June 6, 1972

asbestos 3C

TO: Members of Asbestos Study Committee
SUBJECT: Asbestos Fibers Emissions - Friction Materials

A seminar was held at the Illinois Institute of Technology Research Institute back in April of this year. Dr. Colin Harwood of IITRI was one of the advisors to the Illinois Pollution Control Board who was in favor of the proposed 1971 regulations as written--that is to include a ban on the" use of asbestos in the brake lining of vehicles manufactured after January 1, 1975 and sold for use in Illinois."

The pages from the IITRI paper are: pages 22, 25, 26, 27, 28, 46, 49, 65, 66, 67, 68, 69, 70, 71, 72, 73.

Your Chairman, Mr. I. H. Weaver, sent this data to me for distribution to the Committee. He commented on the paper: "The main issue I would have with Dr. Harwood's conclusion would have to do with whether or not the free fibers or fibrils released from friction material decomposition are truly hazardous in any way, and I also believe he tends to underestimate the problems in non-asbestos containing braking systems."

Your Chairman believes that a meeting of the Committee should be called. I'm asking for a reply on the attached form, for which weeks not to call a meeting. From this I will try to arrive at a meeting date (perhaps late July or late August).

EWD/lmc

E. W. Drislane
Executive Secretary

[redacted]

P-FMSI- 0025

PLAINTIFF'S EXHIBIT WV-06017

PLAINTIFF'S EXHIBIT 1185

WV-06017

TO: Friction Materials Standards Institute, Inc.
E-210 Route #4
Paramus, N. J. 07652

Gentlemen:

Concerning a proposed meeting of the Asbestos Study Committee, PLEASE DO NOT SCHEDULE IT FOR THE FOLLOWING WEEKS:

July 24-28 ____________

August 7-11 ____________

August 14-18 ____________

August 21-25 ____________

August 28-31 ____________

Additional Comments: ____

____

____.

By ______________________________

Company ______________________________

Date ______________________________

Asbestos Steering Comm.

123 E. STIEGEL STREET, MANHEIM, PENN. 17545

Raybestos-Manhattan

June 1, 1972

Mr. E. W. Drislane, Executive Secretary
Friction Materials Standards Institute, Inc
Bergen Mall Office Center, E.210
Route #4
Paramus, N.J. 07652

Dear Ed:

The attached material concerning automotive emissions of asbestos fibre was received from Illinois Institute of Technology Research Institute yesterday and probably will be of interest to other members of the FMSI Asbestos Study Committee . I suggest that you circulate it to them.

This material was forwarded by Dr. Colin F. Harwood of IITRI as a supplement to information presented at a seminar on asbestos they conducted April 4 through 7. Very little attention was devoted to automotive emission sources during the seminar.

The main issue I would have with Dr. Harwood's conclusion would have to do with whether or not the free fibres or fibrils released from friction material decomposition are truly hazardous in any way, and I also believe he tends to underestimate the problems involved in non-asbestos containing braking systems.

Since it appears unnecessary and probably impossible to schedule an Asbestos Study Committee meeting in June and I will be away the first two weeks in July, I think it might be prudent to tentatively schedule a meeting date in July, preferably during the last week. By that time I expect there will be a number of subjects worthwhile reviewing. If you agree, kindly canvass the other members and pick a date. As far as I know, I will be available anytime during the week of July 24. I am also open the week after that in the event this suits the others better.

Best regards,

IHW

I. H. Weaver
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attachments such that the dust created is arrested at the source and collected in filter bags. Commercial devices are available but normally firms with a sincere interest in pollution control, design and fabricate their own devices. Two examples of such devices are shown in Figures 6 and 7. These control hoods work on the high velocity, low volume principle and can be readily adapted to industrial vacuum cleaner systems.

When arrest-at-the-source systems are not possible, techniques similar to those employed by the asbestos spraying industry may be utilized. Rules which relate more specifically to fabrication of asbestos products may be found in such publications as:

1. "Recommended Practices for Fabricating, Handling and Construction Industries," Health and Safety Council-Asbestos Cement Products Association.

