Canadian Crude Chrysotile Asbestos

CANADA
DEPARTMENT OF MINES
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Chrysotile Asbestos in Canada

BY

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PREFACE

Chrysotile asbestos was discovered in Quebec about 1862; the first commercial production was made in 1878. During the two following decades production increased gradually as new uses were found for the fibres; the operations quickly became the most important mineral industry of the province, a position which has been maintained for thirty-seven years.

The important place already attained by the industry at the beginning of the present century naturally focused attention upon it. In 1904, arrangements were made by the Mines Branch with Fritz Cirkel, M.E., of Montreal, for the preparation of a monograph on Chrysotile Asbestos, its occurrence and uses. This monograph, a book of one hundred and eighty-five pages, published in 1905, was the eleventh of a series of economic reports then being issued by the Mines Branch.

Public interest in the industry had already created an unusual demand for the information supplied by the monograph, and the edition was soon exhausted. In the next five years the output of the industry almost doubled, both in tonnage and in value. Arrangements were therefore again made with Mr. Cirkel for the preparation of a second edition of his monograph. This edition was larger and more complete than the first edition, and was published in 1910. Due in part to the Great War and in part to industrial conditions immediately following the war, the industry now entered a period of expansion and prosperity which, with slight setbacks, lasted until about three years ago.

More recently the Canadian industry has had to contend in the markets of the world with an expanding production of asbestos from other world sources, and, in addition, grave difficulties have been encountered in the mining operations in Quebec which have greatly retarded production.

Cirkel died during the war period in August 1914. Copies of the second edition of his report were still available in 1920, but the supply was quickly exhausted. The Department of Mines, however, still continued to receive inquiries for information about the industry, but it was not until late in the season of 1927 that it was possible to arrange for the preparation of a third edition of this monograph.

In December, 1927, James G. Ross, of Montreal, who had had many years' experience as a mining engineer in the asbestos-producing areas of Quebec, was engaged to prepare for publication the third edition of this work. The revision was made during a time of very active professional work in other directions, and was not completed until April, 1929. In the intervening period the Canadian industry encountered a number of setbacks in the mining operations in the Thetford area. These, coupled with the general business depression which now exists, have materially affected the expansion of the industry and the prosperous conditions of three years earlier no longer prevail.

Information available concerning foreign deposits is very meagre and without making personal visits to the more important world occurrences adequate treatment would be impossible. Neither time nor funds were available for this work, and it did not appear that such a study would be of any special advantage to Canadian producers or consumers. The information has already been published elsewhere, and republication at the present time does not appear advisable.

The second edition of Cirkel's report reviewed available information about the geology of the serpentine areas in Canada. No work of importance on this subject has been published since 1910. In the meantime extensive new developments underground in the mining areas, systematic drilling under the supervision of a mineralogist and geologist, and additions to geological knowledge from other sources have made it desirable that the whole subject of the occurrence and origin of these deposits be again reviewed. The Geological Survey of the Department of Mines and the Quebec Bureau of Mines have recently initiated a resurvey of the asbestos-bearing areas of the province of Quebec, which will require at least two years for completion. Under the circumstances it did not appear desirable to reprint a review of the older geological information already available in other publications.

The statistical tables which accompany this report were prepared by John Casey, Statistician of the Mines Branch. In a number of instances special compilations were prepared from the original records on file in this office.

The chapters on the quarrying and dressing of asbestos and that on manufacturing and manufactured products contain new material. They take cognizance of the progress of the industry and the improvement in manufacturing processes which have been developed during the twenty years which have elapsed since the second edition of Cirkel's report was issued.

ALFRED W. G. WILSON,
Chief, Division of Mineral Resources.

MINES BRANCH,
OTTAWA, January 8, 1931.

CHRYSOTILE ASBESTOS IN CANADA

INTRODUCTORY

The increasing importance of asbestos in industry has led to a demand for information on its occurrence, characteristics, treatment, and uses. The report, "Chrysotile-Asbestos," written by the late Fritz Cirkel, and published by the Mines Branch in 1910, has long been regarded as the standard work on the subject. This volume being out of print it was deemed advisable to issue a new one covering descriptions of changes and improvements in methods of quarrying, preparation of fibre, manufacturing practice, and uses.

While the Canadian production has increased from 111,176 tons[1] in 1912 valued at $3,059,084 to a production in 1930 of 242,112 tons valued at $8,390,163, that of Africa (Rhodesia and South Africa) has increased from a few tons in 1912 to 61,178 tons[2] in 1930 valued at $7,225,011 (approximately). The larger amount of fibre recovered in Canada in 1930 has resulted from the operations of fewer companies, only seven now being active. These, at the same time, are quarrying in a lesser number of pits, twelve in all. The capacity of the existing mills, however, is greater. Three old mills have been remodelled and enlarged and two new mills have replaced two of the older ones in which the equipment had become obsolete. While the ground now worked contains on the average a lower percentage of fibre than in past years, yet the value per ton of rock shows an increase, due to improvements in milling and grading methods, by means of which not only is a higher percentage of the fibre recovered from the rock, but a greater proportion of that recovered is retained in the longer and more valuable grades. Some of the richer ground is inaccessible on account of the location of the plants and equipment, and of the system of quarrying in vogue. From the known deposits, however, the present rate of production can be maintained for many years, provided that mining methods adapted to existing conditions, be introduced and that the structural geology be worked out to enable the operators to confine quarrying or mining to the more productive zones.

