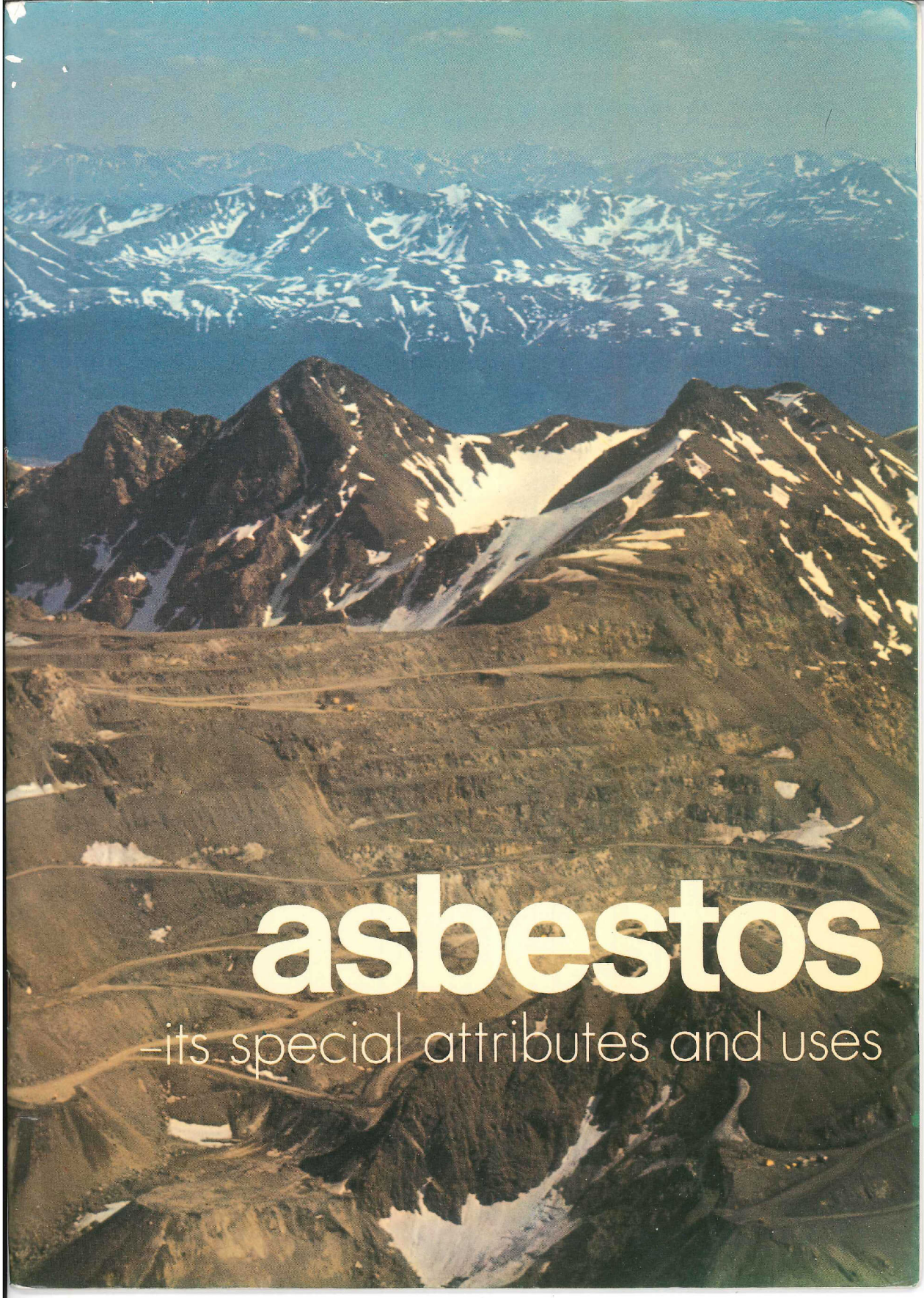


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Cover Picture
A panoramic view of the Cassiar Mine, British Columbia, Canada, which is located at a height of 6,200 ft. on McDame Mountain.

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The Mineral Asbestos

It is well known that the life cycle of this planet depends on the ability of carbon atoms to form chains, sheets and three-dimensional networks. It is less well known, however, that groups of silicon-oxygen atoms known as silicates can also form chains, sheets and three-dimensional networks, that nine-tenths of the earth's crust is made up of silicates and about a quarter of those silicates are crystalline materials. There are about thirty of these crystalline silicate minerals which occur in fibrous form but only five of them are to any extent commercially important, with chrysotile asbestos (by far the most versatile) accounting for 95% of the total of five million tons of asbestos mined annually. Production of amosite and crocidolite fibres accounts for most of the remainder; the other types, anthophyllite and tremolite, are produced only in relatively insignificant tonnages.

Chrysotile is a fibrous form of serpentine; the other four are of the amphibole group. Indeed, it is important to emphasise that the name "asbestos" given to these important minerals does not distinguish between the natural types, of which the two principal mineralogical groups are serpentine and amphibole asbestos. The mineralogical differences are a result of the varieties of host rock in which asbestos occurs. The characteristics of the main types are listed in Table 1.

Serpentine asbestos or chrysotile

The properties of chrysotile fibres which particularly adapt them to the manufacture of such a wide variety of products are length, strength, toughness, flexibility and a minimum of electrically conductive particles. Chrysotile fibres are the most flexible of all asbestos fibres. Their tensile strength is high and, exceptionally, individual values of more than 57×10^3 kg/cm^2 have been recorded.

Chrysotile asbestos



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The other outstanding property of chrysotile is perhaps its resistance to alkaline attack, which makes it supremely useful as a reinforcing fibre in cement and has led to the widespread manufacture of asbestos-cement building products.

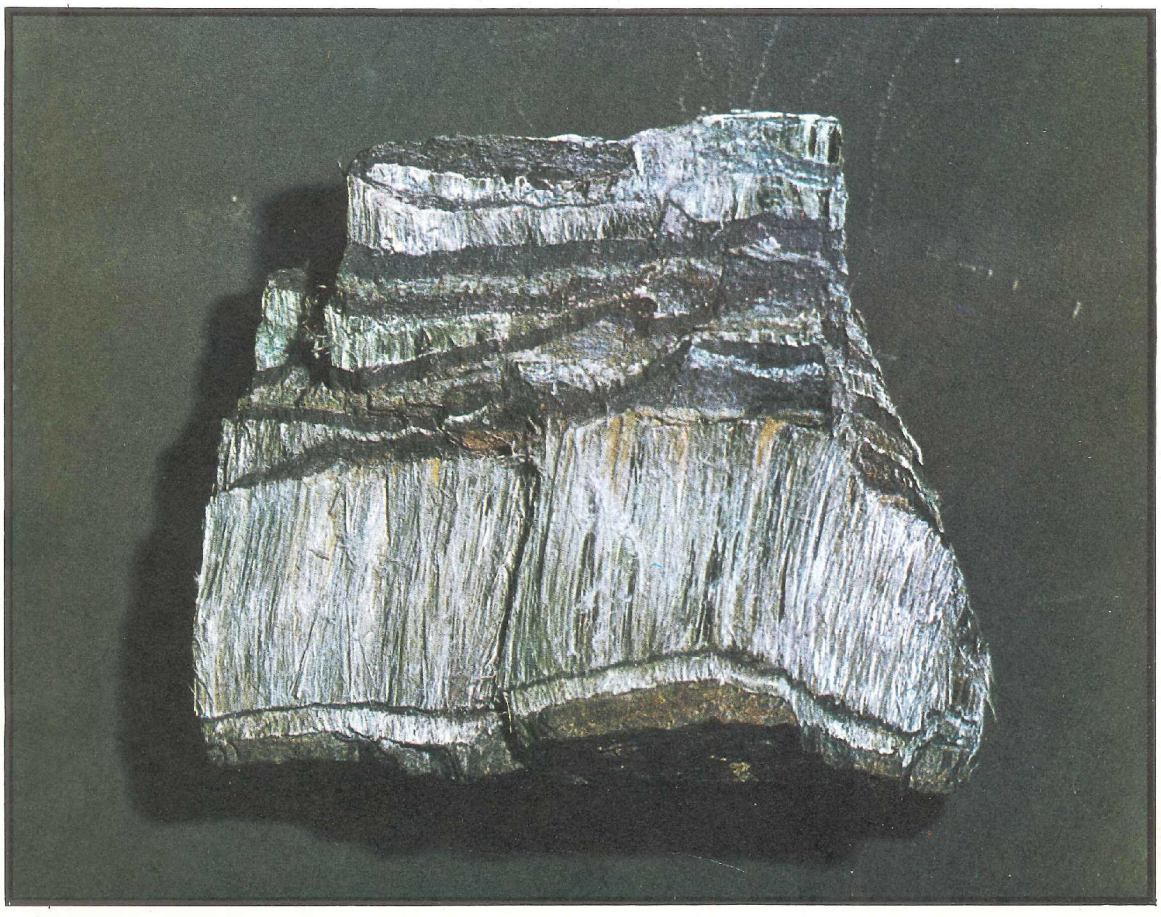
Chrysotile asbestos has tubular unit fibres (more correctly termed fibrils). These individual fibrils have a diameter of roughly one millionth of an inch, and a fibril 1 micron long weighs little more than 10^{-16} grams. A fibril weight of less than 1 gram would stretch from the earth to the moon and back. The macro-fibres familiar to users of chrysotile asbestos are each composed of many hundreds of thousands of fibrils in close parallel array, yet relatively easily separable into very fine, flexible bundles.

Amphibole asbestos

The types of asbestos in this group differ from chrysotile asbestos in containing a larger percentage of silica, less magnesium, and larger amounts of iron, aluminium, sodium and calcium. The most important characteristic of crocidolite is its superior resistance to attacks by acids. It is the strongest of all the asbestos fibres, tensile strength of up to 86×10^3 kg/cm^2 having been recorded. Crocidolite therefore is extensively used in conjunction with chrysotile in the manufacture of asbestos-cement pressure pipes in many parts of the world, though not in the U.K.

Amosite also contains approximately 35% iron expressed as oxides but it is mainly in the less oxidised, ferrous state. Amosite asbestos has good tensile strength and in certain product formulations its resistance to heat is superior to that of chrysotile or crocidolite, so that it is used principally in the manufacture of insulating boards in the U.K.

