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# Asbestos, A Mineral of Unparalleled Properties

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## Introduction

THE DEMAND for general knowledge on asbestos fibres has increased considerably in recent years. A few publications have printed data showing some of the physical and chemical properties of asbestos, but in many cases this information is difficult to find and is seldom available when needed.

During the past ten years, Johns-Manville have received many inquiries on the physical and chemical properties of asbestos fibres. Fortunately, we have had some of the information in our files, and we willingly supplied the data.

To help relieve this need, we have tried to present briefly in this paper some of the interesting and outstanding properties of asbestos. This information was obtained over a period of years by search of the literature and by experimental investigations.

## Properties of Asbestos Fibres

Table I (1, 2) presents, in convenient form for easy comparison, data on the principal properties of the several varieties of commercial 'asbestos' — actinolite, amosite, anthophyllite, chrysotile, crocidolite, and tremolite. Under each variety of fibre is a brief statement describing the properties in terms of structure, mineral association, origin, etc. Some of the more important data in Table I are expanded and presented in Table II (3).

## Solubility of Asbestos

A report (4, 5) discussing the effects of acids and caustic on asbestos fibres was published in Germany in 1927. Re-published several times, it appears to be the only information available on the subject.

When, several years ago, it became necessary to obtain technical data, not available in the literature, on the solubility of commercial grades of asbestos, tests were arranged following the plan adopted by the author of the original article (4).

Samples were obtained of actinolite from Canada amosite from Africa, anthophyllite from Georgia, chrysotile from Canada, crocidolite from Africa, and tremolite from California. These samples represented fibres obtainable in commercial quantities. They contained some mineral impurities and thus their degree of solubility was not identical with that of hand-pickled, high-grade crudes from these localities.

The acids used in these tests were hydrochloric, acetic, phosphoric, and sulphuric. All were diluted to a 25 per cent acid solution, by weight.

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(1) For references see end of paper.

TABLE II.—PHYSICAL PROPERTIES OF ASBESTOS

| | CHRYSOTILE | AMOSITE | ANTHOPHYLLITE | CROCIDOLITE | TREMOLITE | ACTINOLITE |
|---|---|---|---|---|---|---|
| Specific heat B.t.u./lb./°F. | 0.266 | 0.193 | 0.210 | 0.201 | 0.212 | 0.217 |
| Tensile strength, lb./sq. in. | 80,000<br>100,000 | 16,000<br>90,000 | 4,000 & less | 100,000<br>300,000 | 1,000<br>8,000 | 1,000 & less |
| Temp. at max. ignition loss, °F. | 1,800 | 1,600 to 1,800 | 1,800 | 1,200 | 1,800 | — |
| Filtration properties | Slow | Fast | Medium | Fast | Medium | Medium |
| Electric charge | Pos. | Neg. | Neg. | Neg. | Neg. | Neg. |
| Fusion point, °F. | 2,770 | 2,550 | 2,675 | 2,180 | 2,400 | 2,540 |
| Spinnability | Very good | Fair | Poor | Fair | Poor | Poor |
| Resistance to acids & alkalies | Poor | Good | Very good | Good | Good | Fair |
| Magnetite content | 0-5.2 | 0 | 0 | 3.0-5.9 | 0 | — |
| Mineral impurities present | Iron, chrome, nickel, lime | Iron | Iron | Iron | Lime | Lime, iron |
| Flexibility | High | Good | Poor | Good | Poor | Poor |
| Resistance to heat | Good. Brittle at high temp. | Good. Brittle at high temp. | Very good | Poor, fuses | Fair to good | — |
| Ionizable salts, micro-mhos (Relative elec. conductance) | 1.82 | 1.34 | 0.58 | 0.84 | — | — |
| Colour | Green, grey to white | Yellowish-brown | Yellowish-brown, Sometimes almost white | Blue | White | Greenish |

# CHAPTER 1. VARIETIES AND COMPOSITION OF ASBESTOS

## VARIETIES

There are several varieties of asbestos, differing considerably in composition and physical properties. The most important commercially is chrysotile, which constitutes about 95 percent of total world production. Its wide use is due to the fact that its fibers are generally strong and flexible and therefore can be applied to many uses, such as manufacture of textiles and steam packing, for which weak and brittle fibers are not adapted.