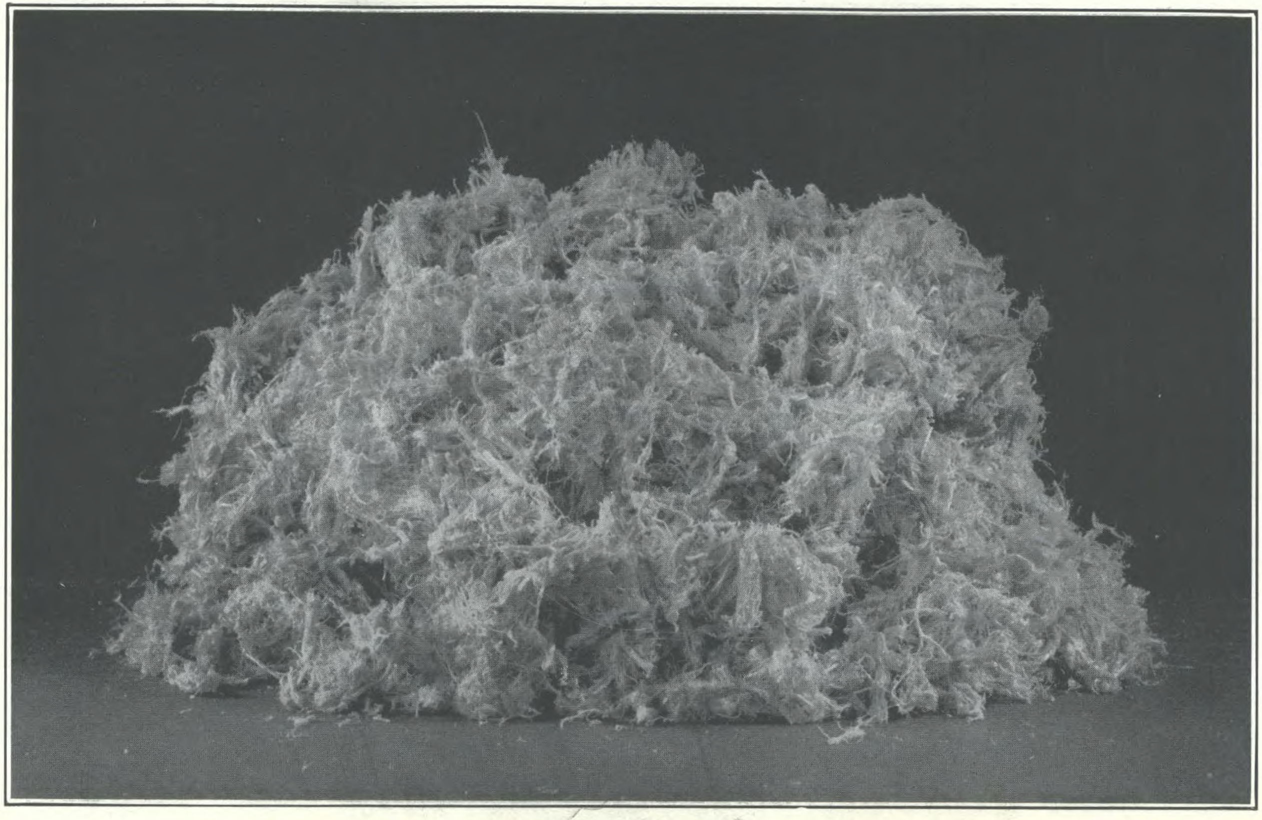
During times of active demand and consequent shortage of the better grades, unduly high prices and customary selling methods have encouraged or forced the opening of deposits in other fields. Asbestos from South Africa and Rhodesia has become firmly established, particularly in the European market. Russia, which for years has been a source of supply to a limited extent, is now threatening to produce on a large scale, and is

[1]Except where otherwise noted, the term "tons" herein used refers to the short ton of 2,000 pounds.
[2]Eng. & Min. Jour., vol. 131, No. 3, p. 101.

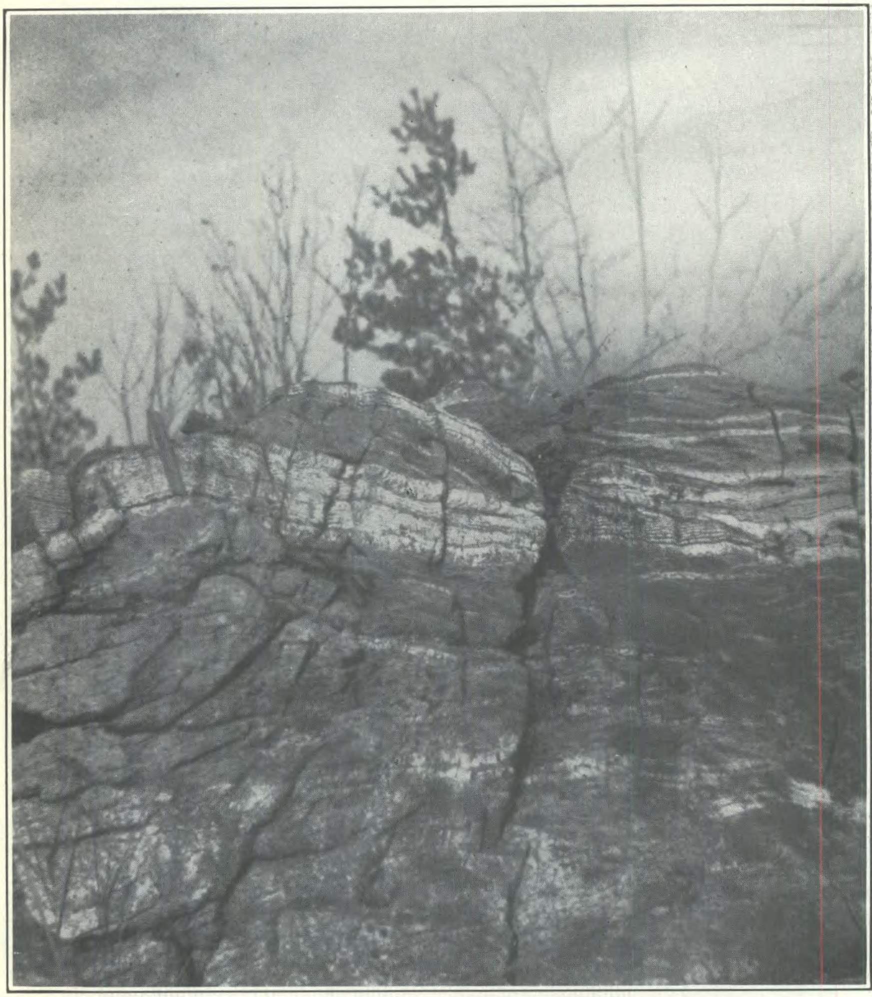
preparing to build a modern mill. Fortunately, from 1912 to 1929 the world consumption of asbestos increased five times in amount; and new uses promise an ever-growing demand.

In order to retain present markets and recover those in which Canadian fibre has been replaced by asbestos of inferior types or foreign origin, a study of existing conditions is advisable. The labour situation, lack of research along definite lines to improve quarrying and milling practices, inadequate publicity, want of system in selling, and absence of technical assistance, are deterrent factors in attaining maximum success in the Canadian asbestos industry.

Important advances in milling design have resulted in considerable reductions in cost of milling and in improved fibre recoveries. Mills built during the past few years have been so designed that facilities are available for study of the relative performances of different units of equipment, and for trials of other machinery which may be adopted from general metallurgical practice.



Canadian fibre milled.



Outcrop of ribbon fibre, Coleraine township, Quebec.

CHAPTER I

HISTORY, PHYSICAL AND CHEMICAL PROPERTIES, AND ORIGIN OF ASBESTOS

HISTORICAL

The use of asbestos can be traced back to ancient times. The Romans drew their supplies from the Italian Alps, and even from the Urals. They believed it to be of vegetable origin; the highly silky appearance and unctuous feel giving them the impression that it was an organic substance.