2. "Recommended Health Safety Practices for Handling and Applying Thermal Insulation Products Containing Asbestos," National Insulation Manufacturers Association (NIMA).

3. The Asbestos Research Council - Control and Safety Guides (London, England).

4. "Recommendations for Handling Asbestos," Engineering Equipment Users Association (EEUA), E.E.U.A. Handbook No. 33.

3.3.3 Friction Material Applications

Typical friction materials contain 30 to 50% asbestos and may be up to 70%, and the industry that manufactures these materials is ranked third (1969) in the consumption of asbestos fibers. Crysotile is the preferred variety because it has better frictional properties than amphibol asbestos and does not exert so much wear on the opposing surface.

The major uses of asbestos-containing friction materials include brake linings, brake discs and clutch facings. These products have been applied to a wide variety of industrial and commercial products.

Sources of Emission - Emission of asbestos from friction materials results from normal day-to-day usage. An idea of the scope of this source can be gained from the estimation that the average automobile wears out 3 to 4 sets of brake linings, and 1 to 2 sets of clutch facings during its lifetime and that commercial public transport vehicles wear out many more sets. Data concerning motor vehicle brake linings for the whole of the United States are given in the following:

Vehicle miles during 1968	1,010,000,000,000
Mileage life of brake linings	27,500
Brake lining sets on new vehicles	10,718,000
Pounds of asbestos per set of brake linings	3

Tests performed on brake linings have indicated that under conditions of normal usage, considerable alteration of the asbestos occurs. It is reported that most of the dust collected from brake drums appears non-fibrous and is similar in appearance to thermally degraded asbestos. The suggestion is that high temperatures at the brake lining/drum contact points actually reach degradation levels.

Tests on brake linings, brake discs and clutches have demonstrated that the quantity of fiber emitted is some function of the severity of the braking conditions (see Table 3). However, even at the level of 1%, the total emissions must be considerable when the total tonnage in use is considered. Further, the emissions are likely to occur at places of high density population and restricted ventilation. That is, in busy main streets of towns surrounded by large buildings.

The effect of different braking conditions and different types of friction materials on asbestos emissions is the subject of a study being sponsored by the Environmental Protection Agency. Other studies are being conducted in California and some work on roadsides has been done at Mt. Sinai, New York. The EPA study will establish the extent and nature of the asbestos

Table 3

ASBESTOS EMISSIONS FROM BRAKE LININGS
(Test Results by Electron Micrograph)

	Product	Brand	Test Method	No. of Samples	Conditions of Test-F	Presence of Free Fibers	% Free Fiber*
1.	Automobile drum brakes	A	Friction	6	300-800	Few	<1
2.	"	B	Friction	6	250-800	None	0
3.	"	C	Friction	5	300-700	Few	<1
4.	"	C	Friction	1	700-900	Numerous	~10
5.	"	D French	Friction	5	300-800	Few	<1
6.	"	E	Friction	5	300-700	Few	<1
7.	"	F German	Friction	5	300-800	Few	<1
8.	"	G	Friction	2	100-500	Few	<1
9.	"	G	Friction	1	600-700	Numerous	~15
10.	"	H	Friction	2	100-600	Few	<1
11.	Automobile clutch	J	Dynamometer	1	normal driving	None	0
12.	Automobile disk brake	K	Dynamometer	1	normal driving	Few	<5
13.	Bus drum brake	L	Dynamometer	1	city driving	None	0
14.		M	Friction	2	450-550	None	0
15.	Truck drum brake (light)	F	Friction	10	300-800	Few	<1

*Weight estimated from fiber volume.

emitted from brake drums, disc brakes and clutches of vehicles operating under real conditions. Hopefully the situation will be more clearly understood at the end of those studies.

Emission Control Techniques

Emission at Overhaul - To avoid blowing the accumulated dust into the atmosphere at the time of overhaul devices have been suggested for extraction of the dust from brake and/or clutch housings by suction. Of the devices tried, a simple hand-held vacuum cleaner has proven to be the most flexible unit. Changes to the original design have been limited to the addition of a disposable paper bag inserted in the original cloth bag. The paper bag may be easily sealed before removal to prevent emission.

