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ASBESTOS

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The United States is the world's largest consumer of asbestos, using more than one-fifth of the 3.5 million short tons³ of world production in 1968. The major use for asbestos is in construction, including cement products, floor tile, paper products, paints, and caulking. Approximately 15 percent of U.S. asbestos requirements are obtained from domestic production and 85 percent from imports. Canada provides about 90 percent of the asbestos imports and the Republic of South Africa most of the rest. The South African material consists largely of the special amosite and crocidolite varieties of asbestos; the other sources supply predominantly the more common chrysotile variety. Domestic demand for asbestos for the year 2000 has been forecast in a range of 1.28 to 1.87 million tons. The main uses of asbestos are expected to remain in the construction materials. The major contingency which is expected to lead to the high of the range is a broadening of the use of asbestos in cement products. The low is based on the uses of substitutable lower cost materials particularly in the areas of ceramics and new plastics.

The developing countries are becoming more important consumers of asbestos products. The necessity of low-cost housing is considered the

principal factor, since asbestos cement is well suited for use in hot and humid countries. At the forecast rates of consumption, there are adequate sources of asbestos to meet the U.S. and rest-of-the-world demands to the year 2000, but shifts in supply centers may take place.

Canada is expected to continue as the leading free world producer, but output from other countries should become increasingly significant. In the United States the demand for asbestos fiber requirements is changing, and the substantial California deposits could reduce the reliance on imports by the year 2000, provided that products from the relatively short fiber receive consumer acceptance. A more remote possibility for a new supply source would be the development of synthetic asbestos production resulting from research in that field by both Government and industry.

Health hazards are present in the entire sequence of extracting, processing, and in some cases even consuming asbestos fibers. Medical research into all aspects of health problems related to the mining and use of asbestos is being performed and should alleviate the problem by the year 2000.

BACKGROUND

INDUSTRY PATTERN

The Province of Quebec, Canada, has the largest asbestos mines and mills in the world. The U.S.S.R. rivals Canada as an important producer. The Republic of South Africa, Southern Rhodesia, Swaziland, Italy, and the United States are substantial producers, and smaller supplies originate in many countries. The variety chrysotile constitutes about 95 percent of the world supply, and unless otherwise designated the data herein relate to chrysotile.

Total world production in 1966 was estimated at 3.5 million tons of all grades and varieties. Of this total, Canada produced about 46 percent; the U.S.S.R., 25 percent (estimated); the Republic of South Africa, 7 percent; Southern Rhodesia, 5 percent; the United States, 3 percent;

and Italy, 3 percent. Most published data on world production of asbestos credit the U.S.S.R. as the largest producer, but Bureau of Mines statistics (17)⁴ indicate that much of the ascribed quantity included low-grade material used for applications such as railway track ballast. This material should not be considered to be asbestos output and accordingly a much lower quantity has been accepted as the most reliable estimate.

Prior to 1962 the only large production of asbestos in the United States was from a deposit in Eden and Lowell Townships, Vt., in what is re-

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³ The quantities used throughout this chapter are short tons unless otherwise specified.
⁴ Italicized numbers in parentheses refer to items in the list of references at the end of this chapter.

garded as a southern extension of the Quebec deposits. In 1963, deposits in the Copperopolis, Coalinga, and Napa areas in California began production. Several operators have small chrysotile mines in an area about 60 miles long and 25 miles wide in the Salt River and Cherry Creek basins of Gila County, north of Globe, Ariz. Chrysotile deposits are known in Montana, Wyoming, and other States, but production has been negligible. In addition, amphibole asbestos is produced in North Carolina (4-6).

The largest known asbestos deposits in the free world are in an area 75 miles long by 5 or 6 miles wide between Danville and the Chaudière River Valley, in the Province of Quebec, Canada. Eight companies are mining in this area. Six of these are subsidiaries of companies that operate large asbestos products plants in the United States. Asbestos also has been mined continuously in northern British Columbia and northern Ontario since the 1950's. In mid-1963 a new mine began operating at Baie Verte in Newfoundland, and in 1968 the Clinton Creek mine was opened in Yukon Territory. Canadian production in 1968 was valued at Can\$210 million, whereas U.S. production had a sales value of about \$10.4 million.

The Soviet deposits, situated in the Bajenova district of the Urals, are extensive. The mines and mills are large, and most of the fiber is used within the U.S.S.R.

Southern Rhodesia is an important producer of chrysotile asbestos, particularly in the Shabani area. The fiber from these deposits has such a low iron content that it can be made into the excellent electrical insulating material that is required in the construction of electric cables for use on shipboard. Most of the other deposits of the world, except the comparatively small ones in Arizona and the recently discovered large one in British Columbia, have a substantially higher iron content, making fiber from them unsuitable for electrical insulation. Swaziland and the Republic of South Africa also produce chrysotile in substantial quantities. The Republic of South Africa produces two special types of asbestos—amosite, found commercially nowhere else, and crocidolite (blue asbestos), produced also in Australia and Bolivia. Most of the African production is exported (15).

Nine companies with nine operations produced asbestos in the United States in 1968. There are four companies in California—Atlas Mineral Corp., Coalinga Asbestos Co., Inc., Pacific Asbestos Corp. (acquired by J. K. Porter Co. Inc. in 1965), and Union Carbide Corp., Nuclear Division. Three companies operate in Arizona—Jaquays Mining Corp., McIntyre Asbestos Corp., and Western Asbestos Manufacturing Company. Powhatan Mining Co. operates in North Carolina, and General Aniline & Film

Corp., The Ruberoid Division (formerly Ruberoid Co., Vermont Asbestos Mines Division), the largest producer, operates the Lowell mine near Hyde Park, Vt.

Total employment in the domestic asbestos industry was 350 in 1968, consisting of 135 at the mines and 220 at the mills. This number has been constant since 1964.

Johns-Manville Corp. is the largest producer of asbestos in Canada and is a fully integrated company. It operates on a worldwide basis and is the price leader in the industry. It owns many consuming plants in the United States.