It is said that cremation cloth, in which dead bodies were enwrapped to be consumed by fire, was made of asbestos. It appears, however, that the high cost of making this asbestos cloth militated against its general use. Pliny refers to it as a rare and costly cloth—"linum vivum"[1]—"the funeral dress of kings" he calls it; evidently assuming that it was of vegetable origin. The fibre used came from the Italian Alps and was called "amianthus". It was apparently very difficult to spin, on account of its shortness; but judging from a piece of asbestos cloth on exhibition in the Vatican, and which is said to have originated in the days of ancient Rome, it is certain that vegetable fibre was intermixed with the real asbestos fibre in the making of so-called asbestos cloths. There is, moreover, according to Sir E. J. Smith, in the library of the Vatican, a winding sheet of Italian asbestos, which, although very coarsely made, is of a very soft and silky texture. This piece of cloth—perfectly preserved—was, together with some ashes, found in a sarcophagus in the Via Praenestina in 1702. It was subsequently placed in the Vatican library by order of Clement XI. It appears that some vegetable fibre was used with real asbestos fibre in the making of the cloth; because it is reported that, when the fire was applied to one end of the cloth, it burned with brightness, but left the real mineral fibre intact.

When Marco Polo was travelling in the thirteenth century through Siberia—at that time known as the Great Empire of Tartary—he was shown some cloth which withstood the action of fire. Marco found that it was made of a fibrous mineral called "amianthus", which resembled the Italian asbestos. Upon further investigation he found that the ore from which this fibre was extracted was first dried, then pounded in a mortar, and after the impurities had been eliminated, the pure silky fibre left was used in a spinning process, the method of which is unknown. The fibre referred to in Marco Polo's travels was long, beautifully white, and silky; and probably belonged to the variety known to-day as "hornblende asbestos". This same variety is found in Corsica. Before its real value became known it was used as a packing tow, and Dana reports that Dolomiea when packing up minerals for his collection on that island used it in tying the boxes.

[1] Quenstedt, Handbuch der Mineralogie.

That asbestos was used in ancient times as lamp wicks is recorded by Plutarch, who called them "perpetual" for the reason that the wicks never seemed to wear out. These lamps were principally used by the vestal virgins. The wicks, made of delicate asbestos fibre, formed small tubes through which the oil passed, while the wick itself remained intact. Pausanias mentions a lamp that was filled with oil only once a year; he evidently attributes to the oil what should have been credited to the wick —which was not consumed at all. He notes that the wick was made of "Carpasian" linen, referring to a mineral fibre obtained from Carpasius in Cyprus. It is said that Kirchner the German philosopher used in his library a lamp which had a wick made of "amianthus". Whatever the uses of asbestos may have been in days of old, it is certain that its peculiar non-combustible and spinning qualities were recognized and taken advantage of from the first; but it remained for modern times to make the mineral of commercial utility and an important factor in the industrial markets of the world.

Although the discovery of this mineral is attributed to the Romans, who, as already related, mined it in a small way in the Alps, the knowledge of its existence—which may not have been more than local—apparently lapsed. Only in a few instances is it mentioned, or its utilization referred to in the literature of the Middle Ages. It appears that in the year 1720, asbestos was discovered in the Ural mountains; and forty years later—under the reign of Peter I—a factory for the manufacture of asbestos articles was established. But the known uses were so few, and the demand so limited, that the industry subsequently disappeared; and it was not until some sixty years ago that technical interest in the mineral was revived in Europe. In the domain of applied mechanics its non-combustible properties were no sooner realized, than investigation of its nature and utility was begun in earnest—with a view to its application on a commercial scale. Since 1860, the search for asbestos has been incessant; the exploitation and development of the discovered deposits remarkable; and the progress made in the invention of mechanical methods for refining and preparing the mineral for utilization in the industrial world simply marvellous.

The first modern attempt to exploit asbestos deposits was made in Aosta valley of the Italian Alps by a London syndicate, for the purpose of experimenting on a large scale; and almost simultaneously with the exploitation in Italy, asbestos was discovered in the Des Plantes River region, between the villages of St. Joseph and St. Francis in Quebec. At the exhibition in London, in 1862, a specimen of fine, silky fibred asbestos from the above locality was exhibited.

The extension of the belt of serpentine rocks in which the mineral was known to occur had been traced with some care from the Vermont boundary in Potton township, to and beyond the Chaudière river; but the deposits of asbestos discovered were comparatively few and small. All attempts to work them profitably failed, and during the next fifteen years nothing was done in the way of exploration or exploitation.

In 1877, however, asbestos was found in another district in Quebec; this time in the serpentine hills of Thetford and Coleraine. The credit of this discovery is claimed by Mr. Robert Ward; although by others it is stated that the first find was made by a French-Canadian named Fecteau.

Following closely upon this discovery, several parties secured areas both at Thetford and Black Lake in Coleraine township, close to the line of the Quebec Central railway, which, for some miles, runs through a belt of serpentine. Large forest fires having swept over the country, the discovery of veins was facilitated by the weathering of the mineral on the surface.

Mining operations on a small scale commenced in 1878, and in this year 50 tons were produced; but, it was difficult to find a market. The quality of the fibre mined was excellent, and the width of the veins everything that could be desired, being from ½ inch up to 2, 3, and sometimes 4 inches. This justified the expectation that large deposits of the mineral might exist in that locality, though their true importance and value were not ascertained for several years later. Shipments of the better grades to London created quite a sensation in the British market; hence, extensive tests and investigations were made, with the result that, on account of its exceptional spinning qualities, high prices were soon established, and the race for the acquisition of additional areas likely to contain the valuable mineral began. The land upon which the asbestos was found was considered of very little practical value, either for agricultural or any other purpose, and mining operations were rapidly extended. The principal areas in which the asbestos-bearing serpentines were found to occur were lots 26, 27, and 28, near the line between ranges V and VI of Thetford township, and in Coleraine township near Black Lake station, four miles southwest of Thetford station, in previously unsurveyed area adjoining range B on the southwest; also on lots 27 and 28, range B; and on lot 32, range C. All these areas were speedily secured, as well as most of the serpentine-bearing ground extending southeastward from the Quebec Central railway towards Caribou lake, and for several miles along the Poudrier road.

During the next twelve years a rapid development of the asbestos industry was witnessed. The mines were operated on a large scale; while prospectors were busy exploring the hills of the surrounding country for new deposits of the mineral. Villages sprang up in the vicinity of the mines as if by magic, although the country—physically speaking—was sterile and very rough. Prior to the beginning of mining operations, the population consisted of only a few scattered families, but now it increased to several thousands, and the whole country showed all the marks of industrial activity and prosperity.