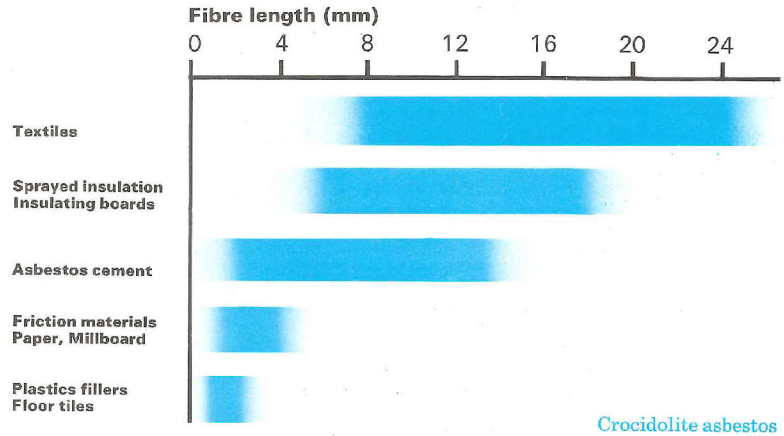
Amosite asbestos



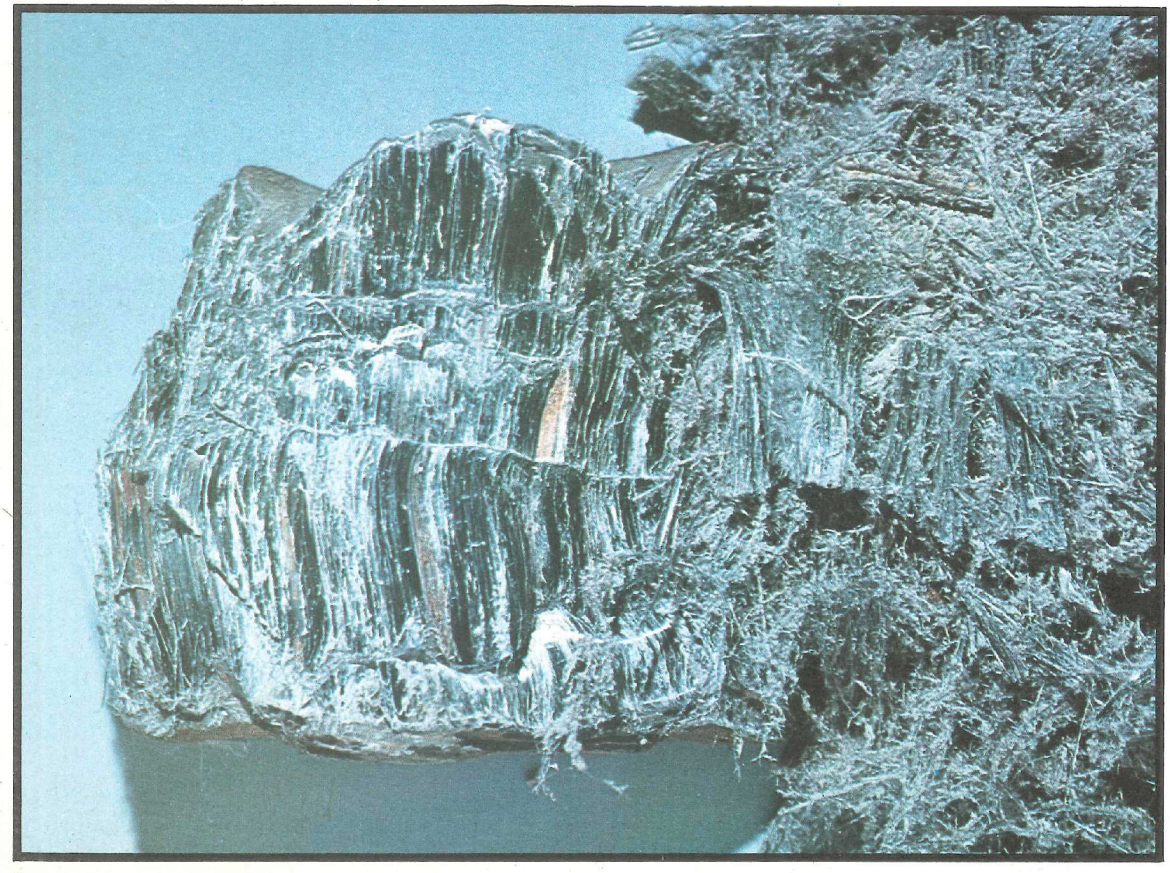
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The best known quality of asbestos is its power of resisting heat, although this quality does not go so far as popular thought would suggest. Asbestos itself cannot be classed as a refractory although normally its qualities are sufficient for it to withstand the temperature of superheated steam or the melting point of many commonly used metals and alloys. Besides its ability to withstand fairly high temperatures it has the valuable property of forming products which are poor conductors of heat; these two qualities are not often combined in a single substance. The low heat conductivity is probably due to the cellular structure which it assumes when processed.
A rough outline of the uses of different fibre lengths is given in Fig. 1.

Fig. 1: Principal length ranges of asbestos fibres for different uses.



Crocidolite asbestos



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Table 1

Characteristics of main types of asbestos fibre

Characteristic	Chrysotile	Crocidolite	Amosite	Anthophyllite	Tremolite	Actinolite
Theoretical Formula	$Mg_3[Si_2O_5](OH)_4$	$Na_2Fe^{II}_3Fe^{III}_2[Si_8O_{22}](OH)_2$	$(Fe, Mg)_7[Si_8O_{22}](OH)_2$	$(Mg, Fe)_7[Si_8O_{22}](OH)_2$	$Ca_2Mg_5[Si_8O_{22}](OH)_2$	$Ca_2(Mg, Fe)_5[Si_8O_{22}](OH)_2$
Chemical Analysis (range of major constituents – per cent)						
SiO_2	38–42	49–56	49–52	53–60	55–60	51–56
Al_2O_3	(0–2)*	(0–1)	(0–1)	(0–3)	(0–3)	(0–3)
Fe_2O_3	(0–5)	13–18	(0–5)	(0–5)	(0–5)	(0–5)
FeO	(0–3)	3–21	35–40	3–20	(0–5)	5–15
MgO	38–42	(0–13)	5–7	17–31	20–25	12–20
CaO	(0–2)	(0–2)	(0–2)	(0–3)	10–15	10–13
Na_2O	(0–·1)	4–8	(0–·1)	(0–1)	(0–2)	(0–2)
H_2O+	11·5–13	1·7–2·8	1·8–2·4	1·5–3·0	1·5–2·5	1·8–2·3
Colour	Usually white to pale green, yellow[1], pink[1]	Blue	Light grey to pale brown	White to grey, pale brown	White to grey	Pale to dark green
Decomposition temperature* (°C)	450–700	400–600	600–800	600–850	950–1040	620–960
Fusion temperature of residual material (°C)	1500	1200	1400	1450	1315	1400
Density g/cm³	2·55	3·3–3·4	3·4–3·5	2·85–3·1	2·9–3·1	3·0–3·2
Resistance to acids	Undergoes fairly rapid attack	Good	Attacked slowly	Very good	Very good	Attacked slowly
Resistance to alkalis	Very good	Good	Good	Very good	Good	Good
Mechanical properties of fibre as taken from rock samples:						
Tensile strength 10^3 kg/cm²	31	35	17	(<7)	5	5
(Average) (10^3 psi)	(440)	(495)	(250)	(<100)	(<70)	(<70)
Young's Modulus 10^3 kg/cm²	1,620	1,860	1,620	—	—	—
(Average) (10^6 psi)	(23)	(27)	(23)			
Texture	Usually flexible, silky and tough	Flexible to brittle and tough	Usually brittle	Usually brittle	Usually brittle	
Producing countries	USSR Canada China Rhodesia USA Italy South Africa Swaziland	South Africa	South Africa	Finland USA Mozambique	USA Italy	

*Bracketed figures denote substituents often present in asbestos.

Notes *Dehydroxylation or dehydrogenation accompanied by disruption of crystal lattice and major loss of strength. [1] From serpentinised dolomite deposits.

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Textiles

Asbestos textiles, which are almost entirely based upon chrysotile fibre, have been in use for many years. As a result of its unique fibrous nature, asbestos can be spun into yarn and woven into cloth. These yarns and fabrics then possess all the valuable properties of asbestos; incombustibility and resistance to heat, corrosion and biological attack, properties which are required in applications covering almost every branch of industry.

Asbestos yarns have a variety of outlets, the main ones being in friction materials, in packings and in woven products. The yarns are produced in a wide range of constructions with properties suited to the applications for which they are intended. Two basic types are produced: plain yarns, possibly braced with an organic fibre, and reinforced yarns, which incorporate either wire or another yarn such as cotton, nylon or polyester to extend the properties of the asbestos yarn. For example, metallic yarns have good heat dissipation, high temperature strength retention with particular friction properties, and their end uses include clutches, brake linings and some packings.

Woven asbestos products, i.e. cloth, webbing, listing and tubing, are produced on looms specially developed for the industry and have a range of applications as wide as that for yarns.

Dust-suppressed asbestos cloths and the new asbestos textiles produced by the wet dispersion process provide a quick, simple and economical method of applying a mechanically strong and durable covering over friable primary insulation on vessels and pipes in which a high temperature has to be maintained. In this application the cloth can be stretched easily and sewn into place, it does not fray and will withstand the high frequency vibrations associated with engines and exhausts, e.g. in ships and power stations.

Another important area of application is in protective clothing and fire protection. As it is inorganic, incombustible and does not melt, asbestos clothing is eminently suitable as a protection for fire-fighters and foundry workers against flame, heat and molten metal splashes. The cloth is particularly effective when coated with a thin layer of aluminium which, by producing a smooth, tough, flexible and waterproof skin with protection against radiant heat, enhances the properties of the asbestos. Asbestos cloth is also used for safety curtains in theatres, welding shops and glass works, and as fire blankets in industry and institutions, while an important new and growing application is as fire and smoke barriers in the roof spaces of modern system-built schools, hospitals and offices.

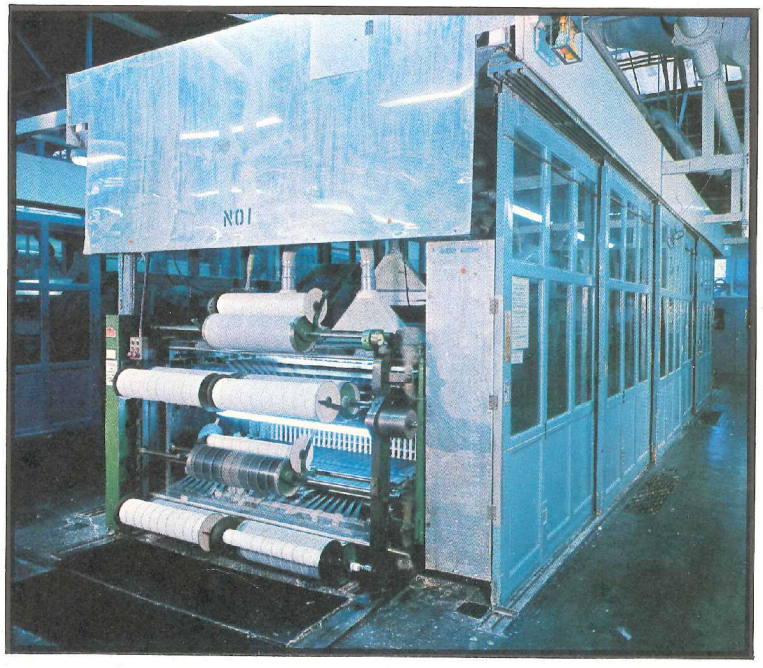
The two other major outlets for asbestos cloth—in packings and jointings, and in heat resistant, high strength laminates—are dealt with in later chapters. Other uses of asbestos cloths are for the diaphragms of electrolytic cells, as filter cloths for various liquids, and as laundry cloths, where their resistance to biological attack is especially important.

Asbestos webbing, listing and tubing are all forms of asbestos tape. Webbing is used for door seals, thermal insulation, fuse box linings, lamp and stove wicks and, in the plating industry, as wipes to remove surplus molten metal.

Asbestos listing tapes are used in the electrical industry to wrap and insulate field and armature coils in electrical machines and conversely to provide a controlled and predictable rate of electrical leakage for corona relief on high voltage alternating current machines.

The main applications of asbestos tubing are also in the electrical industry where it is used for switch box seals, as heat resistant covering for cables and for the insulation of coil leads in switchgear.

Below
Carding machine

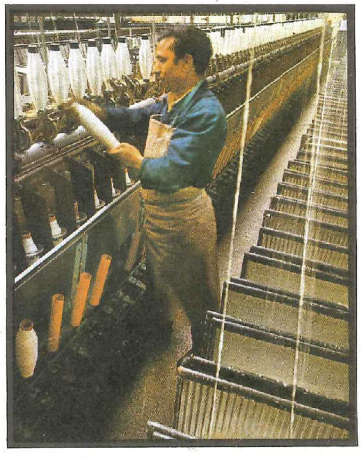


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The physical properties of chrysotile fibres which allow them to be processed into textiles are their high aspect ratio (the relationship between their length and diameter), their comparative flexibility and, not least, their very high tensile strength which may exceed $31 \times 10^3 kg/cm^2$ compared with $25 \times 10^3 kg/cm^2$ for steel "piano wire". This tensile strength is not seriously degraded by heat until temperatures approaching 450°C are attained—though the organic fibre which may be added to asbestos textiles begins to degrade above 150°C. For applications which require strength retention at temperatures up to 600°C, yarns and fabrics may be used which have an inbuilt metal wire reinforcement and in recently reported developments asbestos textiles combined with resins and ceramic binders have been successfully exposed to temperatures up to 2200°C; albeit for very short periods.





