

**THE RISK OF HEALTH EFFECTS
IN VEHICLE BRAKE MAINTENANCE & REPAIR
WORKERS AS A RESULT OF EXPOSURE TO DUSTS
ASSOCIATED WITH BRAKE-LININGS**

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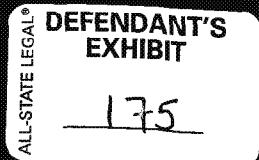


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1.0 PURPOSE

The purpose of this document is :

i. to provide a systematic approach to evaluating whether scientific evidence supports or otherwise a conclusion that..

" workers who have carried out brake repair and maintenance work might reasonably be expected to exhibit health effects directly attributable to exposure to fibrous dusts encountered during the installation and removal of brake friction products in automobiles."

ii. to evaluate critically, the scientific evidence where it falls within my field of expertise and to provide a skeletal framework for developing that evaluation when outside my area of expertise.

2.0 DOCUMENT ORGANIZATION

The document is organized to allow the reader to examine in a stepwise manner, the factors, known or suspected of determining the occurrence of disease or health effects in workers exposed to dusts. Each factor is then examined in the context of information available on the dusts directly associated with brake repair and maintenance.

Technical terms and abbreviations are defined as footnotes to the pages on which they occur. When more detail is needed to convey a concept or clearly explain an issue, this is provided in an appendix to which the reader is referred in the main text.

The various sections of the report are numbered according to the subject matter and the studies to which reference is made in each section are listed under the section number in the "BIBLIOGRAPHY" at the end of the report.

3.0 BACKGROUND

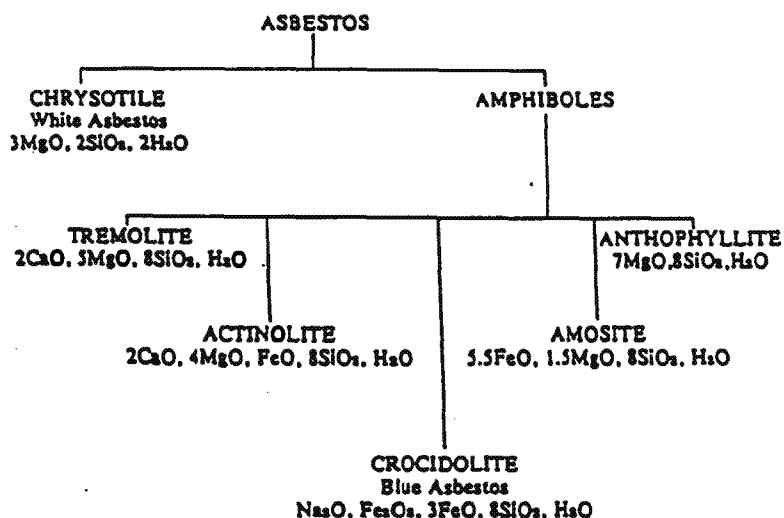
The question of whether one might reasonably expect to find health effects in brake repair and maintenance workers has arisen because asbestos has been used for most of this century as the key component of automobile brake-linings or disc brake pads. The possibility that there may be health effects associated with this work has been inferred in large part by extrapolation, generalization and assumptions that health effects observed in workers exposed to asbestos minerals under totally different circumstances will occur in brake repair workers. It is not the intention in this report to examine the evidence concerning the risks associated with work with asbestos under these other circumstances but to only examine the evidence immediately pertinent to assessing the risk for brake repair workers.

3.1. THE ASBESTOS MINERALS

Asbestos is a generic term applied to the naturally occurring hydrated fibrous silicates. There are six main varieties. (FIGURE 3.1) Each of these has distinct chemical, mineralogical and physical characteristics. Four of them, chrysotile, amosite, crocidolite and anthophyllite have been of commercial importance.

FIGURE 3.1

THE ASBESTOS MINERALS



3.1.1 Chrysotile (White Asbestos)

Chrysotile is an hydrated magnesium silicate and member of the serpentine group of minerals. It usually occurs as white flexible fibres and is sometimes referred to as "white asbestos". This is the variety that has been used most widely in brake linings and will be the variety discussed in detail in this report. As far as I was able to ascertain, it has been the only variety used in vehicle brake-lining and disc brake pad manufacture in the United States. It has been mined in many countries but the major producers have been Canada and USSR. There may be variations in the physical, chemical and mineralogical characteristics of the fibre and associated contaminants depending on source.

3.1.2 The Amphiboles

Unlike chrysotile, the other asbestos minerals are members of the amphibole group of minerals.....

a. Crocidolite (Blue Asbestos)

Crocidolite, often known as blue asbestos because of its colour is mined in South Africa and was for some years mined in Australia. The occupational health experience of persons working with this fibre in respect to malignant mesothelioma has been such that in most countries, much more stringent workplace standards and controls of this variety of asbestos have been in place for many years. Crocidolite may have been used in special application brake-pads in some countries but as far as I was able to ascertain was never used in the USA in the manufacture of vehicle brake linings or disc brake pads.

b. Amosite (Brown Asbestos)

Amosite is a brown-grey or white fibre mined in South Africa. This variety does not appear in the literature surveyed for this report, as having been used in brake-linings.

c. Anthophyllite

Anthophyllite is a white fibre which was mined in Finland and has been reported to have been used at some time in friction product manufacture.

Footnote:

a: Primary malignant mesothelioma are tumours which occur on the pleura and peritoneum. They are described in more detail in section 4.2

d. Tremolite and Actinolite

Tremolite and actinolite are two minerals in a series of minerals in which the iron/magnesium ratio determines the mineral name. Tremolite is not of direct commercial importance at this time. However, tremolite has become quite important in understanding the health risks of chrysotile asbestos as tremolite would appear to occur in extremely small amounts in some chrysotile deposits.

When inhaled by workers in the mines and mills of Quebec the tremolite fibres appear to have become preferentially concentrated in their lungs. Indeed chrysotile miners in Quebec have been found to have as much tremolite as chrysotile in their lungs at autopsy. (Rowlands et al 1982). Tremolite can be a contaminant of vermiculite and talc. The finding of mesothelioma in vermiculite miners (McDonald et al (1986), Amandus and Wheeler (1987)) and in talc miners (Vianna et al 1981) has led to an hypothesis increasingly supported by scientific research results that the tremolite fibre contamination of chrysotile may explain any reported increased mesothelioma risks in chrysotile exposed workers.

In order to avoid confusion in the use of mineralogical terms, the term "CHRYBOTILE" will be used throughout the text. As noted earlier, this appears to be the only variety of asbestos used in brake-linings manufactured in the USA. The term "BLUE ASBESTOS" will be used to identify crocidolite, the mineral mined in South Africa and Australia.

3.2 DIFFERENCES IN HEALTH RISKS OF EXPOSURE TO DIFFERENT ASBESTOS MINERALS AND OCCUPATIONS

Differentiating between asbestos fibre types is important because there is good evidence that they pose different levels of health risk. These differences in risk not only exist between fibre types but also between different industries or applications using the same fibre type. Also many health studies have involved persons exposed to more than one fibre type. Thus the health experience, for example, of workers in other occupations may not be directly relevant to that of brake repair mechanics for many reasons. Some of these reasons are illustrated below..

3.2.1 Mesothelioma risks and Fibre Type.

Table 3.2(a) shows the mesothelioma experience of persons who worked with blue asbestos and chrysotile respectively. The presence of 9 mesotheliomas among 56 deaths of crocidolite gas mask workers (16.1%) and 11 mesotheliomas among 4,247 deaths of chrysotile miners and millers (0.26%) illustrates the dramatic

...

differences in mesothelioma risk posed by these two fibres. This difference is reinforced by the independent study (Table 3.2(b)) of workers manufacturing civilian gas masks using chrysotile where no mesotheliomas could be linked to such exposure while at a plant manufacturing military gas masks using blue asbestos, 2.3% of the deaths were due to this cancer.

Amosite has been implicated in mesothelioma as an important cause of death in an amosite factory (Seidman et al (1979)) with 14 mesothelioma among 528 amosite worker deaths (2.7%). Insulation workers in general have usually worked with chrysotile and amosite and certainly in many countries with blue asbestos.

TABLE 3.2a

Malignant Disease in various groups of workers
Chrysotile and Blue Asbestos workers

	Blue Asbestos Gas Mask Filter Workers	Chrysotile Miners & Millers
Total Cohort ^a	199 (55% male)	11,379 (96% male)
Dead	56	4,247 (since 1935)
Cancer of Lung & Bronchus	7 (12.5%)	242 (5.7%)
Mesothelioma	9 (16.1%)	11 (0.26%)**

** Two cases were common to both series. Some chrysotile workers may have been exposed to other fibre types by work in a Factory in one of the mining towns and in experimental/pilot plants.
Source: McDonald and McDonald (1978)

TABLE 3.2b

Malignant Disease in various groups of workers
Chrysotile and Blue Asbestos workers

	Blue Asbestos Gas Mask Filter Workers	Chrysotile Gas Mask Filter Makers
Total Cohort ^a	757	570
Dead	219	177
Cancer of Lung & Bronchus	15 (6.8%)	7 (3.9%)
Mesothelioma	5 (2.3%)	1*

* This case was also considered to have been exposed to blue asbestos at another factory. There was also an excess number of persons with cancer of the ovary at the blue fibre plant. These were considered by the authors to possibly be additional mesotheliomas.
Source: Acheson et al (1982)

Footnote:

a. A cohort is a study population free of the disease under investigation which is followed over time to observe the occurrence of the disease.

TABLE 3.2c

Malignant Disease in various groups of workers
Chrysotile and Blue Asbestos workers

c.Mixed Amphibole & Chrysotile Workers

New York-New Jersey
Insulation Workers

Total Cohort ^a	632
Dead	478
Cancer of Lung & Bronchus	93(19.5%)
Mesothelioma	28(5.9%)

Source: Selikoff et al (1979)

The mesothelioma experience of New York insulation workers (Table 3.2(c)) is considerably worse than that of Quebec chrysotile miners and millers (Table 3.2(a)). The question of whether blue asbestos was used by these particular insulation workers remains a controversy.

Although the levels of exposure of the various occupational groups have not been sufficiently defined to make direct quantitative exposure comparisons (ie: to know exactly the experience of each group for the same levels of exposure), the experiences have been so different that it is clearly inappropriate to extrapolate from the health experience of persons working with one fibre type to another.

3.2.2 Respiratory Cancer risks and Type of Asbestos Industry.

In the case of the asbestos textile industry where chrysotile has been the main fibre type used, mesotheliomas are rare or absent. Thus the situation in as far as mesothelioma risks are concerned is consistent.

However when lung cancer risks are compared for the "same" levels of dust or fibre exposure, the risks in the textile industry are substantially greater than in all other chrysotile exposed occupations. For example the risk of respiratory cancer was

Footnote:

a. A cohort is a study population free of the disease under investigation which is followed over time to observe the occurrence of the disease.

approximately 50 times greater for textile workers in Carolina than for Quebec chrysotile miners and millers for approximately the same levels of cumulative exposures (McDonald et al(1983)).

The reasons for these respiratory cancer risks being so much higher are not yet known but it is hypothesized that they may be related to other materials used in the textile manufacturing process such as mineral oils which were sprayed on the fibres.(Sebastien et al 1989).

It is for the above reasons that it is not appropriate to directly extrapolate from the health risks in other occupational groups to the risks for brake lining repair and maintenance workers.

3.3 BRAKE LININGS

Brake linings and clutch facings have been manufactured using asbestos since about 1905-1910 (Hatch 1970, McDonald et al 1984). The first asbestos brake linings were made by weaving chrysotile asbestos into bands which were impregnated with resin. "millboard type" linings were introduced in about 1918 and processes which followed were largely wet and involved the mixing, extrusion and moulding of asbestos mixed with fillers.

A description of braking systems and a brief history of the developments in brake-linings and disc brake pads, terminology and technical changes since the mid 1940's is given in APPENDIX 1.

3.3.1 The composition of brake linings and disc brake pads.

While chrysotile appears to have been the only variety of asbestos used in the USA in the manufacture of brake linings there is reference in the literature to the use of blue asbestos in the manufacture of brake blocks and in research projects in the United Kingdom.(Skidmore & Dufficy 1983).

Anthophyllite is also reported to have been used in plants manufacturing friction materials.(Skidmore and Dufficy(1983)); Langer and McCaughey(1982)) The assumption is made in this report that the brake linings encountered by the repair & maintenance workers contained only chrysotile.

Footnote

a: Cumulative exposure is the sum over the workers lifetime (or to a particular point in time) of the products of the concentration of dust or fibre in the air (often expressed as the number of particles or fibres per unit volume of air) and the duration of exposure at each concentration.

Modern brake-linings contain in addition to binders, friction modifiers and fillers. Modifiers are varied in type and content to produce desired levels of wear, fade, effectiveness, recovery and noise. The detailed composition of friction materials have been described by Jacko & Ducharme (1973). The compositions of typical friction materials provided by Jacko & Ducharme (1973) in their report for the Environmental Protection Agency are given in Table 3.3

TABLE 3.3

Composition of typical automotive brake-linings and disc pads (% by volume) from Jacko & Ducharme 1973.

	Drum Linings		Disc Pads	
	Primary	Secondary	Class A Standard	Class B Heavy Duty
Resin Binder	20-30	25-35	18-22	15-18
Asbestos Reinforcement	major	major	major	major
Friction Modifiers				
*Organic Friction Dust	10-15	5-15	20-25	0-15
elastomer		5-15	10-15	0-10
*Inorganic Carbons/Graphites			1-2	2-15
Zinc Chips			1-2	
Oxides		0-5		2- 7
Copper/Brass		0-5		5-10
Misc Inorg.		5-10	0-5	5-15

Product formulations have changed to meet different vehicle requirements. The content of chrysotile in asbestos containing brake linings was reported in 1970 to range 40-60 percent (Hickish and Knight 1970) and there appears to be general agreement that on average the chrysotile content of linings and disc pads is about 50% by weight. In all these products the fibre is encapsulated in resin binder systems.

3.4 THE WORK IN BRAKE REPAIR & MAINTENANCE

Throughout the literature it is clear that brake repair for the vast majority of mechanics does not occupy their full time. It is important to know the work routine of a particular shop for the following reasons...

a. What other work did maintenance workers perform that may have exposed them to materials or situations likely to give rise to the health or other effects claimed ?

Examples of work or exposures in a garage that might confuse the interpretation of findings in an individual include: welding, sanding of autobodies, exposure to diesel and automobile emissions (polynuclear aromatic hydrocarbons and oxides of nitrogen) solvents such as perchloroethylene or other chemicals which are suspected carcinogens, talc or other dusts which are known to be related to radiological changes or other health risks for exposed workers.

b. What was the shop or worker routine? This will identify how long a worker may have been exposed per day to any dusts released during brake repair.

c. What were shop work practices.?

Was a compressed airline available to blow out drums? Was this standard practice?

When did this practice, if used, start and finish?

Was other equipment provided such as a brush to brush out the drums?

Was it standard practice to grind the linings in any way?

Did the shop perform work on automobiles or trucks and buses?

Answers to these questions are important in determining worker exposure. In this report certain assumptions have been made which may require modification in relation to an individual's work experience.

4.0 OCCUPATIONAL DISEASES

An occupational disease is a disease resulting from a professional exposure.

Three types of occupational disease exist.

The first is a disease which occurs very rarely in the general population. When a few cases occur in a working population in relation to a specific occupational exposure this is sufficient to raise a suspicion that the disease is occupational in origin. However there are often factors other than occupation which are common to the cases and working population. Thus the

observation of a clustering of a rare disease should signal the need to seek confirmatory data. This usually involves independent epidemiological study.

The second type of occupational disease occurs quite commonly in the general population. In this situation it becomes necessary to determine whether the disease occurs more frequently in the workers exposed to a specific agent than in workers of the same age, sex etc who are not so exposed. This is the situation in regard to linking health effects such as lung cancer to asbestos exposure.

The third type of occupational disease is that where the disease has been established as only occurring in occupationally exposed persons or is so defined. Such a disease is classical silicosis which only occurs in persons exposed to very high levels of respirable crystalline silica dust over relatively long periods of time such as are only encountered occupationally.

There are several essential considerations in determining the link between an exposure and a disease in groups and in individuals.

First the presence of the disease or health effect must be clearly demonstrated. Second it must make mechanistic sense for the disease to be associated with the agents or dusts to which the individual or group are exposed. Third the nature and level of the dust exposure must be appropriate to explaining the nature of the disease or health effect and frequency with which it occurs. Fourth, other agents or factors known to be associated with, or giving rise to, or influencing the occurrence or course of the disease must be evaluated.

