BUREAU OF MINES

Preprint from BULLETIN 671

202-634-1206

ASBESTOS

A Chapter from
Mineral Facts and Problems,
1980 Edition

UNITED STATES DEPARTMENT OF THE INTERIOR

CTD007113

PLAINTIFF'S EXHIBIT

CT-777

UNITED STATES DEPARTMENT OF THE INTERIOR

BUREAU OF MINES

This preprint is the current revision of the commodity chapter that appeared in Mineral Facts and Problems, 1975 Edition; and may have been updated as a Mineral Commodity Profile in 1977, 1978, and 1979. The data base for the forecasts and longterm analyses terminates with 1978, the last year for which relatively complete worldwide data were available. However, the author includes the latest information and data available in the text and tables when the final draft of the chapter is prepared. Reserves and resources were determined on the basis of information, prices, and technological capabilities current in January 1980. Current Bureau of Mines publications and other reference information sources are listed at the end of this preprint.

This publication is preprinted from Bulletin 671. MINERAL FACTS AND PROBLEMS. 1980 edition. The complete volume, when published, may be purchased from the Superintendent of Documents, Washington, D.C. 20402

For sale by the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402

ASBESTOS

By Robert A. Clifton [1]

The United States has been supplanted by the U.S.S.R. as the largest consumer of asbestos fibers. The construction industry worldwide presently uses the majority of asbestos fibers in such products as asbestos cement pipe and sheet, roofing products, flooring products, paints, and caulking, and should remain the largest user. (U.S. mines produced 17%, 93,000 tons,[2] of domestic consumption, 561,000 tons, in 1979.) Canada is the leading supplier of asbestos imports into the United States, about 95%, with the Republic of South Africa second. South Africa supplies all of the U.S. demand for crocidolite and amosite, and the majority of imports from there are these fibers.

The rate of growth in the use of asbestos continues higher in the developing countries. Asbestos reserves could well be in danger of depletion by the year 2000 at the forecast rates of consumption, if the "find" rate of new sources does not increase or viable substitutes are not found. Table 12 shows present reserves insufficient for probable world cumulative demand by 2000.

Canada has been overtaken by the U.S.S.R. and is no longer the world's largest producer of asbestos. The high level of activity in exploration, evaluation, and development of new ore bodies, however, signals that Canada is likely to continue as the leading world exporter. United States demand shows clear signs of leveling off or even lessening somewhat. The quest for part of the asbestos market by producers of substitutes remains strong, but the substitute materials proposed generally fail to compete with asbestos when measured by quality and/or economic yardsticks. Viable substitutes are needed for both health and economic reasons.

The health hazards associated with asbestos are still undergoing close scrutiny by the Federal and local governments, unions, industry organizations, and concerned environmentalists. The many areas of controversy give promise of prolonged dispute. Efforts to regulate conditions to minimize the hazard are given as a reason for the possible loss of a viable asbestos production industry in the United States.

INDUSTRY STRUCTURE

Canada, with major activity in the Province of Quebec, leads the West in both total quantity produced and the size of individual mines and mills. The U.S.S.R. is the leading world asbestos producer. The Republic of South Africa, Mainland China, Italy, and the United States mine substantial tonnages and, in combination with Canada and the U.S.S.R., produce over 90% of the world's supply. Chrysotile is the variety most in demand by over 95% of the world's consumers, and most of the data in this report relate to chrysotile.

Total world production in 1979 was 5.3 million tons of all grades and varieties. Canada's share was 28%; the U.S.S.R. produced 47%; the Republic of South Africa, 5%; Mainland China, 5% Italy, 2%; and the United States, 2%. U.S. production was 93,000 tons, valued at $2 million. These data on world production do not credit U.S.S.R. production with the lower grades that are not used as fibers.

Geographic Distribution

In 1965, there was only one major asbestos-producing mine in the United States, GAF's Lowell mine in Vermont. During that year, another mine of similar size and output, and three lesser mines began operating in California. In 1974, all of the major producers operated; but in California, the largest mine and a lesser one closed during the year. In 1976, the largest California mine reopened under new ownership. Major domestic production is limited to Vermont and California.

An area roughly 120 kilometers [3] long and 8 to 10 kilometers wide, beginning 130 kilometers east of Montreal, Canada, and continuing eastward contains the world's second largest mine and mill, and, in toto, the largest concentration of known deposits in the world. Mergers and closings have reduced the number of operating companies to five in this "Eastern Townships" region, stretching from Danville to East Broughton, Quebec. Four of the companies were either totally or partially owned by U.S. corporations at the time of writing, most of which manufacture asbestos-containing products. New Canadian mines continue to be opened. The Asbestos Hill Mine of the Asbestos Corp., located in northern Quebec on the Ungava Peninsula, opened in 1973 and continued production, while the even newer United Asbestos Corp. Mine in Ontario closed in 1977 because of financial problems, but is scheduled to reopen in 1980. Canadian production in 1979 totaled 1.5 million tons; that of the United States totaled 93 thousand tons.

Most Soviet asbestos is used domestically or in other countries that have centrally controlled economies. The large mine and mill complexes in the Bajenova district of the Urals, the Dzhetygara Mine in Kazakhstan, and Ak-Dovurak in Tuva are to be joined by the Kiembay combine under construction in Orenburg Oblast and the planned developments of the Molodezhnoye and Il'chirsk deposits at Buryat. A new combine in Kazakhstan is to be a joint venture with several centrally controlled economy nations as partners.

[1] Physical scientist, Section of Nonmetallic Minerals.
[2] All tonnages reported are metric tons unless otherwise specified.
[3] One mile = 1.6093 kilometers; 1 kilometer = 0.6213 mile.

Table 1.—World asbestos production, 1978, and capacity 1978, 1979, and 1985
(Thousand metric tons)

	Production 1978	Capacity 1978	Capacity 1979	Capacity 1985
Chrysotile:				
North America				
Canada	1,422	1,800	1,800	2,500
Mexico	--	--	--	50
United States	93	96	100	150
Total	1,515	1,896	1,900	2,700
South America:				
Argentina	1	1	1	1
Brazil	123	125	130	150
Total	124	126	131	151
Europe:				
Bulgaria	1	24	24	30
Greece	--	--	--	100
Italy	135	150	150	180
U.S.S.R.	2,435	2,600	2,600	3,000
Yugoslavia	10	20	20	50
Other	--	6	6	6
Total	2,581	2,800	2,800	3,376
Africa:				
Zimbabwe (Rhodesia)	249	250	250	260
South Africa, Republic of	79	120	120	150
Swaziland	37	50	50	80
Other	1	1	1	1
Total	366	421	421	491
Asia:				
Afghanistan	13	15	15	20
China:				
Mainland	250	260	260	300
Taiwan	2	4	4	5
Cyprus	34	40	40	50
India	19	22	22	30
Japan	7	22	22	28
Korea, Republic of	14	15	15	20
Turkey	13	15	15	25
Total	352	393	393	478
Oceania:				
Australia	62	70	70	100
World chrysotile total	5,000	5,705	5,715	7,296
Crocidolite:				
South Africa, Republic of	137	210	210	230
Amosite:				
South Africa, Republic of	41	110	110	130

Rhodesian chrysotile deposits retain importance in the world market. The generally tight supply would assure this, but the sporadic worldwide shortage of spinning grade fibers accentuates it. Although occasionally available, domestic and Canadian production of these long fibers has not satisfied U.S. demand during most of the past decade. Imports of the low-iron spinning-grade fibers needed in the electrical-insulation and textile segments of the industry are again entering due to the January 1980 Presidential order ending the United Nations sanctions against Rhodesia. Swaziland and the Republic of South Africa are also major producers of chrysotile. South Africa is presently the sole producer of amosite and crocidolite, which are in diminishing demand. "In continent" use of African asbestos is increasing, but the large majority is still sold on the world market.

Five mine and mill operations were run by as many companies to produce asbestos in the United States in 1979. Three of the operations were in California and one each in Arizona and Vermont. The California companies are Atlas Mineral Corp., Calaveras Asbestos Ltd., and Union Carbide Corp. Jaquays Mining Corp. operates in Arizona, and Vermont Asbestos Group, Inc., in Vermont. Total employment in the five firms was about 380.

The fully integrated Johns-Manville Corp. is the largest asbestos producer in Canada, and is a major supplier to the world market. Johns-Manville's many manufacturing plants in the United States use large quantities of asbestos as a raw material.

Turner & Newell, Ltd., based in Manchester, England, is another fully integrated company with worldwide operations. Its mines are in Rhodesia, the Republic of South Africa, and Canada. Its Canadian subsidiary, Bell Asbestos Mines, Ltd., has a mine at Thetford, Quebec, and a large minority holding in Cassiar Asbestos Corp., which has a mine in British Columbia. Bell acts as selling agent for Cassiar.

Much of the world market for asbestos from the Republic of South Africa is met by Transvaal Consolidated Land and Exploration, Ltd., which now owns the mines formerly belonging to the Cape Asbestos Co., Ltd., London. This once fully integrated company developed the mines there to supply its asbestos-product plants in Europe and North America.