Top
Spinning asbestos fibre
Bottom
Weaving asbestos cloth
Above
Yarns produced by the wet dispersion process

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Resistance to elongation is another important characteristic which enables very strong rigid laminations to be produced in resinating applications. The Young's Modulus of chrysotile asbestos is nearly two-and-a-half times greater than that of glass fibres and considerably stiffer moulded structures can be produced if asbestos, rather than glass fibre, is used as the reinforcing medium.

Whilst tensile strength is the most important physical property of asbestos fibres, their surface area is the most important parameter in many industrial applications. For example, a kilogram of asbestos fibre, after being ''opened'' for use, will have an *exposed* surface area of between 650 and 3000m^2. In industrial terminology, surface area becomes the degree of openness or the degree of fiberisation, and the air spaces between fibres almost certainly contribute to the heat insulation properties of asbestos fabrics.

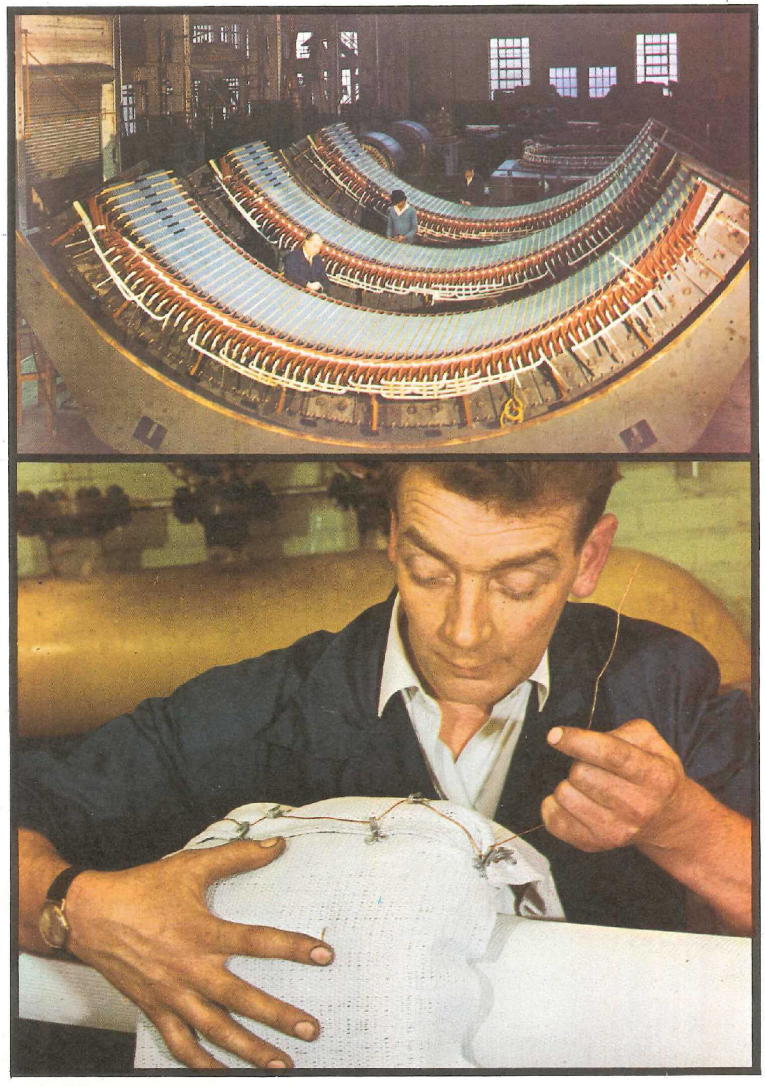


Aluminised asbestos clothing protects this steel worker

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Asbestos textiles are made by two methods, conventional and wet dispersion, which differ in the way in which the yarn is produced. In the conventional method, yarn is manufactured on textile plant by processes not unlike those utilized in the manufacture of cotton or wool textiles. The fibres are received at plant in a semi-opened condition — a partial opening and cleaning process is performed at the mine after extraction of the fibre from the ore by crushing—and are subjected to an intensive opening and cleaning process, the object of which is to separate the large fibre bundles and to break them down into smaller aggregates of fibres in readiness for "carding".

Carding is an intensive opening and aligning process and in it the fibres are subjected to a combing action between the rollers and clearers of the "carding engine".



The densely-packed wire teeth of the carding engine subject the fibres to what is almost an individual opening and cleaning treatment which finally presents the "web", a thin tenuous film of fibres, in strip form known as "slivers" in readiness for spinning.

At the carding stage, organic "carrier" fibres may be added to permit shorter asbestos fibres to be used. The asbestos slivers are twisted into yarns on a spinning frame using either the flyer or ring spinning systems.

Unlike conventional asbestos textile manufacture, wet dispersion techniques of producing asbestos yarns employ what is virtually a chemical process in which the asbestos fibre bundles are broken down and formed into a colloidal dispersion which is then extruded through an orifice, coagulated into twistless strand and spun or twisted into yarn. Wet dispersion processes can therefore be likened to those used in the manufacture of regenerated cellulose fibres.

Asbestos textile materials will withstand, without serious degradation, temperatures higher than those necessary to melt tin and aluminium and play an ever-increasing role in modern industrial technology.

Above
Asbestos listing tape helps to insulate electrical equipment

Below
Covering pipe insulation with asbestos cloth

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Millboard

One of the most versatile asbestos based products currently used in industry and commerce is asbestos millboard. There is no single property which makes millboard so valuable to industry; rather, its particular combination of properties enables it to be employed with advantage instead of many materials (for instance mica, ceramics and steel) which sometimes appear to have a stronger claim.

The features of asbestos millboard which contribute to its versatility are:

1. Easily cut or punched to shape and size.
2. Useful thermal insulation characteristics.
3. Easily impregnated with bonding agents.
4. Can be cemented.
5. Resistance to a very wide temperature range.
6. Non-inflammability.
7. Can be wet-moulded.
8. High compressibility.

Exemplifying its high temperature resistance is its use in the steel industry in which rollers fabricated from discs of millboard are employed for conveying steel plate through heat treatment processes at temperatures up to 1200°C.

A similar application exists in the glass industry for conveying glass vertically from the melting furnace to the sheet cutting floor. In this case the temperature to which the millboard is subjected is around 700°C.

Alternative high temperature resistant materials of suitable composition for these applications tend to be very expensive and are also limited in terms of service life. For example, in the steel annealing application, an alternative is cobalt rollers which would cost many times the price of the present arrangement using asbestos millboard.

Manufacture of electrical resistance formers is another area where asbestos millboard has proved entirely suitable. The millboard is cut to shape and size according to design and the heating element ribbon or wire is wound on to this together with terminal connections, securing lugs, etc. The resultant heating element provides safe and long-lasting service in a variety of appliances.

Although primarily an insulation material, suitable over a wide range of temperatures, asbestos millboard has capabilities as a sealing material, also over a wide range of temperatures. An example of this is the use of it as a flange gasket material in joints of gas ducting and in sheet metal trunking connections in air conditioning systems. In such applications high volume/low pressure conditions exist and, as the flange metal is normally thin with widely spaced bolting, the high compressibility of asbestos millboard is highly suitable.

Internal combustion engine cylinder head gaskets are frequently constructed from thin copper sheathing enclosing a "filler" of asbestos millboard. The millboard provides the required high temperature resistant "body" of the gasket whilst the copper sheathing protects this from the effects of severe sealing conditions at the cylinder head joint.

The variety of uses to which asbestos millboard is applied is wide as the following uses illustrate:

1. An oven lining between internal refractories and outside metal casings for thermal economy.
2. After soaking in water, it is moulded around the outer surface of ceramic moulds to retard cooling in a high precision lost-wax moulding process.
3. Placed in sheet form over a charge of steel ingots to be passed through an annealing furnace to diffuse the furnace flames throughout the ingots.
4. Wet-moulded and wrapped around the journal ends of steel mill rolls during furnace heat-treatment process.
5. Used as a plug or stopper to contain molten metal during bearing manufacture.
(In each of the last four instances, the wet-moulding and/or thermal properties of asbestos millboard, together with its relatively low cost, are of particular value as these are "once-only" uses after each of which the millboard is renewed).
6. In resinated form, asbestos millboard is utilised as a friction material, particularly applicable to clutch facings for the automotive industry.

Right
Millboard rollers help to draw hot sheet glass through cooling towers during glass making

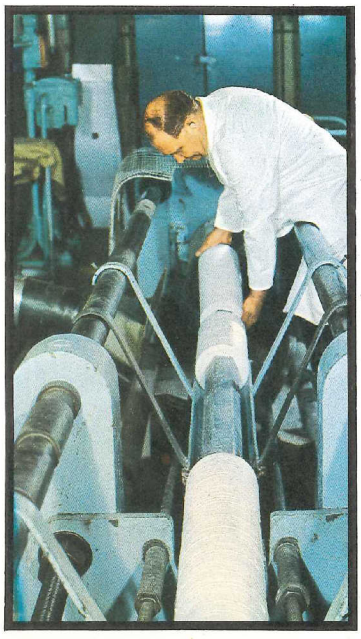
Far right
Millboard is frequently used as a "filler" material in automotive gaskets

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In recent years new qualities of asbestos millboard have been developed which incorporate dust-suppressing agents designed to make handling cleaner and less dusty. Development work towards this end continues in the interest of health and cleanliness.

There are alternative materials available for many of the uses for which asbestos millboard is eminently suitable. However, there is no single product which embodies all the versatile potential of asbestos millboard. Again, its properties derive from the characteristics of chrysotile asbestos fibre, which are in this context:

1. A tensile strength which allows it to be used in the paper making process.
2. Dimensional stability.
3. Resistance to heat which allows it to retain high strength up to 450°C.
4. Heat insulation.
5. Resistance to chemical attack.
6. Rot-proof qualities.





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Jointings and packings

Chrysotile asbestos fibre is a basic constituent of jointings and packings because it combines in one material softness, resilience, strength as a reinforcement and heat resistance.

Compressed asbestos fibre jointing

Compressed asbestos fibre jointing is by far the most widely used static sealing material in industrial and marine applications. It is composed of a relatively high proportion of chrysotile asbestos fibre, bonded under heat and pressure with various elastomers selected for specific ranges of application, e.g. nitrile rubber or polychloroprene for resistance to oil and certain solvents.

The main purpose in compounding CAF jointing is to create a high (or low) temperature resistant material in sheet form which has sufficient tensile strength to withstand high pressures when used as gaskets. It must also be able to "flow" into the imperfections in metal flange faces whilst also maintaining bolt torque to ensure a leak-proof joint.

Compressed asbestos fibre jointing is made to conform to many stringent specifications including British and foreign standards.

Some typical uses are as follows:

As a flange joint material in steam turbine casing joints.

In boiler connections over a wide range of temperatures and pressures.

Between pipe, valve and pump flange connections in oil refinery and chemical plant.

As an essential sealing material in internal combustion engines.

Rubber-proofed packings

These are normally used to seal against the escape of water or oil in hydraulic applications involving reciprocating rods and control valves. The asbestos, in woven or plaited form, provides the inert, temperature-resistant reinforcing fabric which is rendered impermeable by impregnation with rubber of a type to suit the actual sealing conditions.

This type of packing is useful also as a static seal to prevent escape of vapour or liquid from tank covers. It is similarly effective as a door seal in ovens and autoclaves where efficient service is obtained in sealing conditions involving dry heat or steam.

Lubricated packings

Lubricated packings are used to seal the gap between a rotating shaft and the stationary casing of pumps, valves, etc., through which the shaft protrudes. The packings are plaited from asbestos into a construction with a square cross-section. Impregnated with lubricants during plaiting, the asbestos fibres are completely trapped.

