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THE ASBESTOS INDUSTRY

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MODE OF OCCURRENCE

From the discussion of origin, it is evident that there are three types of asbestos deposits — cross fiber, slip fiber, and mass fiber. Cross-fiber asbestos consists of innumerable strands extending across veins from wall to wall, except where interrupted by longitudinal seams. Most commercial deposits of chrysotile, amosite, and crocidolite are of this type, but anthophyllite rarely, if ever, occurs in cross-fiber veins. In slip-fiber deposits the strands more or less parallel the vein walls. They frequently show slickensided surfaces because they occupy shear zones where the rock has been subjected to movement and pressure. Slip fiber is common in the chrysotile deposits near Eden, Vt., and predominates in the anthophyllite deposits near Bedford and Rocky Mount, Va.

In mass-fiber deposits there is no definite orientation of fibers. Almost the entire mass of the rock is composed of bundles of fibers or needles that sometimes show a radiating structure. This type of occurrence is confined almost exclusively to the anthophyllite variety and is well exemplified by deposits at Hollywood and Buck Mountain, Ga., and Kamiah, Idaho.

PHYSICAL PROPERTIES

FIBROUS CHARACTER

The outstanding physical characteristic of asbestos is its fibrous structure. Other important fibers found in nature are those of animal origin, such as wool and silk, and those of vegetable origin, examples of which are cotton and flax. Nonflammability is one of the striking differences between asbestos and the fibrous products of animal or vegetable origin. Of perhaps equal importance is the difference in structure. Each filament of cotton, wool, or silk is of measurable and fairly constant diameter and is indivisible into finer sizes. On the other hand, fibers of chrysotile asbestos can be divided and subdivided until a fineness is attained that is limited only by the delicacy of the machinery used and the skill of manipulation. The ultimate fiber size is presumably the size of the ultimate molecule or crystal lattice of asbestos. In other words, fiberization is a cleavage process, and cleavage in minerals is defined as a tendency to split in a certain direction, that is, to separate along and between layers of molecules.

From the standpoint of use, fiber size (diameter) is important, and the diameter will depend upon the degree of fiberization attained in the milling process. Fibers obtained from different deposits vary in the ease with which they may be fiberized. Thus, two samples of chrysotile asbestos, given exactly the same mill treatment, may furnish products differing considerably in fiber diameter, because one of them separates or fiberizes more easily than the other. Such differences may have great practical importance, because an asbestos having difficult cleavage may require such intense milling to reduce the fibers to desirable fineness that they may be broken into undesirable short lengths. Ease or difficulty of fiberization is therefore an important property of asbestos.

Experiments by Raybestos-Manhattan, Inc., in 1952 on samples of Rhodesian chrysotile, one dark with a total iron content of 2.486 percent and one a light type with 1.939 total iron, disclosed that the darker material requires much more time and energy to fiberize than the lower iron type.

The uses to which a chrysotile asbestos may be applied are governed primarily by length of fiber. The longest fibers command the highest prices, and prices are progressively lower for the shorter grades. It is apparent, therefore, that primary attention must be given to milling processes that will separate the fibers from the parent rock and will fiberize them adequately with a minimum of fiber breakage.

COLOR AND LUSTER

Chrysotile occurs in various shades of green or yellowish green. When fiberized into a fluffy mass, all types of chrysotile are virtually white, unless stained by impurities. Amosite ranges from gray or yellowish gray to white and, if relatively pure, is white when fiberized. Crocidolite is lavender blue, and this color is maintained when the fibers are separated. Anthophyllite and tremolite are gray, greenish gray, or white, and the separated fibers are white unless staining impurities are present. The luster of asbestos usually is silky or pearly.

HEAT RESISTANCE

The heat resistance of asbestos is important in many applications. Some users of asbestos tend to confuse nonflammability with refractoriness. Many substances that will not burn will, nevertheless, melt or decompose at relatively low temperatures. The fireproof property of asbestos is one of its chief assets; but, although unburnable, it will decompose and lose its essential physical properties at moderately high temperatures. The concept of asbestos as a highly refractory substance has been created in the minds of some students of the subject by reading the statement made by Cirkel[1] that temperatures of 2,000° to 3,000° F. are easily withstood, while with some varieties a temperature of 5,000° F. has apparently produced no visible effects. With due respect to Dr. Cirkel, who wrote a splendid pioneer volume on a mineral of which little was known at that time, he was in error regarding the heat resistance of chrysotile.