Species of asbestos other than chrysotile fall in the amphibole group of minerals. The only varieties having significant use are anthophyllite, tremolite, amosite, and crocidolite. Fibers of anthophyllite and tremolite are generally weak and brittle, and their uses are limited. Sales are small, and only small quantities of these materials enter international trade. Amosite and crocidolite are mainly African varieties exported to the United States and other countries in considerable quantities for specialized uses.

### CHRYSOTILE ASBESTOS

Chrysotile is a hydrous magnesium silicate having a composition represented by the chemical formula $3MgO \cdot 2SiO_2 \cdot 2H_2O$. It is a fibrous form of the mineral serpentine. Antigorite is a platy form of serpentine of no commercial value.

In recent work Shaw (*5*)[3] indicates that both OH, the hydroxyl radical or water of constitution, and $H_2O$, the water of crystallization, are present in chrysotile. To indicate the dual nature of the water content, he writes the chemical formula $(OH)_6Mg_6Si_4O_{11}H_2O$. He claims also that in fibers from different locations the proportions of these two forms in which water occurs may vary. Thus, in Canadian chrysotile a greater part of the hydration is water of crystallization, while in the Rhodesian chrysotile the hydration is due largely to the hydroxyl radical. He expresses the view that such a difference in chemical constitution may explain in part the superior electrical resistance of the Rhodesian fiber.

The composition of chrysotile, however, is not rigidly fixed according to either of the formulas given above. Minor quantities of iron, nickel, manganese, or aluminum may replace part of the magnesium. Such small replacements may result in some modifications in the physical properties of the fibers. Furthermore, these properties are influenced to some extent by the presence of impurities; but, in general, chrysotile is more constant and dependable in quality than other varieties of asbestos. Chemical analyses of representative samples of asbestos are given in Bureau of Mines Bulletin 552 (*7*).

[3] Italicized numbers in parentheses refer to items in the bibliography at the end of this chapter.

### AMPHIBOLE ASBESTOS

The amphibole group of minerals was formerly believed to consist of anhydrous silicates of magnesium, calcium, iron, and other elements. However, in 1916 Schaller (*2*), using five exact analyses of tremolite, showed, by calculating the molecular ratios, that water was an integral part of the composition of tremolite and derived the formula $2CaO \cdot 5MgO \cdot 8SiO_2 \cdot H_2O$, which is now the recognized composition as contrasted to the widely published formula $CaO \cdot 3MgO \cdot 4SiO_2$. When X-ray studies of minerals were begun in the early 1920's, Schaller's findings were confirmed, and it was further learned that all amphiboles contained water of crystallization. Only in textbooks of mineralogy published since about 1940 will the definite statement be found: "All amphiboles contain hydroxyl." The water content of amphiboles is low—only 1 or 2 percent—whereas chrysotile contains about 13 percent water.

#### AMOSITE

There is some doubt that amosite is a distinct mineral species. Rabbitt (*4*) found by X-ray analysis of two amosite samples from South Africa that both were monoclinic in crystallization and therefore were not anthophyllites. The chemical composition of one indicated that it was probably actinolite, and the other was probably cummingtonite. Vermas (*6*) concludes that amosite is a fibrous form of the monoclinic amphibole grunerite $(FeMg)_7Si_8O_{22}(OH)_2$. However, it seems desirable to retain the name amosite in commercial usage where it serves a useful purpose.

Amosite may contain as high as 40 percent iron oxide, but, as it is monoclinic in crystallization it is not a true anthophyllite, although it is commonly classed as a high-iron anthophyllite. Amosite, unlike the true anthophyllites, which are almost invariably weak and brittle, consists commonly of long, fairly strong fibers that have certain specialized uses. It is mined only in Africa.