Substitution - Beyond the adaptation of better cleaning practices during brake and clutch maintenance, as mentioned above, additional controls seem to be limited to improve design of brake and clutch assemblies and/or substitution of other materials for asbestos.

The high temperature properties and exceptional tensile strength of asbestos have resulted in very compact and economical design. These same unique properties which make asbestos applicable to friction materials also make the application of substitute materials very difficult. The tensile strength and modules of rigidity of asbestos as compared to several candidate substitute materials follows:

Tensile Strength lb/in.^{2}		Modulus of Rigidity lb/in.^{2}
Asbestos	550,000	30,000,000
Fiber yarns	180,000	3,000,000
Steel wool	50,000	100,000
Mineral wool	25,000	60,000

There is no doubt that substitution of other materials for asbestos is possible, but the design changes required to accommodate the stresses and temperatures involved would result in larger, more expensive components.

Brakes - The recent adoption of disc brakes by the automotive industry makes material substitution more plausible. Disc brakes are capable of greater energy dissipation than similar sized drum brakes because the design results in considerably lower heating rates. This is due to the fact that at any one time the friction pad contacts only a section of the disc surface. The lower operating temperatures permit the use of friction materials which do not contain asbestos. Another feature of disc brake design which has reduced the need of asbestos materials is the lower strength requirement of the friction material.

Clutches - The substitution of other material for asbestos in clutch facings of traditional design could only be done by changes in size and design. Two changes in clutch design which have reduced the requirement for asbestos-containing friction materials are the advent of the automatic transmission and the redesign of manual clutch friction surface.

The clutch surface of the automatic transmission is immersed in an oil bath which virtually eliminates airborne pollutants. Further, the cooling affect of the oil bath reduces the requirement for high-temperature capability materials. Automatic transmission clutch facings may be made from either sintered metals or fibrous cellulose materials.

Many manual clutches have redesigned friction surfaces which consist of numerous small circular pads or discs attached to the clutch face as opposed to the standard annular ring friction surface. These small pads act in the same manner as the disc brakes friction pad. Thus, lower stresses and operating temperatures associated with the new design reduce the need for asbestos-containing friction materials.

10. SPECIFIC PROBLEMS

10.1 Emission Levels

In understanding control techniques and their efficiencies, it is important not to be confused with efficiencies quoted on a weight basis and those based on a particle count basis.

Firstly, considering efficiency based on a weight basis, it is relatively easy to get a very high efficiency with particles whose size is in excess of 5μ with a variety of control devices (see Figure 10). However, the efficiency does drop off considerably with decrease of particle size, for example, see Figure 11 for 1μ particles. (It should be noted that these graphs refer to spherical particles - information on fibrous particles is not presently available.)

Now consider what these apparent high efficiencies mean in terms of numbers of fibers. It can be assumed that 10^3 average fibers of asbestos weigh approximately 1 ng.

If 1 g of asbestos material approaches a filter rated at even as high as 99.999% efficiency, then the quantity passing through will be 0.00001 g, or 10^4 ng. And since 1 ng $\triangleq 10^3$ fibers, then a total of 10^7 fibers will pass through the filter for every 1 g of material impinging upon it.

This is a situation not frequently brought out, but is very significant when exposure levels are monitored in terms of fibers per cubic centimeter.

Thus the quoting of efficiency in terms of mass efficiency is a "red-herring" statement that flatters to deceive. It bears no obvious relation to the number of fibers being emitted.

However, based on tests which actually measure the number of fibers being emitted, it would seem that both fabric filters and high efficiency wet scrubbers are capable of reducing the fiber counts to acceptable levels. British experience is that 0.2 f/cc is routine and Johns Manville finds that 1 f/cc is an acceptable value when the results are averaged over a time period.

The medical evidence as to the size of fiber responsible for adverse health effects is not positive nor is the question of whether fibrils of fibers are most hazardous. Until the medical questions are fully resolved, it would seem premature to impose inflexible or overly rigid regulations.