Brandenberger and others[2] who have made a comprehensive study of temperature effects of chrysotile at the Mineralogical Institute of the University of Zurich, state that the so-called adsorbed water of chrysotile is driven off at about 300° C. Between 550° and 600° C. all of the water of crystallization is driven off, and the mineral gradually alters to olivine. A pronounced change in physical properties accompanies this dehydration. At 400° C. there is a notable deterioration in fiber quality; and above 550° C., with more or less complete dehydration, chrysotile is completely decomposed. The amphibole varieties of asbestos will withstand somewhat higher temperatures than chrysotile; however, crocidolite, although having a low water content, is easily fused into a black, magnetic mass.

HEAT CONDUCTIVITY

Asbestos does not have low heat conductivity. Its value for heat insulation is due to its nonflammability and also to its fibrous structure, which adapt it for manufacture into coverings that are nonconductors of heat because of their porous nature.

CHEMICAL RESISTANCE

Tremolite and anthophyllite are highly resistant to chemicals. It is claimed that crocidolite resists chemicals and sea water remarkably well. Chrysotile is affected more readily by acids and other chemicals than are the amphibole varieties.

ELECTRICAL RESISTANCE

Varieties of chrysotile lowest in iron content are most suitable for electrical insulation. Arizona chrysotile is superior for this use. Apparently the iron content of amphibole does not affect its use for this purpose because crocidolite, which upon analysis shows a content of about 35 percent FeO, has high electrical resistance. This seeming contradiction may be explained by the fact that iron is present in crocidolite as a silicate, whereas in chrysotile it commonly appears as iron oxide impurities.

SPECIFIC GRAVITY

The specific gravity of pure chrysotile is 2.22, but that of the commercial fiber is always higher because of the presence of impurities. The specific gravity of Canadian chrysotile ranges from 2.54 to 2.59; and the Arizona fiber, being lower in iron, has a specific gravity of 2.47. Tests recently made by the Bureau of Mines at Tucson, Ariz., on fiber selected with great care to eliminate impurities gave somewhat lower figures—a 2.38 average for Arizona chrysotile and 2.48 for one sample from Quebec, Canada. The specific gravity of anthophyllite ranges from 3.1 to 3.2, and that of crocidolite is still heavier, ranging from 3.2 to 3.3.

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[1] Cirkel, Fritz, Chrysotile Asbestos, Its Occurrence, Exploitation, Milling, and Uses: Canada Dept. Mines, Mines Branch, 2d ed., 1910, p. [illegible]

[2] Brandenberger, E., Epprecht, W., and Niggli, P., [The Serpentine Minerals and Their Synthesis II]: Helv. chim. acta, vol. 30, 1947, pp. [illegible] (trans. by Frank Rourkan, Jr.)

A fibrous material resembling cotton, silk, or wool but having the added quality of nonflammability satisfies a multitude of needs so admirably that it is difficult to find satisfactory substitutes therefor. A shortage of asbestos is a strong incentive for seeking substitutes. Germany's virtual isolation from sources of asbestos during World War II prompted a great deal of experimentation on possible substitutes. Materials tested included glass wool, steel wool, iron wire, synthetic rubber, organic plastics, cellulose, and treated paper. Some of the so-called substitutes were so unsatisfactory that no further mention will be made of them. The worldwide shortage of asbestos during and after World War II led to extensive research on possible substitutes in the United States and other countries. Consideration is given to individual substitutes as follows:

SODA-LIME-SILICA-GLASS FIBERS

The development of a fiber-glass industry opened up a promising field for substitution because glass fibers, like asbestos, will not burn. However, as will be pointed out later, glass fibers may lack certain physical or chemical characteristics inherent in asbestos and consequently fail to satisfy the exacting specifications that must be met for most uses. For other uses they may be satisfactory. Glass and related fibers are manufactured in two basic forms—a wool-like material and a filament. Rock wool, glass wool, and slag wool are used primarily as lightweight thermal insulation, such as house fill. Such applications in general are not substitutes for asbestos. Glass filaments made by more refined processes, involving the use of platinum dies, are of high quality and uniform size. Some are less than one-half micron in diameter and are adaptable to highly specialized uses, such as weaving into fabrics. Attempts have been made to use glass fibers in place of asbestos in asbestos-cement products; but such tests have given unsatisfactory results, chiefly because of a chemical reaction between the glass and cement, which decomposes the fibers and destroys their effective strength.

Neither glass filaments nor cloth woven from them resists high temperatures. The fibers will not burn, but they will soften and coalesce when the temperature reaches a certain point, and this point varies, depending upon the composition of the glass. The organic film used on woven-glass textiles will decompose and volatilize at about 300° C., and its loss impairs the effectiveness of the fabric to some extent. Normally, glass resists weathering very well. Windowpanes generally show no weathering effects, even after many decades of use. However, the surface area per unit volume of very fine glass fibers is so great that exposure to water vapor results in relatively rapid deterioration.