The larger international asbestos groups and their affiliations are depicted in figure 1 (*23*).[4]

Definitions and Grades

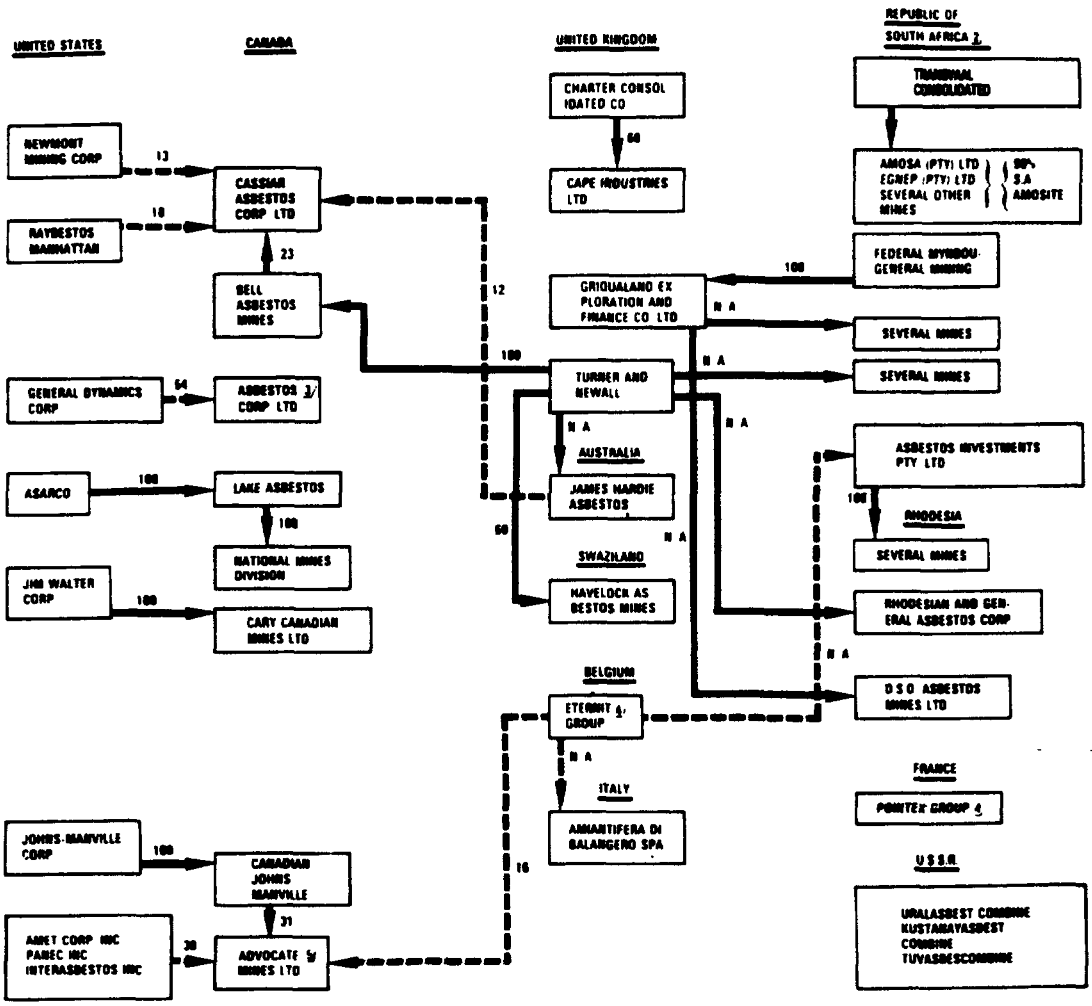
Asbestos is a name applied to a number of naturally fibrous minerals. The principal variety is chrysotile from the serpentine group, a hydrous magnesium silicate with the theoretical formula $Mg_6Si_4O_{10}(OH)_8$. Other commercial varieties (all amphiboles) are amosite, a trade name for a complex iron-magnesium silicate (mostly cummingtonite-grunerite), $(Mg,Fe^{2+})_7Si_8O_{22}(OH)_2$; and crocidolite, a sodium-iron hydrous silicate variety of riebeckite, $Na_2Fe_3^{2+}Fe_2^{3+}Si_8O_{22}(OH,F)_2$. Of minor importance are tremolite asbestos, $Ca_2(Mg,Fe^{2+})_5Si_8O_{22}(OH,F)_2$, and anthophyllite asbestos, $(Mg,Fe^{2+})_7Si_8O_{22}(OH,F)_2$ (*1,5*).

Chrysotile, the principal variety of commerce, is graded and grouped according to fiber length. Most of the groups are divided into several subgroups to comprise the commercial specifications. One producer alone offers its customers 420 grades of fiber in 1,320 different forms (*18*). 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*).

[4] Italicized numbers in parentheses refer to items in the list of references at the end of this chapter.

CTD007116

MAJOR INTERNATIONAL ASBESTOS MINING GROUPS 1/



KEY: MAJOR GROUP — 100 COMPANY (MAJOR SHAREHOLDER AND PERCENTAGE) — 10 COMPANY (MINOR SHAREHOLDER AND PERCENTAGE)

N/A NOT AVAILABLE.

1/ MOST MAJOR GROUPS HAVE MANUFACTURING INTERESTS.
2/ PRODUCTION BREAKDOWN (APPROXIMATE): CROCIDOLITE 50%, AMOSITE 30%, CHRYSOTILE 20%.
3/ IN PROCESS OF BEING ACQUIRED BY QUEBEC PROVINCIAL GOVERNMENT.
4/ PRIMARILY HAVE INTERNATIONAL MANUFACTURING INTERESTS.
5/ OTHER SHAREHOLDERS INCLUDE AMET CORP. INC., 10% PANAC INC., 7% INTERASBESTOS INC., 7%—
ALL U.S. COMPANIES.

SOURCE: MINERAL DEVELOPMENT SECTOR: DEPARTMENT OF ENERGY, MINES AND RESOURCES: OTTOWA, CANADA.

Figure 1. – Major international asbestos mining groups. Figures above arrows indicate percent ownership of company shares.

CTD007117

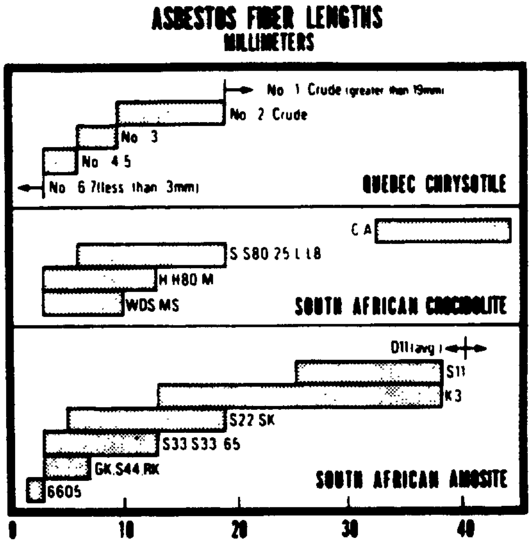


Figure 2. — Asbestos fiber lengths.

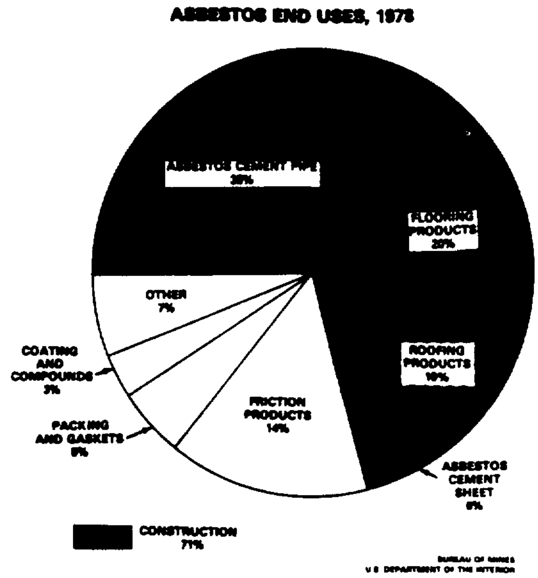


Figure 3. — Asbestos end uses, 1978.

USES

All uses of asbestos are as processed fiber. The processed chrysotile fibers are placed into the following groupings, which are based upon length of fiber:

Groups 1, 2, and 3 — These groups are composed of the longest fibers; the major end-use products include textiles, clothing, theatre curtains, different types of packings, fireproof textile products, woven brake linings, clutch facings, electrical insulation materials, and high-pressure and marine insulation.

Group 4. — Its major use is in asbestos-cement pipe, which is used mainly in transporting water, such as in municipal waterworks, irrigation, and conservation projects.

Group 5. — This group is used in asbestos-cement sheets, flat and corrugated sheets, low-pressure asbestos-cement pipes, and molded products. It is also used in some paper products such as pipe insulation, wrappings, and other products, including brake linings and gaskets.