In 1885 it was reported that seven quarries were in operation, which produced during the same season an aggregate of about 1,400 tons of asbestos. The prices obtained for the different grades were: first quality, $80 per ton at the mines; second quality, $60; third quality, $40; and a lower grade—suitable only for pulp—$10. The total number of men employed by the various operating companies was 350; distributed as follows: King Brothers, 40; Boston Asbestos Packing Company, 100; the Johnson Company, 100; Ward Brothers, 20; Lionais & Company, 40; Irwin and Hopper, 50.

Dating from 1885 a gradual increase in the prices took place; especially for the first and second qualities. In 1900, about $300 was realized for the first quality. This, and other economic features in connexion with the industry, served to give a powerful impetus to the development of the existing asbestos resources: additional mines were opened; the demand for the mineral continued brisk for a time; and properties were sold at a high figure. At a meeting of the Bell Asbestos Company, Limited, held January 30, 1889, at the Cannon Street Hotel, London, England, the Chairman, Mr. John Bell, announced a dividend of 22½ per cent on the capital stock of the company for the year 1888, and said that the large growth of the asbestos business in general promised even better prospects for the current year.

But this state of affairs did not continue long; prices began to drop gradually, the demand slackened, and it was discovered that the prevailing methods of hand extraction were faulty, inadequate, and expensive, especially with regard to the lower grades. As a matter of fact, under prevailing price conditions, only those quarries which were working on rich ground, and had a large percentage of crude asbestos, had a chance to carry on operations with a profit. The natural outcome of these adverse conditions was obvious; many quarries producing only a very small percentage of the higher grades were forced to shut down; and this, together with serious difficulties accentuated by overproduction and a consequent fall in prices, caused the industry to receive a severe set-back in the middle of the nineties. For some years the industry languished, and this had a depressing effect on all except those who would not be discouraged or who were naturally optimistic.

Those engaged in the quarries and those having the development of the industry at heart perceived that only one thing could save the industry, namely, a more economical production; hence they began to exercise their inventive powers; the result being that, mechanical treatment of the lower grades of asbestos gradually supplemented hand-cobbing; and this method, in the course of years, was applied with such conspicuous success that to-day every productive quarry in the district is equipped with a complete milling and fiberizing plant. By means of this improved process, much of the shorter fibre, which in the earlier years was left in the rock and thrown into the dump, was saved; and as new demands for this short material sprang up, the life of a quarry was prolonged and its operations performed with greater ease and economy.

Following the abnormal war-time demand for asbestos with consequent high prices, the industry passed through several lean years. In an attempt to better the situation the operations of twelve companies were combined by merger or purchase into one in 1926. There are now twelve mills producing in Quebec. Seven companies control the active properties and the greater part of the known asbestos-bearing ground in the province.

ASBESTOS MINERALS

Under the term "asbestos"[1] is understood, generally, a group of minerals the fibrous, crystalline structure of which, combined with special qualities and characteristic appearance, entirely differentiates them from any other minerals. Some varieties possess such fine, silky, elastic fibre, that they can be carded, spun, and woven similar to wool, flax, or silk;

[1] The term "asbestos" is derived from the Greek, and signifies "unquenchable", "inextinguishable", "inconsumable". It is defined in a French work as, "mineral filamenteux et incombustible". The Germans call it "steinflachs" (stone flax); and the Italians "amiantho"—from the Greek "amiantos", signifying "undefiled", "pure", "incorruptible"; the French-Canadian calls it "pierre à coton" (cotton stone), in allusion to its similarity in appearance to cotton.

hence, owing to this property, the mineral has been called a "mineralogical vegetable"; also "a physical paradox."

In mineralogy, three minerals are classified under the term "asbestos"; namely anthophyllite, amphibole, and serpentine. Chemically, the two first-mentioned minerals much resemble each other, being silicates of lime and magnesia, with alumina—compounds of silica with an earthy base—generally represented by the formula $RSiO_3$; whereas the last, serpentine, is a hydrated silicate of magnesia, represented by the formula $3MgO\ 2SiO_2\ 2H_2O$.

Anthophyllite

This variety is commonly and commercially known as "amphibole." It is quarried at Sall mountain, Georgia, U.S., for use in making asbestos cement. At Hollywood, Georgia, it is developed for use in plaster, stucco, flooring, electrical composition, and cement.

Anthophyllite is generally of a greyish white colour, but in South America and China it is found in a lavender-blue shade.

Analyses quoted by "Asbestos"[1] of a sample from Sall mountain, Georgia, are as follows:—

—	Silica	Iron oxide	Magnesia	Alumina	Water	Lime
No. 1	57·12	6·36	29·44	0·75	5·47	
No. 2	56·76	2·12	28·34	9·80	1·18	1·66

Amphibole

The amphibole minerals include six varieties, namely:—

1. Tremolite,
2. Actinolite,
3. Asbestos,
4. Mountain leather, mountain wood, and mountain cork,
5. Crocidolite,
6. Amosite.

The three first-mentioned varieties of this amphibole group are very similar in their external appearance and chemical composition, but the so-called asbestos can be readily distinguished from tremolite and actinolite by the long slender flexible fibres, which can be easily separated by the fingers.

Tremolite. This is a calcium magnesium amphibole, $CaMg_3(SiO_3)_4$; 57·7 silica, 28·9 magnesia, and 13·4 lime. It occurs in metamorphic rocks, in long, stout, blade-like crystals of dark grey colour; also in long, thin, fibrous and columnar masses. Its commercial application is very limited. It is, however, frequently used as a substitute for actinolite in the manufacture of a fibrous wall powder and of mineral wool.

Actinolite (Strahlstein) is chemically a silicate of iron, calcium, and magnesium $Ca(MgFe)_3(SiO_3)_4$. It also occurs in metamorphic rocks, usually in fibrous and radiated crystalline masses of a bright green colour.

[1] "Asbestos", April 1928, p. 14; May 1928, p. 20.

The specific gravity is 3·0 to 3·2. The fibrous variety is often mistaken for true asbestos; but it never has the same fibrous texture as asbestos. It occurs in Elzevir township, Hastings county, Ontario; also in Maine and many other places in the United States, and elsewhere. It is found chiefly in magnesian rocks, such as talc, steatite, and serpentine, and is used for a variety of purposes, notably for weighting paper, roofing, and for various forms of adulteration.