The packing is wound round the shaft to form a resilient, closely fitting sleeve within the cylindrical stuffing box which surrounds the shaft. It is pressed into the stuffing box by a gland which holds the packing in place, thus closing the gap between the shaft and the casing.

Because of its good temperature and abrasion resistance, asbestos withstands the high temperatures caused locally by the high rubbing speeds; it is also resistant to attack by a wide range of chemical liquids and remains resilient under a wide range of operating conditions.

Dry asbestos packings

Packings, which are non-proofed and non-lubricated, are used mostly in conditions of dry heat and are particularly useful as a barrier against the spread of flame in buildings of prefabricated construction. An example of this is the insertion of square dry plaited packing as a resilient, flame resistant sealing strip in the expansion gap between the walls and ceilings of hospital buildings.

Furnace door seals, rotary kiln seals (with the contact face of the packing graphited to reduce the coefficient of friction) and high temperature refractory caulking material, are other typical uses for dry asbestos packings.

Where dry packings are used, some dust may be created during cutting and fitting. This can be avoided by damping the packing with water prior to cutting, the resulting moisture rapidly being driven off by most operating conditions or evaporating fairly quickly from the packing as an ambient seal. The protection from heat and flame provided by these packings far outweighs any problems caused by the very small emission of dust during cutting and fitting, which in any case can be expected to be well below accepted threshold limit values.

Recent research and development work on advanced production techniques will, by effectively reducing dust emission from asbestos yarns, ensure that dry asbestos packing will be even more attractive for its particular areas of application in the future.

Gasket materials

The modern internal combustion engine depends for its efficient working on gaskets. These are jointing/sealing materials produced from asbestos fibres bound with rubber or synthetic polymers. For the conditions prevailing in an internal combustion engine, no other fibre is as cost effective as chrysotile asbestos in the fibre/polymer mixtures used because it:

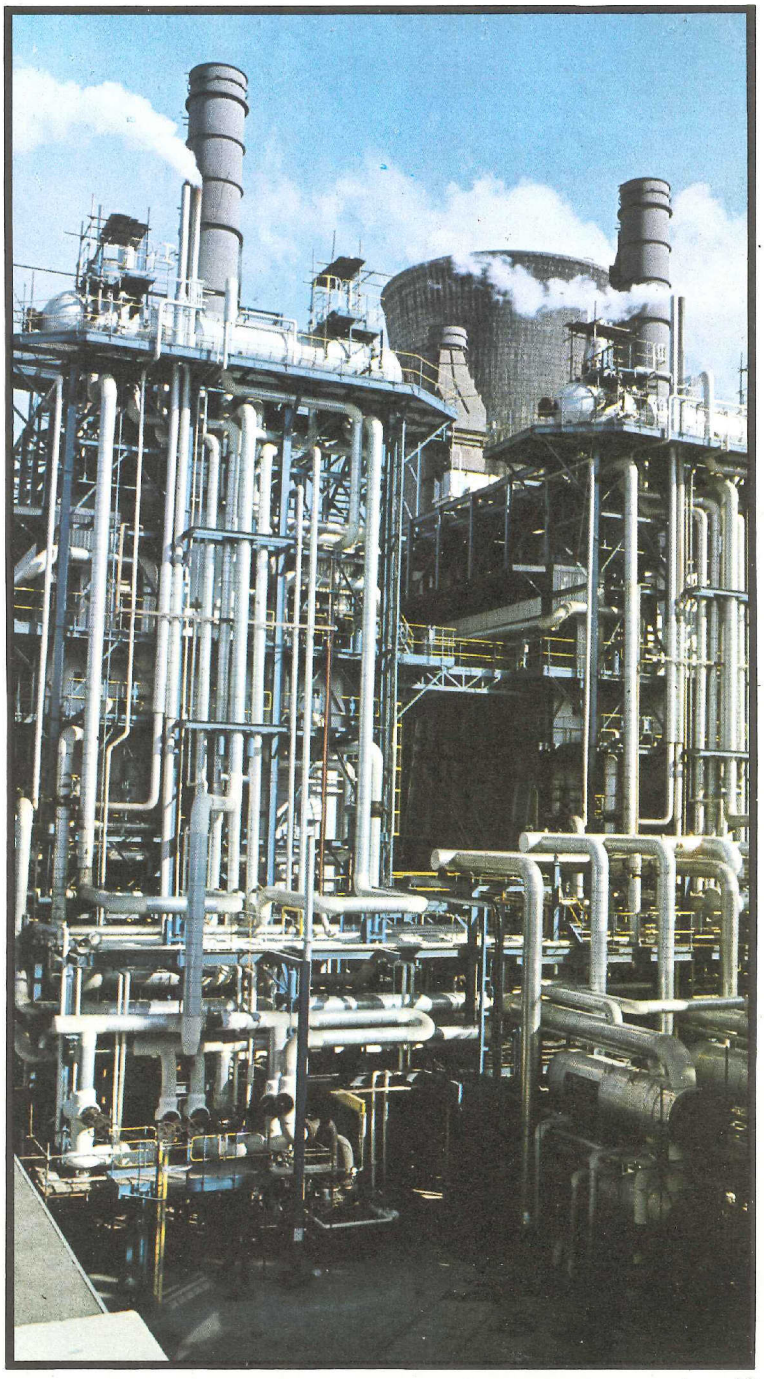
(*a*) resists the attack of hot gases, hot oils and hot water/anti-freeze mixes.

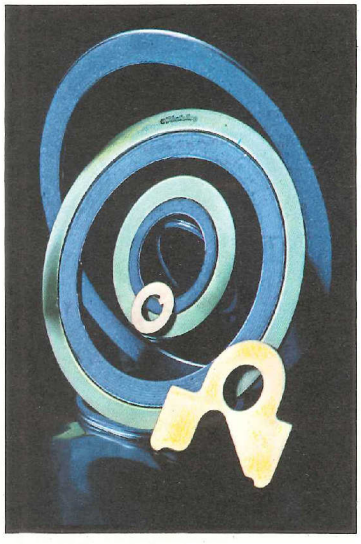
(*b*) is a low cost material, and

(*c*) is more resilient than other fibres, and efficient jointing/sealing materials must be resilient.

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Asbestos sealing materials and industrial gaskets are widely used in modern industrial plants





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Asbestos in the construction, electrical and shipbuilding industries

Well over half of the fibre produced by the asbestos mining industry is used for the manufacture of asbestos-cement sheets, pipes and moulded goods and for insulation and fire-protective building boards. In these applications the fibre is used to a greater or lesser extent as a reinforcement, partly for fire resistance. It suits this role because it is incorrodible, durable, inorganic, non-combustible and therefore fire-resistant. Its plentiful availability, and consequently low price, are added advantages for a fibre which offers tensile strength between 5 and 31×10^3 kg/cm^2, good mechanical strength and a Young's modulus of $1700\text{-}2100 \times 10^3$ kg/cm^2. The stiffness which is exploited for reinforcing purposes is combined with fineness which enables it to be mixed fairly rapidly into a slurry, the first stage in the manufacture of asbestos products bound with cement or silica.



Right
Coloured asbestos cladding sheets on a modern block of flats

Far right
Asbestos roofing slates on the Maltings Concert Hall at Snape in Suffolk

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Asbestos-cement sheet

From an architectural standpoint the subsequent process, in which the slurry is converted first into wet sheets which can be moulded to a range of different contours before they finally harden, clearly holds out interesting design possibilities.

The principal applications for sheets are the roofing and side-cladding of large buildings, particularly factories, and the roofing of barns and other outbuildings on farms. In these applications the use of asbestos-cement sheet, apart from its advantages of durability and non-corrodibility, is more cost-effective than the use of most alternative building materials.

The availability of a great variety of fittings moulded in asbestos-cement makes it possible for the building designer to produce completely integrated roofing and cladding systems.

In the production of asbestos-cement, asbestos fibres offer the cheapest form of high tensile reinforcement that may be used practically. In addition to the high tensile and flexural strengths which the reinforced composites are given by asbestos fibres, the high Young's modulus of the fibre endows the sheet with a desirable degree of stiffness giving lower deflections under a particular loading than could be achieved using lower modulus fibres such as glass, nylon, polypropylene, and cellulose. Of the higher modulus fibres which might be used to provide this desirable stiffness, steel is at least twice as costly as asbestos and the ceramic and carbon fibres are much more costly still.

Apart from its strength, asbestos fibre is a particularly advantageous form of reinforcement because its inherent pliability, high shear resistance and general ease of dispersion enable it to form intimate and well bonded mixtures with cements. Its average fibre diameter can be reduced by comparatively mild treatments to well below the range covered by synthetic fibres, e.g. chrysotile may well be under 0.1μm in diameter in use compared with mineral wool at 5, glass at 12-25, nylon at 70-250 and steel at 250-400 μm.

This extremely finely divided fibrous reinforcement provides the highest possible resistance to crazing, whether created by flexing of the sheet or by atmospheric weathering with sulphurous acid attack of the cement-based binder.

The extremely fine fibres created in normal production treatments provide an excellent carrying web for cement and by virtue of their specific surface areas alone, enable the wet process machines such as the Hatschek and Mazza to operate (synthetic fibres cannot be used on these machines).

The fineness of the asbestos fibre may also be used to great advantage in providing, without necessarily any other artifice, low density reinforced-composite materials possessing high temperature and acoustic insulation characteristics.

The overall surface area of asbestos fibres used may be reduced for improved drainage and higher density production by using suitable blends of e.g. chrysotile and amosite.

Chrysotile asbestos has excellent heat, moisture and alkali resistance, together with a fair resistance to mineral acids. It is not subject to biological degradation as are the cheaper cellulose fibres.

Amosite asbestos has good resistance to acid, and high resilience. In asbestos-cement production it can assist dispersion of chrysotile and improve drainage.

The relative merits of alternative fibres for the reinforcement of cement are brought out in Table 2.



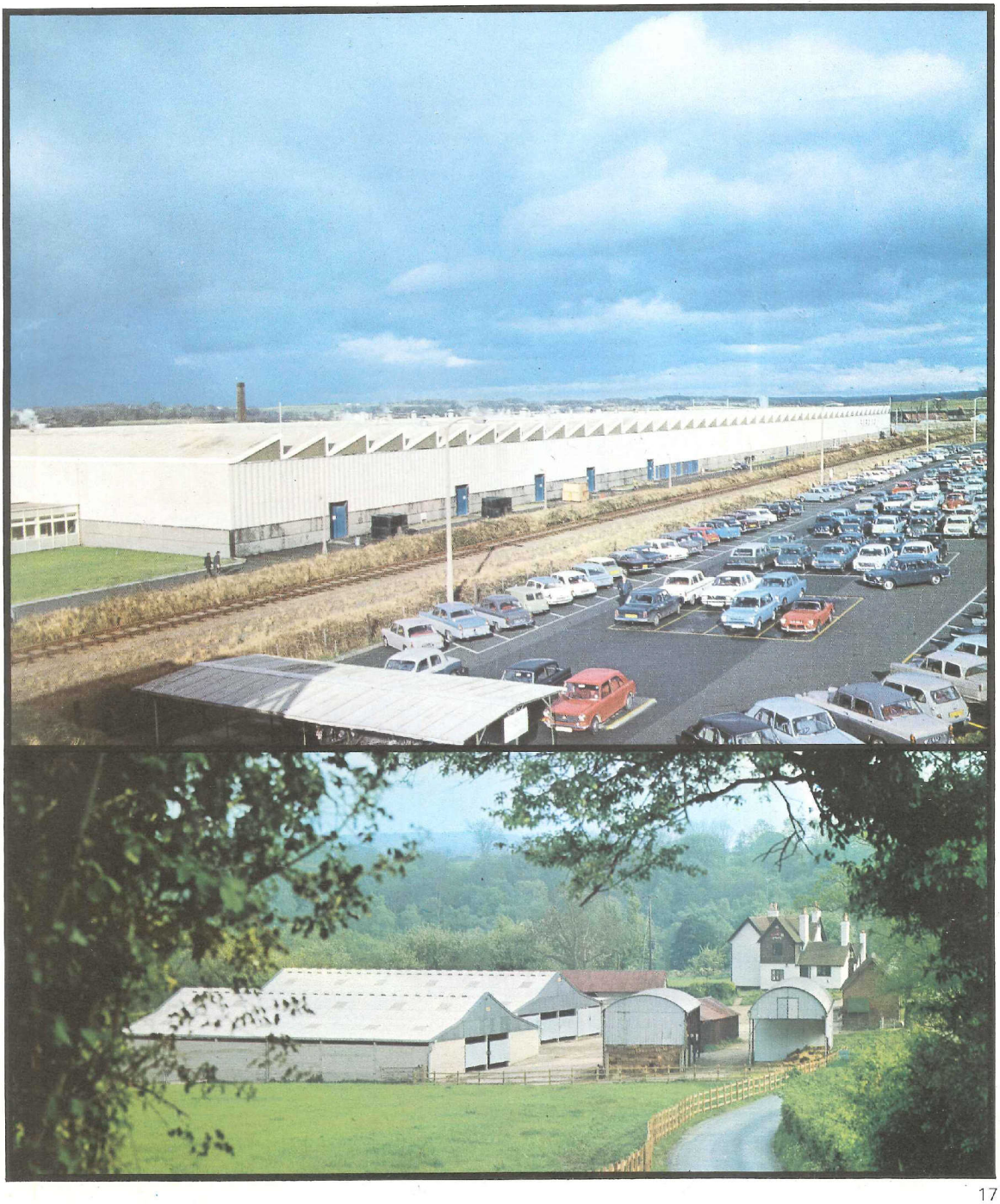
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Table 2
Fibre reinforcement of cement