Group 6. — The main consumption for this group is in asbestos-cement products, gaskets, brake linings, vinyl sheet backings, and millboard.

Group 7. — The group is used in molded brake linings and clutch facings, as a filler in vinyl and asphalt floor tile, and in asphalt compounds, joint and insulation cements, roof coatings, plastics, and caulking compounds.

The ranges of sizes of asbestos classifications are shown in figure 2.

Asbestos-product plants are located in 16 States, principally in the eastern, southern and west coast areas.

Asbestos is adaptable to more than 2,000 uses. Because of its high strength-to-weight ratio and resistance to higher temperatures, it is used in rockets and missiles. Amosite is used for felted insulation in blanket form for high-temperature service up to 480°C. A loosely compacted form is applied as a covering for marine turbines, jet engines, and similar applications. Amosite is also used as a constituent of 85% magnesia insulation and lightweight, fire-resistant marine partition board. Long-fiber crocidolite ("blue asbestos") is woven into fabrics for locomotive-boiler lagging (in Great Britain) and for acid-resistant packings and gaskets. The principal use of the shorter crocidolite fibers is in making asbestos-cement pipe. Tremolite asbestos and anthophyllite asbestos are used for chemical-resistant filters, as welding-rod coatings, and as fillers in various products.

World end-use patterns are not discernible from available data, and projections of U.S. patterns to the rest of the world cannot be justified. In 1970, 70% of the world's asbestos was reportedly connected with products used in the construction industry (*12*). This still seems reasonable and can be used for planning purposes. The remaining 30% is divided among a myriad of uses.

RESERVES-RESOURCES

Whether the U.S. asbestos resources shown in table 2 can become reserves is debatable. Presently, the economic pressures of remaining competitive while making large capital expenditures to meet environmental regulations are being easily overcome by a buoyant world market in which demand exceeds supply. The strong demand is expected to continue, but the industry feels that certain proposed regulations could not be complied with for technological reasons regardless of cost.

The possible million tons of asbestos fiber at the Cop-

CTD007118

Table 2.—World asbestos resources [1]
(Million metric tons)

	Reserves [2]	Other	Total
North America:			
United States	4	59	100
Other	37		
Total	41	59	100
South America	5	4	9
Europe	47	18	65
Africa	35	13	48
Asia	6	7	13
Oceania	8	4	12
World total	142	105	247

[1] Derived in cooperation with U.S. Geological Survey.
[2] Based on average U.S. price of asbestos in 1978 of $273 per metric ton.

peropolis, Calif., deposit are, under present environmental regulations, economic. The future of the millions of tons of short fibers available in the Coalinga, Calif., area is doubtful, because of low demand and environmental costs.

The world reserve situation and its applications for the future remain unclear. The plans of the U.S.S.R. to bring more asbestos mines into production indicate huge reserves, but it is questionable whether we could call them "reserves" using our economic yardsticks. Also questionable is whether the economy and demand for asbestos would raise prices to the level that large Canadian resources would become economically attractive. Present trends in world demand indicate that those resources presently called "reserves" will be inadequate to meet that demand by the year 2000.

Geology

Most chrysotile asbestos deposits, including those of Vermont and California in the United States, Canada, Zimbabwe, Swaziland, Republic of South Africa, and the U.S.S.R., consist of irregular cross-fiber veins (closely packed fibers set at the 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. 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.

TECHNOLOGY

Exploration and Development

Exploration and development are apparently increasing throughout the world because of the increasing demand for asbestos fiber and lack of production capacity to meet that demand. The asbestos showings in the Eagle Quadrant of Alaska have not yet proven to be worthy of production.

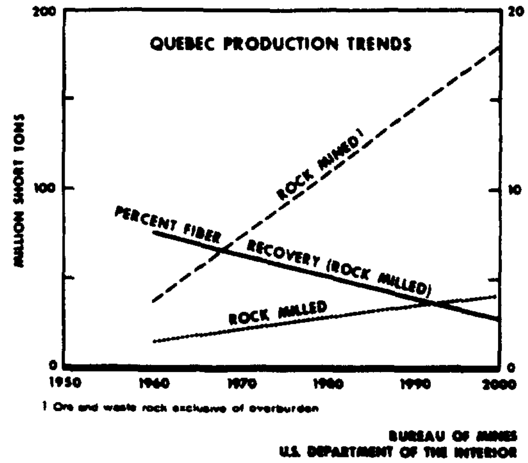


Figure 4.—Quebec production trends, from analysis of 1951-70 data.

Exploration in Canada remains quite active. Some large metal-minng firms are joining the asbestos firms in the searth for new asbestos deposits.

Mining

In Vermont and in the Copperopolis district in California, the fiber-bearing rock is removed from an open pit. In the Coalinga district of California, the highly sheared ore is simply "plowed" and allowed to air-dry, and the coarse fraction is then screened out from the mill feed. In Arizona, a header is driven beneath the fiber zone; the zone is later blasted down and milled. The Canadian mines generally are open pits. The chrysotile of Zimbabwe, the Republic of South Africa, and Swaziland is obtained from underground mines. Amosite is obtained chiefly from large underground workings, and blue asbestos (crocidolite), from small open pits and shallow mines. The Soviet deposits are worked both in open pits and underground. Cyprus has large open pit workings.

The data (*20*) analyzed by least-squares regression analysis and depicted in figure 4 tell a very interesting story about asbestos recovery from established mines over a period of time. In 1951, in the Quebec asbestos mines, 75% of the rock mined was milled, and 9.9% of that milled was recovered as fibers. About 20 years later (1970), only 32.2% of the rock mined was milled, and it yielded 6.1% fibers. Trend projection to the year 2000 indicates that only 24.4% of the mined rock will be milled, and 2.9% of the milled material will be fibers.

Many variables preclude prediction of the point when these trends would produce subeconomic resources, but they certainly portend escalating mining problems and costs.

CTD007119

Processing

Asbestos milling is a complex operation involving primarily the separation of fiber from rock and classification of fiber by length. There has been little change in the basic methods described in a previous Bureau of Mines publication (*4*), and shown in figure 5.

Special milling techniques have been developed for the matted short-fiber chrysotile of the Coalinga district of California, including grinding and wet-milling.

In Copperopolis, Calif., Vermont, and Canada, the mills are large and complex. The fiber is classified in many grades, such as spinning, cement stock, and paper stock.

In many mills, asbestos fiber is packed under pressure in five-ply paper and/or woven vinyl bags. Each pressure-packed bag contains 100 pounds of asbestos and occupies about 2 cubic feet. With this pressure-packing, the asbestos measures 45 cubic feet per short ton.

Asbestos-producer research and development programs are engaged primarily in lowering mining costs and refining processes. For example, at Johns-Manville's Jeffrey Mine in Quebec, 180-ton-capacity trucks are used to haul waste, pit rock, and overburden (*21*). Trucks of 91-ton capacity are used to feed the ore to a primary crusher, which can accept such a truckload from each of two sides simultaneously.

Process refinement research and development has paid dividends in two ways. Techniques have been developed that successfully recover short fibers from waste tailing piles by reprocessing. These also reduce dust levels in the mills, aiding in worker protection.

Automation and computer control of the asbestos milling circuits have been under study (7) and in operation. The new No. 6 mill at Jeffrey mine is a crusher-dryer-concentrator complex that is fully computer controlled (*21*).

Woodsreef Mines Ltd. of Australia and its parent company, Woodsreef Minerals Corp. of Canada, are marketing a new wet-milling process. A prototype mill is proposed for 1980 startup.

Current Research

The largest area of research concerned with asbestos for the last few years has been in connection with the controversial health aspects of the fibers. The National Institute of Environmental Health Sciences, for example, started a multiyear animal-feeding study in 1976 to determine the health effects of ingested (as opposed to respired) asbestos and asbestos-related minerals. Preliminary results, released early in 1980 in a memo from the National Toxicology Program, indicate no difference in mortality rates between exposed and control animals and no carcinogenicity.

In late 1976, the Bureau of Mines established the Particulate Mineralogy Unit now at Avondale, Md., to develop a scientific basis for research into particle-related pollution problems and for the process of decisionmaking by regulatory bodies. The Bureau of Mines, which once had a research program aimed at either synthesizing analogs of the natural fibers or finding substitutes, is again doing asbestos synthesis research, and, by contract, research on substitutes.

In late 1979, it was reported (*16*) that the Société Nationale de l'Amiante (SNA), an arm of the Quebec Provincial Government, had under construction at Thetford Mines, Quebec, a new magnesium salts plant. Using asbestos mine tailings as feedstock, the initial production will be magnesium carbonate, but SNA projects a highly competitive magnesium metal of high purity late in 1982.