4.1. DEFINING THE DISEASE OR HEALTH EFFECT.

The question of what constitutes a health effect is complex. The diseases or health effects which are frequently studied in relation to asbestos exposure are.....asbestosis, lung cancer and mesothelioma.

Other diseases such as gastrointestinal cancer, cancer of the larynx, cancer of the ovary as well as cancers of other sites remain controversial or in some cases speculative.

From a scientific standpoint there are a number of important factors to be considered in weighing the evidence for a health effect. A key one is how well is the health effect established?

Footnote

a: Asbestosis is the scarring of the lung tissue resulting from exposure to normally, high concentrations of asbestos minerals over many years.

In the following sections the various "health effects" which have been shown to be associated with certain asbestos exposures or have been hypothesized as being associated with such exposures will be discussed.

4.2 THE RESPIRATORY SYSTEM

The principal diseases of concern in relation to exposure to the asbestos minerals are those of the respiratory system. The aerodynamic behaviour of particles and fibres in air and how they enter and are deposited in the respiratory system are described in sections 6.0 and 6.1

The respiratory system is shown schematically in Figure 4.2. The thoracic cavity as it is called is bounded at the front by the sternum and costal cartilages, at the back by the vertebral column and ribs and at the sides by ribs. The floor of the cavity is the diaphragm. The space within the above boundaries is divided into two parts by the mediastinum. The lungs are placed in the thoracic cavity, one on either side of the mediastinum. The lungs which differ from one another in shape are each enclosed in their own pleural sac. These pleural sacs are membranes which enable the lung to move freely in the cavity in which they lie. The visceral pleura is the layer which covers the surface of the lung to which it is intimately attached. The parietal pleura is the layer covering the walls of the cavity and is named according to the part of the wall that it covers. The lungs during life are in contact with the walls of the cavity which enclose them, the visceral and parietal pleura are thus in contact and are separated only by a thin film of fluid which enables the two layers to glide freely over one another as we breathe. The pleura are the sites for mesothelioma, pleural thickening and pleural calcification.

The vitality of tissues in the body depends on the appropriate exchange of the gases, oxygen and carbon dioxide between the tissues and the atmosphere. The lungs are the chief organs of this exchange, having the structure of a specialised form of sponge. The cavities in this sponge are called alveoli. These alveoli are grouped together and meet in a chamber called the atrium. Several atria join to form a very fine elastic walled tube called the bronchiole. A number of bronchioles join together forming the small bronchi which join to form the large bronchi of which there are two, one for each lung. They join to form the trachea which communicates through the mouth to the atmosphere.

4.3 MESOTHELIOMA

Primary malignant mesothelial tumours or malignant mesothelioma have been reported for at least 100 years. Until relatively recently the tumour was considered to be rare. In 1960 Wagner et al reported the occurrence of this tumour in individuals with

industrial and residential contact with blue asbestos in South Africa. Since that time the tumour has been reported in many groups occupationally exposed to "asbestos" as well as in persons exposed to the non-asbestos mineral erionite. (Baris et al 1987).

The tumour occurs in both sexes, is unrelated to smoking and has a long "latency" with periods between first exposure and tumour detection of 20-40 years or more.

The tumour itself occurs on the pleura and peritoneum, membranes that surround the lung and line the thoracic and abdominal cavities (see Figure 4.2).

Kannerstein et al (1979) drew attention to the difficulties of diagnosing this tumour and the value of "mesothelioma panels" to review cases. They noted that the "pathologic overlap with other neoplasms continues to give relevance to "...there is scarcely another variety of tumour which is so ill-defined and which admits to so much doubt as to its true nature".

Microscopically the tumour shows considerable variation and the appearance varies from tumour to tumour making accurate diagnosis difficult. Parkes (1975) notes that the diagnosis has either been by biopsy alone or autopsy but that diagnosis made by biopsy alone is not reliable.

The difficulties noted above are exemplified in the study by McDonald et al (1973). Six pathologists reviewed 119 of 165 cases reported as primary malignant mesothelial tumours between 1960 and 1968 in a Canadian national survey. Based on histologic observations only, the panel was in favour of the diagnosis in 50%, uncertain in 14% and against in 36%. This illustrates the tendency at that time to "over diagnose mesothelioma". In the United Kingdom, Greenberg and Davies (1974) reported that of 413 notifications of mesotheliomas 76 were definitely not mesotheliomas when reviewed, 35 of these had been described as mesothelioma on the death certificate. While it is likely that the tendency is now to be more rigorous in diagnosis, diagnosis is difficult and must be based on stringent standards of post mortem examination and not on biopsy material (Parkes 1975). Review by panels of pathologists (the mesothelioma panels) is now the accepted method of obtaining agreement on such cases. The early cases identified by Wagner et al (1960) were diagnosed as having tuberculosis which did not respond to treatment. More recently the possibility was identified that some of the women with "cancer of the ovary" who worked with blue asbestos (crocidolite) making military gas masks may have had mesotheliomas (Acheson et al 1982). This further illustrates the diagnostic complexity.

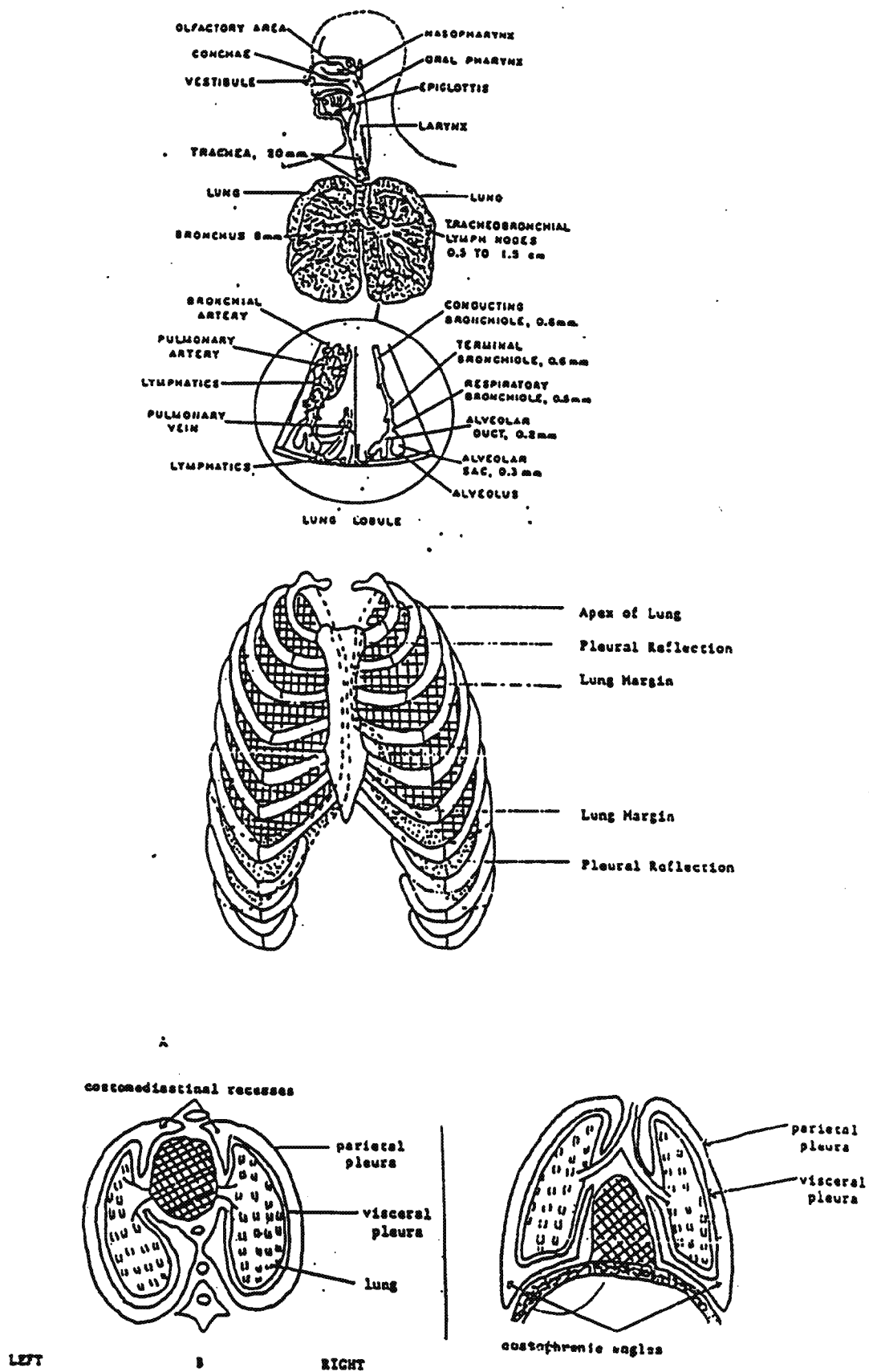


FIGURE 4.2
SKETCHES-RESPIRATORY SYSTEM, LUNGS AND PLEURAL SURFACES

4.4 ASBESTOSIS

There is probably little disagreement in the literature that high grades of certain radiological abnormalities reflecting scarring of the lung combined with certain characteristic symptoms and pulmonary function deficits and clear evidence of long term exposure to high levels of any one of the varieties of asbestos might be called "asbestosis",

However in practice the definition is highly variable. The term "asbestosis" tends to be a clinical term applied to fibrosis of the lungs caused by asbestos. The diagnosis is a clinical opinion which is made taking into account a variety of observations such as changes on the chest radiograph, worker complaints of breathlessness, or crepitations (noises in the lungs), certain lung function deficits, evidence of asbestos exposure etc..

While this may result in an agreed diagnosis when the effects are well advanced, minor radiological abnormalities or lung function changes may or may not be due to "asbestosis". It is for this reason that in epidemiological studies the term "asbestosis" is rarely used.

In most epidemiological studies the frequency of changes on a radiograph or frequency of symptoms etc are treated independently and examined in relation to exposure. In some studies combinations of changes to define asbestosis have been used but this definition has been for study purposes only.

a. Radiological Change

The chest radiograph may show changes. These include: lung markings which obscure the normal lung appearance, pleural thickening pleural calcification, possibly changes to the cardiac outline or shadow and others. These changes can be graded and an internationally agreed classification system exists for the reading of radiographs known as the ILO/UC Classification.

Interpreting these readings is not straightforward for the following reasons.

There is almost always significant variation between even "expert" readers in terms of the existence or degree of radiological change. It is for this reason that scientific studies involve the review of films by multiple readers. Parker et al (1989) recently reported that an initial reading of 566 radiographs found 30% to be positive for pleural change. However only 4% were considered positive by at least 2 out of 3 readers from the NIOSH panel reading radiographs under blind conditions.

Footnote:

a: "Blind" means without information on age, occupation exposures etc.

Some radiological changes such as pleural calcification may be quite marked but have little or no importance in producing respiratory disability.

As the radiological changes become less pronounced, there can be serious difficulties in the interpretation of results as readings of the radiographs of persons without exposure may reveal the same types and degrees of abnormality. It is for this reason that before reaching conclusions that there is a disease or indicator of a health effect in a group of workers it is necessary to know whether the frequency and degree of change is greater in those exposed than in a non exposed comparable group of workers.

b. Breathlessness

While breathlessness relates well to cumulative exposure in asbestos exposed workers, the symptom alone is non specific.

c. Lung Function Changes.

While certain changes may correlate well with cumulative exposure to asbestos, not all tests are equally predictive. Some changes are completely non-specific and are influenced by other factors such as smoking, age, race etc..

d. Clinical observations.

These are rarely used in epidemiological studies because of observer variation. However certain well standardized observations may be useful. (eg: presence of "rales" or "crepitations")

In epidemiological studies the frequencies of certain measured outcomes in exposed workers compared to those in non exposed workers are examined. The relationships between observations and levels of exposure to dusts/fibres are also examined to determine if the rate of adverse outcomes increase sensibly with exposure.

4.5. LUNG CANCER

The occurrence of lung cancer in certain age groups is not uncommon due to past smoking habits. Thus the evidence for an increased risk of lung cancer in an occupational group depends on the demonstration that the lung cancer mortality increases as the level of exposure increases or that there is an excess of lung cancer in a particular group compared to another un-exposed group or compared to the general population. Differences in smoking habits must be taken into account in study design or in interpreting findings.

Although research has been conducted to determine if the histological types of lung cancer associated with asbestos

exposure are different from those associated with smoking, it is not possible at the present time to distinguish on histology whether in an individual he/she has an asbestos or a smoking related lung cancer. However it is important to consider the magnitude of the risk of lung cancer associated with smoking. Table 4.5a modified from Hammond et al (1979) clearly indicates the importance of smoking. The asbestos workers were Insulation Workers and the "control" population was the 73763 men in the Cancer Society's prospective cancer prevention study. McDonald (1980) showed that in chrysotile mine and mill workers the effects were more additive than multiplicative as shown in table 4.5b

TABLE 4.5a

ASBESTOS INSULATION WORKERS AND SMOKING RISK

Group	Exposure to Asbestos	History Cigarette Smoking?	Death Rate /100000	Mortality ^a Ratio
Control	No	No	11.3	1.00
Asbestos	Yes	No	58.4	5.17
Control	No	Yes	122.6	10.85
Asbestos	Yes	Yes	601.6	53.24

a. Ratios of death rates relative to non exposed non-smoking population.

TABLE 4.5b

^b
RELATIVE RISKS ASSOCIATED WITH SMOKING & WORK IN
THE CHRYSOTILE MINING INDUSTRY

	Asbestos Exposure		
	Little	Moderate	Heavy
Non Smokers	1	2.0	6.9
Moderate Smokers	6.3	7.5	12.8
Heavy Smokers	11.8	13.3	25.0

Source: McDonald (1980)

b. These are risks relative to the risk for non smoking lightly exposed workers

4.6 GASTROINTESTINAL CANCER

In 1964, Selikoff et al in studying insulation workers reported that there was an excess of gastrointestinal cancer in their study population. As mentioned earlier these workers will most likely have had a mixed chrysotile/amphibole fibre exposure. Since that time there have been a number of cohorts studied where an excess of gastrointestinal cancer has been claimed and others where the results have been negative.

The fact that the majority of fibres removed from the lung end up in the stomach raises the question of whether this increases the risk of gastrointestinal cancer. This has been well studied in particular in relation to the effect of amphibole fibres exposure in water. The results of ingestion experiments in animals have been negative.

The epidemiological studies have not shown consistent excesses of gastrointestinal cancers of specific sites. Thus there is still some controversy over whether or not gastrointestinal cancer risks are increased. Edelman (1988) in reassessing the results of 32 published cohort studies concluded "asbestos workers are not at an increased risk of gastrointestinal cancer".

The experience in the friction industries and brake maintenance industries in respect to gastrointestinal cancer will be reviewed in a later section.

4.7 OTHER CANCERS

The question of whether laryngeal cancers are associated with exposure to the various asbestos minerals is doubtful although still debated. There have been studies of women working with blue asbestos where an excess cancer of the ovary has been reported. Whether these were cancers of the ovary or mesothelioma remains unclear as does the possibility of an association between asbestos and cancers of this site. There have been claims in the literature that cancers of other sites such as kidney might be associated with asbestos exposure but the cases appear to be isolated.

5.0 FACTORS INFLUENCING THE OCCURRENCE OF DUST RELATED DISEASES IN OCCUPATIONALLY EXPOSED PERSONS

In the following sections the factors which influence the occurrence of dust related diseases in general and then specifically in relation to brake-lining mechanics are described.

The key factors which determine whether or not a person occupationally exposed to a dust gets or is identified with a dust related disease are as follows:

- i. The characteristics and properties of the dust to which the worker is exposed.
- ii. The concentrations of the respirable fraction of the dust to which the worker is exposed.
- iii. Duration of exposure to the airborne dust.
- iv. Pattern of exposure.
- v. Period from first exposure to time when the worker is examined for health effects.
- vi. Personal habits of the worker which might directly or indirectly:
 - a. influence the risk of occurrence of a dust related disease(s) or health effect(s) or influence the course of the disease
 - b. produce a disease indistinguishable from that produced by the dust.
- vii. Individual personal characteristics or pre-disposing conditions which might directly or indirectly influence the occurrence or course of a disease in that worker.

6.0 CHARACTERISTICS & PROPERTIES OF THE DUST

The characteristics and properties of a dust which are important in determining its potential to produce a health effect include:

a. Characteristics and properties which determine the aerodynamic behaviour and respirability of the dust:

- particle size
- particle density^a

Footnote:

a: Density is the number of grams /cubic centimetre of the particle.

b.Characteristics and properties which determine whether and where the particles deposit in the respiratory system.

