course of brake service air concentrations of from 0.4 to 3.6 f/ml were found. The Raybestos data, on the other hand, were obtained during the course of well controlled brake repair work with exhaust ventilation utilized. Here, asbestos exposures of 0.1 to 0.3 f/ml were found during the course of a brake job.

Peak concentrations over 3-8 minute periods were sampled during different activities of brake repair work by Rohl et al[7] in both automotive and truck service. These are listed in Tables 12 and 13 and include, additionally, air samples taken at different distances from specified work activities. The sampling in this study focussed on dust producing practices with a view to identifying problems for control. However, data on asbestos concentrations over the full course of a brake job are lacking.

Two final sets of data have been reported. Hatch[16] provided some limited information on short-term samples taken during brake work. Peak concentrations from 2.1 to 8.2 f/ml were measured in eight samples taken during brake cleaning by compressed air. A ten minute concentration of 0.8 f/ml was also reported. Boillat and Lob[21] measured concentrations of from 0.4 to 21.5 in six samples taken during machining, grinding and drilling of brake material.

Two sets of data on the time course of asbestos concentrations exist. These are shown in Tables 14 and 15. The measurements of total dust by Lee[22] indicate that after air blowing short-term dust concentrations are high but fall within minutes to a lower value. The data on fiber counts by Rohl et al indicate that measurable concentrations of asbestos persist in the workplace

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for as long as 15 minutes after air blowing as far as 75 feet away. These data, coupled with the previous information on asbestos concentrations in general garage areas, indicate that a general, low-level background contamination of asbestos can exist throughout a garage where brake repair is done.

Table 16 and 17 summarize the important aspects of the previously described data. Very limited information exists on asbestos concentrations that occurred over the full course of typical brake repair jobs of past years. The best documented data are those from the twelve samples of Knight and Hickish, which suggests that asbestos concentrations of about 1 f/ml may characterize the average asbestos exposure over the course of a brake job when air blowing is utilized for cleaning. The data of NIOSH in some shops would suggest similiar concentrations, although in other shops lower concentrations appear to have been present. Peak concentrations during specific dusty activities, such as cleaning drums or riveting, drilling, grinding, and punching of lining material are high, ranging from 1 f/ml to 10 f/ml, but with measurements as high as 87 f/ml reported. However, these work activities usually consume a small portion of the time required for a brake job. As most current lining replacement involved bonded brake linings, the only major source of exposure in garages is that from drum cleaning. However, as mentioned in Section II, riveted brake linings were used extensively prior to 1950. Thus, TWA exposures during brake replacement in the earlier years would be higher than 1 f/ml, perhaps 2-3 f/ml over the course of a complete brake job.

Table 18 lists the frequency of brake jobs done by members of U.A.W. Local 259 from information collected in Task III of this contract. The average mechanic performs one complete brake reline less frequently that daily (perhaps

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once every two days). As each job takes about an hour to complete, the long-term TWA average asbestos exposure of typical garage mechanics would be considerably less than 0.5 f/ml, even with air blowing of drums during changes of bonded linings. Such a value corresponds well with long-term TWA exposures measured by NIOSH during 1975-76. In earlier years, when riveted brake linings were maintained, long-term average exposures of garage mechanics might be in the range of 0.5 f/ml to 1 f/ml. However, mechanics employed in brake repair specialty shops or men working extensively in riveting or machining operations could be exposed to higher concentrations.

The existing data indicate that the majority of garage employees are not likely to have been exposed to long-term (over months or years) asbestos concentrations in excess of the current standard of 2 f/ml. The data also show that virtually all asbestos dust is released during easily controlled work activities and that with proper practices TWA asbestos concentrations can be reduced to about 0.1 f/ml or less.

C. Industrial Hygiene Research Needs

1. Size distribution determination

Electron microscopic size distributions of the asbestos in aerosols generated during brake repair are required. Existing data are extremely limited and applicable only to drum dusts.

