SUMMARY AND EVALUATION

Subject: Discussion of the possible use of materials other than asbestos for auto brakes. Of interest and importance.

Evaluation: The conclusion of the author is that asbestos is practically indispensable for auto brakes at the present time. If asbestos were not available, we could "eventually find a substitute, but it could well be at the expense of a considerable loss in performance, and also at a considerable increase in cost." The author also emphasizes that there is no valid health reason why asbestos should be abandoned at the present time. He cites the tests demonstrating the very small percentage of asbestos fiber in brake lining dust and concludes that "the wear products from friction materials are probably no more dangerous to health than many other dusts and can be treated as 'merely dirty.'" He also mentions that technical developments have reduced the quantities of asbestos needed in the production of efficient brakes and clutches.

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Summary: As given above.

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POSSIBLE ALTERNATIVES TO ASBESTOS AS A FRICTION MATERIAL*

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INTRODUCTION

I HAVE been asked to talk on the possible alternatives to asbestos as a friction material. The facts are that if by "alternative" we mean a new or better fibre which might shortly be available as a replacement for asbestos in conventional friction materials, then I think the chances are so remote as to be not worth considering.

This is not to say that if the world supplies of asbestos dried up we would not eventually find a substitute, but it could well be at the expense of a considerable loss in performance, and also at a considerable increase in cost.

THE ROLE OF ASBESTOS IN FRICTION LININGS

Having started on what may appear to be a rather depressing note, let us examine the reasons why asbestos occupies the role of an almost universal constituent in friction materials at the present time.

The first automotive friction linings were made from cotton textile material impregnated with drying oils which were subsequently cured to form a strip of material which, while being flexible and conformable, still exhibited great mechanical strength. The main function of the drying oil was to protect the cotton from attack by atmospheric oxygen, which, even at the temperatures reached by early brakes, would have resulted in the cotton burning had its surface been exposed. A second function of the drying oil was to prevent the cotton from fraying under the influence of mechanical abrasion.

As brake operating temperatures increased, it was found that cotton started to degrade and lose its strength even though still protected from attack by oxygen. In other words, it suffered thermal degradation instead of oxidative degradation.

Around 1910, a technological break-through was achieved when it was discovered that textiles could be woven from asbestos and used to replace cotton, because asbestos neither burns nor loses its strength below about 500°C. However, as brake operating conditions became steadily more severe, a point was reached in about the middle 1940's when, despite the continual improvement of synthetic resins with which the asbestos textile was impregnated, further heat resistance was required, this time because the organic part of the composite was proving inadequate. The solution proved to be to mould brake linings from powdered resins, using short fibre unwoven

*This paper was originally presented at a Conference on Exposure to Asbestos during Brake and Clutch Maintenance, held at Brentwood, Essex, March, 1969.

asbestos to maintain the necessary strength and flexibility. This made possible the inclusion of heavy loadings of mineral and metal fillers which imparted greater heat resistance than could be obtained from resin and asbestos alone, and did so at the expense of a reduction in asbestos content. The last point is important in the context of asbestos substitutes. The question is often asked, "why can't asbestos be replaced by something like glass fibre which, after all, must surely impart sufficient strength?" The answer is possibly "it can", if merely the performance of a textile lining is required, but at the temperatures commonly met in modern brakes, the glass fibre melts even in depth below the operating surface.

Furthermore, as a result of the embrittling effect of mineral and other fillers needed in today's brake lining, glass fibre is inadequate in imparting the necessary strength and flexibility. The same can be said to a greater extent, of the various types of rock wools and mineral fibres which have appeared on the market over recent years. It is interesting to note that not only is the ultimate strength of asbestos almost three times that of glass fibre, i.e. 550,000 lb/in.^{2} but the modulus of rigidity is up to ten times as high, at a value of 30,000,000 lb/in.^{2}. Typical figures for other materials are say 100,000 lb/in.^{2}, for steel wool and down at 60,000 lb/in.^{2} for mineral wool.

The current situation therefore, is that in drum brake linings of normal configuration used for passenger cars and commercial vehicles, there exists no substitute for asbestos which would not result in a deterioration of performance and strength.

DISC BRAKE PADS

Rates of energy dissipation continue to rise and we have now passed the point where moulded drum brake linings are adequate for a large percentage of passenger cars. In this country, nearly 50 per cent of the passenger car axles are equipped with disc brakes, and for the second time in nearly half a century, there seem to be technical possibilities of reducing the asbestos content of friction materials. It is purely fortuitous that the friction materials used in disc brakes are designed to a stronger shape, that is, more or less square or circular pads of considerable thickness, supported, furthermore, by a metal plate of adequate stiffness. The friction material, therefore, does not have to stand up to handling during assembly, does not have to withstand riveting, and could, from the point of view of bulk mechanical strength alone, be made without a high loading of fibrous reinforcement of any kind. There remains, however, thermal shrinkage and thermal shock, and in order to prevent the formation of tensile cracks normal to the operating surface, a percentage of asbestos fibre is still retained. Nevertheless, it cannot be said that the use of asbestos in disc brake pads remains a technical necessity, and it is in this field of friction materials that some departure from resin–asbestos based composites could occur in the next few years on technical and performance grounds.

FRICTION MATERIALS FOR CLUTCHES

As yet, I have confined my comments to brakes, but the development of friction materials for clutches has followed broadly similar lines. In recent years, however, we have seen the start of a growing replacement of manual clutches by automatic transmissions where the clutch packs are immersed in oil and therefore do not give rise to airborne contamination. The friction materials used are, in any case, made from sintered metals or paper based facings in which the fibre is largely cellulose. This feature is made possible by the low operating temperatures, due in turn, to the fact that the materials are immersed in oil.