SUPPLY-DEMAND RELATIONSHIPS

Components of Supply

During the entire history of the asbestos industry in the United States, domestic sources have been able to meet only a small percentage of U.S. requirements. Vermont and the Copperopolis district of California have been the only consistent U.S. sources of Quebec-type asbestos. Both are predominantly producers of short fiber, but the Vermont asbestos mines produce about 450 to 650 tons per year of spinning-length fiber. Most of it is applied to nonspinning uses.

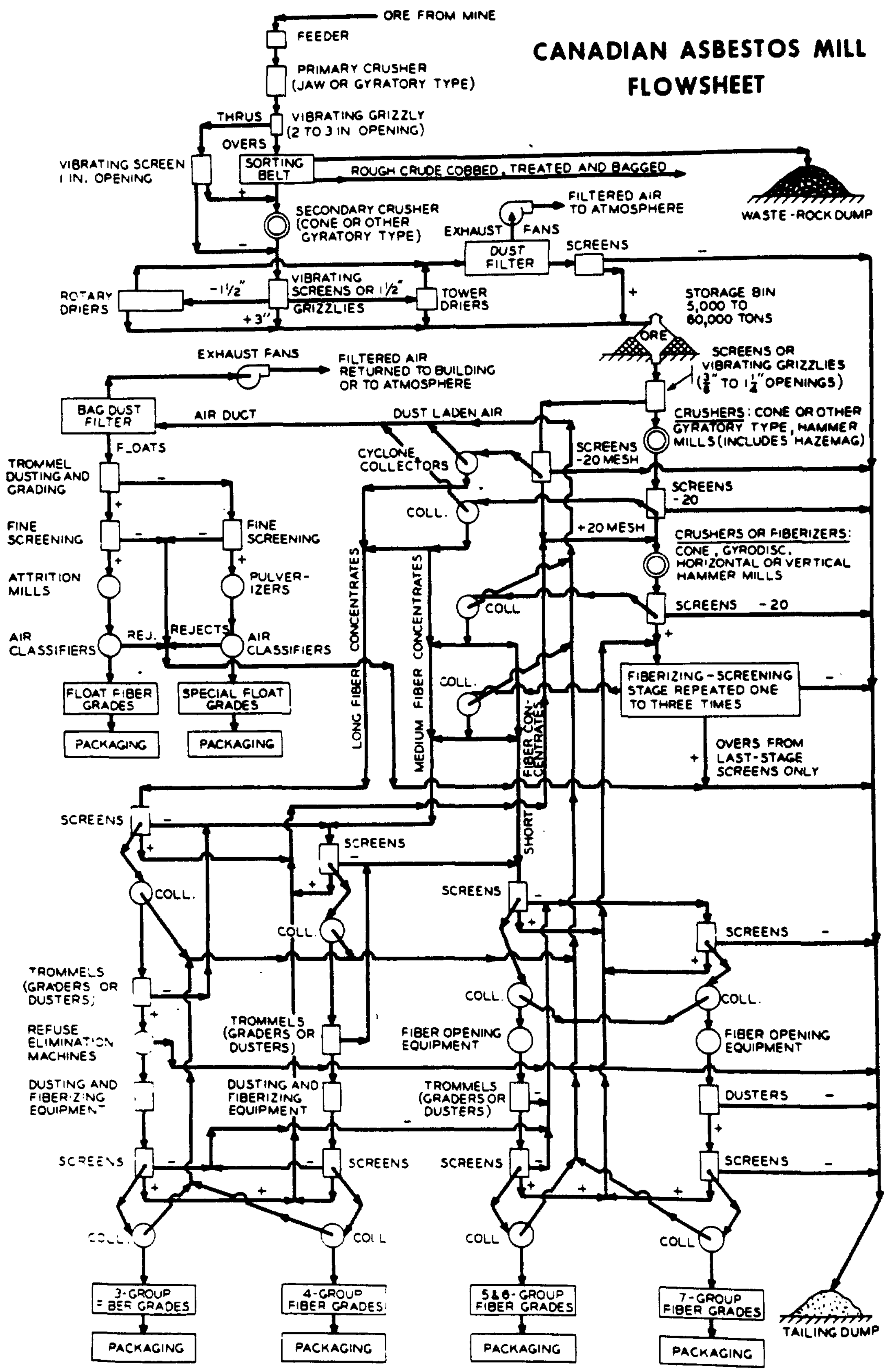
Canada furnished 95% of all the asbestos tonnage imported by the United States (fig. 6) (1974-78), but only a small portion (2%) was spinning-grade fibers. The comparatively small quantities of chrysotile received from Africa, particularly those from Zimbabwe, are more important than would appear on 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 formerly averaged about 13,600 tons per year, but are decreasing. The longer fibers of chrysotile suitable for spinning represent a small fraction of the total production. Shortages of spinning-grade fibers have previously occurred, but no longer seem to be chronic.

Imports of amosite, available only from the Republic of South Africa, into the United States from 1974 to 1978 averaged about 3,600 tons per year. This represented a large decrease from the preceding years when the U.S. Government was actively purchasing for the National stockpile (table 3). In October 1976, the Federal Preparedness Agency announced a stockpile goal for amosite of 23,851 tons. (See "Strategic Considerations.")

Imports of crocidolite, also available only from the Republic of South Africa, advanced from 11,000 tons in 1954 to 22,000 tons in 1966, but averaged only about 11,000 tons per year from 1974 to 1978. Apparently environmental fears reduced product markets.

Figure 5.—Flowsheet of a Canadian asbestos mill. Source: Industrial Minerals and Rocks (by permission). →

CANADIAN ASBESTOS MILL FLOWSHEET



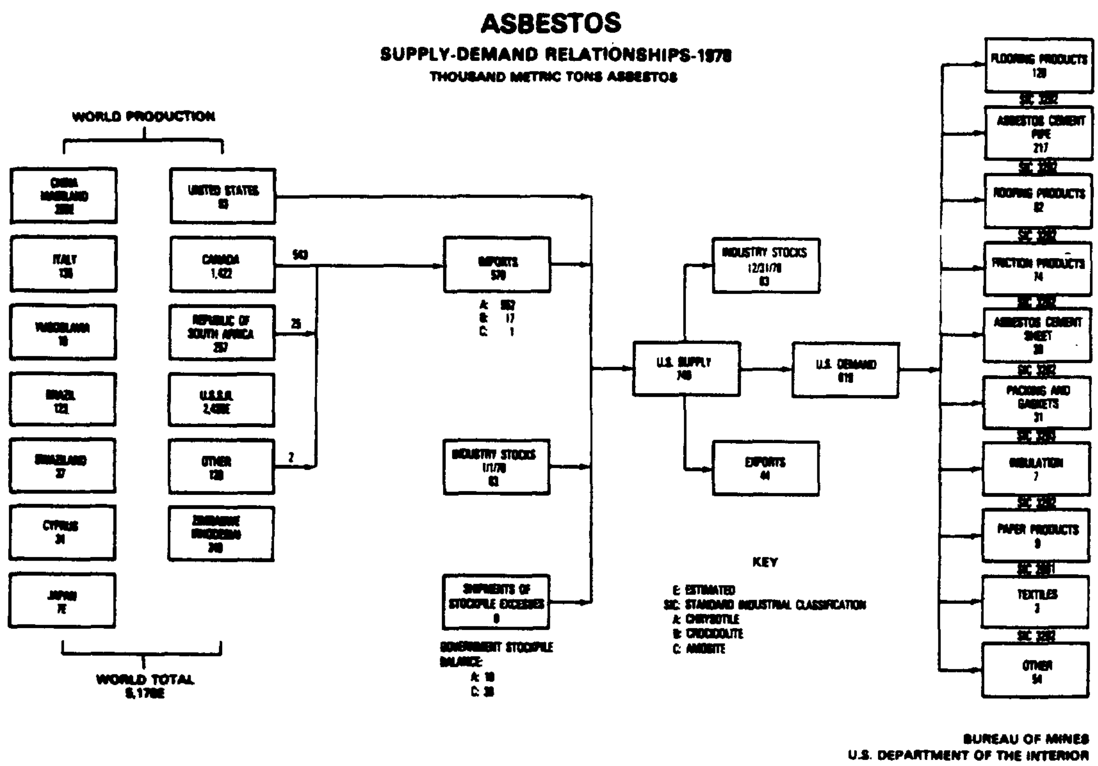


Figure 6. — Supply-demand relationships for asbestos, 1978.

U.S. and World Production

In 1973, U.S. production of asbestos fiber was at an alltime high; however, production in 1974 and 1975 did not reach that level owing to the early 1974 closing of two California mines that represented about 40% of the 1973 production. The reopening of the Copperopolis, Calif., mine in 1976 by Calaveras Asbestos Ltd. brought domestic production up somewhat.

Canadian asbestos production continued to increase until 1974, when there was a small decline in production, followed by an additional 37% decrease in 1975. New production capacity will reportedly reach 472,000 tons by 1980 (*9*).

A total of 1.04 million tons per year of new capacity is expected to become available in world markets during 1973-80 (*9*). This includes 272,000 tons of Soviet exports and production from mines in Australia, Colombia, Greece, New Zealand, Mexico, and Brazil.