This has been the view held by the Federal occupational health authorities in assessing their standards. It would seem that thei approach in limiting exposure to that which is possible using good modern technology is sensible. The same may be said for their monitoring techniques.

10.2 Water Pollution

Recycling of waste water is possible and is practiced in certain segments of the industry. The question of the damage done to streams, rivers, and lakes by indiscriminant dumping of asbestos containing waste waters needs careful study. One must remember it is a natural material which will appear in water in any case. On the other hand, there is evidence that asbestos particles ingested into the stomach may cause stomach cancer.

Again, until medical evidence is clear, it would seem sensible to recycle water whenever this can be accomplished.

ASBESTOS AIR POLLUTION RESULTING FROM THE WEAR OF BRAKE LININGS

By

Colin F. Harwood, Ph.D.

ABSTRACT

Asbestos containing brake linings have been cited as a source of ambient air asbestos pollution. This paper reviews the suggestion and an estimate is presented which indicates that the asbestos emission from brake linings is significant. The ways in which this emission may be reduced or eliminated are briefly reviewed.

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ASBESTOS AIR POLLUTION RESULTING
FROM THE WEAR OF BRAKE LININGS

INTRODUCTION

Recent interest in asbestos and the realization of its health hazard have raised the question of the extent to which people are exposed to asbestos on a non-occupational basis. Measurements have been made on urban background levels and it has been shown that small but definite concentrations are to be found in areas quite remote from any apparent source.

Since virtually every motor vehicles carries several pounds of asbestos contained in its brake linings and since these are worn away to some degree every time the brakes are applied then it is reasonable to expect that they could present a significant emission source. This is especially acceptable when one considers the 100 million or so vehicles on the nations roads.

The paper investigates the possible extent of such emissions and presents an estimate of the contribution to urban asbestos concentrations. Possible means of reducing such emissions by use of an alternative or sealing the system are briefly reviewed.

The Extent of the Emission

The best information available at the present time[1,2] indicates that the percentage of asbestos contained in the dust normally emitted from brake linings is of the order of 1%. However, under conditions of severe breaking, this may rise to 15%.

The average brake friction material contains of the order of 50% asbestos, thus an explanation is necessary to account for the discrepancy between the measured and theoretical values. The most likely explanation results from the known facts with regard to heat generated at friction surfaces. The work of Bowden and Tabor[3] has shown that when two surfaces are placed together the contact area is dramatically less than the apparent area.

This means that very large energy transfer takes place at these contact points and extremely high temperatures are reached.

In the case of brake linings, some evidence of these temperatures has been generated in unpublished work by the General Motors Company[4]. In this study, a small hole was cut through a brake shoe and the radiation collected from the exposed shoe surface was monitored. The results suggested that under light braking temperatures of the order of 800-900°C were found, while during heavy braking the temperature reached 1700-1800°C.

The significance of this data to the present case is that it is known that asbestos decomposes above 500°C[5] to give forsterite (Mg_2SiO_4), talc ($Mg_3Si_4O_{10}(OH)_2$) and water vapor.

Acceptance of the value of 1% of asbestos emitted allows an estimate to be made of the effect of this emission on the quality of the atmosphere.

Estimation of Urban Concentrations of Asbestos From Brakes

Assumptions

a. There are approximately 100 million* motor vehicles.

b. Motor vehicles have an approximate average weight of 4 lbs of friction material, when new, of which 50% is asbestos.

c. The average motor vehicle will require replacement of the brakes after three years of use at which time they will have lost 50% of their weight by abrasion.

d. The dust emitted will contain 1% of asbestos fibers.

e. Of the wear dust, 80% is emitted and 20% is lodged within the system.

*The AAA claims there are 109,000,000 licenced vehicles including 90,000,000 passenger vehicles and 19,000,000 trucks.