Turner & Newall, Ltd., Manchester, England, runs a fully integrated operation which operates on a worldwide basis. The company owns mines in Southern Rhodesia, the Republic of South Africa, and Canada. In Canada, it owns Bell Asbestos Mines Limited, at Thetford, Quebec, has a large minority interest in Cassiar Asbestos Corp., Ltd., McDame Lake, British Columbia, and acts as selling agent for Cassiar.

Cape Asbestos Co., Ltd., London, England, is a fully integrated operation whose mines are located in the Republic of South Africa. Manufacture of asbestos products is carried out in Europe and North America.

TECHNOLOGY

Definition of Terms, Grades, and Specifications

Asbestos is a name applied to a group of naturally fibrous minerals. The principal variety is chrysotile, a hydrous magnesium silicate having the theoretical formula $3\text{MgO} \cdot 2\text{SiO}_2 \cdot 2\text{H}_2\text{O}$. Other commercial varieties are amosite, a complex iron-magnesium silicate, $(\text{FeMg})\text{SiO}_3 \cdot 1-5$ percent H_2O ; and crocidolite, a sodium-iron hydrous silicate, $\text{NaFe}(\text{SiO}_3)_2 \cdot \text{FeSiO}_3 \cdot \text{H}_2\text{O}$. Of minor importance are tremolite, $\text{Ca}_2\text{Mg}_5\text{Si}_8\text{O}_{22}(\text{OH})_2$, and anthophyllite, $(\text{MgFe})_2\text{Si}_2\text{O}_7(\text{OH})_2$ (2).

Chrysotile, the principal variety of commerce, is graded according to fiber length. According to the Canadian classification, fibers three-eighths of an inch long or longer are classed as crudes and comprise groups 1, 2, and 3. Group 3 is the usual product obtained from the crude and is used largely for spinning fiber. The succeeding groups have progressively shorter fibers. Group 4 is designated as shingle stock; group 5, paper stock; group 6, waste stucco and plaster; and group 7, refuse or shorts. Most of these groups are divided into several subgroups. Such groupings comprise the commercial specifications. The consumer designates the grade desired.

In Arizona fiber which remains on 1/2-inch screen is classed as No. 1; that which passes 1/2-inch mesh and remains on 1/4-inch mesh, No. 2; that which passes 1/4-inch mesh and remains on 1/8-inch mesh, No. 3; and that which passes 1/8-

inch, No. 4. Nos. 1 and 2 are classed as spinning grade if the fibers are not too harsh. Some spinning fiber is obtainable from No. 3.

Grades may be blended to satisfy special needs. For some uses the chemical composition is important. Thus, for electric insulation an upper limit for the iron content may be specified. The methods of classification used in the principal producing countries are discussed in detail in a Bureau of Mines publication (3).

Current Technology

Most chrysotile asbestos deposits, including those of Vermont and California, Canada, Southern Rhodesia, Swaziland, the Republic of South Africa, and the U.S.S.R., consist of irregular cross-fiber veins (closely packed fiber set at a right angle to the faces of the rock (fractures) or slip-fiber zones (shear planes in rock filled with fiber matted together parallel to the seam) in massive serpentine. Such deposits commonly extend to unknown depths. Those of Arizona, however, consist of more or less horizontal asbestos-bearing serpentine zones in thin-bedded limestone. Such deposits are generally less extensive and less persistent than those in massive serpentine. The amosite and crocidolite of the Republic of South Africa occur in banded ironstones that are so folded and contorted that the veins are very irregular.

In Vermont, the fiber-bearing rock is removed from an open pit. Similar methods are employed in the Copperopolis district in California, but in the Coalinga district the highly sheared ore is simply "plowed" and allowed to air-dry, and the coarse fraction is screened out from the millfeed. The usual practice in Arizona is to drive a heading in barren limestone beneath the fiber zone, which is later blasted down and hand-cobbed. The Canadian mines generally are open pits. The chrysotile of Southern Rhodesia, the Republic of South Africa, and Swaziland is obtained from underground mines. Amosite is obtained chiefly from large underground workings, and blue asbestos from small open pits and shallow mines. The Soviet deposits are worked both in open pits and underground. Cyprus has large open-pit workings.

Asbestos milling is a complex operation involving primarily the separation of fiber from rock and classification of fiber by length into a series of grades. The operator has little control over the proportions of the various grades, which are fixed in nature, but he has the important task of minimizing fiber damage. He must mill the rock with as little fiber breakage as possible, because short fibers are worth much less than long ones. Special types of rock disintegrators have been developed, and reduction is accomplished in stages with fiber removal by air suction at each stage.

In Arizona the hand-cobbed rock is reduced in jaw crushers, and the fiber is separated by screening. Special milling techniques have been developed for the matted short-fiber chrysotile of the Coalinga district of California, including grinding and wet-milling processes. In Vermont and Canada the mills are large and complex. The fiber is classified in many grades, such as spinning, cement stock, and paper stock.

A pressure-packing process is used in many mills, where asbestos fiber is packed under pressure in five-ply paper bags. Each pressure-packed bag contains 100 pounds and occupies about 2 cubic feet.

Research

Research on production has been conducted by companies operating mines in Canada. Substantial research has been conducted on utilization of the more plentiful shorter grades in applications where longer grades are preferred. For instance, it has been found that more complete fiberization, permitting better contact of cement and fiber, will allow groups 5 and 6 to be blended in increasing proportions with group 4 in making asbestos-cement products.

Two companies have developed processes for reducing the iron content of Quebec asbestos to make it suitable for electrical uses. The Johns-Manville Corp. manufactures Quinterra paper from such fibers. Raybestos-Manhattan, Inc., has developed a process for making a low-iron product known as Novabestos. Both Quinterra and Novabestos papers may be interlaminated with a fiberglass fabric or grid to give additional strength. These products are now manufactured commercially and are used extensively in cable construction and for other nonferrous applications.

The Cape Asbestos Company Ltd., London, has investigated tensile testing of crocidolite and amosite, their chemical resistance, and their behavior in solutions of various chemicals and surface active agents. The only laboratory in the world devoted entirely to fundamental research on asbestos fibers was recently constructed by Turner and Newall Ltd., Manchester, England. New types of equipment were developed to sort asbestos fibers according to diameter and length (1).