In Elzevir township, Hastings county, the actinolite deposits are closely associated with a blackish green hornblende rock, which runs in ridges in a northeasterly direction, bounded on both sides by granites. The width of these hornblende belts varies from 250 to 500 feet. The whole area is affected by faults. Zone patches, vein-like occurrences of an asbestiform mineral, and a fibrous hornblende are frequent. An analysis of this mineral made by Professor Coleman, of Toronto, gave the following results:

Silica	61·82
Magnesia	23·98
Ferrous oxide	6·55
Lime	1·63
Alumina	1·12
Water	5·45

This mineral was mined intermittently from 1884 to 1903, near Actinolite, and the output hauled to Bridgewater, a distance of about 8 miles, where a mill, operated by water-power, ground all material. It was separated into four grades: Nos. I and II being employed for boiler coverings; No. III, which was finely ground, for plaster; and No. IV for covering rolled roofing. There were two companies operating in the district: the International Asbestos Company, with head offices at New York, and the Joseph James Company at Actinolite. It is claimed that from 30 per cent to 40 per cent of all the rock mined went through the mill, and that of this about 10 per cent was extracted as fibre.

Actinolite is also found in some of the hornblende rocks of the Sudbury district.

Actinolite and tremolite are chemically treated and used in the preparation of filter pads for Grooch filters, the filters being used for the filtering of fruit juices, acids, etc.

The following analyses of samples of hornblende minerals from different localities[1] will illustrate the chemical percentage of the composition:—

No.	SiO_2	Al_2O_3	Fe_2O_3	FeO	MgO	CaO	Na_2O	H_2O	F_2	XyO*	Total
I	57·5	1·3	0·2	0·2	24·9	12·8	0·7	1·3	0·8	0·6	100·3
II	56·1	1·2	0·8	5·5	21·2	12·1	0·2	1·9	0·1	0·6	99·7
III	41·9	11·7	2·5	14·3	11·2	11·5	2·7	0·7	0·8	2·6	99·9
IV	43·8	4·4	3·8	33·4	0·8	4·6	8·1	0·1	......	1·5	100·5
V	55·6	15·1	3·1	6·8	7·8	2·4	9·3	......	......	0·5	100·6

*Small quantities of minor components.

I. Tremolite, Richville, Gouverneur, New York.
II. Actinolite, Grenier, Tyrol.
III. Hornblende, Edenville, Orange county, New York.
IV. Arfvedsonite, Kangerdluarsuk, Greenland.
V. Glaucophane, island of Syra, Greece.

[1] Pirsson: "Rocks and Rock Minerals"; (Sec. Ed., p. 61.)

Asbestos. Tremolite, actinolite, and other varieties of amphibole—excepting those containing much alumina—pass into fibrous varieties, the fibres of which are sometimes several inches long, fine, flexible, easily separable by the fingers, and looking like flax. These varieties are called " asbestos ", " hornblende asbestos ", or " amphibole asbestos ". They usually exhibit a dull green colour, have a somewhat unctuous feel, and display occasionally a pearly lustre. They are closely allied with the pyroxene and hornblende rocks, and the name " asbestos " should be applied only to these varieties; the true silky kind which forms the basis of extensive mining in Canada is called chrysotile. The trade name, however, for all varieties which may be used in manufacturing is " asbestos ".

The Italian asbestos is asbestos properly so-called, for it consists of the highly fibrous form of hornblende, hydrated, and is mineralogically distinct, and entirely different, both in form and appearance, from the Canadian chrysotile. Notwithstanding the totally different physical character of the two, as found in the rock, in chemical composition they are very similar, and in many of the uses to which both minerals are put they are treated as identical. When mechanically prepared, however, the Canadian chrysotile looks so much like real " asbestos " that both are often sold one for the other.

Mountain Leather and Mountain Cork (Bergfleisch, Bergleder). Mountain leather occurs in thin flexible sheets made of interlaced fibres; mountain cork is the same, only in thicker pieces. These varieties contain little or no alumina; they do not readily separate into fibres; and are unsuitable for most of the purposes for which asbestos is generally used. The cork variety, which possesses the elasticity and lightness of cork, is usually of a light brown colour, and has a specific gravity of 0·68 to 0·99. The water in both mountain leather and cork is occasionally from 2 to 3 per cent, and sometimes more. According to Quenstedt, the composition of mountain cork is:

Silica	57·20
Peroxide of iron	4·37
Magnesia	22·85
Lime	13·39
Water	2·43
	100·24

Mountain Wood (Bergholz, Holzasbest, Ligniform Asbestos). Mountain wood is compact, fibrous, and grey to brown in colour, looking somewhat like dry wood, also like petrified wood; in fact, it might be readily mistaken for it, especially when sufficient oxide of iron is present to impart to it the tawny tinge of decayed wood or bark. The crystal fibres, however, are readily recognizable under the microscope; the absence of vegetable cells—which are always present in petrified wood—being clearly noted. The fibres are generally long, from a few inches up to 1 or 2 feet, and are curved and compact, but varying much in texture. This mountain wood is occasionally found in the Canadian asbestos deposits.

Crocidolite (Blue Asbestos, Blauer Asbest). This variety is found in Griqualand, South Africa. It is a beautiful mineral, of a highly fibrous texture, the fibres being easily separable by the fingers. Its specific gravity is 3·20 to 3·30; its lustre very silky; and of a dull, lavender blue colour due to the presence of ferrous oxide. The fibres are quite elastic, and are, occasionally, several inches long. Its chemical composition is Na Fe $(SiO_3)_2$. Fe SiO_3. Theoretically it contains:—

Silica	49·6
Iron sesquioxide	22·00
Iron protoxide	19·80
Soda	8·60
	100·00

Amosite. According to Hall:—[1]

It is possible that amosite may represent a variety of crocidolite with less soda, and that the differences in colour are conditioned by variations in that constituent; on the other hand, there appears to exist some affinity to the cummingtonite or grünerite group.

The following analyses are quoted by Hall:—

—	Amosite		Cummingtonite			Grünerite
	III	IV	V	VI	VII	VIII
SiO_2	50·24	49·10	56·55	51·09	50·74	43·90
Al_2O_3	....	....	....	0·95	0·89	1·90
Fe_2O_3	7·80	....	....	....	....	....
FeO	32·00	43·86	21·67	32·07	33·14	52·20
MgO	3·96	6·14	....	10·29	10·31	1·10
CaO	trace	0·46	....	trace	trace	0·50
Na_2O	2·12	....	8·44	0·25	3·04	....
Water (const.)	....	....	3·18	3·04	....	....
Moisture	....	....	....	....	....	....
Ignition	3·00	....	....	....	....	....
	99·12	99·56	97·64	99·69	100·43	99·60

$+7·8\ MnO_2 + 1·5\ MnO_2 + 1·77\ MnO_2$

III. Best quality "white asbestos"; analysis by C. Gardthausen.
IV. Second quality "white asbestos"; analysis by Prof. Hahn.
V, VI, VII. Cummingtonite from Massachusetts; Hintze, vol. II, p. 1242 (1897).
VIII. Grünerite from France; Hintze, vol. II, p. 1256 (1897).