Calculation

The total weight of brake linings in use is

$$\frac{100,000,000 \times 4}{2000} = 200,000 \text{ Tons.}$$

The quantity worn off these linings per year follows from the assumptions made in c.

$$\text{as } 200.000 \times \frac{1}{3} \times \frac{50}{100} = \frac{200,000}{6} \text{ Tons/yr.}$$

This wear dust contains 1% asbestos, hence emission is

$$\frac{200,000}{6} \times \frac{1}{100} = \frac{2000}{6} \text{ Tons/yr.}$$

Allowing for the fact that 20% is not emitted, the total emission is thus

$$\frac{2000}{6} \times \frac{80}{100} = \frac{1600}{6} = 270 \text{ Tons/yr.}$$

Effect on the Atmosphere

There are no facts relating directly to asbestos on which one may judge the effect of these emissions on urban air. However, there has been a considerable amount of study done on the diffusion of other materials from automobiles, particularly lead and carbon monoxide. At a recent ACS Symposium in Minneapolis[6] evidence was presented which placed the level for lead emission at 0.01 $\mu g/m^3$ in Thule, Alaska and 2.5 $\mu g/m^3$ in New York City. Next to busy highways a level in excess of 50 $\mu g/m^3$ may well be possible. In the light of this data the value of 2 $\mu g/m^3$ for average urban air conditions, suggested by GM[4], ~~seems eminently reasonable. Considering that~~ 1.25×10^5 tons of lead are emitted in total from automobiles then the following factor is used.

$$\begin{array}{c}\text{Avg. Conc. asbestos} \\ \text{in city air from} \\ \text{automobiles}\end{array} \approx \begin{array}{c}\text{Quantity of} \\ \text{asbestos} \\ \text{emitted}\end{array} \times \frac{2\ \mu g/m^3 \text{ city air}}{1.25 \times 10^5 \text{ tons Pb from cars}}$$

Applying this figure to the present case and assuming that 200 tons are emitted in city areas, then we get that:

$$\text{The avg. conc.} \simeq 200 \times \frac{5}{1.25 \times 10^5}$$

$$\simeq 3.2 \times 10^{-3}\ \mu g/m^3$$

$$\text{or} \simeq 3.2 \times ng/m^3$$

A similar result is obtained using the dispersion factor for carbon monoxide. However, the values for lead are preferred since it is a particulate emission rather than a gas.

The Significance of This Value

The question of whether asbestos containing brake linings constitute a significant source of ambient air background, asbestos levels can now be considered.

Firstly, it is pertinent to review the available evidence on asbestos levels in ambient air. Perhaps the most up-to-date information is reported in a recent paper by Thompson and Morgan of the EPA[7]. Their data suggests that values 0.5-15 ng/m^3 are appropriate to urban sites, while 0.1 ng/m^3 is to be found in nonurban sites. They give a figure of 0.01 ng/m^3 for remote sites.

The California State Health Department in collaboration with the School of Public Health, Berkeley, California, have tested ambient air for asbestos. Their results suggest values of 0.06 ng/m^3 in remote sites and 3 ng/m^3 near a source.

Nicholson and Rohl[8] of the Mt. Sinai School of Medicine have also been active in the measurement of asbestos in urban ambient air. The analysis of a large number of samples has revealed that 33% of the samples contained 0-0.9 ng/m^3, 55% contained 1.0-5.0 ng/m^3 and 10% contained 5-20 ng/m^3 and a few were in excess of this.

All of the workers have been at pains to point out that the results are to be considered preliminary. Thus they should be regarded not as final definite figures, but rather as good, considered, preliminary findings. The similarity of the figures reported by the various workers does suggest that at least an order of magnitude has been established.

Consider now the estimate of 3.2 ng/m^3 calculated previously as the contribution from asbestos brake linings. Firstly, it should be stated that this figure is a conservative estimate and allowance has been made for the many factors which could reduce this figure. Secondly, although there is no reason to doubt the factor for the diffusion of lead, it should be realized that this figure is an average value for the whole of the city air. Consequently, much higher concentrations are to be expected in certain areas of high brake usage. For example, near intersections, tollbooths, etc.

In the light of the evidence here presented, one must conclude that asbestos emitted from brake linings may be a major contributing factor in the overall ambient air concentration.