A mill fire, landslide, and protracted strike combined to reduce Canada's 1975 production to only 1.03 million tons — 61% of its 1973 high — and prematurely widened the expected gap between supply and demand.

Canadian production (all chrysotile) was 1.53 million tons in 1972 and 1977, 1.79 million tons in 1974, 1.03 million tons in 1975, 1.54 million tons in 1976, 1.42 million tons in 1978, and 1.50 million tons in 1979.

The spinning grades of chrysotile 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. They were of renewed importance each time a spinning grade shortage appeared. The only new source of asbestos with substantive amounts of spinning-grade fiber that has become available in the postwar years is the low-iron deposit of chrysotile that was opened in 1953 in British Columbia. Production of "crudes" from this mine dropped off considerably in 1979.

Production of amosite in the Republic of South Africa, which increased from an average of 18,000 tons per year during the 1940's to 97,000 tons in 1973, dropped to 79,000 tons in 1977, and was 41,000 tons in 1978.

Crocidolite is mined only in the Republic of South Africa. African production of crocidolite has increased from an annual average of 9,000 tons during the 1940's to about 200,000 tons in the 1970's, but was 137,000 tons in 1978.

U.S. and World Consumption

The data in table 4 have been adjusted to reflect 100%

Table 3.—Asbestos supply-demand relationships, 1969–79
(Thousand metric tons)

	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979 p
WORLD PRODUCTION											
Mine production:											
United States	114	113	119	120	136	103	89	105	92	93	93
Rest of world	3,667	3,331	3,462	3,674	4,035	4,012	4,050	4,980	5,129	5,085	5,185
Total	3,781	3,444	3,581	3,794	4,171	4,115	4,139	5,085	5,221	5,178	5,278
COMPONENTS AND DISTRIBUTION OF U.S. SUPPLY											
U.S. mines	114	113	119	120	136	103	89	105	92	93	93
Shipments of Government stockpile excesses	5	10	7	14	7	26	6	3	--	--	--
Imports, chrysotile	607	568	599	657	700	678	475	585	539	562	496
Imports, crocidolite	10	8	6	5	12	10	11	9	11	17	14
Imports, amosite	14	13	14	6	7	7	4	2	1	1	1
Industry stocks, Jan. 1	16	21	19	27	86	93	93	93	83	83	83
Total U.S. supply	766	733	764	829	948	917	678	797	728	746	689
Distribution of U.S. supply:											
Government acquisition	--	6	--	--	--	--	--	--	--	--	--
Industry stocks, Dec. 31	21	19	27	86	93	93	93	83	83	83	82
Exports	33	43	49	53	60	56	33	54	34	44	46
Industrial demand	711	686	689	734	795	768	552	660	609	619	561
Apparent surplus (+), deficit (−)	+1	−1	−1	+44	--	--	--	--	--	--	--
U.S. DEMAND PATTERN											
Flooring products	178	187	173	183	198	139	123	104	140	128	121
Asbestos cement pipe	136	128	131	140	151	202	139	127	146	217	213
Roofing products	72	66	69	73	79	89	42	231	57	62	66
Friction products	64	60	62	66	72	73	60	58	83	74	61
Asbestos cement sheet	50	46	48	52	58	86	40	21	40	38	11
Packing and gaskets	22	20	21	22	24	28	15	16	25	31	19
Insulation	22	20	21	22	23	13	6	8	18	7	15
Paper products	14	14	14	15	16	57	60	28	22	9	1
Textiles	14	14	13	14	16	18	5	6	9	3	8
Other	140	133	137	147	158	85	62	59	70	54	48
Total demand	711	686	689	734	795	768	552	660	609	619	561

p Preliminary.

Table 4.—U.S. asbestos consumption by end use, grade, and type, 1979
(Metric tons)

	Chrysotile											
	Grades 1 and 2	Grade 3	Grade 4	Grade 5	Grade 6	Grade 7	Grade 8	Total chrysotile	Crocidolite	Amosite	Anthophyllite	Total asbestos
Asbestos-cement pipe	--	--	146,100	31,600	700	--	--	178,400	34,700	(¹)	--	213,100
Asbestos-cement sheet	--	--	100	100	3,900	6,600	--	10,700	--	200	--	10,900
Flooring products	--	--	6,600	44,400	11,000	58,500	--	120,500	--	--	--	120,500
Roofing products	--	--	1,300	100	18,500	46,900	--	66,800	--	--	--	66,800
Packing and gaskets	--	1,300	3,100	8,500	400	5,800	--	19,100	100	--	--	19,200
Insulation:												
Thermal	--	--	--	200	1,800	8,100	--	10,100	--	--	--	10,100
Electrical	--	200	600	200	1,200	3,100	--	5,300	--	--	--	5,300
Friction products	--	800	3,400	16,200	5,400	35,100	--	60,900	--	--	300	61,200
Coatings and compounds	--	(¹)	400	(¹)	400	18,700	--	19,500	--	--	--	19,500
Plastics	(¹)	(¹)	100	800	(¹)	1,400	--	2,300	600	--	--	2,900
Textiles	--	5,800	(¹)	(¹)	--	--	--	5,800	--	--	--	5,800
Paper	--	100	--	400	100	--	--	600	300	--	--	900
Other	100	600	400	2,800	9,400	10,700	--	24,000	--	1,300	--	25,300
Total	100	6,800	162,100	105,300	52,800	193,900	--	523,000	35,700	1,500	300	560,500

(¹) Less than 50 metric tons

of the apparent consumption. The 11 major uses in 1979 were as follows: Asbestos cement pipe (38%), asbestos cement sheet (2%), coatings and compounds (3%), flooring products (21%), friction products (11%), insulation (3%), packing and gaskets (3%), plastics (1%), roofing products (10%), textiles (1%), and other (7%).

World consumption of asbestos is increasing at a much faster rate than that in the United States. Maintaining the 4.4% predicted growth rate may not be possible within the limits or production capacity. The recent economic recession had no apparent effect on world asbestos demand, because the Canadian production troubles in 1975 have masked trend developments.

World Trade

If one were to remove from consideration the asbestos produced in Mainland China (nearly all is used domestically) and that produced in the U.S.S.R. (most of which is used domestically or in other COMECON countries), a

CTD007123

Table 5.—Characteristics of some fibers (6)

Fiber	Tensile strength		Young's modulus		Specific gravity
	Kg/cm²	Lb/in² × 10³	Kg/cm²	Lb/in²	
Crocidolite	36,000	500	172.2 × 10⁴	24.6 × 10⁶	3.2
Amosite	21,000	300	153.3 × 10⁴	21.9 × 10⁶	3.1
Chrysotile	28,000	400	156.4 × 10⁴	22.2 × 10⁶	2.4
Glass	17,500	250	59.5 × 10⁴	8.5 × 10⁶	4.6
Aluminum	1,800	25.6	70.0 × 10⁴	9.9 × 10⁶	2.7
Steel 5137	3,700	52.6	190.0 × 10⁴	27.0 × 10⁶	7.8

truer picture of Canadian prominence emerges. In the rest of the world, Canada had 59% of the market in 1979; the Republic of South Africa, 10%; Italy, 5%; and the United States, 4%.

Canada's main markets are the United States and Europe, but there is a considerable trade in the Far East. South Africa sells most of its asbestos to European and Africa sells most of its asbestos to European and African companies. The market for Italian asbestos is mainly in Europe.

Recycling

Asbestos fibers cannot be recycled in their common role of reinforcing a host matrix because removal from the matrix would destroy the fibers.

There are few asbestos uses (mainly textile) that have uncombined fibers in the end product. When these products are no longer useful, niether is the asbestos because of the physical and/or chemical changes that have made it a different mineral with less strength or shorter fibers of less value that reclamation costs. Thus, asbestos is a nonrenewable natural resource.

Substitute

There is great interest among present and potential manufacturers of both organic and inorganic fibers in acquiring some portions of the asbestos market. The environmental problems with asbestos keep reminding people of the market and its present vulnerability. Few substitutes, however, will be able to meet the four criteria below, which, even if the substitute is environmentally acceptable, must be met in order to acquire any substantial part of the asbestos market:

1. The substitute must approach the strength of asbestos;
2. The substitute must have the chemical inertness of asbestos;
3. The substitute must have the durability of asbestos; and
4. The substitute must approach the cost of asbestos.

There are several synthetic inorganic fibers available commercially, and more are becoming available each year. Most efforts seem to be aimed at thermal insulation, which constitutes only a small portion of the asbestos market. The most desirable characteristic of asbestos, its tensile strength, is compared with other fibers in table 5.

Glass-reinforced cement, now available commercially in the United States and Europe, could affect the future of the asbestos industry. The glass used is a high-zirconia, alkali-resistant fiber developed by the United Kingdom's Building Research Station. However, several drawbacks to glass-reinforced cement products have been reported (*14*): The glass fibers have inferior drainage characteristics; they are formed by a costly spray-suction process; their strength gradually fails with time; and they cost about four times as much as the equivalent asbestos.