#### ANTHOPHYLLITE

The composition of anthophyllite is now generally expressed by the formula $Mg_7(Si_4O_{11})_2(OH)_2$, sometimes written $7MgO \cdot 8SiO_2H_2O$. The magnesium may be replaced in part by certain other elements, but complete replacement is not possible because the anthophyllites possess only limited isomorphism. Ferrous iron may replace magnesium up to 26.53 percent, but such an anthophyllite would still contain as much as 11.48 percent MgO. When the ferrous iron content exceeds 26.53 percent, the mineral ceases to be anthophyllite, as it becomes monoclinic in crystallization whereas all anthophyllites are orthorhombic.

The MgO content of anthophyllite is said to range from 5 to 30 percent. A series of 46 chemical analyses of anthophyllites assembled by Rabbitt (*4*) shows a maximum of 31.53 percent and a minimum of 11.48 percent. The one with the maximum MgO content contained 5.6 percent FeO. The CaO content of anthophyllites is very low; it averages about 0.5 percent and rarely exceeds 2 percent.

Aluminum is a more important constituent of anthophyllites than is commonly supposed. Of Rabbitt's 46 tabulated analyses, 14 show more than 10 percent $Al_2O_3$, and 20 show more than 5 percent. Aluminum may replace magnesium or silicon.

#### TREMOLITE

In tremolite the calcium may be replaced in small part by sodium. The magnesium is replaceable by iron in considerable quantities and by aluminum to a lesser degree. Also, a small part of the silicon may be replaced by aluminum. Tremolite usually consists of gray to white silky fibers, which are for the most part weak and brittle, although fibers of considerable strength and flexibility are found at times. Both tremolite and anthophyllite are superior to chrysotile in resistance to chemical reaction.

#### CROCIDOLITE

Crocidolite or blue asbestos belongs to the hornblende group of amphiboles. Its simplest chemical formula is $3Na_2O \cdot 6FeO \cdot 2Fe_2O_3 \cdot 16SiO_2 \cdot H_2O$. Considerable variation in composition has been noted. Sodium may be replaced by potash, ferric and ferrous iron by magnesium. Mineralogists now regard crocidolite as identical with riebeckite, being merely a fibrous form of that mineral. Crocidolite therefore bears the same relation to riebeckite that amosite bears to grunerite and that chrysotile bears to massive serpentine. Blue asbestos is produced chiefly in South Africa, but substantial quantities are now obtained in Western Australia, and a small output is obtained in Bolivia. Except for those in Bolivia and a recently discovered occurrence in New Quebec, Canada, no commercial deposits of blue asbestos are known in the Western Hemisphere. In Bolivian blue a large part of the iron is replaced by magnesium. The magnesium content of African blue asbestos is somewhat lower.

#### ERRATIC CHARACTER OF AMPHIBOLE FIBERS

As may be observed from the foregoing discussion, the replacement of one element by another in varying proportions is a prevalent characteristic of the several varieties of amphibole asbestos. This variation in composition results in corresponding changes in their physical properties. These properties may also be influenced by the presence of impurities. The somewhat erratic and unpredictable physical characteristics of the amphibole fibers have a profound influence on their use. An anthophyllite from one locality may give satisfactory service for some specific use, while one from another deposit, although appearing to be exactly the same, may be unsatisfactory. Thus, problems in amphibole asbestos procurement are much more difficult and complex than the procurement of mineral products like iron or copper, which, when pure, have constant properties, irrespective of the part of the world in which they may originate.

## IMPORTANCE OF PHYSICAL PROPERTIES

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, such as cotton and flax. Incombustibility 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 mate 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.

With respect to use, fiber size is important, and the size will depend upon the degree of fiberization attained in milling. 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 that is difficult to fiberize 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.

The use to which a chrysotile asbestos may be applied is governed largely by fiber length. The longest fibers command the highest prices and the shorter grades progressively lower prices. Apparently, therefore, 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.

The heat resistance of asbestos is important in many applications. Some users of asbestos confuse nonflammability with refractoriness. Nevertheless, many substances that will not burn will 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. Some students of the subject have conceived the idea that asbestos is a highly refractory substance by reading the statement made by Cirkel (*1*) that it can withstand temperatures of 2,000° to 3,000° F. easily, while some varieties can be subjected to a temperature of 5,000° F. with no apparent 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 coworkers (*3*), who have made a comprehensive study of temperature effects on 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. Accompanying this dehydration is a pronounced change in physical properties. 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.

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