Clutches for heavy duty manual shift gear boxes are, in the U.S.A., being superseded at a significant rate by the spider clutch. This is a type of clutch in which the friction material, instead of being in the form of a thin annulus, consists of a number of buttons rather like disc brake pads, and these again could be made from asbestos-free material such as sintered metals or cermets (ceramic–metallic compositions).

Summarizing the situation at the present time therefore, it can be seen that there is a drift towards the use of smaller quantities of asbestos in friction materials as a result of a number of purely performance considerations and design changes, that is, reduced amounts of asbestos in some disc brakes, and replacement by other materials in automatic transmissions and some dry clutches.

OTHER FACTORS AFFECTING EXPOSURE TO ASBESTOS

There are, however, several other factors which enter the equation when considering the exposure to asbestos during brake and clutch maintenance, which is the subject of this meeting.

The first is that the durability of friction materials is increasing, as is the temperature at which they will operate satisfactorily. I mention these facts not only because they tend to offset the adverse effect of increase in vehicle miles per year, but because they affect the whole chemistry of asbestos in friction materials. The second important point is that the type of asbestos used in friction materials is chrysotile or white asbestos, and is different from blue asbestos or crocidolite, not only in colour, but in chemical composition and also in chemical decomposition. The third important point is that under the influence of heat alone, chrysotile asbestos decomposes by loss of water of crystallization at a temperature of around 600°C. The process is rather slow, taking well over an hour to convert 50 per cent of the asbestos to its degradation products. These form a series of iron magnesium silicate materials known as olivine, the end member of which is forsterite. The olivine series of minerals are quite unlike asbestos, both physically and chemically, being non-fibrous, and in fact, widely occurring as the major part of many common rocks (basic and ultramafic igneous). One would not expect that a significant amount of asbestos would be converted to olivine during braking except under conditions of very severe duty such as a fade test, but in fact it is exceedingly difficult to detect asbestos in friction material wear products. It has only on rare occasions been possible to detect asbestos in wear products by X-ray diffraction methods, and one has to resort to electron diffraction, selecting occasional individual small fibres to show its existence. This rather surprising fact has been known for several years and current theory suggests that it is accounted for by very high temperatures which are said to exist at the points of real contact between the lining and drum or disc, even at bulk temperatures as low as 100°C.

Whether this explanation is correct or not, it remains a fact that very little asbestos survives in the wear products after brakes or clutches have been used under normal operating conditions. As the durability of brakes improves, further reductions will occur in the percentage of asbestos which survives the wear process, because each particle of asbestos is then subjected to more heat treatment. Of the approximately 1 per cent of asbestos remaining in wear products, a large proportion is ground down during the wear process to much less than the 5 μ length at which particles are judged to be fibres. This is easy to understand when one considers that under normal conditions a lining will lose about one-millionth of an inch of thickness for every 20 ft of sliding.

Over recent weeks I have had regular tests performed in which employees' private cars, and trucks from the Company fleet have been brought into the garage for brake cleaning. The drums have been removed and in a garage with no forced ventilation, all loose dust has been removed from the drums and back plates by the use of a compressed air jet. As each brake was cleaned, instantaneous atmospheric samples were rapidly taken by a hand-pump from the centre of the dust cloud. Several of the dust clouds were visibly filthy, and would, in my view, be avoided by the operator; the dust counts taken at the point of maximum dust density were as given in Table 1.

TABLE 1. DUST COUNTS DURING BRAKE CLEANING BY COMPRESSED AIR-JET

Test No.	Non-fibrous above 2 μ	Fibre count 2–5 μ	Fibre count Above 5 μ
Samples			
1	2000+	306	5·4
2	109	11	2·1
3	402	17	2·5
4	607	21	3·7
5	475	37	5·3
6	1513	49	8·2
7	628	35	3·2
10 min average	181	5·0	0·8

The interesting points from this exercise are, firstly, the ratio of the number of particles of asbestos to the total dust particles of a similar size, showing a very small percentage of asbestos, and, secondly, the distribution of size of the fibrous element, suggesting that those particles over 5 μ must have been only just over.

I am not suggesting for a minute that the practice of blowing out brake drums with a compressed air line is to be recommended, merely that an intense dust cloud of this composition is a lot less harmful than one might think.

Unfortunately, at the present time, no corresponding data is available from clutches but one would expect the situation to be better than in brakes rather than worse, because on the one hand, surface rubbing speeds are higher, giving rise to higher point contact temperatures, and on the other hand, wear rates are very much lower resulting in an even finer subdivision in the wear products.

POSSIBLE ALTERNATIVES TO ASBESTOS

I have confined my comments to an account of changes which are taking place in friction materials at the present time in the normal course of technical development, in the belief that, although the use of raw asbestos must be tightly controlled, the wear products from friction materials are probably no more dangerous to health than many other dusts and can be treated as "merely dirty". If further evidence comes to hand to suggest that a substitute for asbestos must be found, then under the pressure of necessity, a list of possible replacements could be drawn up as follows:—

Glass fibre	Low strength—low melting point—severe frictional instability.
Steel wool	Low availability—high cost—low strength—damage to drums.
Mineral wool	Very low strength—brittle to the extent of limiting mixing processes.
Carbon fibres	£100/lb currently forecast to fall to £1/lb in several years' time. Still ten times too expensive.
Sintered metals and cermets	Probably the best possibility eventually, but cost will always be relatively high.