The exotic and very expensive inorganic whiskers, such as sapphire (Al_2O_3), are the only synthetic fibers that equal or surpass the strength of asbestos. Even the newer inorganic fibers available commercially (*11*) are not as strong as glass and cannot be considered seriously competitive with asbestos.

The present shortages and projected demands indicate serious depletion of present reserves by the end of the century. Accelerated research is necessary to find substitute fibers that will have at least some of the attractive asbestos characteristics of strength, chemical inertness, heat resistance, and economy.

STRATEGIC CONSIDERATIONS

During World War II, controls were in effect to restrict 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 spinning fibers in 1954; however, export licenses are still required for shipments to nations that have centrally controlled economies.

The United States joined the United Nations embargo of Zimbabwean products in 1967. By 1969 all Zimbabwean asbestos except occasional small lots released from bonded warehouses or the Government stockpile had disappeared from the U.S. market. In 1971, an exception to the sanctions for strategic materials, including asbestos, was enacted by Congress. Significant amounts of Zimbabwean asbestos were appearing at U.S. ports by the time the sanctions were reimposed early 1977. The Presidential lifting of sanctions in January 1980 should see the the reemergence of Zimbabwean asbestos on the U.S. market.

Table 6.—Stockpile status-11-30-80

Material	Goal	Total inventory	Authorized for disposal	Sales, 12 months
Chrysotile (metric tons).............	2,722	9,034	---	---
Crocidolite (metric tons)............	---	2,163	2,163	---
Amosite (metric tons)...............	15,422	38,861	14,736	---

Chrysotile and amosite are the only types of asbestos remaining o[redacted] lists. The stockpile goal [redacted] had been reduced to zero, but a 1977 moratorium on disposals preserved some prior to [redacted]

The status of the asbestos in the stockpile as of November 30, 1980, is shown in table 6.

The United States is historically dependent upon foreign sources for about 90% of its requirements for all grades and types of asbestos. The principal sources of low-iron, spinning grade chrysotile asbestos are British Columbia in Canada and Zimbabwe. 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 the Transvaal, Republic of South Africa. The United States is completely dependent on foreign sources for crocidolite. Although the United States is an asbestos-importing country, there is some export trade, because domestic chrysotile producers have significant markets in Japan and Latin America. There are some reexports of foreign fibers.

The Asbestos Corp.'s bulk shipments of concentrate (30% fibers) from its Asbestos Hill Mine in Canada to its new mill in Nordenham, Federal Republic of West Germany, was novel. The operation, started in 1972, may portend other changes in the world market, since it has been singularly successful.

ECONOMIC FACTORS AND PROBLEMS

Prices and Costs

Prices for Canadian asbestos continued to climb, with a 7.1% increase in 1979. Quebec chrysotile fiber prices in 1979, f.o.b. mine, ranged from Can$125 per metric ton for 7T, which is the shortest of the regular grades generally produced, to Can$1,770 for the longest of the milled fibers. Crude No. 2 was quoted at Can$2,530 per ton. British Columbia (Cassiar) sold for Can$375 for CZ to Can$3.991 per ton for Crude No. 1.

Vermont chrysotile, produced in grades similar to those in Canada, ranged in price in 1979 from $110 per ton for Group 7 to $651 for Group 4, f.o.b. mine. Arizona fibers ranged in price from $110 for Group 7 to $3,307 per ton for No. 1 crude, f.o.b. Globe, Ariz.

The average price for amosite, f.o.b. U.S. ports in 1979, was $499 per ton; for crocidolite, prices averaged $683 per ton.

The total value of the 93,354 tons of asbestos produced in the United States during 1979 was $29 million, averaging $310 per ton, f.o.b. mine site. The imports of asbestos for consumption were valued at $135 million.

Table 7.—Time-price relationships for asbestos

Year	Average annual price, dollars per metric ton	
	Actual price	Based on constant 1978 dollars
1958	98.76	228.60
1959	100.50	228.30
1960	104.30	230.86
1961	105.38	231.30
1962	104.56	225.33
1963	101.90	218.44
1964	108.80	227.52
1965	107.84	220.82
1966	110.92	219.73
1967	112.34	218.16
1968	109.06	200.83
1969	121.29	212.88
1970	127.47	212.14
1971	129.86	205.16
1972	128.56	196.48
1973	134.72	183.82
1974	134.78	176.84
1975	168.89	190.02
1976	228.31	257.34
1977	273.90	283.92
1978	272.89	272.89
1979	283.62	242.15

Taxes and Tariffs

There are no special taxes on the asbestos industry. Producers are granted a depletion allowance of 22% on domestic production and 10% 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, although African markets are increasing. Transportation from British Columbia, Canada, to any market area is costly. The Arizona producer also has transportation problems. The mines are in the vicinity of Globe, the nearest railhead, with an average haul to the railroad of about 80 kilometers, compounded by the distance to the major consumption centers in the northeast.

Consumption of asbestos is also growing along the west coast of the United States and other areas where fiber from California would be competitive, in terms of freight rates, with that from Quebec.

Packing for ocean transport, either way, is changing to containerization. South African shippers have developed packaging techniques that conform to our container requirements. Western U.S. producers package their export asbestos in intermodal containers. Rail shipments

CTD007125

Table 8.—Energy used by the U.S. asbestos mining industry

Source and unit	Used in mining	Used in milling	Total used	Total (thousand kilowatt hours)
Heavy fuel oil .... thousand gallons....	852	1,345	2,197	96,356
Natural gas .... million cubic feet....	---	168	168	50,736
Electricity .... thousand kilowatt hours....	2,641	44,974	47,615	47,615
Diesel oil .... thousand gallons....	412	133	545	22,147
Liquid petroleum gas .... do......	14	168	182	6,987
Gasoline .... do......	52	12	64	2,343
Total energy, thousand kilowatt hours	59,192	168,994	228,186	228,186

Table 9.—Energy consumed in the production of 1 metric ton of cleaned and graded chrysotile asbestos [1]

Stage and type of fuel	Amount [2]	Equivalent thousand Btu
Mining: [3]		
Electric	42 kilowatt-hours	550
Diesel fuel oil	11.12 gallons	1,852
Bunker 6C oil [4]	1.48 gallons	270
Kerosene	0.04 gallon	8
Gasoline	0.51 gallon	77
Total	....	2,757
Primary crushing: Electric ..	7 kilowatt-hours	87
Secondary crushing: Electric	75 kilowatt-hours	963
Drying:		
Electric	42 kilowatt-hours	550
No. 2 fuel oil [5]	0.54 gallon	90
Bunker 6C oil [4]	15.40 gallons	2,859
Propane	0.12 gallon	13
Total	....	3,512
Milling and grading: Electric.	249 kilowatt-hours	3,289
Grand total	....	10,608

[1] Mine-plant transportation not included
[2] Liquids converted from the imperial gallons (Imp gal) to U.S. gallon using 1 imp gal = 1.200949 U.S. gal.
[3] Based on a large Quebec mine with a 3-to-1 ore ratio, 6% fiber per ton of ore, and 25 to 30 inches of mine precipitation per year.
[4] Based on caloric value of 154,046 Btu/gal.
[5] Based on average caloric value of 5,825,000 Btu per barrel.
[6] Based on average caloric value of 3,843,000 Btu per barrel.

Source: University of Illinois (17).

handle about 80% of asbestos shipments, but these are not yet being containerized.

OPERATING FACTORS AND PROBLEMS

Environmental Requirements

In 1970, Congress enacted "The Clean Air Act." Among the provisions of that act was that the Administrator of the Environmental Protection Agency (EPA) could designate substances as "hazardous air pollutants." One of three substances named to the first list on March 31, 1971, was asbestos. This was the first Federal agency to address the growing controversy about the effects of asbestos dust upon the health of humans.

There is insufficient space to document the conflicting reports, and insufficient data to evaluate the validity of each. The few areas of consensus are as follows:

1. Prolonged occupational exposure to heavy concentrations of asbestos dust, in the absence of personal protective devices, can measurably increase the chances of a person contracting the type of pneumonoconiosis called asbestosis.

2. Exposure to asbestos may increase the chances of contracting the very rare type of cancer called mesothelioma.

3. Asbestos workers exposed to heavy concentrations of dust without respiratory protection, and who are also heavy smokers, have increased chances of contracting lung cancer.

4. The evidence concerning the possible hazard from ingestion of asbestos particles is contradictory and inconclusive (10).

There is no consensus about a threshold limit value (an acceptable concentration that would minimize danger from exposure), or even a method of measuring it. EPA indicates there is no acceptable way to measure asbestos in the ambient air. The Occupational Safety and Health Administration (OSHA) of the Labor Department uses a membrane filter and microscopy method with a present standard of two fibers greater than 5 micrometers in length per milliliter of air. The method used by the Mine Safety and Health Administration (MSHA) approaches the OSHA method, and uses the two-fiber level. The controversial aspects of the matter appear to be long-lasting.