- particle size
- particle density
- particle shape

c.Characteristics and properties which determine whether and how long the deposited particle remains at the site of deposition or is removed from the lung

- particle size
- particle shape
- solubility

d.Characteristics and properties of the dust which determine the likely reactivity of the dust in the lung or system.

- chemistry
- mineralogy

e.The toxicity or potential for the dust to produce adverse health effects

f.Associated contaminants which might in their own right have the potential to cause health effects or influence the dust effects.

6.1 PARTICLE SIZE & SHAPE

As noted above, the size, shape and density of a particle are extremely important in determining whether it even gets into the lung and if it does, how well lung defence mechanisms can remove them. In the case of fibres it appears that the ability of fibres to experimentally induce disease is also fibre size dependent.

6.1.1 Aerodynamic behaviour, respirability and deposition

a.Non-Fibrous particles

From the standpoint of evaluating health effects, the particles of significance are all solid particulates and liquid droplets which are suspended in air (collectively known as aerosols) and which may be inhaled.

Airborne particulates may range in size from molecular dimensions up to about 100µm in diameter. The main types are dusts, mists, fumes and smokes. Examples of particles and size ranges are shown in Figure 6.1.

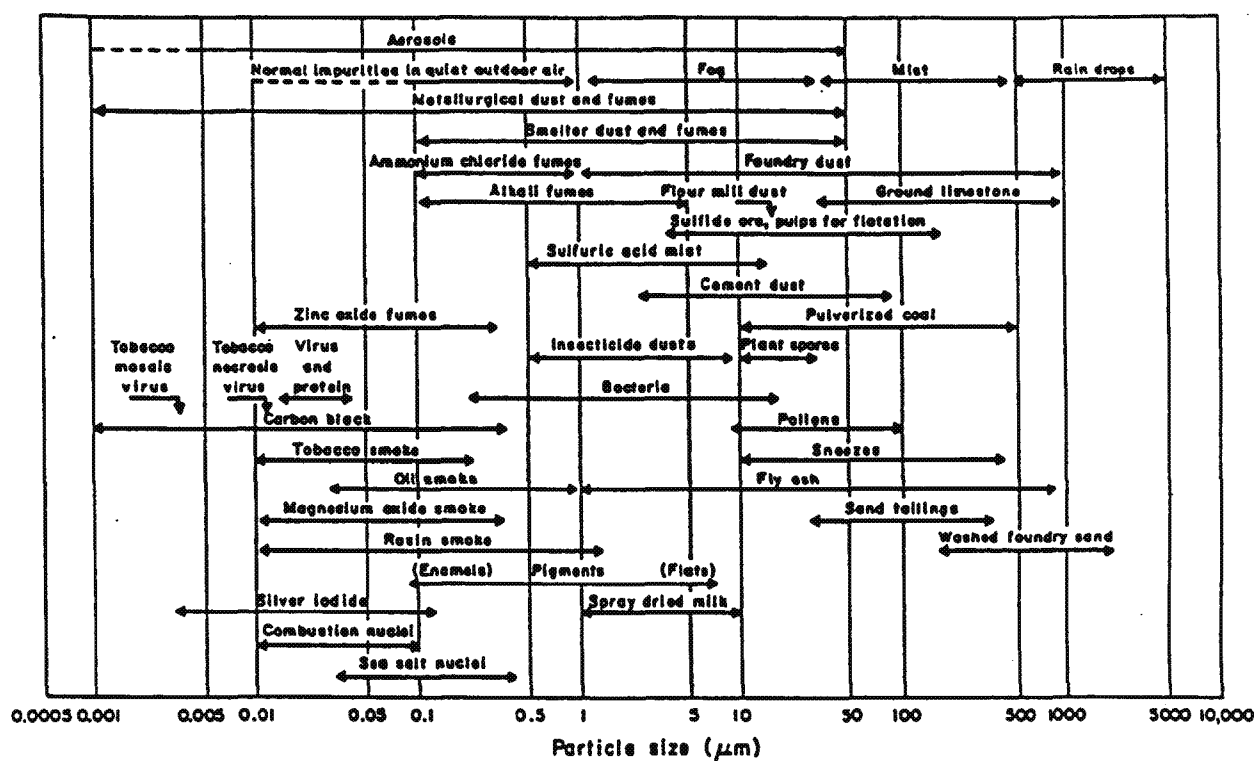


FIGURE 6.1

APPROXIMATE SIZE RANGES OF AIRBORNE PARTICLES
(FROM STUART & RICHLAND 1973)

This present report concerns dusts. They consist of solid particles rendered airborne during crushing, grinding or attrition or by dispersal of fine particles from bulk sources or by pick up of previously deposited particles. Although almost all dust particles are irregular in shape, they can unless highly non spherical be considered to approximate spheres for the determination of their aerodynamic behaviour.

The rate at which particles settle out in air is governed by Stokes' Law. This relates the terminal settling velocity of a particle (rate at which it falls in the air) to its density and radius as it falls in non turbulent air. The aerodynamic diameter is the diameter of a sphere of unit density which has the same terminal settling velocity as the particle. Thus the actual diameter of a particle of the metal lead which has a high density will be much smaller than that of a particle of aluminium (low density) for the same aerodynamic diameter.

As most dust clouds are made up of particles with a wide range of sizes and densities, it is convenient to consider particles equivalent if they exhibit the same settling rates which are defined by the aerodynamic diameter mentioned above. The physical dimensions of an approximately spherical particle thus becomes important only after a particle has been deposited in the lung.

Particles are deposited in the lung by essentially four mechanisms.

1. Particles are removed from the inhaled air by gravitational settlement, the quantity of dust deposited depends on the particle free falling speed or terminal velocity and the time available for settling of the particles to occur.
2. When a change in direction of air flow occurs, particles, because they possess some inertia, tend to continue in the direction that they were originally moving. It is in this way that particles are deposited in the nasal passages and at the back of the throat.
3. Particles in air are perpetually being bombarded by gas molecules. The effect on the particles is referred to as Brownian Movement. This mechanism becomes important in the deposition of very small particles and in the small air spaces.
4. The fourth mechanism involves interception which increases as the diameter of the particle increases. This mechanism is of no importance for compact particles of less than 10µm in diameter even in the finest airways which are several hundred micrometres in diameter. However it can be a very important mechanism for fibre deposition.

Footnote:

a: Brownian movement means that particles are moved about in the lung air by bombardment by gas molecules. In this way they get close to surfaces and deposit.

In a person who breathes through the nose, particles much larger in diameter than 10 μ m are trapped in the nose and in large part are removed by sneezing or by blowing the nose.

If a person breathes through the mouth the larger airborne particles normally trapped in the nose are deposited by impaction in the upper part of the respiratory system, rapidly transferred to the mouth, swallowed and excreted.

In terms of lung effects, the concern is for particles of 10 μ m diameter or less. The particles which can penetrate deep into the alveolar region of the lung are defined as "respirable" and the British Medical Research Council curve shows the percentage % of unit density spheres of various diameters which can penetrate into the alveolar region of the lung. (Figure 6.2a). The regional deposition of particles in the respiratory system is illustrated in Figure 6.2b

Photomicrographs of dust removed from brake drums (Lynch 1968) suggests that the bulk of the dust particles were of diameters less than 2 μ m with very slightly larger particles present in the decomposition products from brake-lining failure. Assuming the density of the particles to be less than about 4g/cc, (forsterite would be approx 3.3g/cc) the small particles would be respirable if rendered airborne.

b. Fibrous dusts

The mechanisms by which particles are deposited in the reparatory system were described above. The sizes of compact particles found in the alveolar or gas exchange region of the lung are 10 μ m or less. On the other hand, fibres of lengths exceeding 100 μ m can be found deep in the lung at autopsy.

As fibre deposition in the lung is governed by the same mechanisms as for particle deposition, (Timbrell 1965, 1970, 1973, ; Timbrell and Skidmore (1971); Timbrell et al (1970)) in an elegant series of experiments studied the relationships between fibre and particle aerodynamic behaviour by measuring particle and fibre deposition rates. Allowing glass spheres of density 1.1g/cc and glass fibres and asbestos fibres of varying length and diameters to settle out on glass slides in an instrument known as an aerosol spectrometer, the equivalent aerodynamic diameters of the fibres... that is the diameters of unit density (1g/cc) spheres which settled out at the same rate as the fibres were measured. They were able to show that length of the fibre was of little importance in determining fibre deposition rates but that aerodynamically, fibre diameter is extremely important.

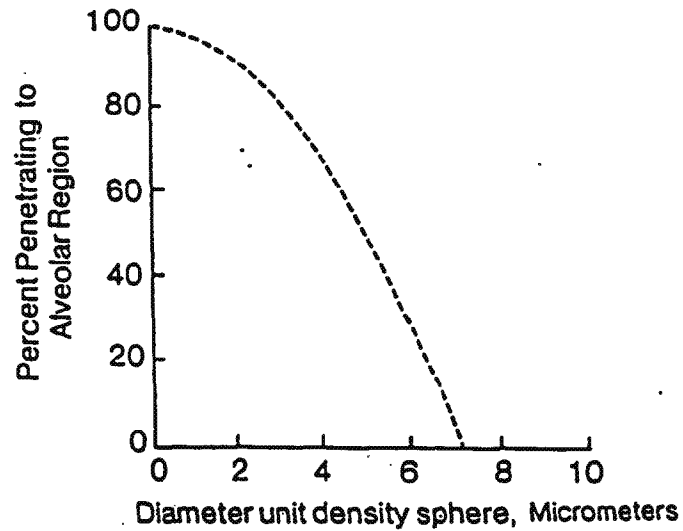


FIGURE 6.2a

PENETRATION CURVE FOR UNIT DENSITY SPHERES
ACCORDING TO BRITISH MEDICAL RESEARCH COUNCIL
SPECIFICATIONS

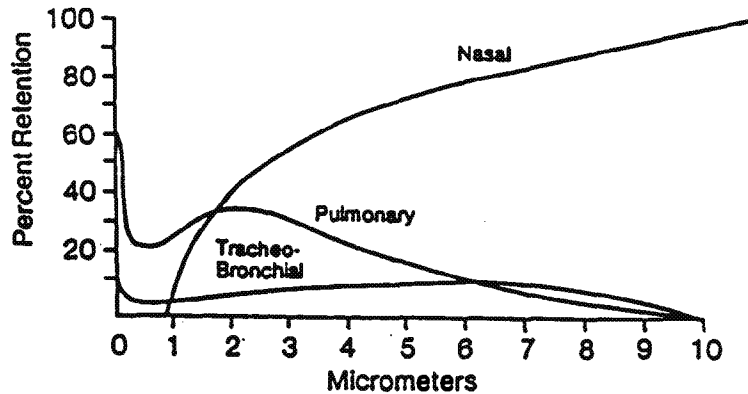


FIGURE 6.2b

REGIONAL DEPOSITION OF AEROSOLS AS A FUNCTION
OF PARTICLE SIZE

Based on these relationships, and assuming that the upper limit of the diameter of a spherical particle of unit density reaching the lung alveolar region is $10\mu\text{m}$, then the expected upper limit of the diameter of the asbestos fibres penetrating to the alveolar region would be approximately $3.5\mu\text{m}$.

The approximate values of equivalent diameters for long fibres, for example found in lung tissue are 3.5, 3.0 and 2.5 times the actual diameters for amosite, crocidolite, chrysotile respectively.

Interception as a mechanism for fibre deposition in the respiratory airways is very important. Timbrell (1965) showed that there was a definite tendency for fibres longer than $5\mu\text{m}$ to align in laminar air flow. He also showed that asymmetry led to a lower rate of alignment which is important because it means that curly fibres have a lower chance of penetrating deep into the lung.

Timbrell (Davies 1970) suggested that this curliness was an important factor in explaining the apparent lower risks of health effects associated with chrysotile asbestos because fibres can be curly. Using UICC^a chrysotile dust samples and glass fibres of various shapes, he was able to show a significant reduction in the penetration into the alveolar regions of the lung of curly compared to straight fibres. Micrographs in both the publication by Lynch (1968) and Rohl et al (1977) show the presence of particles adhering to fibres which will influence respirability.

In a person who breathes through the nose, long fibres are likely to be trapped in the nose and in large part are removed by sneezing or by blowing the nose. If a person breathes through the mouth the larger airborne fibres normally trapped in the nose are deposited by impaction in the upper part of the respiratory system, rapidly transferred to the mouth and swallowed. (See section on gastrointestinal cancer)

In summary, the main factors determining fibre penetration into the lung are fibre diameter and fibre density. Fibres with the same density as chrysotile and of diameter much above $3.5\mu\text{m}$ do not penetrate deep into the lung because their settling rate is too great. Fibre length plays a minor role aerodynamically. However it can be important for long fibres in determining interception and deposition at airway bifurcations. Fibre length is very important once a fibre is deposited in the lung.

FOOTNOTE:

a: UICC is the International Union Against Cancer and under their auspices special samples were prepared for use in animal experiments around the world.

6.1.2.Determining the composition

The fact that entry of particles into the respiratory system is size dependent has important implications in understanding the composition of particles likely to be inhaled in brake repair workers. It should be noted that.....

- * Where dusts present in brake drums have been analyzed for chrysotile asbestos content, they may have included particles separated from the brake lining which are non - respirable. Thus analyses are likely to overestimate the free fibre available for inhalation and deposition in the lung.

- * Where analyses of the dusts released from grinding or cutting brake-linings have been made, they may if they have not taken into account the respirability or size characteristics of the dust, overestimate the free chrysotile fibre content which is available for inhalation and deposition in the lung.

- * Bulk analyses may provide grossly different results as far as the free chrysotile fibre content is concerned from those measurements of airborne respirable fibre.

- * Where airborne dusts are treated for analysis (eg using ultrasonification to produce single fibrils, as is often the case in electron microscopy) the treatment may release fibres for counting which might otherwise be present in particles too large to enter the respiratory system.

Thus measurements of exposure to chrysotile fibre can only realistically be assessed by counts of airborne respirable fibres which have been individually analyzed to determine if they are chrysotile. X-ray diffraction only examines the sample for the presence of chrysotile or serpentine and chrysotile will be reported even if it is embedded in resin.

6.1.3.Role in particle removal from the lung.

The moment that a particle either inert or toxic is deposited in the lung, mechanisms to remove particles from the respiratory tract come into play. They can be divided into those that depend on ciliary action and those that act in the non-ciliated regions of the lung.

As in everyday life, particles and fibres which are deposited on the tracheobronchial part of the respiratory system are transported by mucociliary action upwards to be swallowed. Thus the larger and high density particles and fibres which are inhaled, if they are not absorbed into the bloodstream immediately, are removed rapidly by this mucociliary process.

Footnote:

a; A bundle of fibres is made up of individual fibres or 'fibrils'

This method of particle removal can be hindered by damage to the cilia as for example through the effects of cigarette smoking with clearance of particles severely impaired (Cohen 1979).

If particles are deposited more deeply in the lung, one of the most rapid removal mechanisms involves recruitable macrophages (phagocytic cells contained in the alveolar surface epithelium). A particle is engulfed by the macrophage or phagocyte which moves the particle towards the ciliary escalator for removal. Phagocytes may also serve to render the particles incapable of injuring or irritating the tissues.

Particle size and shape are important in clearance from the alveolar surface because shape and dimension may hinder phagocytosis. Allison (1973) examined the limit to the size of particles that could be ingested by phagocytes, using fractions of chrysotile and blue asbestos containing high and low percentages of short (<5µm) and long fibres. Independently of fibre type the short fibres were rapidly and completely taken up by the phagocytes whereas fibres longer than 20µm were never completely taken up and fibres of length 5-20 µm were sometimes completely ingested. This observation showing that short (less than 5µm) fibres are readily removed has been demonstrated many times in the literature.

Particle solubility becomes important in assessing health effects if the particles are very soluble and absorbed rapidly into the blood stream. In the case of chrysotile it has been well established that its outer magnesium hydroxide layer makes it possible for body fluids to dissolve or leach out magnesium. The chrysotile structure is thus steadily dissolved and at a much greater rate than for the amphibole asbestos minerals (Morgan & Cralley 1973). Thus for longer fibres, increased solubility over the amphiboles may be another factor in the decreased retention of chrysotile in the lung.

6.1.4 Role of fibre size in producing biological effects

Assessing the role of fibre size in the production of health effects in man is complex. The experimental work in animals and other biological systems are consistent with fibre length and diameter being important in both the ability of a fibre to produce experimental fibrosis of the lung and produce mesothelial tumours when introduced directly to the pleural surface.