Serpentine

The principal asbestos of commerce occurs in serpentine.[2] That from Canada, and especially from Thetford Mines, is found to be more uniform in requisite commercial qualities and therefore more desirable and valuable than asbestos from other countries. The principal producing country, after Canada, is Rhodesia, where the development of an asbestos mining and milling industry in recent years has been rapid. Asbestos fibre has been found in almost every quarter of the globe: Newfoundland, United States, Italy, South and Central America, China, Japan, Australia, Spain, Portugal, Hungary, Cyprus, Germany, Russia, South Africa, and Rhodesia. Fibre of exceptional quality has been quarried in Deloro township, northern Ontario. The principal sources of commercial fibre, after Canada, are Rhodesia, South Africa, Cyprus, Russia, and United States.

[1] Hall, A. L.: "Asbestos in the Union of South Africa"; Union of South Africa Geol. Surv., Mem. No. 12, p. 23 (1918).
[2] The name "serpentine" alludes to the green serpent-like cloudings of the serpentine marble.

The Canadian serpentine is of three distinct varieties:—

(1) Picrolite.
(2) Soapstone (talc).
(3) Chrysotile.

Although picrolite and chrysotile—the two offsprings of serpentine—are similar in chemical composition, their differences in external appearance and physical qualities generally is so great, that at first sight their common identity in the same group of minerals seems doubtful; indeed, among all the rocks of igneous origin there are none that so much puzzle the petrologist in his attempts at rational classification, as the small group representing the serpentine. This is due in part to the fact that no comprehensive study has as yet been made of the petrology of the alteration products of the basic rocks of the olivine-dunite-peridotite group. In some localities in eastern Canada serpentine rocks exist in considerable magnitude. Mineralogically, it is a hydrated silicate of magnesia, resulting from the alteration of magnesian rocks, is infusible, and, as a rock proper, without crystallization; chemically, its constituent formula is $3MgO \cdot 2SiO_2 \cdot 2H_2O$=silica, 44·1; magnesia, 43·0; and water, 12·9. It occurs, generally, in the crystalline series, with eruptives, etc., and the common assumption is that it is derived from olivine or peridotite because it sometimes exhibits the characteristics of peridotite, the essential constituent of which is olivine. Serpentine may, therefore, be classed as a hydrated peridotite or olivine. In the latter, under the action of carbonated water, the iron is frequently carried off, instead of being peroxidized; some of the magnesia being removed at the same time. The resulting rock is serpentine, which, in some noted localities, remains for the greater part as a rock mass and in fibrous varieties. Olivine is often full of fissures, and it is in these fissures that its transformation into serpentine commences. Under the microscope it appears as a finely fibrous, green fringe; the fibres lying at right angles to the surfaces from which they originate.

The hardness of serpentine is from 2·5 to 3·5, and its specific gravity 2·5 to 2·7. As a rule, serpentine is found in massive form; but it occurs also as a banded, schistose, and slaty structure. Its colour is from a very dark blackish to a light green; sometimes brown-red on decomposition surfaces often with a greyish white coating. The lustre is sub-resinous to greasy, pearly and waxlike, seldom earthy. On smooth surfaces the rock has a somewhat greasy feel, suggesting talc; but it can readily be distinguished from the latter by its hardness. The yellow-green colour resembles that of epidote rocks, but here also the greater hardness of the latter serves as a distinction.

Other minerals which occasionally accompany the serpentine are described by Poitevin and Graham.[1] The only one occurring in deposits of economic value is chrome iron. At two different periods when the selling price warranted extensive mining, operations were carried on to the south of Black Lake. From pit No. 6 of the Black Lake Asbestos and Chrome Company several tons of chrome iron ore were taken from a pocket in the asbestos-bearing serpentine. Similarly, good crude asbestos fibre was

[1] Geol. Surv., Canada, Mus. Bull. No. 27 (1918).

found in association with a chrome iron deposit at Redmill. As a rule, however, the two minerals are found in separate areas of serpentine. A little chrome iron, in the form of a coating on magnetite, is sometimes found in the asbestos veins.

The harder varieties of serpentine show great resistance at the surface to the action of weathering agencies; but, eventually, they yield to these influences, like the softer serpentine, and decompose. The resulting product shows a loss in silica and magnesia, on the one hand, with enrichment in alumina, volatile matter, and principally iron, on the other. An analysis of a decomposed, brownish serpentine taken from a surface outcrop, gave the following percentage composition:

SiO_2	34·70
Al_2O_3	2·95
Fe_2O_3	6·50
FeO	4·20
MgO	32·10
Moisture	3·96
Loss on ignition	21·03
Total Iron expressed as:	
Fe_2O_3	11·17
FeO	10·05

The soils formed from this decomposed material are extremely barren and are devoid of any vegetative power.

Owing to the brilliant colouring effects of serpentine, efforts have been made to utilize it in ornamental work for indoor decoration; mantle-pieces and statuary have been produced therefrom, showing beautiful effects; and it would be more extensively used for decorative purposes were it not for the fact that, the rock is easily disintegrated under the influence of atmospheric agencies. In the Perkins' area (15 miles northeast of Ottawa), where mining for asbestos was carried on during the years 1891-1893, efforts were made to utilize the highly coloured serpentine for ornamental work, and the Canadian Granite Company, of Ottawa, quarried serpentine for some considerable time and worked it in their factory; but it was found that the many joints and seams interfered seriously in the dressing, and it was difficult to secure good solid pieces for polished work. In the Thetford district, like difficulties were experienced. Comparatively large blocks were obtained in some of the quarries; but owing to the numerous joints and fissures therein, the decorative results achieved were very unsatisfactory. Recently, serpentine has been quarried in Vermont and sold under the name of "verde antique marble".

Picrolite (Pikrit). Picrolite is one of the principal varieties of serpentine. It resembles coarse asbestos, and occurs in fibrous aggregations in fissures or long slickensides (polished rock surfaces originated through rock movements) of the serpentine. It is found in almost every asbestos mine in Canada, and is called by the miners "bastard asbestos". Owing to the difficulty in distinguishing this material from asbestos proper, it finds its way, to some extent, into the mills, where it is fiberized with the asbestos. Its specific gravity is 2·607. The fibres are sometimes 8, 10, and 12 inches long, but are not easily flexible. They are, as a general rule, harsh to the touch, sometimes brittle, not easily separable, and often exhibit a splintery fracture. The colour is dark to light green, sometimes grey and white. Picrolite is not, at the present time, used in commerce, nor in the arts; but judging from the similarity in chemical composition, as well as from its physical properties, to asbestos—as such, there seems to exist a good reason to believe that some day this mineral will be utilized either in its natural state, or after pulverization, cleaning, and refining. Analyses of picrolite from East Broughton and Bolton gave the following results:

—	SiO_2	Al_2O_3	Fe_2O_3	FeO	CaO	MgO	H_2O	Authority
East Broughton........	37·88	1·10	2·70	0·36	0·82	43·29	14·52	Dr. M. L. Hersey, Montreal.
Bolton................	43·70	....	·3·51	......	......	40·68	12·45	Dr. J. T. Donald, Montreal.