	Cost	Fire resistance (ability to hold together up to 1000°C)	Resistance to alkali attack	Reinforcing characteristics modulus of Tensile	Rupture	Impact
Asbestos	Low	Excellent	Excellent	Excellent	Excellent	Fair
Glass	High	Poor	Variable	Good	Good	Good
Cellulose	Low	None	Poor	Poor	Poor	Good
Mineral wool	Low	Good	Poor	Fair	Fair	Fair
Thermoplastic (nylon/terylene polyethylene)	High	None	Good	Fair	Fair	Good
Carbon	Very high	Excellent	Good	Good	Good	Good
Steel	High	Good	Will corrode in time	Good	Good	Good

Factories and farms are a major market for corrugated asbestos-cement sheeting material

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Asbestos-cement pipe

The characteristics of asbestos fibre which make it the best reinforcement of cement for sheet also make it the best reinforcement for cement composites in pipe manufacture. Asbestos-cement pipes have important advantages for water supply, sewerage and drainage.

They withstand the effect of sewage of widely varying chemical and pH values. Similarly they withstand the attack of corrosive soil and water conditions. In particular they withstand the increasing levels of inorganic nitrates and phosphates in the soil. They withstand biological and chemical attack.

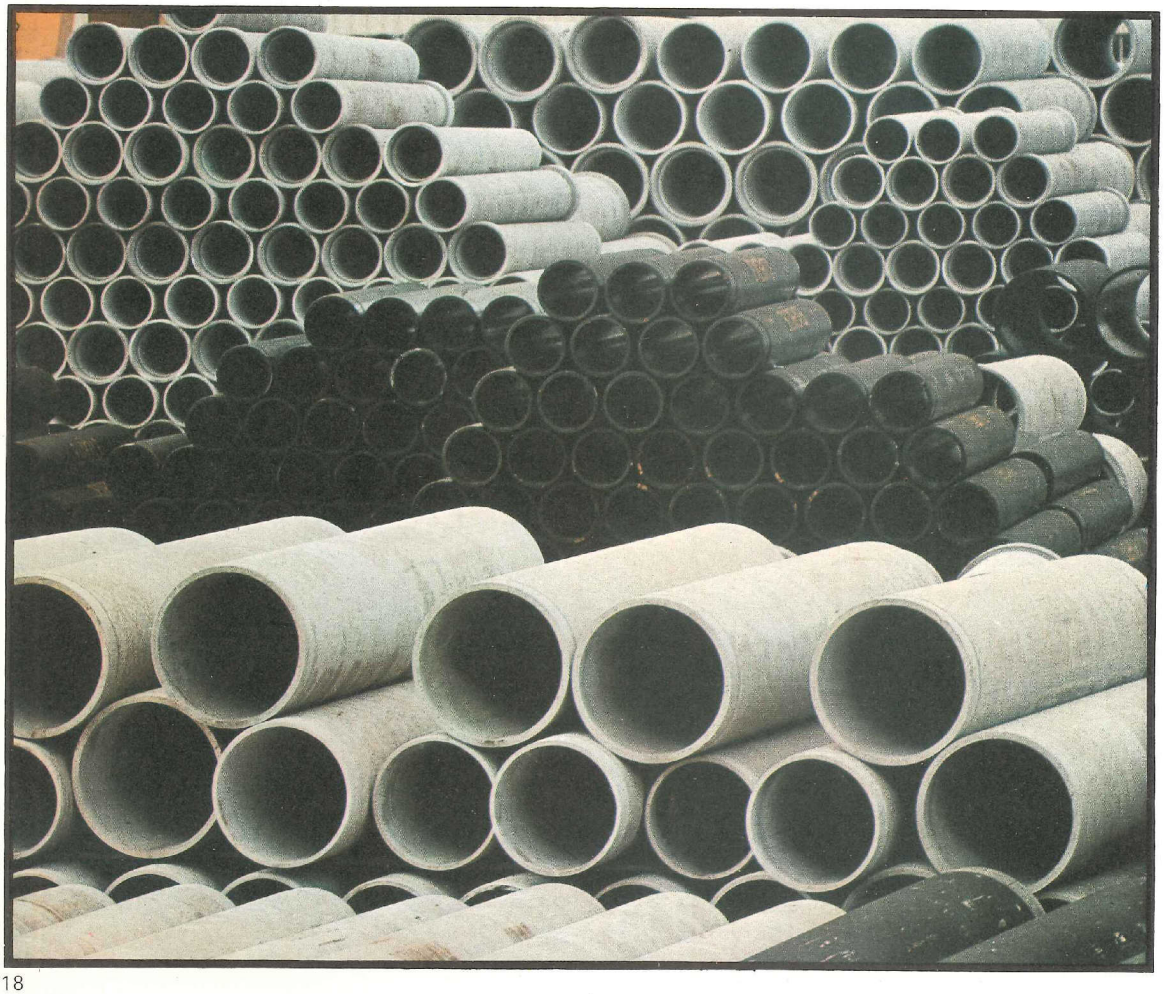
They are relatively light to handle and the joints are flexible.

They do not get encrusted or tuberculated internally, so that in use their bore is not reduced. They maintain a smooth bore, so that carrying capacity is maintained throughout a life which is indefinite—pipes laid 45 years ago still give perfect service.

Their construction is laminar, so that soil and water attack has only very gradual effect. They do not corrode. The strength of laminar construction enables holes for branch pipes to be made with no risk of crack or penetration beyond the area of the cut out.

Asbestos-cement pipes can be made up to 2.5 metres in diameter and 6 metres long, making for simple and economical installation.

Asbestos-cement pipes are used in water-supply, sewerage and drainage schemes



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Asbestos insulating board

An outstanding asbestos product to be developed during the past 20 years has been this asbestos board made with a lime-silica bond. It is used in fire protection to buildings but is also used at sea for fire protection to bulkheads in passenger and cargo ships.

The material is made in board sizes but also as bevelled edge ceiling panels with a range of decorative and acoustic surfaces. It is widely used in all types of buildings for linings and partitions and as ceilings in many of the famous High Street multiple stores.

Whilst its major use is in fire protection, the lime silica (calcium silicate) bond reinforced with asbestos fibres makes the material unique amongst building boards. It has a high strength/weight ratio and is resistant to acids. It is virtually inert with very low moisture movement (0.17 mm per 1000 mm when saturated) and a thermal movement of only 0.05% per 100°C up to 200°C. Complete saturation causes 30% loss of strength which is totally recovered on drying out.

Added to this is the ease with which it can be worked with ordinary hand tools and simply decorated with ordinary paints and emulsions.

The total result is a material which is non-combustible, fire-protective, lightweight, stable, acid-resistant, and easily worked. The relative merits of asbestos insulating board and other common building boards or ceiling materials are shown in Table 3.

Table 3
Relative merits of building boards

Material	Cost	Non-combustible	Surface spread of flame	Resistance to moisture movement	Workability
Asbestos insulating board	Medium	Yes	Class 0	Excellent	Good
Standard mineral fibre	Medium	No	Class 0	Poor	Fair
Woodfibre board	Low	No	Class 1 *	Poor	Excellent
Standard hardboards	Low	No	Class 1 *	Poor	Excellent
Standard gypsum board	Low	No	Class 0	Fair	Good
Standard chipboard	Medium	No	Class 1 *	Fair	Good
Melamine decorative laminate	High	No	Class 1 *	Good	Good

*If flame retardant treated.

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Asbestos and fire protection

Buildings in which people live, work or play are mandatorily required to be safely constructed against the spread of fire and structural collapse for long enough to allow people to escape in the event of a fire. The accepted method of providing safety for the occupants is to divide the area of risk into fire-tight cells, the boundaries of which are constructed from asbestos-calcium silicate composites capable of containing the fire for a prescribed period of time. Asbestos products are made from inorganic materials and as such they are eminently suitable for use where fire protection is required.

Most fires are similar in character but different in intensity according to the fuel involved. For this reason standard laboratory fire tests have been established. British Standard 476, Parts 3 to 8 inclusive define recognised and approved methods of applying the standard fire test to building materials and components.

Asbestos based building materials can broadly be divided into two groups according to their density. Examples of high density products are corrugated asbestos-cement sheets and fully compressed flat sheets, and a typical low density product is asbestos insulating board. Sprayed asbestos is another form of very low density fire-resistant material which has excellent insulating properties and is usually applied *in-situ*.

A unique character of fire-protective building materials made from asbestos is the inability of the product either to burn or to support flame. At sustained high temperatures it will chemically change and gradually degenerate without emitting smoke and toxic fumes. Being classified as non-combustible and unable to propagate and support flame, asbestos products are defined in the best category results when they are fire-tested in accordance with BS 476, Parts 3 to 7 inclusive. These tests are performed on materials whereas BS 476, Part 8 defines the test methods and criteria for the fire resistance of elements of building construction. The results of the latter test are usually expressed as a period of time during which the test specimen is capable of satisfying criteria as to stability, integrity and insulation. Maximum temperatures reached in this particular test are about 1200°C and it is interesting to note that there are many materials commonly used for the construction of buildings and ships which are classified as non-combustible which would have melted long before this temperature was reached. Low density asbestos material in particular will remain stable at high temperatures for a period of four hours, the maximum required by Building Regulations, whereas in really hot fires higher density products such as corrugated asbestos-cement roof sheeting, are inclined to disintegrate. However, many authorities regard this disintegration as advantageous because the heat of the fire is allowed to escape in its natural direction via the vent holes in the roof created by the fire.

Asbestos-cement products such as corrugated roof sheets used as roof coverings to buildings are, when tested in accordance with BS 476 Part 3, ''External Fire Exposure Roof Test'', given the designation AA which is the best result obtainable. The first letter of the designation indicates that during the one hour period of test there was no flame penetration and the second letter signifies that there was no flame spread.

Another distinct advantage of asbestos products is the inability of the material to support the spread of flame across its surface. This has been substantiated by test results after asbestos boards have been subjected to BS 476, Part 7, ''Surface Spread of Flame Tests for Materials''. The test results show that asbestos boards are designated Class 1, the highest classification obtainable in this particular test. Indeed, asbestos boards are used for part of the testing apparatus which provides support for the test specimen.