The Naval Research Laboratory has developed a Fiberglass gas mask filter said to be superior to those made of Bolivian blue asbestos. Bolivian crocidolite is, therefore, no longer regarded as strategic.

Much research has been done on the synthesis of asbestos, but results thus far have no commercial application. The Bureau of Mines has synthesized amphibole asbestos, but the fibers made are weak and brittle. Asbestiform compounds not found in nature that have some of the prop-

erties of asbestos have been formed. Chrysotile, the type of asbestos most in demand, has been synthesized in fibers of only submicroscopic length. The Bureau has performed core drill tests on various properties to determine the occurrence of asbestos, and the U.S. Geological Survey has studied the geology of asbestos deposits in various states (3-6).

APPARENT RESERVES

In Vermont, a reserve of at least 1 million tons of chrysotile fiber appears to be assured. A small proportion of this quantity is of spinning grade. In California, measured and indicated reserves totaling more than 1 million tons are reported for the Copperopolis area; these reserves consist chiefly of types and grades similar to those in Quebec, Canada. Reserves of several hundred million tons of rock that will yield matted short-fiber chrysotile asbestos are reported for the Coalinga area in California (13). The Arizona reserve is difficult to estimate but is probably small.

The world appears to have an adequate asbestos reserve to meet requirements beyond the year 2000 at current or considerably enlarged rates of output. The chief suppliers of U.S. markets—Canada and the Republic of South Africa—appear to have adequate reserves for long-range planning. It is difficult to calculate South African reserves because of the intensive folding encountered in nearly all the asbestos areas. The duplication of the asbestos ban is through folding has resulted in large reserves (16). The U.S.S.R. reserve is probably large enough to supply the Soviet-oriented Eastern European countries for many years.

SUPPLY-DEMAND RELATIONSHIPS

Production, Consumption, and Trade

Most of the asbestos production is chrysotile asbestos, but approximately 200,000 tons of the world's production each year consists of amosite and crocidolite.

The United States is the largest consumer of asbestos in the world. From 1949 to 1953 the United States consumed on an average about 50 percent of the total world production. Domestic consumption more than doubled from 1945 to 1951, but thereafter it remained fairly constant while world production continued to increase. In 1966 the United States consumed about 23 percent of the total world production.

Domestic sources furnished only a small percentage of U.S. asbestos requirements. Arizona, the only present natural source of low-iron chrysotile in the United States, has rarely produced more than 600 tons per year of the spinning grades, and the output usually has been considerably lower. A large part of the production of

crudes No. 1, No. 2, and No. 3 was purchased by the U.S. Government for stockpiling from 1953 until the purchase program terminated at the end of 1962.

Vermont and the Copperopolis district of California are the only consistent U.S. producers of Quebec-type asbestos. Both are predominantly producers of short fiber, but the Vermont asbestos mines produce about 500 to 700 tons per year of spinning length fiber. Most of it is applied to nonspinning uses.

On a tonnage basis Canada furnished 90 percent of the U.S. imports in 1964-68, but only a small portion (3 percent) was of the spinning grade. The comparatively small quantities received from Africa are more important than would appear on a tonnage basis, because they consist largely of special kinds and qualities unobtainable elsewhere. Under emergency conditions imports of spinning fibers are of primary importance. Imports of spinning fibers from Canada average about 17,000 tons per year. The longer fibers of chrysotile suitable for spinning purposes represent a small fraction of the total production. Shortages of spinning-grade fibers have occurred.

The spinning grades of asbestos produced in Southern Rhodesia were of great importance during World War II and the early postwar years, because they constituted the principal source of low-iron chrysotile suitable for shipboard electric-cable construction. Production began from a new source of supply of low-iron chrysotile in northern British Columbia in 1953, and in 1968 more than 6,000 tons of these fibers were imported from that source.

Production of amosite in the Republic of South Africa has increased from an average of 20,000 tons per year during the 1940's to 90,000 tons in 1968. U.S. imports of amosite averaged about 20,000 tons per year during 1964-68. Part of the imported material has been placed in the national stockpile; hence industrial consumption has been somewhat lower than the aforementioned figure.

Most crocidolite originates in the Republic of South Africa, where production of crocidolite has increased from an annual average of 10,000 tons during the 1940's to almost 180,000 tons in 1968. U.S. imports of crocidolite advanced from 12,000 tons in 1954 to 24,000 tons in 1966 and dropped to 14,050 tons in 1968.

Conservation

The worldwide shortage of asbestos that existed during World War II and the early postwar period led to wide research and experimentation on materials that might take its place. To extend and conserve the supply of asbestos fibers, a glass-asbestos cloth was designed during World War II. It has continued in use as a covering on