Soapstone (Steatite). (The massive form of "talc".) This mineral is frequently found associated with serpentine, especially in Broughton township; in the easterly part of Thetford township; at lake Nicolet; in the townships of Wolfestown, Sutton, and Potton, Quebec; also in Elzevir township, Hastings county, Ontario. It occurs in very irregular deposits, which sometimes take the shape of bands, lenticular masses, and so-called "stocks", having a width of from 1 or 2 feet up to 20 or 30 feet, and even larger. Frequently, asbestos veins are abruptly cut off by the intersection of a soapstone deposit; but, generally, they are again found on the opposite side of the latter. Soapstone is an alteration product of magnesian minerals—especially serpentine, and in several localities in the Eastern Townships is almost exclusively associated with the latter. In some places it shows transitions into other rock, such as chlorite schist, crystalline dolomite, quartzite, etc. It occurs in massive form, but has sometimes a pronounced schistose cleavage and character. Other minerals also occur in different varieties of the rock, such as quartz and calcite in grains, lenses and veins; chromite and magnetite in black spots; hornblende in green prisms; also chlorite. Soapstone is soft; the hardness being 1 to 1·5 Moh's scale; and the specific gravity 2·75. Its colour is apple-green to white, greenish grey, and dark green; sometimes bright green perpendicular to cleavage surface. Its infusibility before the blow-pipe, and its insolubility in acids distinguishes it from similar looking minerals. When intensely heated in a closed tube most varieties yield water. When moistened with cobalt solution it assumes on ignition a pale red colour. The rock cleavage is often thinly fissile, sometimes thicker, and oftentimes the cleavage is entirely wanting; it is then nearly massive, compact, and has a wax-like aspect.

The commercial value of talc and soapstone depends chiefly upon their purity, also to some extent upon their colour (white), and upon their soapy touch—when ground very fine. The market requires a plaster or air-floated mineral, free from grit, quartz, mica, etc. Soapstone possesses a variety of qualities which render it adaptable for many uses. It is not liable to corrosion; withstands expansion or contraction in different ordinary temperatures; and is unaffected by moisture, or chemical fumes. When pure it may be sawn into slabs, or manufactured into pots and other vessels. It is utilized, at present, in the manufacture of gas jets, table tops, sinks, etc., and other interior fittings, where its non-corrosive qualities render it valuable. Owing to its refractory character it is admirably adapted for use as firestones, and as lining for furnaces and fireplaces. When exposed to high temperature it loses its small portion of water, and then becoming much harder assumes a dark green colour and is susceptible of a fine polish. In the last-named condition it is used for the manufacture of images,—chiefly by the Chinese and Japanese.

It possesses great power of resisting atmospheric influences, and chemical action. It is used as a preservative of woodwork, and often, in powdered form, is put on buildings and monuments to save the surfaces from disintegration. Utilized in this way, it has the property of clinging to metal and stonework with the tenacity of gold leaf. For hundreds of years it has thus been used in China and Japan with remarkable success.

The use of powdered soapstone in paint is well known. By using a suitable varnish in connexion with powdered soapstone, both sea water and the atmosphere are prevented from coming into direct contact with the steel of ships; rendering their hulls perfectly air- and water-tight. This paint, if properly prepared, will not crack with the vibration of the vessel, nor by the contraction or expansion of the steel. Varnish, used alone, is porous and admits the atmosphere and moisture to the material coated with it; but when mixed with powdered soapstone—owing to the infinitesimal, fine division of the mineral—the pores are completely closed, and are thus shut off from the influence of air and water. It is, moreover, used as a filler for paper, electric insulators, foundry facings, waterproof wall plaster in bathrooms, ornamented finishing on walls, shoe powder, waxing floors, dressings, tailors' chalk and crayons, firebrick, laundry, bath, and chemical tubs, hearthstones, mantels, slate pencils, and griddles. Talc of a dark colour is used as an adulterant of graphite for lubrication. It is used for switchboards, since it is not only hard enough to take polish, but the ease with which the numerous holes required in all switch- and keyboards can be drilled, renders it a very desirable article for this electrical work.

The quarrying and sawing of blocks of soapstone for use as linings of digesters in pulp mills is a growing industry in the Robertsonville district of Quebec, where soapstone underlies the asbestos-bearing serpentine sill.

Deposits of soapstone and talc in other sections of Canada are described by H. S. Spence[1] and M. E. Wilson.[2]

Soapstone deposits are found in many parts of the world. In the United States it can be mined in large quantities, remarkably pure in quality. In California rich deposits have been found in several districts; while in Arkansas a fine quality occurs in Saline county. In the last-named regions the deposits are closely associated with slates and serpentine; but in the aggregate they are very pure, containing about 62 per cent silica, and 34 per cent magnesia.

Chemically, soapstone consists of silica and magnesia, with certain oxides, and a small amount of water. Analyses of four samples of soapstone from Broughton gave the following results:

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[1] Spence, H. S.: "Talc and Soapstone in Canada"; Mines Branch, Dept. of Mines, Canada (1922).
[2] Wilson, M. E.: "Talc Deposits in Canada"; Econ. Geol. Ser. No. 2, Geol. Surv., Canada (1926).