Glass and mineral-wool fibers are efficient thermal insulators in various types of equipment, such as stoves and refrigerators, where temperatures are moderate and corrosive conditions are not encountered. The high tensile strength, the greater thermal stability compared with organic fibers, and the electrical resistance of glass fibers make them suitable for electrical insulation, such as sleeving for wire and tapes for the construction of some types of motors. Fiber glass is used to some extent in conjunction with, or as a substitute for, asbestos in Navy cable insulation. It is claimed, however, that asbestos insulation permits greater flexibility in finished cables than can be obtained with fiberglass insulation. Glass fibers are said to be unsatisfactory for cable filler (material that fills in the spaces in a group of insulated cables), but recent improvements in glass fibers promise future satisfactory use. Very thin glass-fiber paper may find advantageous use in condensers for electronic equipment; for instance, its use may make it possible to reduce the size of the condensers.

A glass-asbestos cloth was designed during World War II to extend the supply of asbestos-textile fibers. It has continued in use as a covering on thermal insulation applied to piping on naval vessels. It is woven with a plied yarn having one strand each of glass and asbestos yarn.

United States Rubber Co. has announced production of a new fabric named "Asbeston," consisting of interwoven glass and asbestos yarns. It is said to be well adapted for theater curtains as well as for fireproof draperies in schools, hospitals, libraries, hotels, and ships.[1]

Coarse glass fibers compressed into batts are efficient lightweight air filters that are used extensively for cleaning large volumes of air. Asbestos is not widely used in this field, but blue asbestos has found important use in gas-mask filters. The Naval Research Laboratory has found that glass fibers make superior gas filters. In recent gas-mask tests in a smoke-filled room, only 1 particle in 100,000 passed through the filter; at the same time, the mask caused no increase in normal breathing resistance. Glass filter paper is said to be "5,000 times more effective than present commercially

[1] Asbeston, Draperies of Asbestos Glass Fabric: Vol. 31, No. 10, April 1950, p. 8.

available filters." The filter paper can be made in any ordinary paper mill.[2] Fiber glass may, therefore, displace blue asbestos in Navy gas masks. It has been claimed, however, that blue asbestos is more satisfactory than glass fibers for civilian gas masks and for those used by the Army.

A considerable part of the present production of fiber glass is being applied to military uses. Many manufacturers of electric insulating materials are listed as users of fiber glass, for instance, manufacturers of asbestos cloth and tapes, laminates, varnished tubing, magnet-wire covering, and mica insulating products. Fiber glass was widely used during World War II for heat, sound, and electric insulation on aircraft. Over 90 percent of the output during World War II was used for military or essential civilian use.

The use of fiber glass as a substitute for asbestos in friction equipment has, in general, given unsatisfactory results. No published information on comparative tests of fiber glass and asbestos in brakebands appears to be available, but verbal statements by those who have made such tests indicate that the principal objection to fiber glass is its rapid abrasion of brake drums.

As fiber glass can replace asbestos in certain fields of application, its future availability is of first importance. It had been claimed that the process of manufacturing fiber glass is controlled by a single company—the Owens-Corning Fiberglas Corp. Such a claim is not now correct. Glass Fibers, Inc., Waterville, Ohio, has its own process for making fibers suited for glass-fabric manufacture, and Glass Floss Corp., Long Island, N. Y., has developed a process for making bonded mats and air filters. In addition to these independent concerns, the following companies operate under license from Owens-Corning Fiberglas Corp.: Gustin-Bacon Manufacturing Co., Kansas City, Mo.; Libbey-Owens-Ford Glass Co., Parkersburg, W. Va.; Pittsburg Plate Glass Co., Shelbyville, Ind.; and Ferro Corp., Nashville, Tenn.

The parent company, Owens-Corning Fiberglas Corp., has increased its capacity greatly. It now has plants manufacturing fiber-glass textiles at Ashton, R. I., Huntingdon, Pa., and Anderson, S. C., the latter plant came into production in July 1951. The company also has four plants making nontextile fiber-glass products, such as block and blanket insulation and pipe covering. These plants are at Newark, Ohio; Kansas City, Kans.; Santa Clara, Calif.; and Sarnia, Ontario, Canada.

The expansion in fiber-glass manufacture indicated in preceding paragraphs would indicate a growing capability of the industry to provide for prospective future needs.