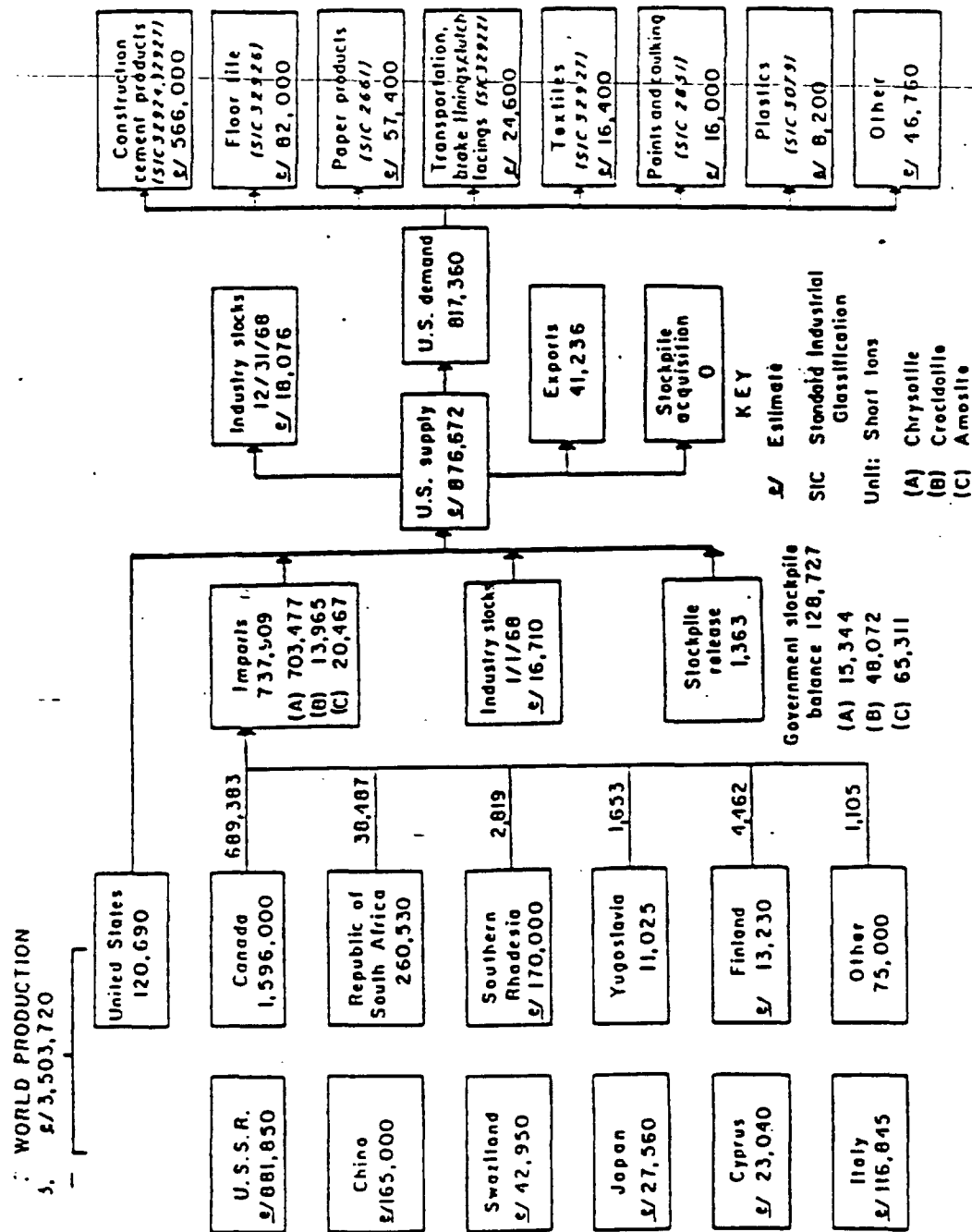


FIGURE 1.—Supply-Demand Relationships for Asbestos, 1968.

thermal insulation applied to piping on naval vessels. It is woven with a plied yarn having one strand each of glass and asbestos yarn.

Some grades of asbestos are more in demand than others. Shortages may develop for the preferred grades, and stocks of the less marketable fibers may accumulate. A great deal of research has been devoted to substitution of the more abundant grades for those that are less plentiful but more in demand. Canadian group 6 fibers have been adapted for use in asbestos-cement products, but groups 4 and 5 are still preferred.

BYPRODUCT-COPRODUCT RELATIONSHIPS

There are no commercial byproducts in the production and milling of asbestos. The fiber comprises 5 to 10 percent of the rock mined, and the waste rock consists of broken and pulverized serpentine for which very little commercial use has been found. One leading producer has devised a practical method for recovering magnesia from a waste rock, and a small quantity of by-product crushed stone has been marketed. In addition, mill wastes containing appreciable asbestos may be usable in producing inexpensive asbestos flooring compositions.

CONSUMPTION PATTERN

Uses

Asbestos is adaptable to more than 2,000 uses. Because of its high strength-to-weight ratio and resistance to searing temperatures it is used in rockets and missiles. Asbestos products plants are located in 16 States, principally in the East and South and on the west coast.

All uses of asbestos are as processed fiber. The long-fibered groups 1 and 2 are marketed in very small quantities for special textile purposes; group 3 is used in the manufacture of fireproof textile products, packings, woven brake linings, clutch facings, electrical insulation materials, and high-pressure and marine insulation; the major use of group 4 is in asbestos cement pipe which is used mainly in transporting water, such as in municipal waterworks, irrigation, and conservation projects; group 5 is used in asbestos cement sheets, flat and corrugated sheets, low-pressure asbestos cement pipes and molded products, in some paper products such as pipe insulation and wrappings, and in other products, including brake linings and gaskets; group 6 is primarily used in asbestos cement products mix, gaskets, brake linings, vinyl sheet backings, and mill-board; and group 7 is used in molded brake linings and clutch facings. The most important application of "shorts" is as a filler in vinyl and asphalt floor tile, while other important uses are in asphalt compounds, joint and insulation ce-

ments, roof coatings, plastics, and caulking compounds.

Amosite is used for felted insulation in blanket form for high-temperature service up to 900° F. A loosely compacted form is used as a covering for marine turbines and jet engines and in similar applications. Amosite is also a constituent of 85-percent-magnesia insulation and lightweight, fire-resistant marine partition board.

Long-fiber crocidolite (blue asbestos) is woven into fabrics used for locomotive boiler lagging in Great Britain and for acid-resistant packings and gaskets. The principal use of the short crocidolite fibers is in making asbestos-cement pipe.

Tremolite and anthophyllite are used for chemical-resistant filters, as welding-rod coating, and as fillers in various products.

About 69 percent of the asbestos consumed goes into the manufacture of asbestos cement products, about 10 percent in floor tile, 7 percent in asbestos paper, 5 percent into friction materials and gaskets, 2 percent in asbestos textiles, 2 percent in paints and caulking, 1 percent in plastics, and 6 percent in miscellaneous other commodities.

Alternate Materials

Fiberglass is used as a substitute for asbestos in some applications, chiefly in the field of heat insulation. Fabrics woven with a plied yarn having one strand each of glass and asbestos yarn are advantageous for some uses where light weight and high strength are needed. Glass filaments are technically satisfactory substitutes for amosite in blanket insulation, but the cost is greater than that of amosite. Fiberglass is not a satisfactory substitute for asbestos in friction materials, asbestos-cement products, and some of the highly specialized electrical insulation uses.