Asbestos products are rated as non-combustible when tested in accordance with BS 476 Part 4 ''Non-combustibility Test for Materials''. Although BS 476 Part 6, ''Fire Propagation Test for Materials'', is a test which provides a means of comparing the contribution of combustible building materials to growth of fire, asbestos boards are specified in the Standard as the lining material of the test equipment and to be used for calibration purposes.

The yield strength of mild steel structural building components decreases rapidly when temperatures in excess of 300°C are reached. To enable the temperature of the steelwork to be kept less than a critical value above which collapse would occur, low density asbestos products in the form of boards and spray are used. Without such protection steel columns have been shown, in standard fire tests, to reach a critical temperature limit in only eleven minutes. This time can be increased, for example, to four hours by surrounding the steel column with asbestos insulating boards of 50 mm thickness or 45 mm of sprayed asbestos insulation.

Smoke from burning materials includes toxic products which are known to be the main contributors to deaths occurring in fires. Asbestos products do not produce smoke and toxic fumes when subjected to fire, thus relieving any anxieties of the specifier and user in this important respect.

Asbestos products used to protect buildings and ships are classified as non-combustible and consequently are unable to contribute to spread of fire and thereby attract favourable fire insurance premiums for the building or ship.

Opposite top
Asbestos ceiling panels provide increased fire protection at an underground station

Bottom
Testing asbestos building materials in a house fire test

Bottom right
Passengers and crews at sea are protected from fire by asbestos panels on walls and ceilings

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Asbestos papers and felts

Felts are mainly used in the roofing business, where the felt is impregnated with bitumen and given various finishes by the roofing felt manufacturers. The use of asbestos fibres imparts dimensional stability and rot-proof characteristics to the felt and also accommodates slight movement (to adjacent sections of a wooden roof) without cracking.

Felts are also used as damp-proof courses, as once again dimensional stability and rot-proof qualities are needed.

Papers are used in the electrical industry for paper tubes and tapes and for thermal insulation. As some asbestos has a good resistance to electrical discharge, which allows it to be used in coil and conductor insulation wrapping, it can be impregnated with resins for electrical laminates, e.g. for switchboards. Special uses include electrofine paper giving high electrical resistance, based on fibres which have been subjected to special opening treatments and cleaning methods, and paper for use as the diaphragm in cells for the electrolysis of brine. Paper is also used in cylinder head gaskets of the copper/asbestos sandwich type. The main characteristics in these applications are the heat resistance and electrical resistance of the basic asbestos fibre.

Beater jointing materials

Made out of latex-bound asbestos papers, there are basically two main types:

1. Flooring and one-ply roofing substrates, where the main characteristics necessary are, once again, dimensional stability, durability with secondary characteristics of heat insulation and resistance to chemical attack —alkali in particular.

2. Automotive gasket materials. Chrysotile asbestos fibres are used in this context because they are dimensionally stable, resilient, resistant to chemical attack and also heat resistant, i.e. have the ability to maintain strength at high temperatures.







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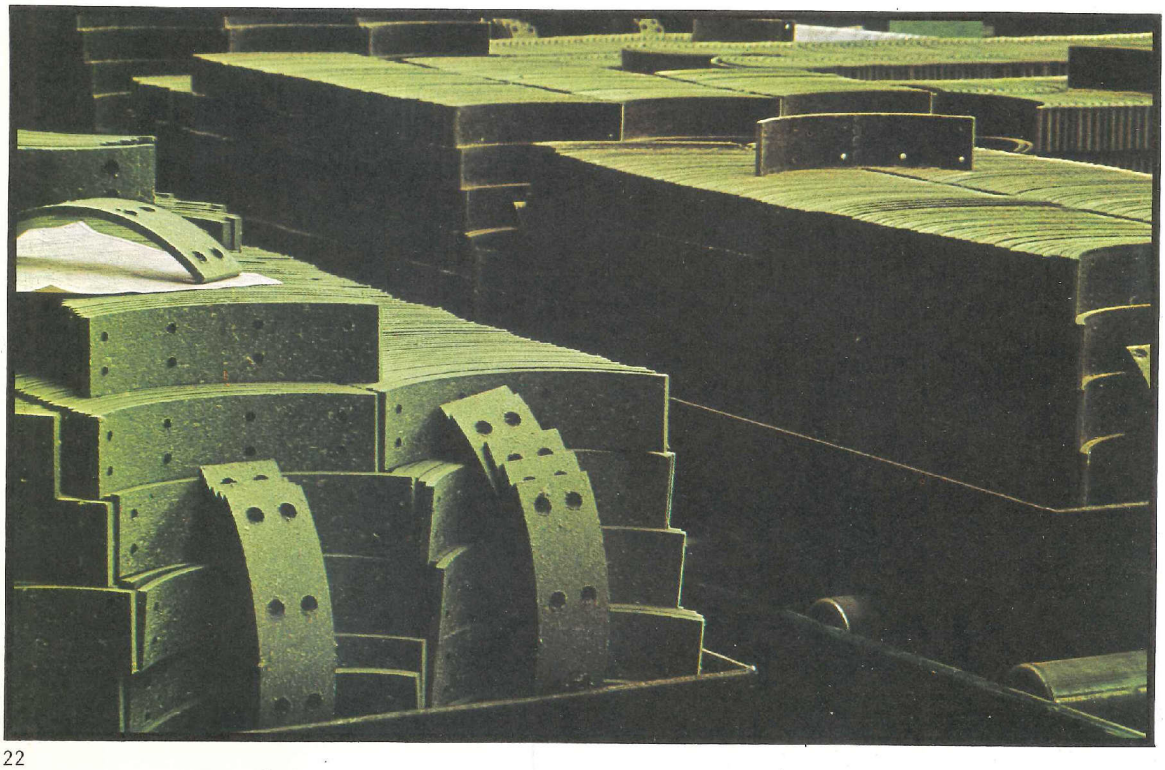
Brake and clutch linings

The first proper friction materials were based on cotton textiles and were a big improvement on the makeshifts which had been used previously. However, cotton has only a limited resistance to heat so these early materials could only be used at modest duty levels; with motor cars proliferating and getting faster, there was a need for something even better. A break-through was made in 1911 when asbestos textiles were first used instead of cotton materials as the basis for friction materials; as before, the cloth used was resin-bonded to achieve strength, wear resistance and a suitable friction level. Since asbestos does not burn, nor lose any of its strength until a temperature of 450° C has been exceeded, it was clearly a most suitable substance for the purpose.

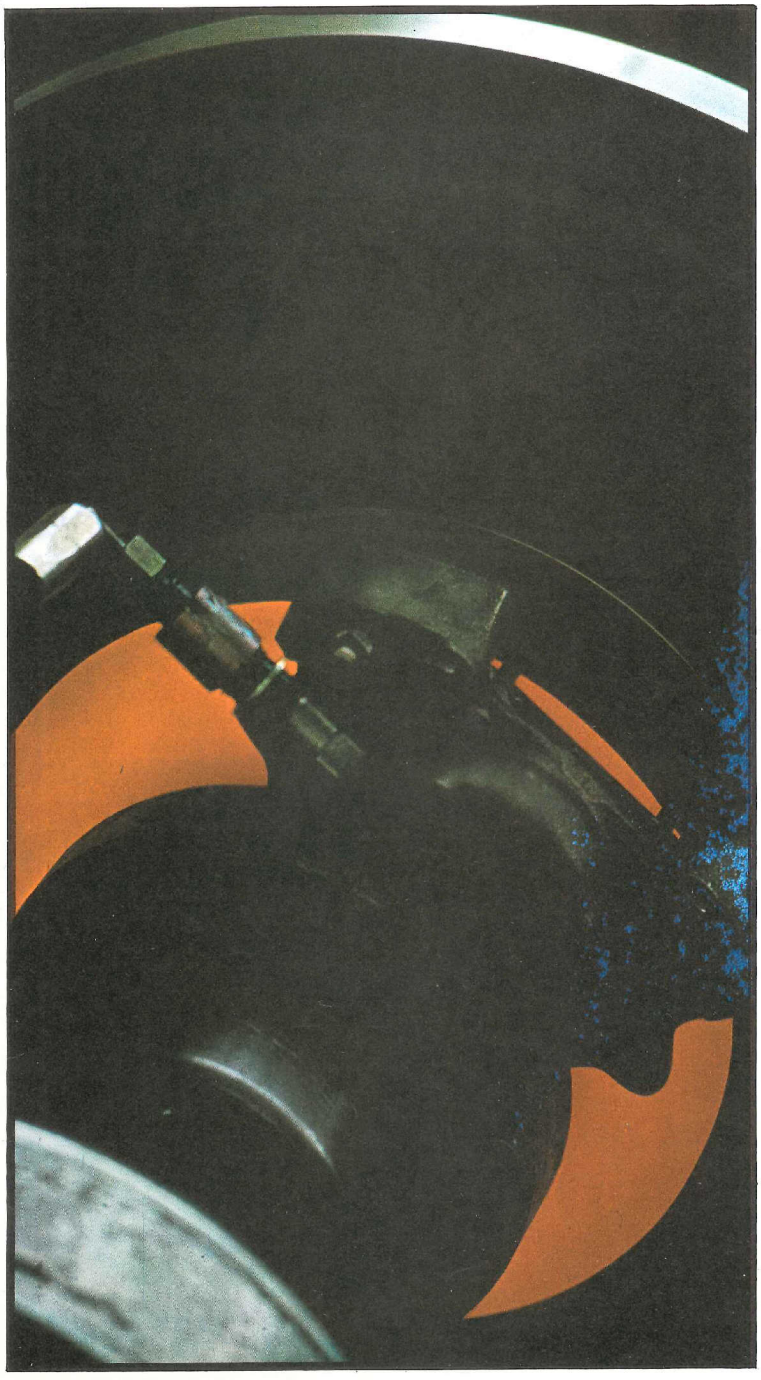
With continuing technical advances in automotive engineering, brake operating conditions became progressively more severe and the asbestos textile-based friction materials offered little scope for improvement; apart from looking for a better liquid impregnant, the only change that could be made was to include a suitably flexible wire of appropriate nature, such as brass or zinc, in the weft of the cloth. A further major development was, therefore, the introduction of moulded materials, based on random asbestos fibre in which many kinds of fillers could be included to give superior frictional properties and which could use a much wider range of resinous binders having better properties at the higher working temperatures being encountered. Textile based materials retained a large share of the automotive brake lining market until well into the 1950s, but the advantages of the moulded materials—which were continually being further improved—were such that the changeover was virtually complete before the end of that decade.

With the introduction of pad type disc brakes, the duty to which the linings were subjected increased again; working pressures and temperatures are commonly much higher because of the greatly reduced lining area. The need for asbestos fibre as a base is therefore greater than ever, it giving the linings strength to resist the thermal and physical stresses to which they are liable to a greater degree than ever before.

Another important use for asbestos-based friction materials is as clutch facings; in a typical automotive clutch application these may either be formed of resin impregnated asbestos cloth or wound yarn into which metal wire is incorporated, or moulded from a mixture of asbestos fibre, resin and other ingredients including metallic particles. The inherent temperature resistance of the asbestos enables these materials to stand up to the conditions which can occur when a clutch is slipped under load for long periods, as may sometimes occur.



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The asbestos used in all friction materials is chrysotile. All known substitutes for this fibre as a reinforcement are less efficient and less consistent. None is as cost effective. Glass fibre has lower strength, a low melting point and damages brake drums. Steel wool is expensive, has low strength and damages drums. Mineral fibre has very low strength and is brittle to an extent that limits the mixing process. Carbon fibre is vastly more expensive. The ultimate strength of asbestos fibre is 31×10^3 kg/cm^2. That of glass fibre is 14×10^3 kg/cm^2, of steel wool 7×10^3 kg/cm^2 and of mineral fibre 7×10^3 kg/cm^2.