A question has been raised as to the limitations on fiber-glass manufacture imposed by the need for platinum. At one stage in the principal process of fiber-glass manufacture, the molten glass is drawn through perforations in a platinum-bottomed cell or bushing, and it appears that no other substance can be substituted for the platinum so used. Because platinum is produced in limited quantities—a world production of about 500,000 troy ounces a year—and has wide scientific and industrial uses, its availability for wider application in this industry deserves careful consideration. Platinum is a critical material during war periods. Three important circumstances tend to relieve, to some extent, the threat of a possible shortage.

1. There is very little loss of platinum during fiber-glass manufacture. The holes through which the fibers are drawn will gradually enlarge, and the platinum bushing will accordingly have to be rebuilt, using the same platinum. Care is taken to recover any dust or fragments of platinum. The first installation is the important consideration, but subsequent replacement of losses is very small.

2. Research is being conducted constantly to find ways of reducing the quantity of platinum required in each bushing. Presumably some saving will be accomplished.

3. Research is also underway on possible substitution of some less costly and more abundant substance for platinum. Limited progress has been made, and there is at least some promise of success.

Another raw material essential to fiber-glass manufacture that may be in short supply in times of emergency is cryolite, sodium-aluminum fluoride (Na_3AlF_6), which is mined only in Greenland. The supply, however, is augmented by artificial cryolite manufactured from fluorspar. If supplies of both these materials are limited, sodium silicofluoride may be substituted; but, as this commodity also is a derivative of fluorspar, it may likewise fall in the category of scarce materials.

Under normal industrial conditions the supply of both fluorspar derivatives and platinum would appear to be adequate for a moderate expansion in fiber-glass manufacture. Most of the raw materials used are plentiful.

HIGH-SILICA GLASS FIBERS

Glass fibers approximating vitreous silica in composition are superior to soda-lime-silica glass fibers in resistance to deterioration from the action of water vapor and to high tempera-

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[2] Office of Public Information, Department of Defense. Glass-Fiber Filter Insulator Developed by Naval Laboratory: Dec. 7, 1950.

tures, but their manufacture is a difficult problem. Fused silica is so viscous, even at temperatures as high as 1,700° C., that its manufacture into thin filaments is almost impossible. To overcome this high viscosity, fluxes are added, the fibers are made, and the fluxes are then removed. Several methods are used, but they are similar in principle. First, filaments are formed from an easily workable composition, such as an alkali silicate. Second, the alkali or flux in the filament is removed by leaching or ionic substitution. The resulting fibers are relatively porous and of high silica content. They will withstand, with little deterioration, temperatures exceeding 1,000° C. The minimum diameter of high-silica fibers on which data are now available is about 2 microns, and the average is much greater. On the other hand, natural asbestos fibers are only a fraction of 1 micron in diameter. Correspondingly, the silica fibers are much less flexible than natural chrysotile. If finer fibers can be made by improvements in processing, this difficulty may be overcome to some extent. Because of their high moisture resistance and ability to withstand high temperatures, the vitreous silica filaments undoubtedly can be substituted for asbestos in some applications, but it is doubtful that they can replace asbestos where flexibility or elasticity is a prime consideration. Furthermore, the cost of manufacture is very high.

Dr. Rudolf Leutz claimed to be the inventor of a process for making synthetic asbestos in Germany. His product, however, could not be called synthetic asbestos because its base was sodium silicate, and an analysis of the final product indicated that it consisted of over 97 percent SiO_2. It was, in fact, a silica-glass fiber. Three companies were licensed to manufacture this product in 1943, but because of the military reverses suffered by Germany no progress was made.[3]

OTHER SILICEOUS FIBERS

A new series of aluminum silicate fibers, made by the mineral-wool process after fusion by means of an electric arc, has been developed. This process has the decided advantage of eliminating the use of platinum. The products, which are available under various trade names, have thermal stabilities in the order of 2,300° F. They have been successfully employed where extremely high temperatures are encountered and where glass fibers are unsatisfactory, as in jet aircraft. Possible substitution of these new fibers for asbestos in cable coverings and electronics is being explored. Uses extensive enough to justify commercial production have been established.[4]

Both high-silica glass (quartz) and ceramic (aluminum silicate) fibers have been used successfully by the Naval Research Laboratory, Washington, D. C., for making paper that has superior properties for electrical insulation. A regular papermaking machine can be used if the fibers are of fine sizes and properly purified. Quartz paper is said to withstand temperatures up to 3,000° F. and ceramic paper 2,500° F., whereas the upper limit of asbestos paper is not more than 1,000° F.[5]

Hydrous calcium silicate is another insulating material used to quite an extent during the past 10 years, particularly as an alternate for 85-percent magnesia where high temperatures are involved. It will give satisfactory service up to 1,200° F.