Silicone products, organic compounds, and plastics are used as substitutes in certain limited applications. The use of calcium silicate, diatomite, and magnesia in some instances reduces asbestos requirements in end products.

Aluminum sheets are being used as a partial substitute for asbestos where insulation against radiant heat is required.

New types of heat-resistant plastics are being substituted for chrysotile in some forms of electrical insulation. Substantial progress has been made in substitution of Novabestos and Quinterra papers for electrical insulation. There is, however, no satisfactory complete substitute for strategic grades of chrysotile in some forms of dielectric insulation.

Fibrous glass and chrysotile asbestos are substitutes for amosite, but they are not as resistant to steam, sea water, and alkalis under all working conditions. For 85-percent-magnesia and cal-

cium silicate insulation, textile grades of chrysotile may be substituted for amosite.

ECONOMIC FACTORS

Prices and Costs

Asbestos has had an erratic price history, but since 1965 the price has been quite stable. Prices for Vermont and Canadian asbestos increased about 5 percent in 1967. Quebec chrysotile fiber prices in 1968, f.o.b. mine, ranged from Can\$45 per ton for 7T, the shortest of the regular grades generally produced, to Can\$700 for the longest of the milled fibers. Crude No. 1 from British Columbia (Cassiar) sold for Can\$126 to Can\$1,522 per ton while other Crude No. 1 from Canada was quoted at Can\$1,410 per ton.

Vermont chrysotile is produced in grades similar to those in Canada and ranged in price in 1968 from \$41.50 per ton for group 7 to \$342 for group 3, f.o.b. mine. Arizona fibers ranged in price from \$65 per ton for group 7 to \$1,650 per ton for the highest grade No. 1 Crude, f.o.b. Globe, Ariz.

Prices quoted for amosite, f.o.b. U.S. ports in 1968, ranged from \$130 per ton to \$220. Crocidolite prices ranged from \$180 per ton to \$470.

The total value for the 120,690 tons of asbestos produced in the United States during 1968 was \$10,406,000 an average of \$86.22 per ton, f.o.b. mine. The imports of asbestos for consumption were valued at \$75 million. The value placed on U.S. demand for 1968 was \$79 million. The price plotted in figure 2 was based on the average domestic sales value. Assuming that the proportions of various grades produced remain the same, the price in terms of 1968 constant dollars is expected to increase to \$100 per ton by the year 2000.

Taxes and Tariffs

There are no special taxes on the asbestos industry. Producers are granted a depletion allowance of 23 percent on domestic production and 10 percent on foreign production. Domestic asbestos producers have no tariff protection.

Transportation

The Quebec and Vermont deposits are within easy rail haul to most of the plants manufacturing asbestos products in the industrial areas of the Eastern United States. The African deposits are remote from the principal markets and have high transportation expenses. Transportation from British Columbia is difficult and costly, but a shorter route is in prospect. The Arizona miners have difficult transportation problems; the nearest railhead is at Globe, and the haulage distance from the mines ranges from a few miles

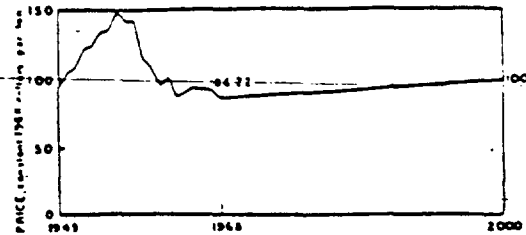


FIGURE 2.—Time-Average Price Relationship for Asbestos.

to 104 miles, averaging 50 miles. Furthermore, the major consumption centers are in the Northeastern United States, and are much closer to Quebec, Canada, than to Arizona. Consumption of asbestos is growing along the west coast of the United States, and comparable growth has taken place in other areas where fiber from California would be competitive, in terms of freight rates, with that from Quebec.

A 10-percent increase in the ocean freight rates for amosite and crocidolite asbestos from the Republic of South Africa to U.S. ports went into effect in 1968. The rate was raised from \$27.75 to \$30.50 per long ton.

Government Programs

During World War II controls restricted exports of asbestos needed in the military program. These controls were removed by executive order on September 10, 1945. During the Korean war the supply situation again became acute, and in 1950 and 1951 controls were invoked that required licenses for export of all grades of asbestos. The license requirement was removed for the nonspinning grades in 1953 and for the spinning fibers in 1954; however, export licenses still are required for shipments to Communist nations.

The discovery and development of new asbestos deposits have long been considered desirable. A program to assist in asbestos exploration was initiated in 1950 with the responsibility vested in the Defense Minerals Exploration Administration. The program is now conducted by the Office of Minerals Exploration, and exploration contracts have been awarded. Three have resulted in certified discoveries.

A Government depot in Globe, Ariz., was opened for the purchase of domestically produced asbestos meeting certain specifications. Under Public Law 735 (1956), a Government purchase program at premium prices for domestic low-iron chrysotile asbestos was established which was terminated on December 31, 1958. In 1959 the stockpile objectives for low-iron chrysotile were raised, and a barter program was established to acquire the additional fiber needed

through exchange of agricultural surpluses. The U.S. Department of the Interior recommended purchase of 500 tons of low-iron chrysotile from domestic mines to assist the domestic industry and to establish a domestic mobilization base for production. Amosite and chrysotile have been acquired for the stockpile by purchase and barter, and crocidolite has been acquired by barter.

Strategic Considerations

Asbestos kinds and grades of greatest strategic importance are being stockpiled. The national stockpile items are spinning-grade chrysotile and amosite. Bolivian blue crocidolite is no longer considered strategic. On December 31, 1968, the maximum stockpile objective for chrysotile was 13,700 tons. Government inventories totaled 15,344 tons, of which 6,060 tons was in the national (strategic) stockpile, 4,383 tons was in the supplemental stockpile, and 4,881 tons was nonstockpile grade. The stockpile objective for amosite was 40,000 tons, and inventories totaled 65,311 tons, of which 11,705 was in the national (strategic) stockpile and 53,606 in the supplemental stockpile. The stockpile also contained 48,072 tons of crocidolite that had no objective.