Further work is necessary to establish more definitely the major contributors to urban asbestos concentration levels. It is not possible to state with assurance how much these low concentrations of asbestos constitute a threat to the health of the general public. Medical evidence and opinion is widely divergent on this issue. However, asbestos has been rated as a hazardous substance by the EPA and as such it should be treated with due respect. Emissions should be reduced or curbed wherever this is possible. To this end it is worth briefly reviewing how this may be achieved.

TECHNOLOGY OF ELIMINATING EMISSIONS

The emission of asbestos to the atmosphere from asbestos containing brakes could be prevented in two ways: its use could be banned altogether, or, the brakes could be sealed. In the former case, an alternate would have to be found.

Alternatives to Asbestos

For a replacement to be as suitable as asbestos, it would have to fulfill a list of desirable features as:

- Resist high temperatures without degradation or loss of frictional properties.
- Combine excellent friction characteristics without severe abrasion.
- Provide great strength - asbestos fibers have a greater tensile strength than steel and yet are more flexible.
- Have relative economy.

Of the materials which have been considered, sintered metal with ceramics and fiberglass have been the most likely candidates thus far.

Sintered Metal - This material has been used and indeed has the desirable quality of being fade-free, for this reason it is still used in some racing cars. However, it has several disadvantages. It tends to be noisy and brake screetch is a problem. They suffer from what is known in the trade as "morning sickness", this means that the first stop is very severe, or, that the cold friction is high. Wear is higher than with asbestos and thus the brakes have to be replaced more frequently. Replacing the brakes is more difficult since all brakes are honed to fit the drum. Honing metal is more difficult than asbestos friction material.

Ceramic Metal (Cermets) - A sintered metal and ceramic composition has been developed and tried. Its use at this time seems to be restricted to the clutches on heavy-duty vehicles (tractors, etc.); in these cases it is usual to use buttons of the material rather than a complete annulus. Although to a lesser degree, it suffers from the same complaints as sintered metal with respect to noise, wear and severe first stop, and in addition, it is relatively expensive. However, its anti-fade characteristics have led to extensive testing. For example, the Ford Motor Company put inserts of ceramic metal at the position of maximum brake wear on their 1958 Thunderbird. The concept was abandoned, reportedly due to uneven braking leading to a directional pull when braking.

Fiberglass - Attempts to use fiberglass instead of asbestos have been attempted since 1938. So far, no design has met the exacting standards required. As with the other materials, the first stop is harsh. Apparently the design is better for disc brakes than drums. A problem is the sensitivity of the brake to moisture.

Owens-Corning are undertaking development research in this area. They are very guarded with regard to the status of their work, but state that they are actively engaged in developing a product. To date, no vehicles are known to employ fiberglass in their brake friction product.

Sealed Systems

Sealed systems have been seriously considered. Normally, cars rely on air cooling and the movement of air round the brake caused by the motion of the car. However with high performance cars, more cooling is required. This is achieved in a simple manner by fabricating a superstructure which scoops up air and directs it inside the brake drum. If a filter were added on the exiting side, this would cause a substantial reduction in emissions.

A more elaborate design which has been used is to liquid cool the brake system. This enables the braking system to be completely sealed and thus no emission are possible. The one problem area with this design is that the oil seals must be extremely reliable. However, with a well designed system problems due to overheating could be largely eliminated.

CONCLUSIONS

An estimate has been made of the asbestos concentrations to be found in urban air resulting from the use of asbestos containing brake materials. The results indicate that brake use may well constitute a major source of asbestos background levels. The quantity in comparison to occupational levels is extremely low. A time weighted average occupational exposure level of 5 f/cc would be of the order of 100,000 times greater than a background level of 3.0 ng/m^3. The medical significance of these results is not known with any certainty.

At the present time, no alternative to asbestos containing friction products is developed to the stage of finesse required by the industry. It is difficult to believe that modern technology cannot overcome the problems presented by the use of alternates.

The use of sealed brake units is a second possibility. Again there do not seem to be any insurmountable technological problems, but no information is available as to the cost and time factors.