In experiments where the various long asbestos fibres have been placed on the pleura, all have produced mesothelioma. On the other hand the experience in humans has shown no clear high risk of mesothelioma for workers exposed to anthophyllite or chrysotile. While the reasons for such differences remain conjecture, a convincing argument is that in experimental animals with a lifespan of approximately 2 years the lung

protection/removal mechanisms have less than 2 years over which to act. Thus if solubility of the fibre or removal mechanisms are important in reducing the number of fibres at a site, the time over which these mechanisms can act is truncated. Exposure levels in animals also tend to be high and this might further impede fibre removal mechanisms. Fibres being placed directly on the pleura also excludes consideration of the mechanisms impeding fibres from reaching the pleura under normal circumstances. In humans the time frames are measured in tens of years rather than months which provides the fibres with the opportunity to be dissolved or removed from the lung.

In spite of the apparent difference between the human and animal experience, the experimental data are never-the-less useful because they provide yet another important perspective on the importance of fibre shape and dimensions.

Studies by Stanton and Wrench (1972), Stanton (1973), Stanton and Layard (1978) showed that fibres greater than 8 μm in length and less than 0.25 μm in diameter had the higher probability of producing cancers. They also demonstrated that by reducing the length of blue asbestos fibres by pulverization that the carcinogenicity as far as mesothelial tumour production is concerned was reduced. They concluded that pulverized blue asbestos of sizes less than 1.25-3.75 μm could be discounted as far as mesothelioma production was concerned. Demonstrating that glass fibres, aluminium oxide fibres also produced mesothelioma when in contact with the pleura suggested that mesothelial tumour carcinogenicity was linked primarily to length and diameter and possibly durability.

The work of Stanton and colleagues has been supported by several independent investigators. It is noteworthy that Stanton (1973) found that "No tumours have developed in rats exposed to either blue asbestos or chrysotile pulverized to the extent of reducing all optically visible fibres to non-fibrous form". The latter approximates the situation with dusts in brakes drums.

A second consideration is fibre size in relation to fibrosis of the lung in experimental animals. Kuschner and Wright (1977) found that short fibres (glass and blue asbestos) less than 10 μm in length did not produce lung fibrosis while the long fibres did. The explanation for this would appear to be the removal of these shorter fibres from the lung.

6.1.5 FIBRE SIZES IN BRAKE LINING DEBRIS AND EMISSIONS

In instances where it has been shown that fibres were present in brake lining or disc brake pad debris there is some information on the fibre sizes. (See Table 6.1)

The apparent variation in the proportions of fibres of different sizes in the airborne dusts or drum dust is likely due to differences in the sample preparations, magnifications used as well as the sampling variation. Nevertheless the data are clear that the vast majority of remaining fibres or fibrous structures are of length considerably less than $5\mu\text{m}$. Only one paper made reference to a control filter and this had as many longer fibres on it as the test filter.

Regardless of whether they are chrysotile or not, the dusts to which brake-lining maintenance personnel are likely to be exposed to dusts derived from brake - linings and disc brake pads are virtually all less than $5\mu\text{m}$ in length. Therefore they are all likely to be rapidly phagocytosed and hence not be retained in the lung to present a serious hazard.

TABLE 6.1

OBSERVATIONS ON THE PARTICLE SIZES OF DUSTS
ASSOCIATED WITH BRAKE LINING MAINTENANCE

YEAR	AUTHOR	METHOD	OBSERVATION
1973	Anderson et al	e em	The largest observed fibre was $0.2\mu\text{m}$ in diameter and over $1.1\mu\text{m}$ long. The quantity of the larger asbestos fibres on the test filter was no greater than on the background filter.
1976	Rohl et al	dd em -	Almost all fibres less than $0.4\mu\text{m}$ in length.
1976	Lorimer et al	dd em	More than 80% of fibres in drum dust was less than $0.4\mu\text{m}$ in length.
1977	Rohl et al	dd em	80% of chrysotile was in free fibril form More than 80% of fibres were less than $0.4\mu\text{m}$ in length
1978	Rowson DM	wd em	Brake lining debris particle size 10nm . ($0.01\mu\text{m}$) Chrysotile fibres almost absent
1982	Williams & Muhlbaier	e em	Median Length of fibres $0.5\mu\text{m}$ For drum brakes, the ratio of fibres $>5\mu\text{m}$ in length to $<5\mu\text{m}$ was 1/460
1986	Rodelsperger et al	dd em	less than 1% of fibres greater than $5\mu\text{m}$ in length

e-emitted dust, dd-drum dust, wd-wear dust, em-electron microscopy. dd and wd are terms used by different authors but refer to dust found in the brake drum and are synonymous.

6.2 THE NATURE OF EXPOSURE

The differences between the chemistry and mineralogy of the various asbestos minerals was described earlier. In the context of assessing the health risks associated with brake repair, it is important to know the chemical/mineralogical composition not of the brake lining itself but of the dusts to which the worker is exposed.

6.2.1 The Chemical/Mineralogical composition of the dust

This section will address only those agents to which a person involved in the maintenance of asbestos brake-linings might be exposed. The exposures can be broken into "installation" and "removal".

6.2.2. Materials to which workers are exposed when installing linings.

When installing a new brake lining or disc pad the worker comes into contact with the brake lining or pad as delivered by the manufacturer. As the chrysotile fibre is intimately bound into the resin the new lining is not in a form to generate a dust or fibre exposure for the worker. Thus there will be no exposure to chrysotile during installation if the lining is already on the shoe and the worker does not modify the pad or disc.

6.2.3 Materials to which worker may be exposed when removing linings and discs.

The materials with which a mechanic has the potential to come into contact when removing used brake-linings from a vehicle are

- i. the remaining brake lining in which fibre is still intimately bound to the resin
- ii. the residues of dust in the brake drum resulting from predominantly the wear on the brake lining but also to dusts and mud adhering to the drum from the highway.

The assumption will be made that the district served by the brake repair centre is one in which fibres from natural occurrences or use of fibres in road beds is not a factor.

Several studies have been conducted to determine the composition of these residues and more importantly the nature of the airborne dusts to which a worker might be exposed if the residues are rendered airborne in the breathing zone of a worker.

An important question is whether the chrysotile is changed during brake use. In fact, there is general agreement in the literature

that during use, the chrysotile originally present in a brake lining through local high temperatures generated during braking undergoes compositional changes.

Lynch(1968) appears to be the first to report on the decomposition of chrysotile during braking. He used electron microscopy to identify the fibres and reported less than 1% of asbestos in the airborne dust near a brake-dynamometer. Based on x-ray diffraction he concluded that the chrysotile was destroyed during the wearing of the brake lining.

Hickish & Knight(1970) in reporting on tests of fibre exposure during brake maintenance noted that "it was somewhat surprising to find that particles of a fibrous nature were scarce in the air samples collected." They also noted that in samples of drum dust, chrysotile was present in only trace amounts or at most 1%. The decomposition materials were mainly an amorphous magnesium silicate which was non-fibrous.

Rowson(1978) using electron microscopy, examined samples of used and unused pad surfaces. No fibres were present in the wear debris. Chrysotile was also not detected in the wear debris. Use of Differential thermal analysis on the debris also did not reveal any patterns characteristic of chrysotile. Jacko & Ducharme (1973) based on electron microscopic counts converted to mass calculated that the overall average content of asbestos in the brake emissions was 0.23% with a range of from 0.05% - 1.65%.

Williams & Muhlbaier(1982) reported in 1982 that "it appears that more than 99.9% of the mass of the original asbestos is broken down into non-fibrous magnesium silicates."

Anderson et al(1973) found that the asbestos fibre released from lining wear was less than 0.02% of the lining wear. Anderson et al noted that their background concentration of asbestos fibres on the blank filters used to collect the fibres was equivalent to 0.33ng/cm of the filter area.

In 1977 Rohl et al analyzed the dust in ten brake drums in New York City using electron microscopy, x-ray diffraction and energy dispersive analysis.

The results of analyzing 39 samples of brake drum dusts from various countries by x-ray diffraction gave positive results for chrysotile in 29(75%) and means from various countries ranged from 1.4%(Australia) through 4.5%(USA) with a mean of 2.4%. The New York samples were considerably higher than those from other countries.

The validity of applying x-ray diffraction may be questioned on several grounds...

The reliability of x-ray diffraction analysis at these levels might be questioned if serpentine were present as it would have

an identical x-ray diffraction pattern to small fibrils of chrysotile. Jacko and Ducharme (1973) also noted difficulties in distinguishing olivine and forsterite from the chrysotile diffraction pattern.

Chrysotile embedded in resin would be measured and that is not free to be inhaled in a fibrous form.

Thus the x ray data provide upper limits to the fibrous chrysotile likely to be present, not the free fibre to come into contact with the lung tissue if inhaled..

Prior to being able to observe fibres on the electron microscope, the samples must be prepared. The electron microscopic preparation techniques applied in some cases can lead to complete disruption of the particles and do not represent the dust available for inhalation. It is not clear how agglomerates were considered in counts of fibres using electron microscopy.

In summary it is well established that chrysotile undergoes change during braking to form an amorphous magnesium silicate. The residues of free chrysotile fibres in the brake drum would appear to range from a few fibres to well less than 1% by weight of the dust debris in the drum and perhaps closer to 0.2%.

The temperatures during braking and further evidence of the conversion of chrysotile to forsterite during braking is provided in Appendix 2.

6.3 OTHER CONTAMINANTS

The question of tremolite contamination of chrysotile under some circumstances was mentioned earlier. In the case of brake-lining repair it is highly unlikely to be a factor. However the possibility of exposure to asbestos from other sources, gaskets, muffler bandages, body fillers should not be overlooked. Also using talc, exposure to polynuclear aromatic hydrocarbons from automobile exhausts etc may contribute significant exposure that should be considered in eliminating other possible even probable sources of exposure with potential to contribute to or explain an observed radiological abnormality or lung cancer.

7.0 TOXICITY AND HEALTH EFFECTS

Assuming that a dust is inhaled and deposited at a site in the lung a crucial question remains as to whether the dust, can, given the right circumstances, produce a health effect.

A conclusion that the potential exists for a dust to cause a disease might be based on:

a. the demonstration of effects on cells (in vitro studies) which may or may not be directly transferred to conclusions relevant to assessing a risk of a health effect in man

b. the demonstration of effects in one or more species of experimental animals and extrapolation to man

c. the report of a disease in workers who have used or been exposed to the material

d. the demonstration that a group of workers in a particular occupation or working in a workplace when the material which might produce the dust is used have

- a higher rate of occurrence (incidence), of the health effect or disease (defined in various ways) than in the general population or some other group variously defined

- the more frequent presence (prevalence) of the disease or health effect in workers who are still working or have worked at the same or similar worksites as seen at one point or over a relatively short period of time than in another group or groups variously described.

- the mortality from the disease compared to the rates of mortality from this disease in the general population or in other groups variously defined.

In this section we will examine the evidence from animal experiments and the friction materials industry concerning the potential for the dust to produce health effects or pose a risk of health effects. The experience of brake maintenance workers will be considered later.

7.1 PULMONARY RESPONSE TO BRAKE DUSTS-EXPERIMENTAL

Gross (1968) carried out a study of the effect of brake drum dust on the lungs of experimental animals for the Johns Manville Corporation. One gram of brake drum dust was suspended in water so that each 1 ml contained 3.5mg. Ten rats and 12 hamsters were injected intratracheally with brake-drum dust, 10.5mg for each hamster and 21 mg for each rat. Three hamsters were examined after 7.5 months and the remainder after 12 months. The reactions were considered to be those associated with an inert dust.

Davis and Coniam (1973) studied the effects on mice of intrapleural injection of chrysotile heated to various temperatures and also to automobile brake lining dust. They found that the heating of fibre to temperatures below 400 C tended to produce dust samples containing many long fibres.

However heating chrysotile to temperatures above 400 C resulted in low aspect ratio(length:diameter ratio) particles.They also found that in mice,the chrysotile heated above 400 produced smaller granuloma and less fibrosis than that heated at less than 400 and that the automobile brake lining dust contained little "recognizable chrysotile and consisted mainly of particles with low aspect ratio.When this dust was injected into the pleural cavities of mice it produced very small granulomas and little fibrosis."

The results of these experiments are in agreement with the many studies suggesting that physical shape of asbestos and other particles are important in determining the degree of fibrosis produced in tissues.For example,Vorwald et al(1951) and Kushner & Wright(1977),twenty six years apart showed that fibre length determines fibrotic reaction in lung tissue.Davis(1972) showed the same on the pleura.

Thus the experimental evidence suggests that the tissue response to brake lining dust particles is minimal or likely to be of no disease significance in terms of fibrosis.

7.2 THE RISK OF HEALTH EFFECTS

Does exposure to the asbestos used in the brake linings pose a health risk?

In seeking information to determine whether the materials incorporated in the brake lining could in an unbound and unaltered form pose health risks,it seems appropriate to examine the experience of workers in the manufacture of the friction materials.Some of these workers:

- a.will have been exposed to chrysotile fibres in their unbound state.
- b.may have worked with the same grades(lengths,degrees of openness)of the fibre which will have been used in brake lining manufacture.
- c.may have been exposed to fibre levels much greater than encountered in brake maintenance where the percentage of any free chrysotile fibres is very low.
- d.involved in manufacture of linings may have been exposed to other materials including those incorporated in the lining.
- e.may have been engaged in operations involving drilling,boring,turning and grinding asbestos brake linings.

Work and dust conditions in a brake-lining manufacturing plant from the standpoint of the relationships between exposures in that industry and those in brake maintenance work are described in appendix 3.

The exposures to chrysotile in friction materials manufacturing are considerably greater than those in brake repair work even when operations such as drilling and grinding were undertaken as this would not be a continuous job for repair personnel.

It has already been shown that the residual dust in a brake drum contains few if any chrysotile fibres as they are altered by the heat generated during braking. Those that might remain are very short compared to those encountered in the manufacture of friction products. This means that any residual fibres that are inhaled can be readily dealt with by lung clearance mechanisms. Thus it seems reasonable to conclude that the risks of health effects related to asbestos exposure in brake maintenance if they exist would be expected to be considerably less than those in the friction materials manufacturing industry. This is a view also expressed by McDonald et al (1984) who note "It seems probable that exposure to chrysotile in garages, although not negligible, are usually much lower than in the manufacture of brake-linings."

The fibre length distributions reported by Skidmore and Dufficy (1983) for a friction materials manufacturing factory are not dissimilar from those reported by Gibbs and Hwang (1980) for the chrysotile mining and milling industry. They show the significant proportion of longer fibres present compared to the situation in brake maintenance. (see Table 7.2)

TABLE 7.2

LENGTH DISTRIBUTION OF AIRBORNE FIBRES
LONGER THAN 5µm IN FRICTION MANUFACTURING
FACTORY IN THE UK.

Size Range µm	Frequency %
5-10	58.0
11-20	30.5
21-30	5.2
31-40	2.2
41-50	2.4
51-100	1.3
100+	0.5

These figures contrast with the "almost all less than 0.4 µm" for the fibres in brake drum residues.

There have been two major epidemiological studies of the brake lining manufacturing industry. The workers studied were employed at two factories. One of these factories was based in Connecticut and the other in the United Kingdom. Taken together the studies involve the study of over 17,000 workers with adequate times to reveal any serious cancer or pneumoconiosis risks in that industry sector. The studies indicated that in this industry sector there are no excesses of cancer resulting from chrysotile exposure.

a. There were no mesotheliomas which could be linked to chrysotile exposure in these cohorts.

b. There was no excess of lung cancer in either cohort and in both cohorts there was no clear relationship between mortality from lung cancer and cumulative exposure suggesting that the observed lung cancer mortality was not related to the chrysotile exposure.

c. The Connecticut study did not reveal any deaths from asbestosis.

More details concerning the studies follow:

a. THE CONNECTICUT STUDY.

McDonald and Fry (1982) and later McDonald et al (1984) reported on the experience at a factory in Connecticut manufacturing brake linings, other friction materials and paper from chrysotile mainly from Canada. A little anthophyllite was used from 1957 for making paper discs and bands.

In a cohort of 4028 men and 931 women of whom 74% had worked at the plant before 1948 there were 1508 male deaths and 122 female deaths as of December 31 1977. There were no deaths from mesothelioma.

In 1984 McDonald et al reported on the same plant redefining the cohort for analysis. There were 3641 men employed for more than 1 month in the years 1938-58. There were 3513 traced (96.5%) and 1267 had died. There was an all cause standardized mortality ratio (SMR)^a for men who had worked more than 1 year of 101.2. There was evidence of an increasing risk of respiratory cancer with increasing exposure when the short low exposed workers were excluded.