Under the influence of heat, chrysotile asbestos decomposes rapidly by loss of water of crystallisation in the temperature range 500-600°C. The degradation product is forsterite, a member of the olivine series of iron magnesium silicates. The olivine series of minerals are unlike asbestos both physically and chemically and are non-fibrous. This explains how at the very high temperatures existing at frictionally effective points of contact between brake lining and the drum or disc, asbestos fibre largely decomposes during the time the brakes are applied. Certainly the amount of asbestos found in the dust arising from braking is rarely more than 1% of the wear products.

Sintered metal, ceramic and sinter-ceramic friction materials, which represent radical alternatives to asbestos/resin composites, carry certain inherent risks. Heat transference creates a risk of brake fluid boiling, tends to erratic behaviour on cars and creates inconsistent behaviour between cool and hot conditions.

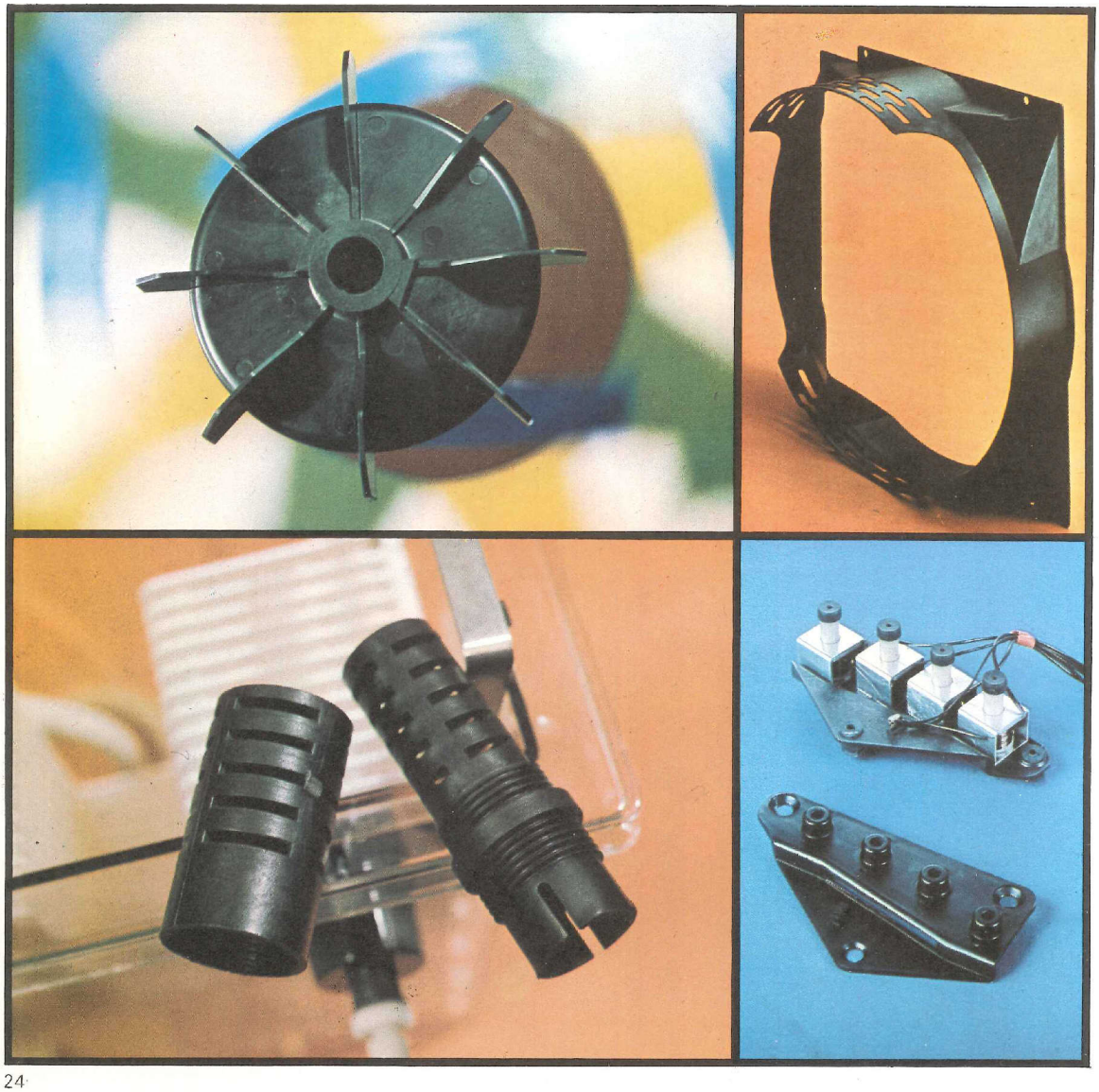
Opposite page
Moulded drum brake linings
Bottom right
Disc brake pad on test

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Asbestos composites

Composites are multi-component materials or structures in which the fibre is the load carrying member and the continuous material, or matrix, fills in the gaps between the fibres and distributes the applied stresses to the individual fibres. Floor tiles, asbestos-cement sheets and brake linings are three examples of composites in which asbestos is the reinforcing fibre. In composites such as reinforced plastics or metals, the matrix provides shape and a smooth surface to the component and protects the fibres against weathering, chemical attack and mechanical damage. The matrix may also be a thermal or electrical insulator.

If the fibre is to reinforce the matrix its properties must be superior to those of the matrix and in the case of asbestos-reinforced plastics, typical fibre/polymer strength ratios are of the order of 100 to 1 and typical modulus or stiffness ratios are of the order of between 20 and 40 to 1.



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Table 4 shows the strength and modulus of asbestos fibres compared with those of thermoplastics and thermoset polymers.

The organic textile fibres such as Nylon or Terylene are considerably lower in both strength and modulus and are used in cement and laminated plastics to impart toughness or in some cases, abrasion resistance. They do not impart high strength and stiffness as asbestos does.

One other factor which must be taken into account in choosing fibres for the reinforcement of polymers is that the fibres should not be soluble in or attacked by the resins and polymers, neither should they be softened by the polymer processing temperature. Asbestos fibres satisfy these criteria.

How fibres reinforce polymers

A composite material consists of fibre dispersed in a polymer matrix. The fibres may be aligned parallel to each other, as in some types of filament wound structures. They may be random in all three directions, as in a dough moulding compound or a reinforced thermoplastic, injection moulding compound. They may be in two directions at 90° to each other in the plane of a sheet, as in a woven cloth reinforced laminate, or they may be randomly oriented in the plane of a sheet, as in an asbestos felt reinforced polymer.

Whichever way they are oriented, the function of the fibres is to carry the loads and stresses applied to the composite. The function of the matrix is:

(*a*) to protect the fibre from loss of strength by abrasion.

(*b*) to separate the fibres and prevent a crack from passing directly from one fibre to another thus causing premature failure of the composite.

(*c*) to transfer the load on the composite to the fibres.

(*d*) to allow the fibres to be formed into a useful shape.

The strength (and modulus) of the composite is governed by the proportion and strength of the fibres it contains.

If the fibres are not parallel to each other, the potential strength of the composite is distributed in a number of directions. Many practical applications require strength in more than one direction and thus modified fibre orientations are used, with the inevitable penalty in strength in any particular direction.

Three other factors influence the performance of fibre reinforced composites.

(*a*) Fibre imperfections:
Because fibres contain flaws and surface cracks along their length, they fail at stresses lower than the maxima assumed for perfect fibres. When they fail, they then act as shorter discontinuous fibres which continue to provide reinforcement to an extent which depends on their residual length. Successive failures reduce the fibre length until they are too short to be held by the matrix, when the interfacial bond fails and they pull out.

(*b*) Fibre polymer bond strength:
The polymer matrix must not be so brittle that when the first fibres fail, the energy released causes the matrix to fail catastrophically. The matrix must be able to deform and dissipate the shock wave. It is also

Opposite
Asbestos-reinforced thermoplastics materials are used in a wide variety of products: (top) cooling fan and fan shroud; (bottom) water filter unit and door chimes

Table 4

Fibre and Polymer properties

Fibre	Tensile strength 10^3 kg/cm²	Tensile modulus 10^3 kg/cm²
Chrysotile	31	1680
Amosite	25	1650
Crocidolite	35	1900
For comparison		
Polymers	0·36–0·7	2–3
Mild steel	3·6	2100

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advantageous if the fibre/polymer bond can allow limited slip of the fibres so that the energy produced by an adjacent fibre breakage can be absorbed by a limited amount of debonding rather than causing further fibre breakage.

These effects control not only the realisable strength but also the toughness of a composite.

In commercial asbestos reinforced composites the energy absorbing characteristics are achieved partly by the use of particular resins as matrices and partly by the use of fibres which are coarse bundles of fine filaments. The fracture of an individual filament releases energy, of course, but this is dissipated by debonding along the length of adjacent filaments and the fibre bundle retains its reinforcing value.

(*c*) Fibre content:

There is a critical minimum fibre content below which the fibre does not provide reinforcement. When the concentration of fibre is so low that the fibres are widely separated, they weaken the matrix by acting both as stress concentrators, which can initiate cracks and as voids, i.e. volumes containing no matrix. The critical minimum fibre content depends on the ratio of the matrix strength to the fibre strength.

The physical characteristics of fibres

Asbestos fibres have very small diameters and large length/diameter ratios as shown in Table 5. Asbestos exists in the form of bundles of varying diameter (fibres) each consisting of hundreds or thousands of very fine fibrils bonded together by an amorphous cement. This is a unique structure, unlike any of the synthetic fibres, and is responsible for the particular properties of asbestos. The fibres can be separated by chemical or mechanical means into individual fibrils or smaller bundles of fibrils.

Composites reinforced with asbestos will be stiffer (of higher modulus) than those reinforced with glass fibre and, as the outstanding differences between reinforced plastics and metals is their stiffness, this property of asbestos reinforcement is commercially attractive.

Secondary reinforcement forms and their applications

(*a*) Chopped yarns and short discontinuous fibres:

Fibres in this form are used for the reinforcement of phenolic, polyester and epoxide thermosetting resins and the whole range of thermoplastic polymers. The reinforced moulding compounds are produced by intensive mixing of the fibres and liquid resins in the case of the thermosets. In the case of the thermoplastics the fibre is mixed with the molten polymer. In both cases the work carried out on the fibres must be controlled to minimise damage to them.

The advantage of a short fibre reinforced moulding compound lies in its ability to be moulded into intricate shapes. Alignment of fibres in the mouldings is basically random with some degree of orientation due to flow patterns during filling of the mould.

(*b*) Random mats and felts:

Because of the random alignment of fibres in the plane of the sheet, this type of reinforcement offers users isotropic strength properties in a component and has thus become one of the most popular methods of using asbestos fibres.

Asbestos felts consist of partially aligned fine fibres held together by mechanical entanglement to form a dense web which necessitates the use of low viscosity resin solutions to produce impregnation and wetting of the fibres. The resulting composites exhibit very high strength and stiffness due to the fine fibres, the homogeneous fibre dispersion and the planar alignment of the fibres in the polymer.

Recent developments in alignment techniques for asbestos fibres have produced sheets showing increased degrees of alignment and very high strength and modulus figures in the direction of alignment. Such products are not yet commercially available, but the level of properties which can be obtained is shown in a later table. Such products will no doubt find uses in engineering and aircraft applications where strength and stiffness-to-weight ratios are important and where their low density compared with metals is an advantage.

Table 5
Physical characteristics of fibres

Fibre type	Fibre diameter μm	Fibre length μm	Density g/cm³
Glass	10	Continuous	2·5
Carbon	7	Continuous	1·5–2·0
Boron	102	—	2·6
Asbestos fibre	0·03–100	1000–30,000	2·5
fibril	0·03	250–5,000	2·5
Silicon carbide	1–3	1–100	3·2

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(*c*) Woven cloths:

The packing of asbestos fibres in a cloth is much denser than in a random mat and cloths therefore offer the laminator a means of obtaining high fibre contents in a moulding, with the resultant high strength, stiffness and toughness.