The United States is dependent upon foreign sources for 90 to 95 percent of its requirements for all grades of asbestos. The principal source of low-iron spinning grade chrysotile asbestos is British Columbia, Canada. A small amount of low-iron long-fiber chrysotile is available from Arizona. The only source of commercial grades and quantities of amosite is a limited area in Transvaal, Republic of South Africa. The United States is also completely dependent on foreign sources for crocidolite.

ENVIRONMENTAL CONSIDERATIONS

Many investigators from various countries have established the fact that an occupational or nonoccupational inhalation of dust of different chemical and physical types of asbestos results in the development of asbestosis of the lungs which, depending upon the type of exposure, may be designated as an occupational, neighbor-

hood, or household pneumoconiosis. The hazards are recognized and steps have been taken by industry to filter the air and properly ventilate mines and processing plants.

One leading producer of asbestos instituted programs to prevent possible health and safety hazards and to improve the quality of air and water used in manufacturing operations. Environmental control activities included the development of a rotary filter system that permits the continual reuse of industrial process water. The new system which uses diatomite filter aid products reduces water demand and eliminates high-solid-effluent problems (9).

An epidemiological survey is being carried on throughout the Quebec asbestos industry by the Quebec Asbestos Mining Association as a part of a planned international effort. Fact-finding medical research on the effect of asbestos on human health was centered in the Thetford Mines and Asbestos districts. Similar surveys are being conducted in the United States, Finland, the U.S.S.R., Republic of South Africa, Italy, and other countries. Because of the universal use of asbestos and asbestos products, national and international authorities are pressing for careful investigations so that dangers can be identified and controlled (10). Dust control is very important in the asbestos industry and much has been done to develop effective control methods and to safeguard the workers in mining and milling operations. Through ventilation engineering steps have been taken by the asbestos industry to create better working conditions and as a safeguard against industrial diseases (11).

No land use conflict problems seem likely to inhibit the production of asbestos. Virtually all of the deposits are in rugged country far removed from major populated areas. The mining operations are on privately owned or leased lands. Waste rock is hauled to nearby dumps and as the pile builds up, a bulldozer spreads it out. Water sprays allay the dust as the tailings are discharged. The milling of asbestos is generally a dry operation and all the screens are hooded and operate under a slight negative pressure for dust control. The King City, Calif. operation of Union Carbide Corp. uses a wet milling ore beneficiation method.

OUTLOOK

DEMAND

Domestic demand for asbestos is expected to increase at a moderate rate and to occur within the range from 1,282,000 to 1,865,000 tons in the year 2000. The low of the range indicates an average annual growth rate of 1.4 percent while the high indicates 2.6 percent. The midpoint or

median for the forecast range is 1,573,500 tons (fig. 3). The forecast was derived by contingency forecasting of the major end-use demands considering possible shifts caused by changing technology during the forecast period (table 1).

Much higher than normal growth in demand was experienced by asbestos in the decade be-

be as high as the growth rate for total new construction due in part to the great dependence on imports to meet demand. Use of asbestos in floor tile has been increasing in recent years but because of the many competing materials it is not expected to grow at an annual rate of 4.5 percent. Asbestos paper products used in electrical appliances as well as in construction are expected to grow at an accelerating rate but the quantity of asbestos for such uses is relatively small.

A judgment analysis of the demand contingency factors led to a forecast range for 2000 of 983,000 tons or $\frac{1}{2}$ of the forecast base for the low and 1,475,000 or $\frac{1}{2}$ of the base for the high.

Transportation

Asbestos is an important part of many types of friction materials used in automobiles, trucks, and other transportation equipment. Modern industry could scarcely function without asbestos friction materials. In addition to using asbestos in brake linings, today's motor cars equipped with automatic transmissions get their drive from metal transmission disks, which are covered with a super-tough paper containing crocidolite asbestos. The average automobile with power shift contains eight to 12 of these disks. Although the quantity of asbestos in each transmission is small, the output of more than 6 million automatic transmissions annually requires disk paper production in hundreds of tons.

A new composition brake shoe unit containing asbestos, designed to meet the critical braking requirements for the new 150-mile-per-hour passenger train systems, has been developed.

In 1968 almost 11 million linear feet of woven brake linings were manufactured containing asbestos yarn, tape, or cloth. Based on an estimated forecast of the number of motor vehicles produced in the year 2000, approximately four times 1968 production, and on the assumption that the use of asbestos per vehicle will decline to 60 percent of the 1968 levels, the forecast base for asbestos demand in user-operated vehicles is projected to 60,000 tons. Increasing the number of transportation vehicles and equipment using parts made of asbestos or maintaining the present quantity used per vehicle could result in a demand as high as 100,000 tons. It is quite possible that the forecast production of vehicles will not be attained in 2000. However, the lowest quantity of demand is not expected to be less than one-half of the forecast high, or 50,000 tons.

Textiles

Demand for asbestos in textiles was projected to 56,000 tons in the year 2000 based on the fore-

cast growth rate for gross national product (GNP).

Asbestos textiles are used in the manufacture of yarn and cloth which is used in safety clothing, packings, brake linings, filters, etc. Carded fibers are 100 percent asbestos and are used for the clarification of such liquids as beer, wine, oils, and chemicals. Asbestos lap is a felted form of carded asbestos fiber made for the electric wire and cable industry, as insulation for heater cords, fixture wires, and other electrical conductors. Asbestos rovings are used by the electric wire industry as insulation for heater cords, cables, and electrical heating elements. The projected growth of asbestos demand in electrical appliances, coupled with design improvements that increase asbestos use, could result in increased asbestos demand. On the other hand, other insulation materials could replace asbestos for some purposes. Because of its inherent incombustibility and thermal stability, asbestos cloth is extensively used wherever these properties are essential in a fabric. Many Government specifications, particularly those of the U.S. Navy, require pipe insulation to be protected by an outside jacket of asbestos cloth. All maritime specifications and many industrial and utility powerplants also require asbestos cloth to hold the insulation in place and to serve as a permanent protection and fireproof jacket over pipe and boiler insulation. Specially processed lint-free asbestos cloths also serve as protective shields in "clean" areas adjacent to nuclear reactors (1).