Footnote:

a: An SMR or standardized mortality ratio is the ratio of the number of observed deaths (o) divided by the number of deaths expected (e) to occur in that population if that study population were to die at the same rate as a reference population (for example the population of the US). The ratio is usually multiplied by 100 and expressed as %

In men 20 years after first employment with cumulative levels of exposure between 10 and 20 million particles per cubic foot years(mpcf.y) the SMRs were 101.7, between 20 and 40 - 105.4, between 40 and 80 -162.8 and 80+ was 55.22.

The lung cancer mortality at various exposure levels fitted on or below the exposure - response line for chrysotile miners and millers. Lines fitted to the chrysotile mining exposure response data using dust exposure accumulated to age 45 gave the following equation..

$$SMR = 95.15 + 0.16 \text{ mpcf.y}$$

$$RR = 1 + 0.0017 \text{ mpcf.y}$$

The Relative Risks^a derived from SMR's for respiratory cancer deaths 20 years after first employment and accumulating dust exposures in mpcf.y to 10 years before death as reported by McDonald et al(1984) were as shown in Table 7.2a

TABLE 7.2a

Relative Risks -Connecticut Friction Manufacturing Plant.(McDonald et al 1984)

Cumulative exposure in mpcf-y				
<10	10<20	20<40	40<80	>80
1.0	0.59	0.64	0.98	0.31

In their 1984 report on the Connecticut asbestos friction manufacturing plant, McDonald et al noted that out of 1267 deaths(1228 death certificates) there were 12 deaths ascribed to pneumoconiosis but none of these were identified as asbestosis.

Footnote:

a:Relative Risk is the ratio of the rate of occurrence of the attribute(eg smoking or dust exposure) in cases to the rate of the attribute in non cases.If there is no association between the attribute and disease,the ratio will be 1.0

b: mpcf means million particles per cubic foot and is a measure of the number of particles in a cubic foot of air as measured using a method known as the midget impinger method. mpcf-yrs are the units used to express cumulative exposure when the concentration is in mpcf and the period of work in that concentration is in years.The product of concentration and duration of exposure summed over the working lifetime is the workers cumulative exposure.

b. UK study.

Skidmore and Dufficy (1983) reported on the processes used in a brake lining manufacturing plant in the UK. At this plant woven chrysotile was brought into the factory in 1910 with loose fibre used in block making two years later. There were two 4 year periods before 1945 when the variety of asbestos used in a defined area of the plant was blue asbestos.

In 1983 Berry & Newhouse reported on the mortality of workers manufacturing friction materials in this plant. Mortality was examined for the period 1942-80 with 13460 workers in the cohort. The only type of asbestos used was chrysotile except for the well defined periods when blue asbestos was used. Over 99% of the population was traced.

There were 11 mesothelioma deaths. A case control study showed that 8 workers had been exposed to blue asbestos and another possibly intermittently exposed to blue asbestos. The other 2 had been employed for most of their working lives outside the factory and their mesotheliomas could not be attributed to chrysotile. Limiting the study to persons exposed to more than 5 fibres/ml showed that 5 out of the 6 cases had been exposed to blue asbestos and 2 out of the 10 controls. Thus the mesotheliomas were associated with blue asbestos exposure, not chrysotile.

Compared to national statistics there was no detectable excess deaths from lung cancer, gastrointestinal cancer or any other cancers. A case control study of all deaths due to lung cancer, and gastrointestinal cancers did not reveal exposure - response relationships. Newhouse & Sullivan (1989) concluded that experience at this factory over a 40 year period showed that chrysotile was processed with no detectable excess mortality.

The notable difference between the lung cancer risks in the manufacture of brake linings using chrysotile and other industry sectors was illustrated by McDonald in 1982 and later McDonald (1984) when he compared the dose response relationships derived from various studies. The risks in the friction materials manufacturing industry, if any, were extremely low.

Over the past 40-50 years there have been continual changes in brake technology which have continually reduced the probability of asbestos exposure for brake maintenance personnel. These changes include replacement linings already mounted on shoes, changes from drum to disc brakes and changes from asbestos to non metallic brakes. More detail is given in Appendix 1. The availability of brake linings in a form ready to install has eliminated the need for any further work on the brake linings before installation.

As will be shown in section 9.0 it is now virtually impossible to measure the levels of fibre in the work environment of a properly run and maintained brake repair shop because they are so low.

8.0 US STANDARDS AND GUIDELINES

The American Conference of Governmental Industrial Hygienists is an organisation which since 1943 has annually reviewed and published "Threshold Limit Values (TLV's)". These have been adopted in many countries as guidelines or even as legal standards for the protection of workers. "These (TLV's) refer to airborne concentrations of substances and represent conditions under which it is believed that nearly all workers may be repeatedly exposed day after day without adverse effect". These levels have reduced over the years and now reflect the differences in the health risks posed by the different asbestos minerals. The values since 1946 for asbestos are summarized in Appendix 4. Legal standards for the workplace in the USA have been set by the Occupational Safety and Health Administration (OSHA). The standards for the asbestos minerals have changed over the years and these are also summarised in Appendix 4. It is apparent that the measured levels of exposure of workers in the brake repair industry are well below any legislated or recommended standard.

9.0 LEVELS OF EXPOSURE TO DUST

There have been many studies to measure the levels of fibre to which workers are exposed. Almost all have the limitation that the fibres that were counted may not have been asbestos but pseudomorphs which would have no crystal strength. They provide the upper limits of any exposure to asbestos.

In order to determine the levels of exposure of brake maintenance workers a survey was conducted by Rodelsperger et al (1986). The results are summarized in Table 9.0.

Rohl et al (1977) reported very high fibre concentrations at the time of blowing out brake drums with compressed air (6.6-29.8 fibres/ml). Use of dry brushing reduced these to 1.3-3.6 fibres/ml.

Kaupinen & Korhonen (1987) measured asbestos concentrations in different operations in 24 Finnish workplaces.

* The estimated 8 hr time weighted average exposure during the repair of brakes on trucks and buses was 0.1-0.2 fibres/ml.

* For passenger cars the estimates were under 0.05 fibres/ml. A concentration of 1f/ml could be exceeded during brushing or blowing out the drum without exhaust air.

Hickish & Knight(1970) in the United Kingdom measured the daily exposure of a worker who carried out brake maintenance on 11 vehicles during the day.

* The average time weighted exposure was 0.67 fibres /ml.

* The time weighted average exposure of a worker during truck service was greater(0.79f/ml).

TABLE 9.0.

PERSONAL AIR SAMPLES TAKEN OVER 30 MINUTES
DURING VARIOUS BRAKE MAINTENANCE OPERATIONS
(Rodelsperger et al 1986)

Job	Passenger car		Truck Bus	
		mean	No tests	mean
Blowing Out	4	0.10	4	0.05
Dry Brushing	4	0.09	1	0.15
Rivetting	-	-	7	0.10
Grinding by hand	7	0.12	-	-
Machine grinding	5	0.06	1	0.39
Turning	-	-	18	0.08
Combinations	11	0.04	5	0.08
Total	31		36	

Concentrations were reported in number of fibres x 10^{6/m³}.

The measurements by various groups illustrate the variability in likely exposure levels which depend on the work done and techniques applied in the workplace and how the measurement was made. However the bulk of the measurements suggest very low exposure levels compared to those in friction materials manufacturing plants and to the recommended or permissible workplace standards for chrysotile asbestos in almost all countries. (eg: ACGIH 1989 - The 1989-90 recommended time weighted average exposure for 8 hours for chrysotile is 2 fibres/cc and standards in most countries today range 0.2 - 5.0 fibres/cc as 8 hour time weighted average exposures).

The OSHA standard established in 1988 is 0.2 fibres/cc as a time weighted average concentration with an excursion limit of 1f/cc over a 30 minute period permitted for workers whose total exposure does not exceed 0.2f/cc

Footnote:

a: Time weighted Average concentration is the concentration calculated as the average for a 8 hour workday.

It is interesting to note that the research observations in Finland and Germany do not differ in any important way from the results of a number of unpublished surveys conducted by the National Institute for Occupational Safety and Health(NIOSH)or the United States Public Health Service (USPHS) to measure fibre concentrations in various brake repair shops.
(Table 9.0a).

TABLE 9.0a
RESULTS OF MEASUREMENTS DURING BRAKE
REPAIR AND MAINTENANCE
(USPHS AND NIOSH SURVEYS)

Author & Location	Results
Dement(1972) Municipal Garage Cincinnati	Very little asbestos dust found in the samples examined by x-ray diffraction and optical microscopy. Highest concentration - blowing off dust from drums-3.0f/ml(Measured peak values 2.0;0.8; 0.6;3.0;2.1 f/ml) Reassembly -concentrations were 0.2;0.2;0.9f/ml
Roberts(1980) Allied Brake Shop Cincinnati	The time weighted average(TWA) concentrations (Breathing zone personal samples)taken on 2 brake mechanic were 0.04f/ml and 0.006 f/ml but brake activity reported low on day of survey Two and 6 minute peak samples during compressed air blow off gave concentrations of 0.25 and 0.37 f/ml respectively.
Roberts(1980) Reading Brake and Alignment Service, Reading,Ohio	Time weighted average concentration for brake mechanic(personal samples) was 0.04 f/ml Peak sample during compressed air blow off 0.33 f/ml Area next to turn down lathe - 0.01f/ml
Johnson(1976) Auto Brake Clinic, Cincinnati Ohio	The concentrations measured using personal samples on 3 brake maintenance employees were 0.02,0.05,0.07 and 1.82 f/ml

TABLE 9.0a

Author & Location	Results
Sheehy et al(1987) Ohio Dept Transportation Lebanon, Ohio	Personal sample concentrations for the brake mechanics averaged less than 0.004f/ml with none of the 18 samples above the detection limit of 0.004f/ml Transmission electron microscopic concentrations ranged 0.013-0.294 (mean 0.031f/ml)
Sheehy et al Cincinnati Bell Fairfax, Ohio (1987)	Individual personal samples for brake mechanics averaged 0.007f/ml.(range <0.004 - 0.016 f/ml). OHSA standard was 0.2f/ml and NIOSH standard was 0.1 f/ml at that time. Few asbestos fibres of any size were found in the mechanics samples analyzed by transmission electron microscopy.
Cooper et al Cincinnati Gas & Electric Ohio & Kentucky (1988)	Personal sample concentrations for the brake mechanics averaged 0.006f/ml The concentrations measured by transmission electron microscopy averaged 0.213 f/ml. Concentrations in the three garages surveyed averaged 0.005f/ml and outside 0.006f/ml as measured by transmission electron microscopy

Cooper et al(1988) in their survey report pointed out the effectiveness of the wet spray method and the wet brush method. The effectiveness is evidenced by the exposures of the mechanics which were below the limits of detection of the phase contrast microscope method for counting the fibres in this workplace. Almaguer and Matte(1987) also found levels below the limits of detection of the measurement method in measurements at the Four Wheel Drive Corporation, Clintonville, Wisconsin as did Gunter and Albers(1983) at the Drive Train Industries Inc., in Casper, Wyoming. These concentrations are well below any regulatory standard.

It should be noted that in the above table, the concentrations were measured by counting the number of fibres collected on a membrane filter when a known volume of air is drawn through it. The fibres were generally defined as having length to breadth ratios of 3:1 and length greater than 5µm and were counted on a phase contrast microscope. The methods applied varied somewhat but were all standard NIOSH methods.

Because fibres with diameters less than about $0.3 \mu\text{m}$ cannot be seen by light optical microscopy some measurements were made using transmission electron microscopy...where such measurements are reported in the table they are noted as being transmission electron microscopic measurements.

There are no workplace standards based on electron microscopic fibre counts. The results are also reported as if they were without error...all will have margins of error associated with them. However their importance is that they are consistently low.

Lee(1970) in making measurements over a sampling time of 5 minutes with a static sampler close to the brake assembly during the use of compressed air reported concentrations of the order of 3-5 fibres/ml. (The assumption is made that all fibres are asbestos).

There seems to be good agreement in the literature that some fibrous appearing particles can be measured in the air during brake replacement. The sources would appear to be debris in the drum which contains predominantly particles and if fibres are present they have lengths mainly less than $0.4 \mu\text{m}$. The concentrations of dusts to which mechanics on the job are exposed would seem to vary with the techniques used in the various countries and plants. Time weighted averages of fibres counted using phase contrast light optical microscopy would appear to be well less than even 0.1 f/ml.

The reason for the apparent very high levels reported by Lorimer et al (1976) is probably because their samples were taken over periods of 2-10 minutes to record peak exposures. Longer term personal sampling is more reliable in assessing longer term risks.

It must be remembered that when counting fibres using optical microscopy, all elongated particles with aspect ratios $>>3:1$ and length greater than $5 \mu\text{m}$ will be counted. In practice not all these particles will be asbestos or chrysotile. There are several reasons to believe that this may be so in the case of counts of fibres collected on filters during brake maintenance.

First the heat effect on chrysotile will cause loss of water and composition changes. Thus a chrysotile fibre might change from being chrysotile to being forsterite or some other magnesium silicate. It is now not asbestos but may appear as an elongated particle known in mineralogical terms as a pseudomorph. Rohl et al (1976) in fact, observed some fibres without characteristic chrysotile morphology, with mottled surfaces and obliterated fibrils indicating partial or complete recrystallization.

Second, the lining itself is made up of a number of constituents in addition to the chrysotile asbestos. Rohl et al (1976) note the use of a variety of property modifiers including some such as wollastonite which is itself fibrous.

They also report that using x-ray diffraction they found lead compounds, quartz, calcite mica, clays, barite, graphite and alpha-iron particles. The sources of all of these is not clear and not explained by the authors. However, they note using transmission electron microscopy, the presence of road debris. Some minerals such as mica occur as flat plates which if they stand on edge appear as elongated particles or fibres (length : breadth greater than 3:1).

Some clay minerals are also fibrous in their own right. Metal fragments might also appear as elongated particles or fibres. Such composition differences are not noted when counts of fibre to determine fibre concentrations. Thus workplace fibre measurements likely overestimate the exposure to asbestos.

Third, the fact that transmission electron microscopic examination reveals almost all chrysotile fibres to be very short raises the question of what proportion of the longer elongated particles counted as fibres are asbestos. Rohl et al (1976) for example report "Thus both the optical fibre count data in other studies and the electron microscopic fibre size distribution data indicate that the chrysotile fibre population generated by brake wear is a strongly skewed one, with almost all fibres concentrated in the smaller than 5µm region." The standard methods to assess exposure in relation to control standards uses phase contrast light optical microscopy. The concentration of fibres determined by this method includes only fibres longer than 5µm.

9.1 GRINDING

It is clear from the literature that there are differences in the work done by different brake maintenance workers and hence the nature and likelihood of dust exposure. For example exposures may differ depending on whether the repair work is being done on passenger cars or trucks and buses; or as the residues of dust associated with brake discs are less than in drum brakes whether disc or drum brakes are under repair. (Kauppinen and Korhonen (1987)). Another factor which is likely to be very important is the operation conducted at a particular shop.

Grinding is an operation which may or may not be done and may or may not be done with the appropriate exhaust ventilation normally required for grinding operations. The historical review provided in Appendix 1 indicates that changes were made fairly early to the brake lining so that it was not necessary to bevel the lining for example. Also, the grinding normally removed large fragments which fall to the floor. During brake maintenance exposures 0.3-125 (mean 56) fibres/ml were observed if machine grinding was done without the exhaust ventilation on. (Kauppinen and Korhonen (1987)). The extent to which large fragments influenced these observations is not known. In the Federal Republic of Germany grinding by hand gave a concentration over a 0.5 hour period of 0.12 fibres/ml and machine grinding of 0.06 fibres/ml.

Rodelsperger et al (1986) found that the fitting of new brakes for cars in Germany was done using special grinding machines in 20 garages out of 36 automobile maintenance shops. Rodelsperger in analyzing the job profiles of maintenance workers found that machine grinding was described in 25-36% and grinding by hand in 55-75% of jobs for trucks, cars and buses.

The cutting, drilling of brake linings was necessary in Germany mainly before 1960 as since then pre-cut and pre-drilled brake linings have been used (Rodelsperger et al (1986)). They appear to have been introduced somewhat sooner in North America. (See Appendix 1).

10.0 DURATION OF EXPOSURE

The job profile for brake mechanics based on an analysis of 459 job profiles by Rodelsperger et al (1986) is shown in table 10.0

TABLE 10.0

PATTERN OF WORK PERFORMED BY 210 VEHICLE MECHANICS

(Rodelsperger 1986)

In 60% of cases, mechanics repaired car brakes...	4.6 jobs/week
Duration of repair.....	2 hours
Brakes of buses trucks repaired	2.6 jobs /week
Duration	4 hours
Clutch repair.....	1.8 jobs / week

This would suggest that on average the total weekly period of work on brake lining jobs would approximate 9.2 hours for cars, 9.2 hours on trucks plus any clutch repair.