The yarns in a woven cloth are crimped as they pass over and under other yarns. The crimp provides a greater surface area to the cloth which improves inter-laminar bonding. On the other hand the crimp disturbs the alignment of the fibres in the plane of the sheet and this reduces the composite strength. In a plain weave cloth, there may in fact be no significant portion of the yarns which lie parallel to the plane of the laminate. To minimise crimp many weave variations are available which provide warp yarns which pass over and under the weft only at every second, fourth or eighth weft yarn thus providing long sections of straight yarns in the plane of the sheet. With the correct selection of weave pattern it is possible to obtain an acceptable balance of properties in the plane of the sheet and in interlaminar cohesions.



Top
Road signs manufactured from asbestos-reinforced pvc sheets

Bottom
Asbestos-reinforced plastics provide high performance components for modern aircraft

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Table 6
Mechanical properties of composites

Material type	Tensile strength 10^3 kg/cm²	Tensile modulus 10^3 kg/cm²	Impact strength Joules per cm of notch	Density g/cm³	Comments
Unreinforced polymer	0·36–0·71	7·1–34	0·7–52	0·9–1·5	
Asbestos fibre reinforced nylon	1·3	124	4·1	1·37	Random alignment
Glass fibre reinforced nylon	1·45	84	6·9	1·33	Random alignment
Glass mat reinforced polyester	0·87	105	34·4	1·60	Random alignment in the plane of the sheet
Asbestos reinforced PVC sheet	1·07	175	12·1	1·65	Random alignment in the plane of the sheet
Asbestos felt reinforced phenolic (I)	2·80	246	17·2	1·75	Random alignment in the plane of the sheet
Asbestos felt reinforced phenolic (II)	4·80	759	24·1	1·90	Near parallel alignment
Glass yarn cloth reinforced polyester	2·80	168	50–100	1·80	Cross plied alignment in the plane of the sheet
Glass woven roving reinforced polyester	3·20	168	85–170	1·80	Cross plied alignment in the plane of the sheet
Glass fibre roving reinforced polyester	8·41–10·4	352	70	1·80	Parallel alignment
Carbon fibre reinforced epoxide	9·17–12·7	1427–1732	35–70	1·50	Parallel alignment
Aluminium alloy sheet	2·09	71·4	85	2·7	
Mild steel sheet	3–52	2141	170	7·8	

Properties of fibre reinforced composites

Tables 6 and 7 show the mechanical properties of composites containing various fibres and reinforcements. These illustrate one of the advantages of reinforced plastics materials compared with metals. There are of course many others such as corrosion resistance, colour possibilities, ease of moulding complicated shapes, electrical resistance, low thermal conductivity and in the special case of asbestos-reinforced composites, resistance to ablative conditions as in rocket motors and nose cones, resistance to fire and resistance to deformation at high temperatures.

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Table 7

Specific strengths and moduli of materials (strength/specific gravity)

Material	Specific tensile strength 10^3 kg/cm²	Specific tensile modulus 10^3 kg/cm²	Material	Specific tensile strength 10^3 kg/cm²	Specific tensile modulus 10^3 kg/cm²
Unreinforced polymers	0·4	17	Glass yarn cloth reinforced polyester	1·55	92
Asbestos-reinforced nylon	0·95	90	Glass woven roving cloth reinforced polyester	1·7	92
Glass fibre reinforced nylon	1·1	64	Parallel glass fibre reinforced polyester	5	193
Glass mat reinforced polyester	0·5	65	Parallel carbon fibre reinforced epoxide	7	1050
Asbestos-reinforced PVC sheet	0·6	105	Aluminium sheet	0·75	255
Asbestos felt reinforced phenolic (I)	1·6	165	Mild steel sheet	0·45	265
Asbestos felt reinforced phenolic (II)	2·55	393			

New materials

The search for stronger, stiffer, lower density and cheaper fibres continues in many laboratories throughout the world, but although many new fibres have been developed, few are cheap enough to compete with asbestos fibres for commercial applications.

Although asbestos fibres have been in use for many years as the reinforcement for thermoset polymers, new techniques of fibre preparation and alignment and new systems of fibre/polymer bonding are providing asbestos-reinforced products with improved combinations of properties. The new materials are opening up extended fields of application and asbestos is thus rapidly gaining acceptance as a reinforcing fibre for high performance, relatively low cost composites.

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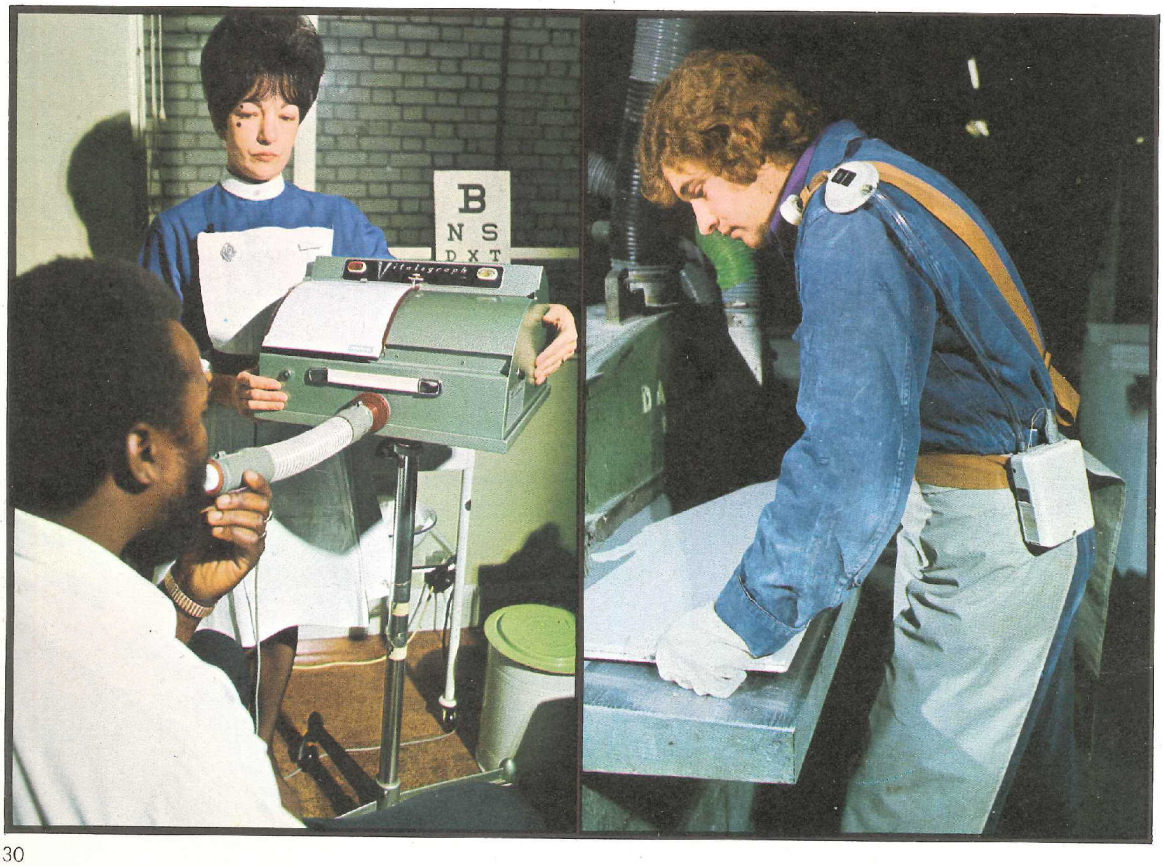
Asbestos and health

Much has been written and spoken about the health hazards of using asbestos products and the need to seek alternative materials in order to obviate such a hazard. Experience shows that this is easier said than done. Many materials tried as alternatives have failed in performance, and clearly substitutes should themselves be free from any kind of danger in use. In any case, the asbestos industry, as a result of its now long experience over a wide range of manufacture, is confident that many asbestos products are quite harmless in use, for example where the fibre is encapsulated in a rubber binder or synthetic resin, or thoroughly impregnated with a lubricant, and that others can be used without risk provided that certain practical precautions are taken.

A health hazard may arise in some occupations where heavy concentrations of asbestos dust are combined with prolonged exposure for the individual. Many of the cases now being diagnosed originated in conditions thirty or more years ago when, in some instances, the standards of hygiene and of dust control were much lower than they are today. Indeed, many occupations involving heavy dust exposure, such as stripping and fitting insulation, were not subject to control or the personal protection of workers at all.

Initial screening for medical fitness and continued surveillance of the health of people working with asbestos has long been the practice in the asbestos manufacturing industry and this form of medical care is now being extended in the UK by means of the Employment Medical Advisory Service to all people who come within the jurisdiction of the Asbestos Regulations 1969. The medical examination included under these schemes include periodic X-ray examination and in many cases measurement of lung capacity.

The formulation of the Asbestos Regulations1969 established a statutory responsibility to identify those operations where precautions are necessary and laid down rules for the protection of workers in those cases. The Asbestosis Research Council has been foremost in the development of methods of sampling and monitoring environments where asbestos dust may be produced and its Technical



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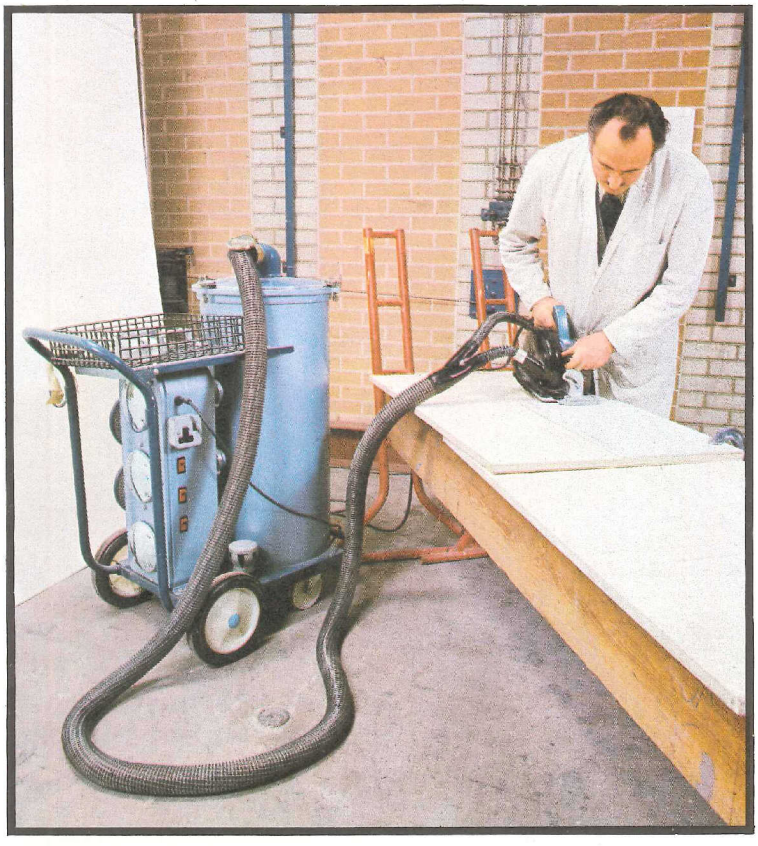
Notes explaining these methods of sampling have been internationally accepted and have been recommended by the International Labour Organisation as the basis for international comparisons. The identification of operations where the protection of workers is required is achieved by these methods and enable the Asbestos Regulations to be appropriately applied. These Regulations are explained and amplified in the form of practical work procedures and methods by such publications as the Asbestosis Research Council's Control and Safety Guides and Codes of Practice* and ensure that all who work with asbestos are protected from health hazards which may arise from the inhalation of asbestos dust.

*Available from The Secretary
Environmental Control Committee
Asbestosis Research Council
114 Park Street
London W1Y 4AB

Opposite left
A worker tests his lung capacity by breathing into a lung function machine

Opposite right
Personal samples are taken regularly in asbestos factories to determine the dust content of air inhaled by workers

Below
Dust extraction equipment being used in cutting asbestos sheets



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