It was reported in February 1952 that Glass Fibers, Inc., Toledo, Ohio, had developed a process for making pure quartz fibers in submicron sizes.

ORGANIC SUBSTITUTES

German scientists attempted to manufacture yarn using short-fiber asbestos mixed with long organic fibers such as cotton, cellulose, or synthetics, but the product obtained was very weak.[6] Cardboard with an organic plastic was used in Germany as a substitute for asbestos packing in flanges of steam and water pipes. This packing was satisfactory for pressures up to 5 atmospheres and temperatures up to 160° C. It is stated that substitutes for asbestos in high-pressure packings have not been successful and that all substitutes developed and used up to 1944 were inferior to asbestos.[7]

A diaphragm of Perlon paper coated with barite paste was tried by I. G. Farbenindustrie as a substitute for asbestos cloth as a diaphragm in a Siemens-Billiter cell in the manufacture of NaOH by electrolysis of NaCl solution. It failed within 30 minutes. Perlon is a German synthetic fiber similar to nylon. However, a polyvinyl chloride diaphragm gave results equal to those obtained with asbestos cloth.[8]

Although reports are somewhat conflicting, polyvinyl fibers appear to be inferior to asbestos in asbestos-cement products. Silicone rubber has been used successfully as a wire covering in certain applications.

[3] FIAT. Technical and Scientific Developments Related to the Asbestos Industry in Germany: Final Report 1070, 1947.

[4] Chemical Engineering. Ceramic Fiber Resists 2,300° F.: Vol. 59, No. 9, September 1952, p. 195.

[5] Chemical Engineering. Insulating Papers vs. Asbestos: Vol. 59, No. 7, July 1952, p. 245.

[6] Blakely, J. D., Dawson, E. L., Gaze, R., and Henderson, M. B., BIOS Final Report 404 PB 34622, 1945.

[7] Krannich, W., I. G. Farbenindustrie A.-G., Ludwigshafen, PB 32025, 1944, pp. 175–181.

[8] Lichenwirth, I. G. Farbenindustrie A.-G., Ludwigshafen, PBL-70315, FIAT Reel —, B-31 Fr 40634-5.

SUBSTITUTES FOR AMOSITE

As indicated elsewhere, an important use for amosite is for the manufacture of light, fluffy insulation for use on marine turbines and jet planes. The fluffiness appears to be a function of fiber diameter; the finer fibers show the higher degree of thermal efficiency per unit weight. Accordingly, it has been found that fiber glass having diameters of less than 1 micron has a thermal efficiency comparable with that of amosite. However, an ordinary lime-soda glass has too low a thermal efficiency for the specialized insulation uses of amosite. Aluminum silicate fibers mentioned in a previous paragraph have melting points as high as 2,300° F., which is much higher than the temperature at which amosite disintegrates. Such fibers, now being made in submicron sizes, are said to be satisfactory substitutes for amosite, but their cost is 5 or 6 times as great.

Some progress has been made in substituting fiber glass for amosite in making 85-percent magnesia insulation.

SUMMARY OF CONCLUSIONS ON SUBSTITUTES

Other materials may be substituted for asbestos in some fields of use. Glass fibers are satisfactory thermal insulators for low-temperature equipment and other applications in which the fibers are not exposed to water vapor or continued flexure. Glass fibers are good electric insulators and therefore are used to some extent for wire covering and similar applications. Vitreous silica fibers will withstand more severe weathering conditions and higher temperatures than the soda-lime-silica glass fibers, but their manufacture is difficult. Moreover, their flexibility is much inferior to that of asbestos but is improved as processes for making finer size fibers are developed.

Glass fibers are now substituted to some extent for long-fiber chrysotile in cable coverings and fabrics, and more extensive substitution is anticipated. Shortage of platinum might, in an emergency, limit the available supply of fiber glass. The glass fabrics, or the combined glass-asbestos fabrics, have some advantages over asbestos fabrics in lighter weight per square yard and in strength, but they are generally inferior to asbestos fabrics in resistance to high temperatures, flexure, and chemical action. The processing of combined glass-asbestos fabrics introduces problems affecting the comfort of workers, because glass fibers cause skin irritation. Extremely fine fibers create less irritation than the coarser ones.

Glass fibers in submicron sizes are much more costly than asbestos. With improvement in quality and substantial reduction in cost of manufacture, a wider substitution of fiber glass for asbestos is forecast.

In some applications where the temperatures encountered are low and where chemical resistance is not important, organic fibers are satisfactory substitutes.[9]

[9] Data on substitutes included in this discussion were supplied in part by Jay E. Comeforo, Electrotechnical Laboratory, Bureau of Mines, Norris, Tenn.