11.0 CUMULATIVE LIFETIME EXPOSURES

Based on measurements Rodelsperger(1986) calculated, the cumulative exposure distribution for 210 vehicle mechanics.

This exposure which combines the individual periods of exposure at various concentrations over the workers lifetime was found to be...

- * for 99% of the mechanics less than 3 fibre/ml.years
- * the highest was 13 fibres/ml.years.
- * the average cumulative dose was (0.54 ± 1.1) fibres/ml years for an average duration of employment of 21 ± 10 years.

While the length of employment for different workers will vary a fairly realistic estimate of exposure for a mechanic can be made using various assumptions. As the concentrations measured in Germany during brake lining maintenance were not out of line with those other studies these may approximate exposures in North America if the pattern of work is similar.

12.0 THE HEALTH EXPERIENCE OF WORKERS IN BRAKE REPAIR AND MAINTENANCE

12.1 CASE HISTORIES

Evidence concerning an increased risk of a disease can only be determined by information on groups of workers. However there are individual case reports in the literature and in this section pertinent case reports will be reviewed.

12.1.1 Mesothelioma

Cases of mesothelioma reported in the literature are largely individual isolated cases. This presents a major problem in inferring that these demonstrate an association between asbestos exposure in brake maintenance and mesothelioma as there is a background rate of mesothelioma in the general population and isolated cases will occur in mechanics.

The number of such cases identified in the literature is few. Recognising the number of persons around the world engaged in brake repair work they are unlikely to be in excess of general population rates as the disease will occur in persons with these occupations as a matter of random chance.

Langer and McCaughey in 1982 reported what might appear to be the first carefully described case of a mesothelioma in a brake repair worker. The man diagnosed with mesothelioma at the age of 55 had been in the used car, tire and car business since the age of 19 including the replacement of linings. He apparently had no other occupational exposures likely to have given rise to other asbestos exposure.

The report does not indicate when the man was last exposed prior to death. Recognising the extent to which chrysotile has been reported to disappear from the lung, it is likely that the results of lung analyses could reflect recent exposures unrelated to the mesothelioma occurrence. The % of fibres longer than 5µm in the lung was also considerably greater than reported by Pooley & Clark (1980) for fibres extracted from lung tissue. The concentration also was expressed in µg/g and not directly comparable with other published figures. The location of the specimen and the possibility of uneven distribution of fibres in the lung are not discussed. Berry & Newhouse (1983) noted that in the UK blue asbestos was used for railroad pads. McDonald (1988) makes the point in discussing tissue analyses. "It follows that only studies, well controlled for time-related variables can be interpreted" ... "lung burdens provide just one more element in the jigsaw of causation but do not necessarily outweigh other types of evidence."

In fact Langer (1979) examined for fibres, the lung tissues of brake maintenance and repair workers and in a positive comparison group of construction workers and negative comparison group of white collar workers and housewives. He concluded that the asbestos body and fibre content of the lung was a poor exposure index for brake maintenance & repair work.

Huncharek et al (1989) reported a pleural mesothelioma in a man who had been exposed in various occupations spanning 30 years. He was an aircraft mechanic from age 18-21 in the US Army. He worked from age 21-23 in a heavy equipment factory and from ages 24-29 on the assembly line of two major US car manufacturing plants. It was stated that he was not known to have worked with asbestos. From age 30 to 41 he worked as a brake mechanic in 5 car dealerships. He was diagnosed as having a mesothelioma at the age of 47. Although no previous exposure to asbestos fibre was identified there is very good reason in this case to suspect that the mesothelioma was unrelated to the brake work. This would have meant a considerably shorter latency (<17 years) than normally reported elsewhere, with apparently exposure only to chrysotile (not linked with mesothelioma excesses). Information on lung tissue fibre types or burden were not available.

Paur et al (1985) reported on 4 cases of mesothelioma in brake repair workmen. One had repaired trucks and cars for 27 years as an automobile mechanic.

Although there were 4 cases described in this report, an analysis of them is important. According to the report itself, one case began work as a construction mechanic and no information is provided concerning his possible exposure to asbestos in that work, whereas asbestos exposure is quite possible. This case was also an auto electrician. This case did not work directly on brake systems or clutches and the report "assumes as probable that due to the vicinity of the workplace there existed a "by-stander effect".

There is so much doubt concerning exposure in this case that it cannot be used as evidence of a link with brake-lining dust exposure. The second case worked for three years in brake repair. He was also reported, as a welder to place "a moist asbestos fibre mass" on the sheet metal for cooling and when dried it was blown away. The type of asbestos used was not noted, but from the description, this would be likely to give rise to substantially greater and true fibre exposure than working with brake-linings. If the asbestos used was blue asbestos this has also been clearly linked to mesothelioma occurrence.

The work histories of the other two cases are not given in sufficient detail in the report to clearly exclude other exposures.

Unfortunately there are also no analyses of fibres in the lung at autopsy to help define the occupational exposures more fully.

A further single case of mesothelioma was reported in a brake mechanic in Spain (Montenari et al 1977). This worker would appear to also have had extensive pleural calcification. The case was a peritoneal mesothelioma. In chrysotile mining & milling at least to 1977, the cases known at that time were pleural. (McDonald & Liddell 1977) while peritoneal mesotheliomas have tended to occur in amphibole exposed populations.

Castleman (1985) refers to a further case in a report by Sullivan and Athanassiadis (1969). Review of the original paper indicates that this paper is referencing the case from another report where the case had worked not only as a "brake liner". This case, often quoted in the literature is that of a brake liner in the report on mesothelioma in the London area by Newhouse and Thompson (1965). Review of the original paper shows this person to also have been a pipe coverer and to have worked in an asbestos factory and to have worked mainly with blue asbestos.

Given the rarity of the cases, indefinite descriptions of work histories in most cases and the fact that there is probably a background of about two per million population of mesotheliomas (McDonald 1985) that has existed for several hundred years, the finding of a few isolated cases over the last few years in mechanics unrelated to their work would be anticipated especially if some of them have performed other work. This rarity of cases supports the other evidence that this occupation is not associated with increased health risks associated with asbestos exposure. Individual cases without an idea of the population base from which they are drawn cannot serve to reach conclusions about an association with brake lining repair.

12.2 POPULATION STUDIES

12.2.1 Mesothelioma

Jarvholm & Brisman (1988) linked the 1960 census in Sweden with the Swedish Cancer Register and the Swedish Death Register. There were 21905 men coded as occupational code "mechanic" and industry "car repair" on the file. The file was linked for the period 1961-79 to the Cancer Register. There was 1 case of mesothelioma in the tumour registry. The case had also worked in the construction industry although where exposed is not known. Between 1961 and 1973 there were 741 deaths among mechanics but no mesothelioma deaths. This would give a proportional mortality of less than 0.013% which is compared to the proportional mortality for the general population being reported at that time based on a thorough survey of world literature of around 0.03-0.06% (McDonald & McDonald (1977)).

In 1985, Malzer et al reported on the linking of the national population based registries linking cancer incidence since 1961 to 1979 with census data for 1960.

There were 318 cases of pleural mesothelioma in males in this 19 year period. Occupations with at least two fold excess of mesothelioma included the craftsmen categories of plumbers, mechanics and repairmen, electricians, painters, tire makers and stationary equipment operators. It appears that there was only one case reported in an auto mechanic and this person was likely exposed in construction (Jarvholm & Brisman (1988)).

This would indicate that mesothelioma is certainly not a common cause of death in auto mechanics as a group. This is certainly not surprising because among the 7 mesothelioma cases in the Quebec Chrysotile Mining Industry to 1975, the case with the lowest exposure had 59 fibre/ml years of exposure (Liddell 1988) while Rodelsperger (1986) reports the highest cumulative exposure in his vehicle mechanics of 13 fibres/ml years. Even in the chrysotile industry, the probability is that these mesothelioma are not due to the chrysotile.

12.2.2 Respiratory and other cancers

Schwarz (1987) studied the proportional mortality (PMR) for all white male residents of New Hampshire over 20 years of age. Among automobile mechanics and gasoline service station workers there was an elevated PMR for leukaemia, cancers of the oral cavity, bladder, rectum, lymphatic tissues (all PMRs > 160) and lung (PMR 112). Proportional mortality studies examine the percentage of persons dying from a particular cause to all deaths. They have serious shortcomings if, for example there are likely to be large age or sex differences between the groups being compared.

Nevertheless in a population with significant excess proportional mortality from other cancers (unlikely to be related to asbestos exposure) there was no significant excess of respiratory cancer.

Damber & Larrson(1987) studied occupational etiological factors in Sweden using a case control approach.Cases were all male lung cancers reported to the Swedish Cancer registry 1972-77.Each case was matched for age,sex and residence with a living person.They found large geographical variations and links with exposure to materials previously linked to increased cancer rates.Workers who had been exposed to suspected carcinogens for more than 25 years (mechanics and professional drivers)were at slightly increased risk but this disappeared after adjustment for smoking.

In her study of auto mechanics in Denmark (Hansen 1989)noted that the overall cancer SMR was 115(95% CI 97-136)^a No excess was seen for cancer of the lung and bronchus(observed = 41,expected =40.7).The cohort was identified from the files of a nationwide census in Denmark in 1970 and the self recorded occupation,trade and employment on the day of the census were use to constitute a cohort of men aged 15 -74.There were 21,800 in the cohort and 586 deaths.There was 1 mesothelioma.The possibility of other exposures cannot be ruled out.

Jarvholm & Brisman in 1988 in Sweden found between 1961 and 1973 an excess of lung cancer deaths (39 vs 23 expected) in automobile mechanics.However the total morbidity (occurrence) from lung cancer for the period 1961-1979 was 93 lung cancer observed and 93 expected. The authors conclude that a possible elevated risk of lung cancer was found but because of so many confounding factors they cannot attribute it to asbestos exposure.

12.2.3 Asbestosis and fibrosis of the lung.

Marcus et al (1987) studied the possible impact of asbestos exposure on car mechanics by studying 925 car mechanics and 109 referents(office workers in a car repair firm).Pulmonary function tests were conducted.The Forced expiratory volume (FEV_{1.0}) and Forced Vital Capacity(FVC) of mechanics were close to those of the referents.Pleural plaques were found in 41 mechanics but none in the referents.The rates of pleural calcification were 50% in those with more than 40 years since first exposure,14% in those exposed 30-39 years and 3% in those with 10-29 years since first exposure.Only minor parenchymal changes on chest radiographs were detected (<1/1) and the authors concluded that there was no substantial impairment of lung function in the car mechanics.

Nicholson et al (1982) studied 900 members of the United Auto workers union.Many had previous exposures to asbestos (eg in shipyards) There were 450 who had worked more than 10 years in "brake work".The pulmonary function was poorer in those who were not involved in brake-lining work.

Footnote:

a: C I = 95%Confidence Intervals.They show that we are 95% confident that the true value lies in between these values.

The study showed that there was not a significant increased prevalence of x-ray abnormalities in commercial garage workers exposed on average to 0.2f/ml while there was a significant excess in workers who ground and machined brake linings for installation on larger vehicles. Higher levels of abnormality in autobody shops was ascribed to sanding asbestos auto body fillers.

Out of 387 workers with normal pleura there were 66 with 1/0 or greater abnormality(17%) among the brake lining workers. Out of 105 workers with garage employment but no brake work there were 18(17%) with parenchymal changes, very similar rates suggesting no evidence of any increased parenchymal effects. The pleural change rates were also greater in the non brake repair garage employees..

The Pulmonary function of the garage mechanics was no different than that of non garage workers and other general population controls.

Boillat and Lob(1973) analyzed the working conditions and the clinical, radiological and spirometric test results of 39 workers engaged in renewing brake-lining(including operations such as grinding, drilling, and adjusting the linings which were dusty). The workers came from 9 workshops.

Lung function tests showed that one person had obstructive, one obstructive restrictive pattern with the rest being "normal". There was no confirmed case of asbestosis in this group. There were two men with some changes but the authors thought that it was unlikely that these abnormalities were linked to asbestos exposure. Three men with 21, 21 and 35 years of work in this industry had no asbestos related abnormalities on the radiographs.

13.0 CONCLUSIONS

Based on available scientific evidence:

- * It is highly improbable that brake maintenance employees will exhibit increased rates of lung cancer, mesothelioma or asbestosis as the result of their exposure to chrysotile fibres released from brake linings.

- * There does not appear to be any increased rates of lung cancer in friction materials manufacturing workers exposed continuously to chrysotile asbestos.

- * Overall exposures even including occasional grinding will on average lead to lower exposures than in the friction materials manufacturing industry.

* Exposures to dusts released from the linings during use and collected in the drums are predominantly not asbestos and fibres that do exist are short and hence likely to be readily dealt with by normal lung particle clearance mechanisms.

* Systematic studies of lung cancer and mesothelioma in brake mechanics have not revealed any excesses of such cancers compared to the rates occurring in non asbestos exposed workers or the general populations or other appropriate comparison groups in the countries in which studies were conducted.

* Studies of the pulmonary function and radiographs of brake maintenance workers, apart from a claimed increased rate of pleural calcification in one study, have failed to find any significant fibrotic changes or functional abnormalities related systematically and consistently to exposures involved in brake-lining maintenance.

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APPENDIX 1

A BRIEF HISTORY OF THE DEVELOPMENTS IN BRAKE LININGS
AND DISC BRAKE PADS FROM THE STANDPOINT
OF ASSESSING THE NATURE OF EXPOSURE FOR BRAKE REPAIR MECHANICS.

The majority of brake maintenance personnel expressing concern that their health has been affected by their work, have worked in that occupation since the end of World War 2. Hence the following describes the situation since about 1945.

The perpetual change in vehicle design, engine size, vehicle speed etc. has meant that braking systems have undergone continual evolution to meet the changing demands placed on them. Technology which works well, for example, on an airplane with a whole runway to stop, is not directly transferable to the family car which might need to stop instantaneously. Thus, this overview does not address the underlying technical complexity in the evolution of the braking systems but provides some terminology and highlights some of the changes impacting on assessments of the exposure of brake maintenance mechanics.

THE BRAKE SYSTEM:

A modern car (Figure A1) is stopped by the use of DISC BRAKES on the front of the vehicle and DRUM BRAKES at the rear. A typical modern brake system is shown in Figure A2. The parts of this system of importance in evaluating the exposure of workers to asbestos are the DISC BRAKE PADS and BRAKE LININGS (SEGMENTS AND BLOCKS) and the conditions under which these come into contact during normal brake use with the ROTOR (in the case of disc brakes) or DRUM (in the case of drum brakes).

a. Disc brakes. (Figure A3)

The two surfaces coming into contact during braking are the two DISC BRAKE PADS and the ROTOR. The latter rotates between the pads and stopping is accomplished by the pads pressing against this rotor.

Of importance is the fact that the calliper assembly is not enclosed and products resulting from the wear of the pad on the rotor will fall to the road surface.

The opportunity for brake wear residues to adhere to the calliper or other surfaces handled during brake repair is slight and the potential for exposure to wear dust during the repair of disc brakes is low.

b. Drum brakes.

Drum brakes are somewhat more complex than disc brakes. As shown in Figure A4, braking is achieved by the BRAKE LINING which is attached to the BRAKE SHOE coming into contact with a cast iron BRAKE DRUM. The PRIMARY SHOE is the shoe facing the front of the car. The other is referred to as the SECONDARY SHOE. There can be some composition differences in the brake linings and while minor in terms of asbestos content, they are noted in the main report.

The type of brake system illustrated here is a DUO SERVO system. When pressure is applied to the top of the brake shoes through the wheel cylinder, the lower ends of the shoes are free to move and pressure is transmitted to the bottom of both the primary and secondary shoes. Since 1986 it has become common for brakes to be of a NON SERVO design in which the bottom ends of the shoes are pivoted and the braking action is different.

In the industry:

A brake lining of thickness of 1/2 inch or less is known as a SEGMENT (commonly used in passenger cars and light trucks).

A brake lining of thickness of 2/3 + inches is known as a BRAKE BLOCK (commonly used on medium and heavy trucks).

ASBESTOS FIBRE TYPE USED.

I am informed that the only asbestos used in Bendix brakes, whether disc or drum type was chrysotile.

DRUM BRAKES

Prior to the 1960's all cars were fitted with drum brakes. Modifications to compositions and designs were necessary to meet the changing nature of the vehicles in use.