2. Environmental Assessment of Garage Mechanics during Brake Repair

Data on the average asbestos concentrations experienced by workmen over the course of a brake job are needed. These evaluations should be made during work practices characteristic of earlier years utilized during the changing of both bonded and riveted linings.

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Table 1

Drum cleaning practices before 1970 in brake repair and maintenance

Cleaning practice	Number of men using procedure
Air blowing and/or brushing of drum dust	91
Brushing of dust - no air blowing	5
Wet wiping of dust	3
No dust removal done	1

From: Sample of 100 consecutive work histories of U. A. W. 259 members engaged in brake repair work.

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Table 2

Estimated chemical composition
of brake wear debris

Description	Present	
Low molecular weight degradation products	2-10	20-30
Polymeric components	12-20	
Carbonaceous material	1-5	
Inorganics		
mineral	~ 10-30	70-80
olivine	~ 20-40	
Oxides (from lining)	0-10	
Fe_2O_3 (from drum)	5-15	
asbestos	<1	

From: Jacko, M. G., R. T. DuCharme, and J. H. Somers
Soc. Auto. Eng. paper 730548, Auto. Eng.
Meeting, May 14-18, 1973

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Table 3

Estimated chemical composition of brake wear debris

Inorganic		
Decomposed asbestos	36.9	
Decomposed limestone	8.6	
Zinc metal	3.9	
		49.4
Organic		
Volatile	10.5	
Uncertain	15.7	
Low volatility	12.1	
		38.3
Unknown material		12.5

From: Anderson, A. E., R. L. Cealer, R. C. McCune, and J. W. Sprys. Soc. Auto. Eng. paper 730549, Auto. Eng. Meeting, May 14-18, 1973

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Table 4

Length distribution in micrometers
of chrysotile fibers in airborne brake drum dust

Sample	0.075-0.15 (%)	0.15-0.225 (%)	0.225-0.03 (%)	0.3-0.375 (%)	>0.375 (%)
1	40	34	11	11	4
2	32	23	32		13
3	20	25	25		30
4	26	37	26	7	4
5	57	17	4		22
6	23	9	12	12	44
7	50	26	21	2	1
8	29	30	21	17	3
9	6	41	18	10	25
10	11	6	31	31	21
Average	29.4	24.8	20.1	12.8	16.7

From: Rohl, A. N. et al. Env. Resh. 12, 110-128 (1976).

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Table 5

Characterization of garages studied by NIOSH

Garage	Number of mechanics	Brake jobs done per week by facility
A	7	not specified
B	5	not specified
C	3	2 - 5
D	3	3 - 5
E	3	4 - 5

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Table 6

Long-term personal sampling of brake lining repair and maintenance work

Garage	Number of samples	Number of sets of samples	Time weighted average asbestos concentration during sampling period (fibers/ml)	
			Range	Mean
Changing Lining Materials				
A (1976)	16	5	0.05-1.68	0.59
B (1976)	71	21	0.01-0.17	0.09
C (1976)	3	1	0.12	0.12
D (1975)	4	1	0.04	0.04
E (1976)	2	2	0.02-0.03	0.03
Riveting				
A	14	2	3.71-4.47	4.09
Punching out rivets				
A	11	2	0.95-7.52	4.24
Parts Man				
A	1	1	1.21	1.21
B	13	5	0.03-0.16	0.10
Replacing Lining Materials				
F (1972)	2	1	0.2	0.2

From: NIOSH (1975-1976, unpublished data)

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Table 7

Long-term area sampling of brake lining repair and maintenance work

Garage	Number of samples	Number of sets of samples	Time weighted average asbestos concentration during sampling period (fibers/ml)	
			Range	Mean
		General Area Samples		
A (1976)	30	6	0.03-1.34	0.57
B (1976)	99	18	0.01-0.17	0.07
C (1976)	4	1	0.04	0.04
D (1975)	7	1	0.02	0.02
E (1976)	1	1	0.01	0.01
F (1972)	1	2	0.6-0.9	0.8