An example of litigation in the controversy is the Reserve Mining Co. case, in which the company was sued by the Federal Government primarily for polluting Lake Superior with asbestos bearing tailings from its taconite plant, and secondarily for air pollution with asbestos fibers. The judgment rendered said there was no indication of harm from ingested asbestos, but that both the water and air pollution must be abated in a reasonable time.

The controversy had no effect in the marketplace in 1973 and 1974, in which years there were record high consumption and production. Any effects in 1975 and 1976 were masked by the shortages attendant to the Canadian production troubles and were not discernible.

Much research was funded by Congress to answer environmental questions. Some of these questions are as follows:

1. Is asbestos by and of itself a true carcinogen?
2. Are there significant differences, under the same conditions of exposure, between the toxicities of different types of asbestos?
3. What is the dose-response relationship to asbestos dust exposure, or what exactly is a safe level of exposure?
4. Are there any physiological effects from the asbestos in the ambient air?
5. Is there a valid correlation between measurements of asbestos dust by the various methods?

Table 10.—Projections and forecasts for U.S. asbestos demand by end use
(Thousand metric tons)

End use	1978	2000			
			Contingency forecasts for United States		
		Statistical projections [1]	Forecast range		Probable
			Low	High	
Asbestos cement pipe	217	260*	130	270	210
Asbestos cement sheet	36	70*	0	20	0
Flooring products	126	240*	110	220	170
Roofing products	62	160*	130	210	120
Packing and gaskets	31	38*	0	30	25
Friction products	74	120*	0	70	60
Insulation	7	4*	0	10	0
Paper	9	51*	27	40	35
Textiles	3	0*	0	10	0
Other	54	17*	0	40	0
Total	619	---	397	920	620

[1] Statistical projections, provided by the Branch of Economic Analysis, are derived from regression analysis based on historical time series data and forecasts of economic indicators such as GNP, FRB index. Projection equations with a coefficient of determination (R squared) less than 0.70 are indicated by an asterisk (*).

substitutes. The low end of the range for asbestos construction products was obtained by assuming a continuation of the 20-year trend. This shows the probable total loss of any asbestos cement sheet and insulation markets.

On the high side of the demand range, the most apparent opportunities for increases appear to be asbestos-cement products, which compete with lumber and other building products, many of which are increasing rapidly in price. The growth rate for asbestos-cement products could average 0.6% per year. Use of asbestos in floor tile has been increasing in recent years because of shortages and higher prices for competing materials. Paper products are used in electrical appliances as well as in construction. The consumption of asbestos for such uses is expected to grow more than 1% per year.

Asbestos demand for friction products was forecasted to the year 2000 to grow at an annual rate of 2.2%. This figure was based on a formula derived from analysis of total asbestos demand modified by the estimated growth in the automobile industry. Asbestos is an important part of many types of friction materials for use in automobiles, trucks, and other transportation equipment. Based on an estimated number of motor vehicles produced in the year 2000, and on the assumption that the use of asbestos per vehicle will remain below present levels, the forecast for asbestos demand in user-operated vehicles is estimated to be 60,000 tons. An increased 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 70,000 tons.

The probable demand for asbestos in textiles was estimated to be zero tons in year 2000 as indicated by statistical projections.

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, there are other materials used as insulation that could replace asbestos for some purposes.

Competition from other substitute material is likely to be important, and a competitive factor is considered. Assuming that there will be some increased use of asbestos for such items as electrical appliances and firefighting equipment, the high forecasted demand could be 10,000 tons in the year 2000.

With low-cost, short-fiber asbestos 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-temperature or corrosive conditions.

The myriad small markets covered in "Other" seem to be the most vulnerable to environmental pressure, and many probably will vanish.

Adequacy of Supply

The United States has been dependent on foreign supplies of asbestos for certain essential and strategic grades. Canada supplies most of our requirements for chrysotile, with South Africa supplying amosite and crocidolite. The increasing world demand coupled with the forecasted shortfall in foreign supplies should encourage development of domestic resources. Such development of domestic asbestos deposits, if feasible under environment regulations and coupled with advancing technology in the use of substitutes, could shift our position from heavy reliance on foreign supplies for this mineral.

Domestic resources of chrysotile are found mostly in California, Vermont, and Arizona. Although deposits are known to exist also 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 occasionally produced in North Carolina.

Nine of the major asbestos-product-manufacturing firms have captive fiber sources through U.S. and Canadian mines, either wholly or partially owned (22). The total present production capacity of these mines exceeds 1.8 million tons per year.

United States and Canadian chrysotile resources are more than ample to meet the high of the forecast domestic demand for the year 2000, but could affect Canadian

Table 11.—Summary of forecasts of U.S. and rest-of-world asbestos demand
(Thousand metric tons)

	1978	2000 Forecast range Low	2000 Forecast range High	Probable 1990	Probable 2000	Probable Average annual growth rate 1978–2000 (percent)
United States:						
Total	619	397	920	620	620	0.0
Cumulative	---	10,884	16,867	7,440	13,640	---
Rest of world:						
Total	4,535	9,806	14,420	7,720	11,987	4.5
Cumulative	---	153,071	193,009	73,433	172,481	---
World:						
Total	5,154	10,203	15,340	8,340	12,607	4.1
Cumulative	---	163,955	209,876	80,873	186,121	---

Table 12.—Adequacy of U.S. and world asbestos reserves
(Thousand metric tons of asbestos)

	United States	Rest of World	World total
Reserves	4,000	138,000	142,000
Cumulative demand, 1978–2000	13,640	172,695	186,335

capability for supplying a major part of the demand in the rest of the world. The relationship between Quebec producers and U.S. consumers could be altered if the Provincial Government carries through on its announced interest in nationalizing (*13*) a portion of the industry.

Asbestos to meet relatively small requirements for amosite will continue to come from the Republic of South Africa unless deposits of a similar asbestos are discovered in other countries, or unless 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 or Bolivia, so long as it remains competitive with chrysotile, but substitution is practicable in end uses, and continuation of crocidolite supply is not particularly significant.

No real shortfall is expected in asbestos in 2000 contrary to the data shown in table 12. Either the demand will decrease at accelerated rates or higher prices and new technology will make current subeconomic deposits into useful resources.

Possible Supply-Demand Changes

Demand for asbestos in the United States for domestic consumption in 1979 was 561,000 tons, about 17% of which came from domestic sources; most of the balance was obtained from Canada and the Republic of South Africa. Annual requirements for asbestos in the year 2000 are not expected to reach 0.9 million tons, the high of the forecast range (table 10). If the 1978 ratio of domestic production to demand prevails in the year 2000, the domestic production component required to meet the maximum expected demand would be 138,000 tons. This production could be accomplished from known resources by more extensive use of the low-cost, very-short-fiber Coalinga, Calif., material. Historical and projected domestic production and demand for asbestos are shown in table 13 and figure 7. The trend projections for demand are low compared with the forecast

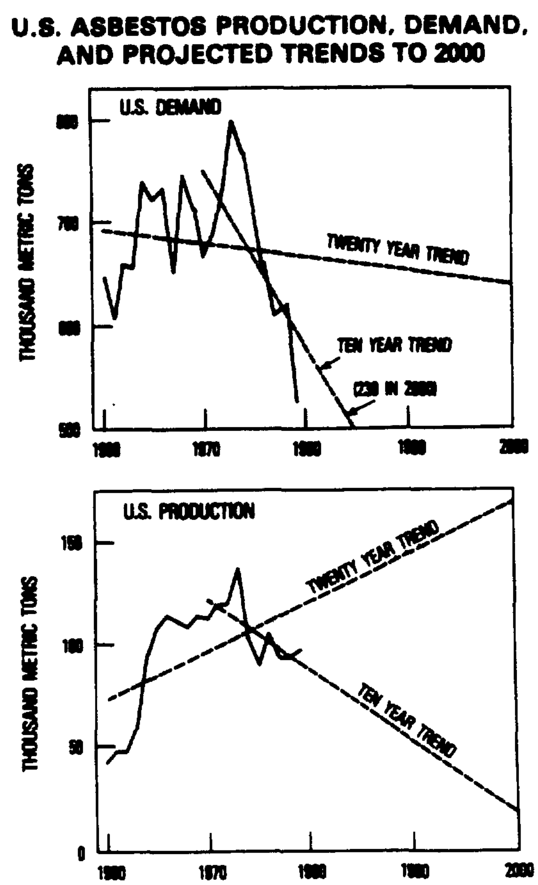


Figure 7.—U.S. asbestos production, demand, and projected trends to 2000.