Composition of drum brake linings:

In 1945, brake linings were manufactured using cresylic acid, tongue oil, sulphuric acid as a catalyst, chrysotile asbestos and the solvent xylol.

The linings were extruded through a nozzle and the solvent allowed to evaporate, leaving a hard matrix which encapsulated asbestos and other ingredients. The size of the linings was varied by changing the size of the nozzle.

Phenolic resin was introduced in 1946 but these linings were basically used for trucks only.

By 1958, Cashew Nut Shell Liquid (CNSL) was used and the end product was able to withstand higher temperatures. The linings were now prepared by passing them between rollers. This new process eliminated the need to evaporate xylol, while still producing an encapsulated product.

By 1960 a modified CNSL process was introduced with the addition of 20-25% phenolic resin.

The linings were pressed, trimmed and warmed in steam and bent to shape.

By the Mid 1960's a semi-metallic lining had been introduced for trucks. These tended to be expensive and needed a very true brake shoe and thus had limited use. Cars continued to use asbestos brakes.

In 1986 asbestos free brake-blocks and segments were introduced.

DISC BRAKES

The introduction of disc brakes as opposed to drum brakes became essential as the construction of vehicles changed. Besides reducing weight and improving the braking capability of a vehicle, they also reduced considerably the potential for a mechanic to be exposed to dust from the brake system. Unlike drum brakes where the dust which is worn from the linings remains to some degree within the drum, the disc pad is not enclosed in any way. Thus the only dust that would be encountered during brake repair would be that adhering to the surface of the rotor, pad or brake assembly. An estimate is that the total amount of dust on such brakes would be conservatively less than one fifth of that in drum brake systems. Because as much as 80% of the braking for a modern car is on the front, the disc pads are exposed to considerable heat.

Composition of Disc Brake Pads

Disc brake pads fit essentially into three types from a composition standpoint.

1. Those manufactured using chrysotile asbestos and other ingredients
2. Those known as semi - metallic in which the wearing surface was asbestos free but where there was an asbestos backing which did not come into contact with the rotor of the disc brake system.

The asbestos was not in place to provide a wearing surface but to modify the transmission of heat from the semi-metallic pad to the mounting plate.

The semi-metallic pad was developed in the 1960's and first released in 1969 and was used in police vehicles and taxis. They were generally available for use in vehicles by 1971.

3. Totally asbestos free.

Asbestos-free rubber based disc brake pads were first introduced in certain 1984 model trucks and in 1986 model cars.

As the decision to use various brake systems on vehicles rests with the automobile manufacturers and not with the brake manufacturers, it is possible for a product to be available for some time before introduction in all automobiles. However the above dates provide a guide as to when the different types were used.

WEAR FRAGMENTS:

The residue in a brake drum when the drum is removed results from the rubbing of the lining with the drum surface together with road dusts. When particles from the brake lining are released into the brake drum, the natural motion of the drum will continually return them to the surface between the drum and the brake lining. Thus the particles are continually reduced in size. Occasionally a larger particle might be released. These are usually large and the asbestos is still embedded in resin and non respirable. It is probable that some of the higher fibre counts in the literature have used a procedure (one is known as the rub-out method) for the preparation of samples for electron microscopy that releases individual fibrils from these particles for counting.

CHANGES REDUCING EXPOSURE

It is clear that changes in brake systems which have taken place since 1945 and even before have all served to reduce the chance of exposure of the brake maintenance workers to dust and asbestos. Some of these changes are...

- * Introduction of disc brakes
- * Introduction of semi-metallic linings and pads
- * Introduction of asbestos-free linings, pads and brake blocks.
- * Since the early 1950's, exchange shoes have been available. The linings were riveted or bonded to the shoe at the factory and it was not necessary for the mechanic to do any additional work on these linings prior to installation.

Linings were also made available in sizes 30/60/90 thousandths of an inch over-size eliminating the need to grind linings to fit drums which had been enlarged as a result of "turning" the drum.

* Pre. - Drilling and counter-sinking of rivet holes in brake linings.

The attachment of the lining segment to the shoe involved rivetting. Even in the early 1940's segments were pre-drilled and countersunk so that mechanics did not need to drill the lining prior to riveting it to the shoe.

* For early linings, the mechanic might use a file to put a side chamfer and a bottom bevel on the segment. This was done by hand and not associated with dust production. However this was rendered unnecessary by the late 1940's when linings which were already chamfered and bevelled were available from the factory.

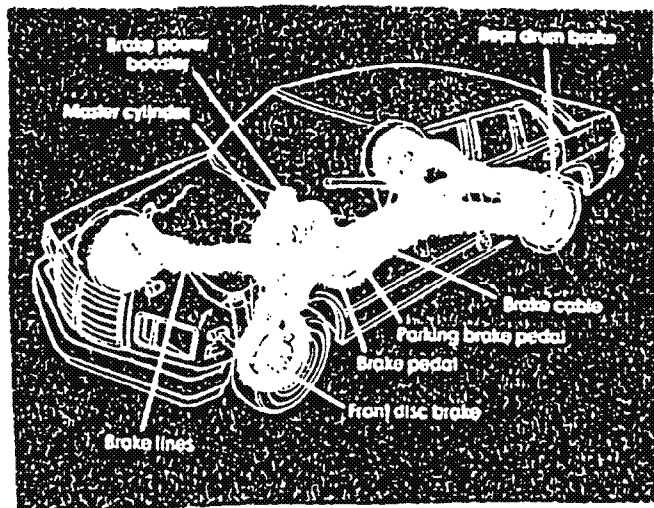


FIGURE A1

A MODERN CAR BRAKE SYSTEM

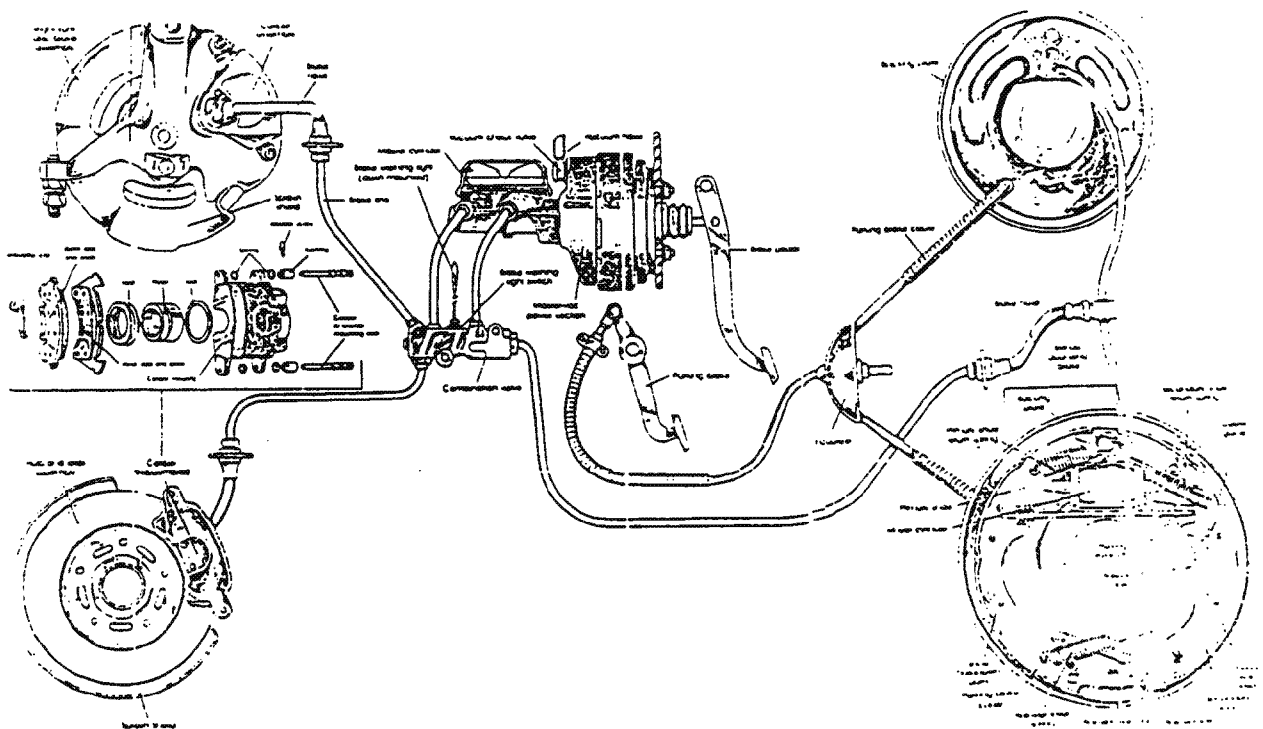


FIGURE A2

A MODERN BRAKE SYSTEM

(Diagrams reproduced from Bendix Poster)

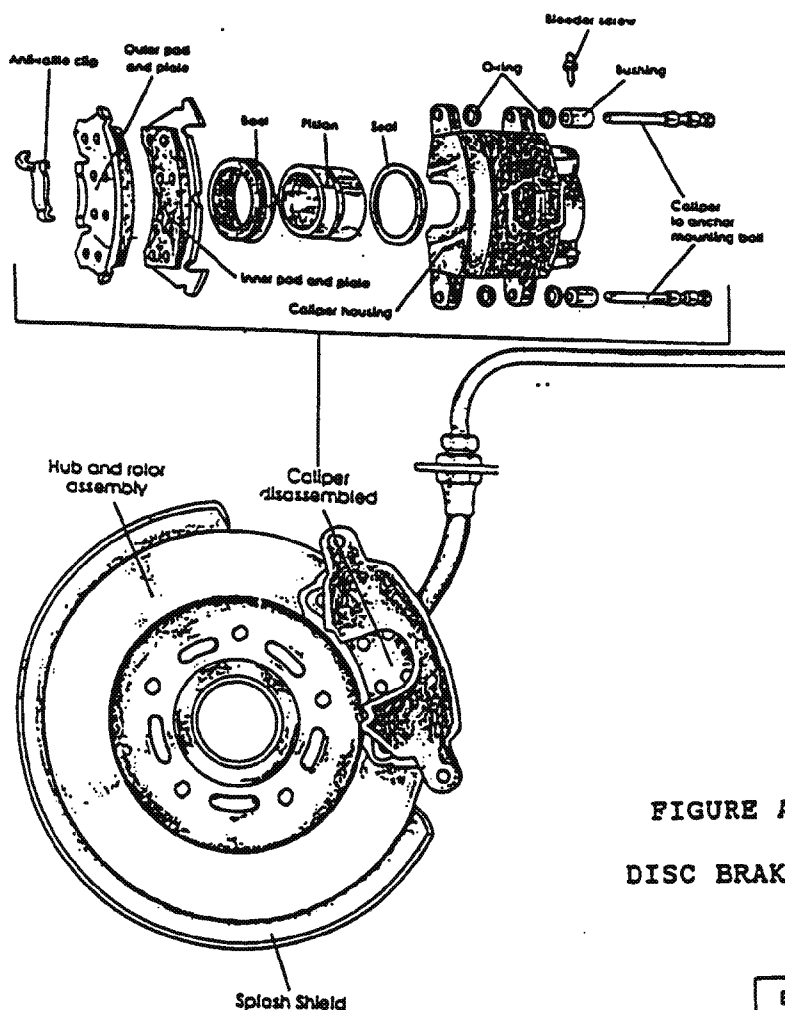


FIGURE A3
DISC BRAKES

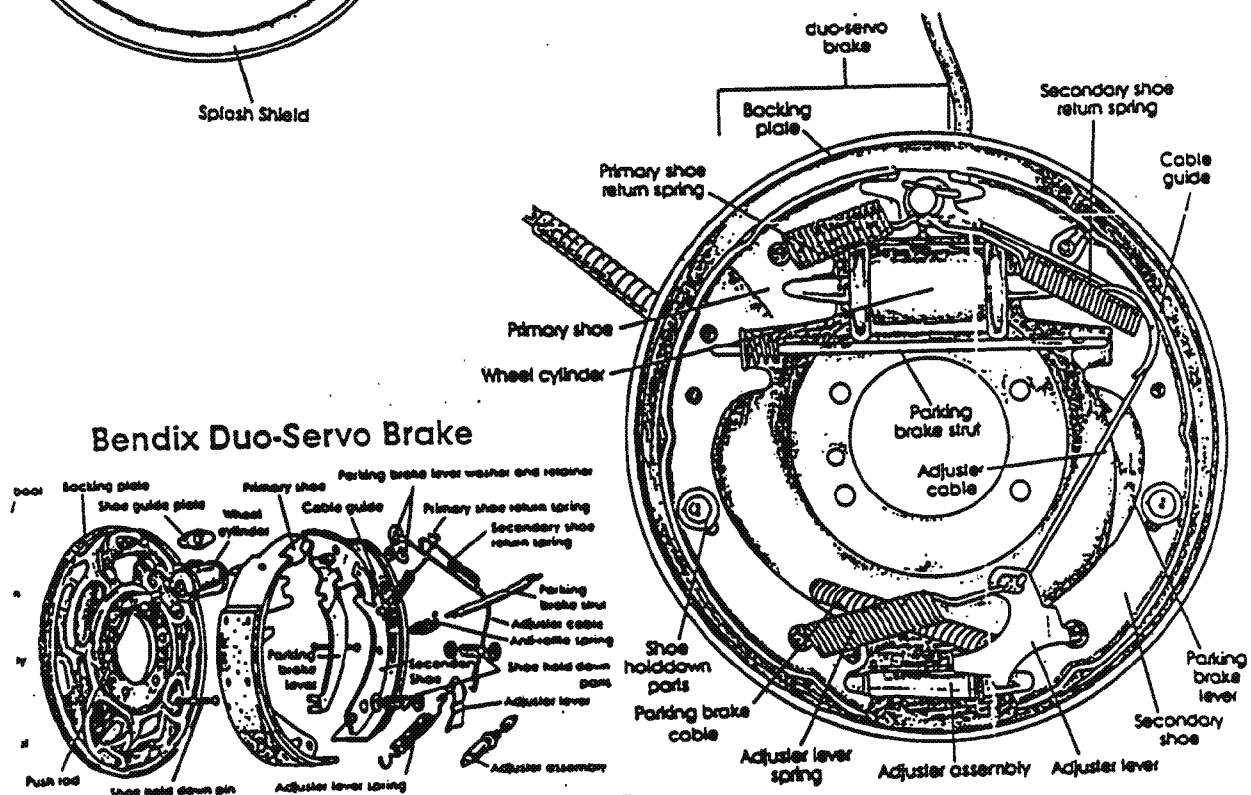


FIGURE A4
DRUM BRAKES

(Diagrams reproduced from Bendix poster)

APPENDIX 2

TEMPERATURES & FORSTERITE FORMATION

The "wear" and "fade" characteristics of brakes are tested with a temperature measuring device set 1 to 1.5 mm below the surface of the brake lining. Temperatures recorded are around 550F. This temperature should not be mistaken for the temperature at the interface between the fibres and other particles in the lining and the brake drum or surface.

In practice the total surface of the lining is not in contact with the drum surface at any one time and braking gives rise to contact asperity "hot spots". These hot spots are well recognized in the brake industry because of their importance in understanding the characteristics of braking systems, wear, fade etc.. Braking at only 5 mph produces surface temperatures above 1000C and temperatures at these hot spots range up to 1200C. These are well above temperatures needed for the alteration of chrysotile to forsterite. As the transformation from chrysotile to forsterite gives out heat, it has been possible in experimental work to observe the flow of the forsterite as it formed from chrysotile in the resin. The composition of materials taken from the areas where the "flow" has been observed has been determined using a x-ray diffraction methods with a Gandolfi stage. The material was shown to be forsterite.

Examples of hot spots and the "flowing" forsterite are shown in Figures 2A1 and 2A2.