From: NIOSH (1972-1976, unpublished data)

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Table 8

Short-term sampling of brake lining repair and maintenance work

Garage	Activity	Number of samples	Sampling time (min)	Asbestos air concentrations (fibers/ml)	
				Range	Mean
B (1976)	Drum housing cleaning	6	0.5-2	0.45-14.54	3.6
D (1976)	(unspecified)	1	3	1.82	1.8
F (1972)	Blowing off drum with air hose	4		0.8-3.0	2.0

From: National Institute for Occupational Safety and Health (1972-1976, unpublished data)

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Table 9

Long-term asbestos fiber concentrations during brake maintenance service involving air blowing of drum dust

Sampling circumstances	Approximate total sampling interval	Number of samples	Asbestos concentrations (fibers/ml) Range	Mean	Activities or comments
Static samples by side of car	90	2	1.12-1.42	1.25	3 brake changes done
Static samples by car in dust cloud	90	2	1.71-3.62	2.55	" "
Personal samples on mechanic engaged in brake cleaning	480	6	0.38-1.12	0.68	11 vehicles serviced
Personal sample	100	1	7.09	7.09	truck brake service incl. cleaning
Personal sample	300	1	0.08	0.08	truck brake service after cleaning
Time weighted average of above two samples				1.83	
Static area samples	180	4	0.07-0.28	0.15	nearby work bays

From: Hickish, O. E., and K. L. Knight, Ann. Occup. Hyg. 13, 17-21 (1970)

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Table 10

Long-term asbestos fiber concentrations during brake maintenance services involving cleaning of brake drums

Approximate total sampling interval	Number of samples	Asbestos concentrations (fibers/ml) Range	Mean	Activities or comments
60	2	0.84-5.35	3.1	Air blowing of brakes
few sec	2	87	87	Peak, airblowing
60	1	0.22	0.22	Vacuum brush cleaning of brake
60	1	3.5	3.5	Vacuum funnel cleaning of brake

From: Knight, M. L. and D. E. Hickish. Investigations into alternative forms of control for dust generated during the cleaning of brake assemblies and drums. Ann. Occup. Hyg. 13, 37-39 (1970)

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Table 11

Asbestos concentration during auto brake service

Operation	Number of samples	Sampling time (min)	Asbestos air concentrations (fibers/ml)	
			Range	Mean
Four wheel reline, grinding with dust exhaust	4	15-30	0.1-0.3	0.1
Front axle reline no grinding	3	15-30	0.03-0.03	0.05
Four wheel brake maintenance and adjustment	2	15-30	0.05-0.1	0.1
Grinding brakeshoes, poor vacuum exhaust poor housekeeping	4	5-12	2.8-14.0	8.3
Grinding brakeshoes, good exhaust	1	10	0.4	0.4
Grinding eight brakeshoes	2	60	0.02-0.2	0.1
Brush cleaning of brake drum	1	15	0.02-0.2	0.1

From: Raybestos Manhattan (unpublished, personal communication from John Marsh, Director, Environmental Affairs)

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Table 12

Asbestos concentration during truck brake service*

Operation	Distance (ft)	Number of samples	Fiber concentration (fibers/ml) Range	Mean
Renewing used linings by grinding	personal	10	1.7-7.0	3.8
Background to grinding used linings	10	2	1.2-1.7	1.5
	25	2	0.6-1.0	0.8
	60	1		0.2
Beveling new linings	personal	5	23.7-72.0	37.3
Background to beveling new linings	8	1		0.6
	12	2	0.3-0.5	0.4
	30	1		0.3
Punching rivets into brake linings	personal	2	1.9-2.0	1.9
Chipping rust off used brake linings	personal	1		2.4
Sweeping floor around grinder	personal	1		3.6
Background to sweeping floor around grinder	15	1		3.1

* Fibers 5-100 μm in length, counted by optical microscopy.

From: Rohl, A. N. et al. Env. Resh. 12, 110-128 (1976).