Competition from substitute material is not likely to be important, and no competitive factor is considered. Therefore, the forecast base of 56,000 tons is taken as the low forecast. Production of asbestos textile yarn, cord, and thread in 1963 was 19.7 million pounds, compared with 8.2 million pounds in 1958, and output of asbestos cloth in 1963 was 9.4 million pounds, compared with 7.3 million pounds in 1958. Data for 1964-68 are not available. Assuming that there will be increased use of asbestos for such items as electrical appliances and firefighting equipment, the high projected demand could be perhaps 60,000 tons in the year 2000.

Plastics

The forecast base for 2000 was determined by use of the forecast growth rate for GNP.

Plastic materials can be reinforced with such different fibers as asbestos, glass fiber, and cotton. Short asbestos fibers are used in the manufacture of such items as handles on cooking utensils, and long asbestos is used in the manufacture of reinforced plastic rocket nose cones. Asbestos phenolic materials are used in aerospace applications. In many applications glass is a competitive reinforcing material for plastics. Although

glass fibers have many superior property and processing characteristics, asbestos can often provide a better combination of heat and corrosion resistance and high strength and stiffness at lower cost. Asbestos and glass fibers are not always competitive materials, and as numerous applications demonstrate, they can complement each other. For example, some epoxy pipe wound with high-strength glass fiber contains an asbestos-phenolic liner to provide broad chemical resistance. Asbestos also can be used in combination with other reinforcing materials, such as sisal, to produce economic moldings with improved impact strength and reduced water absorption. Auto heater ducting, fan shrouds, and instrument panel components are typical of the many products produced from phenolic reinforced with asbestos and sisal fibers (6).

Use of asbestos as a reinforcing material is becoming more significant. However, the base projection of 28,000 tons is not expected to increase importantly unless more use of asbestos is made in the bodies of automobiles as a reinforcing agent in the joining of various parts and in phenolic materials for aerospace applications. A modest increase of 2,000 tons per year was added to the forecast base for this contingency. No factors are foreseen which appear likely to reduce the demand in the year 2000 below the forecast base.

Other Uses

On the basis of past performance it is likely that new uses for asbestos will be forthcoming, and the forecast base of 165,000 tons in the year 2000 was obtained by direct correlation with the projected growth for GNP. With low-cost short fiber available from domestic sources in large quantities there should be a significant impact on the mineral filler market for a wide range of end products, particularly in products that must withstand high temperatures or corrosive conditions. The high side of the forecast range was obtained by adding an increment of 35,000 tons to the forecast base to provide for possible significant increases in filler demand. No developments are anticipated that would cause demand to decrease below the forecast base.

SUPPLY AND FUTURE SUPPLY-DEMAND RELATIONSHIPS

Domestic resources of chrysotile are found mostly in California, Vermont, and Arizona. Although deposits also exist in Montana, Oregon, Wyoming, and a few other States, production from these has been negligible. California has the greatest potential of becoming a substantial producer of short-fiber asbestos. In addition, anthophyllite asbestos is produced in North Carolina.

The United States has been dependent on foreign supplies of asbestos for certain essential and strategic grades in the necessary quantities for times of emergency. Canada supplies most of U.S. requirements for chrysotile, while amosite and crocidolite originate in the Republic of South Africa. World expansion and increasing demands indicate a possible inadequacy of foreign supplies, thus encouraging the development and production of domestic resources. Such development of domestic asbestos deposits coupled with advancing technology in the use of substitutes, in the manufacture of synthetic asbestos, and in the removal of iron from chrysotile, could reduce our reliance on foreign supplies.

U.S. and Canadian chrysotile resources are more than ample to meet the high of the forecast domestic demand for 2000, without affecting Canadian capability for supplying a major part of the demand in the rest of the world. The relatively small requirements for amosite asbestos will continue to come from the Republic of South Africa unless deposits of this variety of asbestos are discovered in other countries, or adequate substitutes become available at competitive prices, thereby providing acceptable options to the consumers. Crocidolite asbestos will also be obtained from the Republic of South Africa, and perhaps from Australia so long as it remains competitive with chrysotile, but substitution is practicable in essentially all end uses and continuation of crocidolite supply is not considered of strategic importance.

Estimated demand for asbestos in the United States for domestic consumption in 1968 was 817,000 tons, of which about 15 percent came from domestic sources; most of the balance was obtained from Canada and the Republic of South Africa (fig. 1). Annual requirements for asbestos in the year 2000 are not expected to exceed 1.9 million tons (fig. 4). If the 1968 ratio of domestic production to demand prevails in

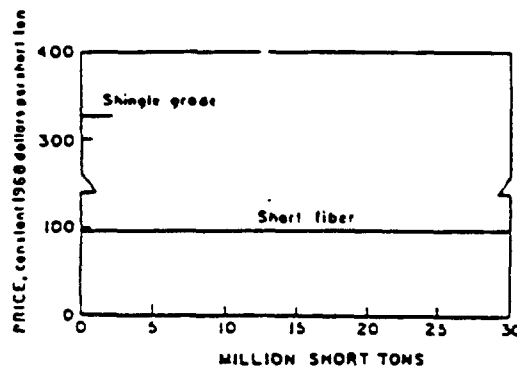


FIGURE 4.—Projected Domestic Availability of Asbestos.

the year 2000, the domestic production component required to meet the maximum expected demand would be 275,300 tons. This production could be accomplished from known resources only by much more extensive use of the low-cost, very-short-fiber Coalinga, Calif. material than prevails at present (fig. 4). Historical and projected domestic production and demand for asbestos are shown in figure 3. The trend projections for demand are low compared with the forecast range, mainly due to the time periods chosen for the trend projections. Based on the entire postwar period, the demand growth for asbestos has averaged about 3.5 percent per year which is greater than the rate required to achieve the high point of the demand forecast in the year 2000.