Table 13.—Comparison of U.S. asbestos production and demand 1958–79, 1990, and 2000

(Thousand metric tons)

Year	U.S. demand	U.S. production	
1958	621	40	
1959	684	42	
1960	643	41	
1961	604	48	
1962	659	48	
1963	657	60	
1964	738	92	
1965	721	107	
1966	730	114	
1967	654	112	
1968	741	110	
1969	711	114	
1970	666	113	
1971	689	119	
1972	734	120	
1973	795	136	
1974	768	103	
1975	[e] 700	89	
1976	660	105	
1977	609	92	
1978	619	93	
1979 [1]	561	93	
1990	[2] 620	[3] 146	[e] 40
2000	[2] 620	[3] 170	[e] 60

[e] Estimated.
[1] Not included in forecast base.
[2] Probable forecasts from table 11.
[3] 21-year trend projection.

Table 14.—Increased use of fillers in plastics in the United States, 1975, 1980, 1990, and 2000

Material	Consumption, 1,000 metric tons			
	1975	1980	1990	2000
Alumina trihydrate	50	200	800	1,600
Asbestos	180	350	800	1,700
Carbonates [1]	700	1,500	3,500	9,000
Cellulosic types [2]	40	90	300	500
Glass [3]	5	15	50	200
Silicas [4]	25	80	300	500
Silicates [5]	6	15	50	100
Talc minerals	40	200	900	1,800
Miscellaneous [6]	14	50	200	500
Total	1,060	2,500	6,900	15,000

SOURCE: *Modern Plastics* and industry estimates.
[1] Calcium carbonate, chalk, limestone, etc.
[2] Cellulose, cork, cotton, shellflour, woodflour, starch, etc.
[3] Beads, bubbles, flakes, spheres, etc. Does not include fiber reinforcements such as chopped strand, filaments, yarn, ribbon, mat, etc.
[4] Novaculite, perlite, sand, synthetic silicas, quartz, etc.
[5] Other than asbestos and talc; includes clay, mica, nepheline syenite, etc.
[6] Plastic spheres, comminuted resins, castor oil, wool, metals, various inorganic compounds, etc. *(Courtesy Modern Plastics, October, 1975).*

range, which is caused mainly by the time periods chosen for the trend projections. The demand growth for asbestos averaged about 1.0% per year from 1954 to 1973, about 0.4% per year from 1956 to 1975, and was negative from 1968 to 1978.

Possible Technological Progress

Although asbestos was synthesized in the late 1920's, and much work has been done since that time, an economical method of synthesis has not yet been announced. Technology must come up with competitive synthetic asbestos or asbestiform products and make them available in significant quantities before the end of the century for potential world demand to be met, unless significant price increases convert resources to reserves. The mineral raw materials needed for production of synthetic asbestos and other inorganic fibers are abundant.

Among the factors that should tend to increase asbestos demand within the next decade is the newly developed potential for large-scale production of low-priced asbestos from domestic deposits, which should in time spur research into new uses and ways to substitute short-fiber asbestos for the longer, more expensive types. The 1975 shortages drove some manufacturers to try such substitution with a degree of success. The domestic product is being used in asbestos-cement pipe and undoubtedly can be used in other products by adapting the production processes.

Work is under way 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 subject 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. Resurfacing requires about 20 tons of asbestos per kilometer of 12 meter pavement and probably has the greatest potential for large-volume asbestos use. Technological changes in road building methods could result in capping new highways with asbestos-rich asphalt. The environmental effects of fully encapsulated asbestos, such as this, are considered minimal.

Table 14 (above) from a recent publication shows that asbestos may play an important part in energy conservation in the automobile and other steel-consuming industries (*15*). If these applications should develop, then three times as much asbestos would be consumed in 2000 as in 1978. The lighter weight plastics contemplated for use can be even lighter in weight and have better engineering characteristics when reinforced by asbestos.

Medical problems connected with asbestos have been under intense study in recent years and undoubtedly will continue to receive 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 for protecting workers in mines, mills, and fabricating plants. Among the possibilities for solving the problems 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.

Remaining Problems

One of the most serious problems confronting the domestic consuming industry is U.S. dependence for the greater part of its supply of asbestos on foreign sources.

About 85% of the supply of chrysotile and all of the amosite and crocidolite comes from foreign countries. Complete dependence upon foreign supply for strategic grades can be minimized by adequate stockpiles.

Adequate information on the methods of mining and processing 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; however, there is no information on the wastage that takes place in the manufacturing of the end item.

The number of materials that are economically competitive with asbestos is limited. Although much research has been directed to synthesizing fibers that have properties similar to asbestos, it has met with only limited success. The development of practical technologic advances in the broad area would substantially improve the supply outlook.

Health hazards are present in the whole sequence of mining, processing, and utilizing asbestos; and the expanding use of this material demands continued attention to the problem.

Asbestos is not an energy-intensive mineral; on the contrary, it has a long association with energy-conservation products. Nonetheless, energy-conservation practices need further development in all phases of the mining, milling, and utilization of asbestos.

REFERENCES

1. Ampian, S. Asbestos Minerals and Their Nonasbestos Analogs, Pres. at Microfibers Symp., Pennsylvania State University, University Park, Pa., Aug. 23-25, 1976, 11 pp; available from W. J. Campbell, Bureau of Mines, Research Center, Avondale, Md.
2. Battelle Columbus Laboratories. Energy Use Patterns in Metallurgical and Nonmetallic Mineral Processing (Phase 7 – Summary of the Results of Phases 4, 5, and 6). BuMines Open File Rept. 117(2)-76, 1976, 31 pp. Available for reference at Bureau of Mines libraries in Tuscaloosa, Ala., Avondale, Md., Twin Cities, Minn., Rolla, Mo., Boulder City, Nev., Reno, Nev., Albany, Oreg., Salt Lake City, Utah, and at the Central Library, U.S. Department of the Interior, Washington, D.C.; and from National Technical Information Service, Springfield, Va., PB 261 151/AS.
3. Bowles, O. The Asbestos Industry. BuMines Bull. 552, 1955, 122 pp.
4. Burmeister, H. L., and I. E. Matthews. Mining and Milling Methods and Costs, Vermont Asbestos Mines, Ruberoid Co., Hyde Park, Vt. BuMines IC 8068, 1962, 43 pp.
5. Campbell, W. J., R. L. Blake, L. L. Brown, E. E. Cather and J. J. Sjoberg. Selected Silicate Minerals and Their Asbestiform Varieties: Mineralogical Definitions and Identification-Characterization. BuMines IC 8751, 1977, 56 pp.
6. Cape Insulation and Asbestos Products Ltd. (London). Noramite: A New Concept in Plastics Reinforcement. P. 7.
7. Cossette, M. Automation of Asbestos milling Circuits. Can. Min. and Met. Bull., v. 64, No. 608, April 1971, pp. 25-33.
8. Dayton, S. The Greatest Challenge: Growing in New America. Eng. Min. J., v. 177, No. 6, June 1976, pp. 92-98d.
9. Farrell, E. A. Asbestos. Min. Eng., v. 26, No. 2, February 1974, pp. 101-102.
10. Federal Register. V. 40, No. 51, Mar. 14, 1975, p. 11866.
11. Imperial Chemical Industries Ltd. (London). Saffil Fibres. P. 2.
12. Industrial Minerals (London) Asbestos. No. 28, January 1970, p. 12.
13. ———Quebec to Assume Asbestos Control? No. 113, February 1977, p. 9.
14. ———Asbestos Alternatives. No. 109, October 1976, pp. 45-47.
15. Katz, H. S. and J. V. Milewski, Handbook of Fillers and Reinforcements for Plastics, 1978, p. 5 (introduction).
16. Mining Magazine. V. 141, No. 6, December 1979, p. 615.
17. Penner, P., and J. K. Spek., Stockpile Optimization: Energy and Versatility Considerations for Strategic Materials. University of Illinois, May 1976, 97 pp.
18. Quebec Asbestos Mining Association. Asbestos Producer. June-July 1974, p. 15.
19. Schattberger, W. M. Survey of Energy Contents of Three Cladding Materials. Schape Associates Reference 9706, Sept. 24, 1979, 9 pp.
20. Tiphane, M. Asbestos in Québec. Ministere des Richesses Naturelles due Quebec, E.S.-14, 1973, pp. 22-23.
21. Trauffer, W. E. Canadian Johns-Manville's Jeffrey Mine at Asbestos, Que. Pit and Quarry, v. 66, No. 9, March 1974, pp. 59-66.
22. U.S. Environmental Protection Agency. Economic Analysis of Proposed Effluent Guidelines: The Asbestos Products Manufacturing Industry. EPA-230/1-73-001, September 1973, 120 pp.
23. Vagt, G. O. Asbestos. Department of Energy, Mines, and Resources, Ottawa, Canada, Mineral Policy Series MR 155, July 1976, 26 pp.

SOURCES OF CURRENT INFORMATION

U.S. Bureau of Mines publications:

Mineral Commodity Profile, July 1979.
Mineral Commodity Summaries, annual.
Minerals Yearbook, annual.
Mineral Industry Surveys, annual.

Other sources:

Company annual reports.
Industrial Minerals.
Engineering and Mining Journal.
World Mining.
Mining Engineering.
Mining Journal (London).

U S GOVERNMENT PRINTING OFFICE 1981 – 341-582:57

CTD007131