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Table 13

Asbestos concentrations during automobile brake service

Operation	Distance (ft)	Number of samples	Fiber concentration (fibers/ml)	
			Range	Mean
Blowing dust out of brake drums with compressed air jet	personal	4	6.6-29.8	16.0
	5-10	3	2.0-4.2	3.3
	10-20	2	0.4-4.8	2.2
Cleaning brake drums with dry brush	personal	2	1.3-3.6	2.5
Background samples taken 3 minutes after cleaning brake drums with dry brush	12	3	0-0.2	0.1

From: Rohl, A. N. et al. Env. Resh. 12, 110-128 (1976).

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Table 14

Total dust concentrations at various times from brake drum cleaning operations

Sampling time	Number of brake dust particles/5 cm^3
Airblowing of brake drum dust	
Taken at beginning of operation	5000
Taken approx. 20 sec later	4500
Taken approx. 80 sec later	4000
Taken approx. 111 sec later	1800
Taken approx. 140 sec later	580
Brushing of brake drum dust with exhaust ventilation	
Taken at start of process	1070
1 min later	404
2 min later	426
Taken at end of process	446

From: Lee, G. L. Ann. Occ. Hyg. 13, 33-36 (1970). Removing dust from brake assemblies during vehicle servicing - alternative cleaning methods

HWBU0012288

Table 15

Asbestos air concentrations at various distances and times after air blowing of brake housing

Distance from operation (ft)	Time lapse (min)	Concentration (fibers/ml)
10	0	0.3
20	0	0.8
12	5	0.2
50	5	0.1
65	7	0.1
75	14	0.1

From: Rohl, A. N. et al. Env. Resh. 12, 110-128 (1976).

HWBUI0012289

Table 16

Summary of asbestos concentrations during automobile and truck brake maintenance activities

Long-term samples during lining removal and replacement

Source	Reference	Range of concentrations of measures (f/ml)	Range of means of concentrations (f/ml) (from Tables 5-11)	Comments
		Personal		
NIOSH	18	0.01-3.24	0.03-0.59	Sampling may have been done during non brake work. No information on on work practices
Hickish and Knight	19	0.08-7.09	0.68-3.1	Appears typical of past work practices with air blowing of drums. Sampling throughout complete brake repair jobs.
Raybestos Manhattan	20	0.05-0.1	0.05-0.01	Well controlled exhaust ventilation utilized
		Area		
NIOSH	18	0.01-1.72	0.1-0.57	
Hickish and Knight	19	0.07-0.28	0.15	

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Table 17

Summary of asbestos concentrations during automobile and truck brake maintenance activities

Short-term samples during specific brake repair activities

Activity	Reference	Range of concentrations measured (f/ml)	Range of means of concentrations (f/ml) (from Tables 5-12)
Air blowing dust from drums	7	6.6-29.8	16.0
	18	0.45-14.54	1.8-3.6
	19	87	87
Brushing of dust from drums	7	1.3-3.6	2.5
	20	0.02-0.2	0.1
Grinding linings			
good exhaust	20	0.02-0.4	0.3
poor exhaust	7	1.7-7.0	3.8
	20	2.8-14	8.3
Beveling	7	23.7-72.0	37.3
Riveting	7	1.9-2.0	1.9
Punching out rivets	20	0.18-10.92	1.0-7.5
Sweeping and cleaning	7	2.4-3.6	2.2.9-3.6

HWBU0012291

Table 18

Distribution of frequency of brakework in U. A. W. Local 259 shops from personal estimates

Number of brake jobs done	Number of men	Percentage of men
1/day or more	24	14
2-5/week	71	41
2-5/month	27	16
less than 1/month	4	2
no brake work (engine mechanics, parts personnel, etc.)	46	27
Totals	172	100

HWBU00012292

1. Much of the historical information on the development of friction products was obtained from interviews with Edward W. Drislane, Friction Materials Standards Institute, Paramus, N. J., Harry H. Wagner, Jr., Molded Materials Co., Ridgway, Pa.

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HWBUI0012294