The following tabulation summarizes the comparative quantities and assigned values for domestic demand and production for 1968 and 2000. Production figures for 2000 are the constant ratio quantities of figure 3. The values for both demand and production are in terms of constant 1968 dollars based on the estimated average domestic sales value of \$100 per ton.

	Quantity (thousand tons)			Value (million dollars)		
	2000			2000		
	1968	High	Low	1968	High	Low
Demand	817	1,885	1,222	79	187	122
Production	121	275	189	12.4	28	19

POSSIBLE ADVANCES IN TECHNOLOGY

Although asbestos synthesis was accomplished in the late 1920's, and much work has been done since that time, commercial synthesis has not yet been announced. However, with the accelerating rate of technological progress, competitive synthetic asbestos or asbestiform products may become available in significant quantities before the end of the century. The mineral raw ma-

terials needed for production of synthetic asbestos are abundant.

Among the factors that should tend to increase asbestos demand within the next decade is the potential for larger scale production of relatively low-priced asbestos from domestic deposits, which should spur research into new uses and into new ways to substitute very short fiber asbestos for the longer, more expensive types. The domestic product is being used in asbestos cement pipe and should be adaptable to other products.

Work is underway which is aimed at developing large-scale asbestos uses. Foremost among these is the potential for use in asphalt paving materials which must bear up under various difficult conditions. Examples are airport runways and hangar areas which are subjected to high-temperature corrosive effects of jet exhausts; street curbing, which must be able to absorb shock and forces from the wheels of motor vehicles; and resurfacing of old roads. The latter use requires about 35 tons of asbestos per mile of 40-foot pavement and probably has the largest potential for large volume asbestos requirements. Technological changes in roadbuilding methods could result in capping of new highways with asbestos-rich asphalt.

Medical problems connected with asbestos have been under intense study in recent years and undoubtedly will continue to warrant increasing attention in the future. In addition to study and medical treatment of the effects of asbestos on the respiratory system, work should be aimed at improved methods protecting workers in mines, mills, and fabricating plants. Among the possibilities for solving the problems, in addition to medical study and treatment, are much greater use of automation where feasible, remote control of fabrication processes, improved protective equipment and respiratory devices, and development and strict enforcement of safety procedures.

PROBLEMS

One of the most serious problems confronting the domestic consuming industry is our dependence for the greater part of our supply of asbestos on foreign sources. About 85 percent of the supply of chrysotile and all of the amosite and crocidolite comes from foreign countries. Complete dependence upon foreign supply for strategic grades is minimized by adequate stockpiles but imposes long-term concern.

Adequate information on the methods of mining and processing of asbestos and development of equipment is available, but cost data are lacking. Information is available on the principal end products in which asbestos is utilized, but

there is no information on the wastage that takes place in manufacturing the end items.

To fully appraise the current future supply situation of asbestos, information is needed on stocks and consumption. Presently, data on consumption and stocks are available on stockpile grades only. Information on the quantities of asbestos going into the various individual end uses is not satisfactory and the estimates are made on the basis of insufficient data. This illustrates the need for an occasional canvass of the principal industries in order to establish the quantitative end use consumption pattern.

Health hazards are present in the whole sequence of mining, processing, and utilizing as-

bestos, and the expanding use of this material demands continued attention to this problem.

REFERENCES

1. Asbestos Textile Institute. Handbook of Asbestos Textiles. Philadelphia, Pa., 1961, pp. 29-43.
2. Badollet, M. S. Asbestos, A Mineral of Unparalleled Properties. Trans. Canadian Inst. Min. and Met., v. 54, 1951, pp. 151-160.
3. Bowles, Oliver. The Asbestos Industry. BuMiner Bull. 552, 1955, 122 pp.
4. Burmeister, H. L., and I. E. Matthews. Mining and Milling Methods and Costs. Vermont Asbestos Mines, The Ruberoid Co., Hyde Park, Vt. BuMiner Ind. Circ. 8068, 1962, 43 pp.
5. Cady, W. M., A. L. Albee, and A. H. Childester. Bedrock Geology and Asbestos Deposits of Upper Missisquoi Valley and Vicinity, Vermont. U.S. Geol. Survey Bull. 1122-B, 1963, 78 pp.
6. Childester, A. H., and A. F. Shride. Asbestos in the United States (Exclusive of Alaska and Hawaii). U.S. Geol. Survey Miner. Inv. Res. Map MR-17, 1962.
7. Cryer, Robert E. Asbestos Reinforced Plastic Resist Heat and Chemicals. Materials in Design-Eng., v. 63, No. 4, April 1966, pp. 92-96.
8. Huggins, Charles W., M. V. Denny, and H. R. Shell. Properties of Palygonitic, an Asbestiform Mineral. BuMiner Rept. of Inv. 6071, 1962, 17 pp.
9. Johns-Manville Corp. Annual Report, 1964, p. 5.
10. Mining in Canada (Ontario). Epidemiological Survey, January 1967, p. 7.
11. ———. Health Controls Are Advanced in the Asbestos Industry, October 1967, pp. 33-36.
12. Mining Journal (London). New Asbestos Fiber Laboratory—Unique Research Facilities. V. 260, No. 6636, Mar. 15, 1963, pp. 249, 253, 255.
13. Rice, S. J. California Asbestos Industry. California Div. Mines and Geol. Miner. Ind. Service, v. 16, No. 9, 1963, pp. 4, 6.
14. Rosato, D. V. Asbestos, Its Industrial Applications. Reinhold Publishing Corp., New York, 1959, pp. 198-199.
15. Sinclair, W. E. Asbestos: Its Origin, Production, and Utilization. Mining Publications, Ltd. (London), 1955, 363 pp.
16. South African Department of Mines. Geological Survey. Mineral Resources of The Union of South Africa. 4th ed., 1959, p. 365.
17. Strishkov, V. V. The Mineral Industry of the U.S.S.R. BuMiner Minerals Yearbook 1967, v. 4, 1969, p. 794.