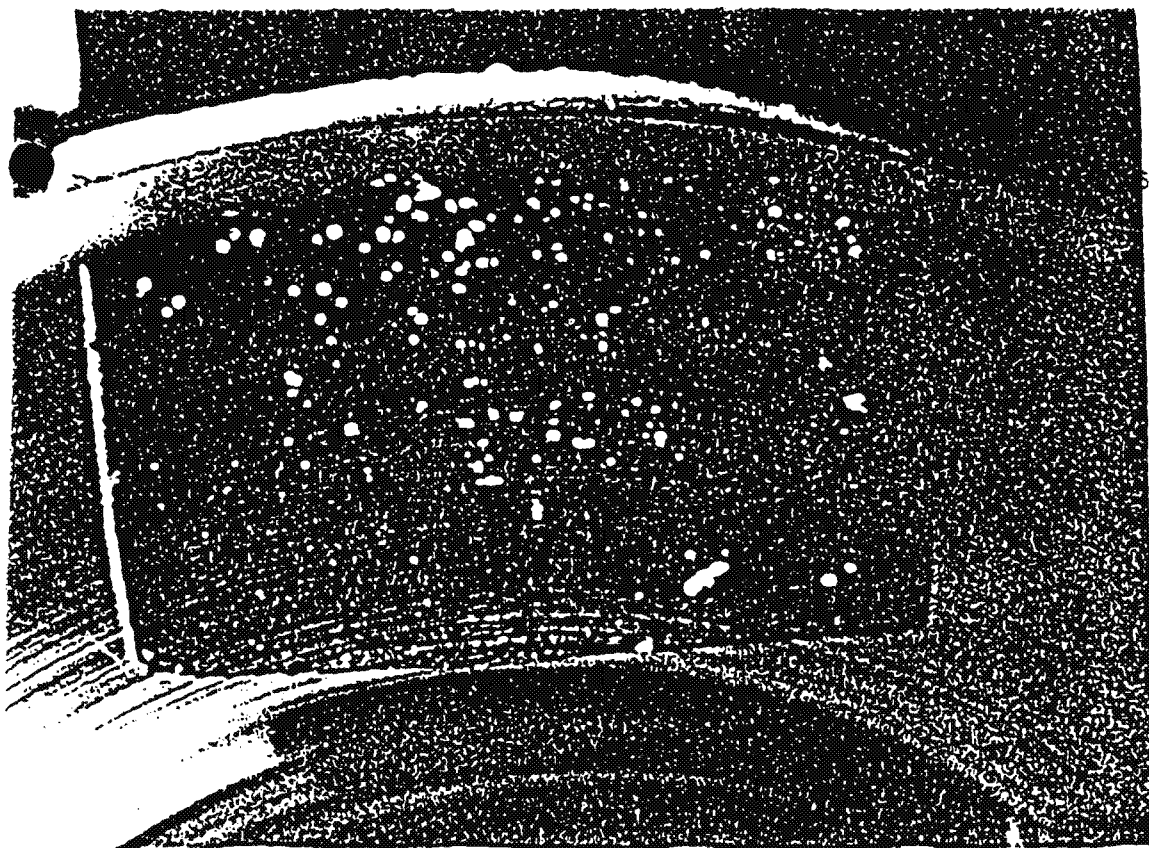
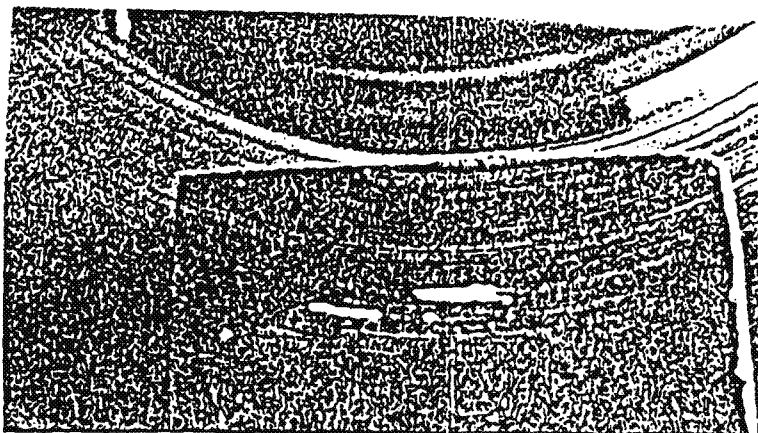


FIGURE 2A1

"HOT SPOTS" DURING BRAKING.



The two circumferential glowing streaks were produced by flowing forsterite from two asbestos crudes. X-ray diffraction of the residue, using a Gandolfi stage to support the specimens, confirmed the material to be forsterite. Lattice spacing strains indicated significant residual stresses, apparently from quench-cooling.

FIGURE 2A2

FORSTERITE FORMATION
(Photographs, Courtesy of A. Anderson).

APPENDIX 3

OBSERVATIONS CONCERNING FRICTION MATERIALS MANUFACTURE FROM THE
STANDPOINT OF ASSESSING THE RISKS OF HEALTH EFFECTS FROM BRAKE
MAINTENANCE WORK.

A description of the brake manufacturing industry historically has been published by Skidmore and Dufficy(1983).The factory that they described is the one studied by Berry and Newhouse,(1983) and later by Newhouse and Sullivan (1989).

There were four periods in the plant's environmental history.

- 1.Pre 1931,before the British asbestos regulations and when all operations were carried out in one open plan area.
- 2.1932-1950 when exhaust ventilation was applied to many machining operations and larger premises provided for greater separation between the stages of production.
- 3.1951-69 which was a gradual period of improvement including product cleaning and the application of exhaust ventilation to machines not included in the asbestos regulations.
- 4.1970-79 after the introduction of the 2f/ml standard in the United Kingdom.

Based on measurements available and realistic simulation,the average concentrations of chrysotile fibres from loose fibre products in fibres/ml of length greater than 5um were as shown in table 3A1

It can be seen that the concentrations of fibre encountered were considerably greater than those that would be encountered in brake repair.These time weighted average exposure are for workers whose full time jobs were,for example,drilling brake linings which has not been necessary in brake repair shops for many years because the linings were already drilled during manufacture.Secondly,the grinding done during manufacture meant that it was not necessary to grind later.In a repair shop a maintenance worker might grind only occasionally and since 1950 one would expect exposure to be considerable less than for a worker in production grinding where large as well as automobile brake linings were drilled and ground.This is borne out by the measurements made by Rodelsperger who reported concentrations of the order of 0.1f/ml over 30 minutes for a mechanic grinding passenger car brake linings.

It is evident that overall exposures in the manufacturing plant are higher than in repair shops. Also exposure in the manufacturing plant is to chrysotile fibres. Exposures in the maintenance shops are to particles formed from the destruction of the chrysotile during braking plus a much reduced exposure over that in the friction products manufacturing plants from grinding and drilling linings.

TABLE 3A1

ASBESTOS FIBRE CONCENTRATIONS IN FRICTION MATERIALS MANUFACTURE

Process	Pre-1931	1932-1950	1951-69	1970 -
Storage/ Distribution	>20	1-2	1-2	0.5-1
Preparation	>20	1-2	1- 2	0.5-1
Impregnation/ forming	>20	1-2	1- 2	1-2
Grinding	>20	5-10	2-5	1-2
Drilling, boring, turning	>20	2-5	1-2	1-2
Inspection/ Stencilling	>20	2-5	2-5	1-2
Packing/ Dispatch	>20	1-2	1-2	0.5
Office/ Laboratory	10-20	<0.5	<0.5	<0.5

This comparison is significant in that the absence of demonstrated lung cancer and mesothelioma risks in the friction materials manufacturing industry provides considerable supporting evidence for not expecting health effects in the brake repair personnel associated with chrysotile exposure.

APPENDIX 4

TABLE A4A

THRESHOLD LIMIT VALUES(TLV'S) ESTABLISHED BY
THE AMERICAN CONFERENCE OF
GOVERNMENTAL INDUSTRIAL HYGIENISTS(ACGIH).
: 1946-1989

* M.P.P.C.F. = Million Particles per Cubic Foot of air as measured using midget impinger sampler and standard light field count

** Fibres/ml measured using phase contrast light optical microscopy. Fibres longer than 5µm with aspect ratios greater than 3:1

YEAR	SUBSTANCE	CONCENTRATION TLV	
		M.P.P.C.F	Fibres/ml
1946	Asbestos	5	
1947		5	
1948		*	
1949		*	
1950		*	
1951		5	
1952		5	
1953		5	
1954		5	
1955		5	
1956		5	
1957		5	
1958		5	
1959		5	
1960		5	
1961		5	
1962		5	
1963		5	
1964		5	
1965		5	
1966		*	
	Tremolite	5	
1967		5	

* Asbestos not listed

TABLE A4A cont.

YEAR	SUBSTANCE	CONCENTRATION	
		TLV	
		M.P.P.C.F	Fibres/ml
1968		5	
	Intended change.....	2	12 +
1969		-?	
1970	Asbestos,all types	5	
	Intended change.....		5 +\$
	Talc(fibrous) USE ASBESTOS LIMIT		
1971	Asbestos,all types	-	
	Intended change		5 +#\$
	Talc(fibrous) USE ASBESTOS LIMIT		
	Tremolite SEE TALC FIBROUS		
1972	Asbestos,all types	-	
	Intended change.....		5 +\$# A1a
	Tremolite SEE TALC FIBROUS		
	Talc(fibrous) USE ASBESTOS LIMIT		
1973	Asbestos,all forms		5 +@# A1a
	Talc(fibrous) USE ASBESTOS LIMIT		
1974	Asbestos,all forms		5 +@# A1a
	Tremolite,SEE ASBESTOS		
	Talc(fibrous) USE ASBESTOS LIMIT		
1975	Asbestos,all forms		5 +@# A1a
	Tremolite,SEE ASBESTOS		
	Talc(fibrous) USE ASBESTOS LIMIT		
1976	Asbestos,all forms		5 +@# A1a
	Tremolite,SEE ASBESTOS		
	Talc(fibrous) USE ASBESTOS LIMIT		
1977	Asbestos,all forms		5 +@# A1a
	Tremolite,SEE ASBESTOS		
	Talc(fibrous) USE ASBESTOS LIMIT		
1978	Asbestos,all forms		5 +@# A1a
	Tremolite - SEE ASBESTOS		
	Talc(fibrous) USE ASBESTOS LIMIT		
1979	Asbestos,all forms		5 +# A1a %
	Tremolite - SEE ASBESTOS		
	Talc(fibrous) USE ASBESTOS LIMIT		

TABLE A4A cont

YEAR	SUBSTANCE	CONCENTRATION	
		TLV	
		M.P.P.C.F	Fibres/ml
1980	Asbestos		
	Amosite	0.5	A1a + #
	Chrysotile	2.0	A1a + #
	Crocidolite	0.2	A1a + #
	Other Forms	2.0	A1a + #
	Talc(fibrous) USE ASBESTOS LIMIT		
1981	Asbestos		
	Amosite	0.5	A1a + #
	Chrysotile	2.0	A1a + #
	Crocidolite	0.2	A1a + #
	Other Forms	2.0	A1a + #
	Talc(fibrous) USE ASBESTOS LIMIT		
1982	Asbestos		
	Amosite (12172-73-5)	0.5	A1a + #
	Chrysotile(12001-29-5)	2.0	A1a + #
	Crocidolite(12001-28-4)	0.2	A1a + #
	Other Forms	2.0	A1a + #
	Talc(fibrous) USE ASBESTOS LIMIT		
1983	Asbestos		
	Amosite (12172-73-5)	0.5	A1a + #
	Chrysotile(12001-29-5)	2.0	A1a + #
	Crocidolite(12001-28-4)	0.2	A1a + #
	Other Forms	2.0	A1a + #
	Talc(fibrous) USE ASBESTOS LIMIT		
1984	Asbestos		
	Amosite (12172-73-5)	0.5	A1a + #
	Chrysotile(12001-29-5)	2.0	A1a + #
	Crocidolite(12001-28-4)	0.2	A1a + #
	Other Forms	2.0	A1a + #
	Talc(fibrous) USE ASBESTOS LIMIT		
1985	Asbestos		
	Amosite (12172-73-5)	0.5	A1a x #
	Chrysotile(12001-29-5)	2.0	A1a x #
	Crocidolite(12001-28-4)	0.2	A1a x #
	Other Forms	2.0	A1a x #
	Talc(containing asbestos fibres)		
	USE ASBESTOS TLV. However, should not exceed 2mg/m ³ respirable dust.		

TABLE A4A cont.

YEAR	SUBSTANCE	CONCENTRATION	
		TLV	
		M.P.P.C.F	Fibres/ml
1986	Asbestos		
	Amosite (12172-73-5)	0.5	A1a x#
	Chrysotile(12001-29-5)	2.0	A1a x#
	Crocidolite(12001-28-4)	0.2	A1a x#
	Other Forms	2.0	A1a x#
	Talc(containing asbestos fibres)		
	USE ASBESTOS TLV-TWA.However,should not exceed 2mg/m ³ respirable dust.		
1987	Asbestos		
	Amosite (12172-73-5)	0.5	A1a x#
	Chrysotile(12001-29-5)	2.0	A1a x#
	Crocidolite(12001-28-4)	0.2	A1a x#
	Other Forms	2.0	A1a x#
	Talc(containing asbestos fibres)		
	USE ASBESTOS TLV-TWA.However,should not exceed 2mg/m ³ respirable dust.		
1988	Asbestos		
	Amosite (12172-73-5)	0.5	A1a x##k
	Chrysotile(12001-29-5)	2.0	A1a x##k
	Crocidolite(12001-28-4)	0.2	A1a x##k
	Other Forms	2.0	A1a x##k
1989	Asbestos		
	Amosite (12172-73-5)	0.5	A1a x##k
	Chrysotile(12001-29-5)	2.0	A1a x##k
	Crocidolite(12001-28-4)	0.2	A1a x##k
	Other Forms	2.0	A1a x##k

EXPLANATION OF NOTES

TLV Threshold Limit Value

TWA Time weighted average

+ Fibres/ml >5µm in length

x Fibres/ml longer than 5µm and with an aspect ratio equal or greater than 3:1

TABLE A4A cont.

EXPLANATION OF NOTES cont.

@ A more stringent TLV for crocidolite may be required

* As determined by the membrane filter method at 400 - 450 x magnification (4mm objective) phase contrast illumination.

\$ Concentrations 5 fibers/ ml but not to exceed 10, may be permitted for 15-minute periods each hour up to 5 times daily.

A1a Human Carcinogens. Substances or substances associated with industrial processes, recognized to have carcinogenic or cocarcinogenic potential with an assigned TLV

% Cigarette smoking can enhance the incidence of respiratory cancers from this or others of these substances or processes.

* Substance identified by other sources as a suspected or confirmed human carcinogen

k Substance for which OSHA and/or NIOSH has a permissible exposure limit (PEL) or a recommended exposure limit (REL) lower than the TLV.

APPENDIX 4

TABLE A4B

FEDERAL REGULATORY PROGRAM
OSHA

1971 - 1988

DATE	RULE
29.05.71	PEL of 12 f/cc over 8 hour time weighted average(TWA) Section 6(a) of the OSH Act codified at 29 U.S.C. S 655(a) (36 FR 10466)(29 C.F.R. Part 1910)
12.07.71	PEL of 5 f/cc over 8 hour time weighted average(TWA) and peak exposure of 10 f/cc as Emergency Temporary Standard (36 FR 234207)(29 C.F.R. Part 1910.93a)
7.06.72	New Final rule - PEL of 5 f/cc over 8 hour time weighted average(TWA).To be lowered to 2f/cc in 1976 (37 FR 11318)(29 C.F.R.Part 1910)
09.10.75	<u>Proposed Rule</u> PEL of 0.5 f/cc over 8 hour time weighted average(TWA).Ceiling limit of 5f/cc for 15 minutes (1980)-withdrawn. (40 FR 47652)
07.76	PEL of 2f/cc as 8 hour time weighted average became effective as in 1972 final rule (29 CFR 1910.1001)
04.11.83	Emergency temporary Standard(ETS) of 0.5 f/cc as 8 hour time weighted average.

TABLE A4B cont.

DATE	RULE
03.84	1983 ETS Overturned
10.04.84	<u>Proposed rule</u> - PEL to be lowered to 0.5 or 0.2 f/cc as time weighted average. (49 FR 14116)
12.07.85	<u>EPA Proposed rule</u> Immediately effective to extend OSHA provisions to state and local workers. (50 C.F.R.28530)
25.04.86	EPA Final Rule-extends OSHA protections to state & local workers. (51 FR 15722)(40 C.F.R. Part 763,Subpart G)
20.06.86	PEL lowered to 0.2f/cc as 8 hour time weighted average. (Final Rules 51FR 22612)(29 C.F.R.Part 1910,Subpart Z and 29 C.F.R.Part 1926,sunpart D).
17.10.86	Partial Stay of 20.06.86 standards as they applied to non asbestiform tremolite,anthophyllite and actinolite pending further review and rule making. (51 FR 37002).
25.02.87	EPA Final Rule- Revised rule extended current OSHA requirements to state and local workers involved in abatement and lifted repair exemption for projects 3 feet or less. (52 FR 5618)(40 C.F.R.Part 763,Subpart G).
14.09.88	Amendment - excursion limit of 1 f/cc over a 30 minute period added to cover employees involved in jobs with irregular peak whose total exposure may not reach 0.2 f/cc as time weighted average over an 8 hour exposure period. (53 FR 35610)(29 C.F.R. Part 1910,Subpart Z and 29 C.F.R. 1926,Subpart D).