Constituents	Sample A	Sample B	Sample C	Sample D
	H. Verger (Paris)	H. Verger (Paris)	Prof. McCandles Jones, from "Asbestos"	Dr. M. L. Hersey (Montreal)
Moisture	0·30	3·60	0·48	2·64
Chemically bound water	3·95		....	....
SiO_2	61·50	62·80	63·70	56·20
Fe_2O_3	0·11	0·25	......	....
FeO	......	......	1·46	....
Al_2O_3	0·89	0·20	0·42	....
MgO	33·03	33·10	33·75	32·65
CaO	0·16	......	......	....
Loss	......	......	0·19	....
	99·94	99·95	100·00	91·49

Analysis of soapstone from range VII, lots 5 and 6, Thetford township, Megantic county, Quebec:—

SiO_2	59·66
FeO	4·12
Fe_2O_3	0·37
Al_2O_3	1·67
CaO	Nil
MgO	29·26
CO_2	Nil
Water above 105° C	4·90

Analyses[1] of the foreign varieties of talc and soapstone are given in the following table:—

ANALYSES OF FOREIGN TALC AND SOAPSTONE

Countries	SiO_2	MgO	FeO	CaO	H_2O, CO_2 etc.	Al_2O_3	Na_2O, K_2O
Austria	59·59	32·92	0·79	0·59	3·79	1·76	0·56
France	50·91	24·86	2·58	1·82	6·64	13·19	....
Italy	51·23	33·32	1·89	1·80	5·46	7·08	0·22

Soapstone is sometimes found in fine granular or crypto-crystalline form, milk-white in colour, and of pearly lustre. In this condition it is often used as "French chalk" by tailors for marking cloth, removing grease, and other stains. The following are two partial analyses[2] of this variety:

SiO_2	62·80	63·49
MgO	33·50	31·75
H_2O	3·70	4·76
	100·00	100·00

Chrysotile. The next, and most fibrous form of serpentine is "chrysotile", or, as it is generally called, "asbestos". Previous to the general application of chrysotile asbestos, the beautiful, white, flexible fibres in

[1] "Mineral Industry"; p. 634 (1897).
[2] Jones: "Asbestos", p. 327.

use were distinguished by the Roman name of "Amianthus", in contradistinction to the brittle and less silky varieties. "Amianthus" is found in the older crystalline rocks; in the Pyrenees; on Mount St. Gothard; in the Ural mountains; and in New South Wales. This name, however, is applied to-day to all fine qualities of asbestos and chrysotile alike. Dana refers to the mineral thus: "Amianthus includes the fine silky varieties, much so-called in serpentine which is hydrous and therefore easily distinguished".

Sterry Hunt[1] says: "Chrysotile constitutes the common 'Amianthus' and has hitherto been regarded as a variety of serpentine, with which it agrees in centesimal composition. It is, however, distinguished from it by a lower specific gravity, and by its fibrous character, which like that of amianthoide amphibole, indicates a prismatic crystallization."

Summary

The name *asbestos* as commercially used at the present time embraces three minerals with a number of subdivisions, having in common fibrous structure, and possessing more or less fire- and acid-proof properties.

These minerals are enumerated in the following table:

1. *The Anthophyllite Group.* Chemical composition (Mg. Fe) SiO_3.

2. *The Amphibole or Hornblende Group.* Chemical composition, R SiO_3; usually associated with oxide of iron and manganese, and in a general way analogous to the pyroxenes; sodium and potassium are also present:

(*a*) Tremolite.
(*b*) Actinolite.
(*c*) Hornblende asbestos; hydrated Italian asbestos.
(*d*) Mountain leather, mountain wood, and cork.
(*e*) Crocidolite ("African Blue" or "Cape Blue" from West Griqualand).
(*f*) Amosite, a yellow variety of crocidolite.

3. *Serpentine Group.* Chemical composition 3 MgO. 2 SiO_2. 2 H_2O; hydrated silicate of magnesia.

(*a*) Picrolite: found in Canadian asbestos deposits along with chrysotile.
(*b*) Chrysotile asbestos: as found in the Quebec serpentine belt, Canada.
(*c*) Talc.

All these minerals resemble each other chemically; and the following table (computed from Dana) shows the average theoretical composition of some of them:

[1] "Mineral Physiology and Physiography", 1886.

—	Actinolite	Hornblende asbestos	Chrysotile asbestos	Talc
Silica	57·13	57·82	43·56	61·95
Alumina	1·15	0·43	0·52	0·98
Ferrous oxide	6·39	5·23	1·00	1·91
Manganese oxide	0·65	0·66	....	....
Magnesia	20·66	21·86	41·36	30·87
Lime	13·28	13·88	....	....
Water	1·57	0·77	13·79	4·08
	100·83	100·75	100·83	99·79

In external appearance, and in chemical composition, they are much alike, so much so, that in the hornblende group, when the crystals occur in long slender prisms, or in radiating masses, the mineral is called actinolite; but, when in slender, flexible fibres, easily separable, it is named asbestos. The difference between good and bad asbestos can be perceived by subjecting the fibres, or long slender crystals, to a bending, twisting and tearing action between the fingers. Good asbestos, applicable to the manufacture of fine materials, will withstand considerable tensile stress and will come apart in silky threads. Such is amenable to the various spinning processes. Poor asbestos will split up into harsh and sometimes brittle fibres, occasionally breaking up when rubbed between the fingers.

The heat-resisting property of both of these varieties is approximately the same, so that when this characteristic of the asbestos is the only quality desired, the amphibole variety, other than crocidolite, or amosite, is found to be equally as satisfactory as the chrysotile; whenever strength of fibre, as well as non-conductivity of heat is desired, the chrysotile variety is the only one which can be used to advantage. Chemically the two species are much alike; chrysotile asbestos is a hydrous silicate of magnesia, while the amphibole varieties are all either silicates of lime and magnesia, or compounds of silica with an earthy base—part of them hydrated. Crocidolite is a silicate of iron and sodium; and amosite is characterized by a high percentage of iron with variable amounts of aluminium, magnesium, and calcium.

None of the anhydrous varieties have much of the unctuous feel which is so common a characteristic of the serpentine species.

PHYSICAL PROPERTIES OF ASBESTOS

To be of any commercial value, asbestos needs length, fineness of fibre, combined with infusibility, toughness or tensile strength, and flexibility. It is surprising that sometimes specimens from foreign countries—although very beautiful in appearance—are often wanting in some of these essential physical properties. Qualities like silkiness, length, and flexibility may be determined very easily by the eye and fingers; but tensile strength, and infusibility—those necessary qualities upon which the great value of asbestos depends—can only be determined by systematic tests, made either in a practical way during the course of manufacture or in the laboratory. The Canadian chrysotile asbestos possesses all the above-mentioned properties and qualities in a marked degree, the length of the fibre being one of the principal factors determining the different grades. The main difference between asbestos and any other material or substance is its finely fibrous structure; and it may be said that these beautiful fibres—resembling fine, silk-like threads—may be termed "a mineralogical phenomenon." When separated from the rock and all gritty particles, most of the chrysotile asbestos fibre exhibits extreme delicacy and silkiness to the touch with great adaptability for spinning. For a time, however, the fibre produced from asbestos—unlike any other—resisted all attempts in this direction; the difficulty arising from the peculiar formation of the fibres, which, possessing perfectly smooth surfaces, and being much less elastic than fibres of organic origin, slipped past each other when subjected to the spinning process. But all these difficulties have been overcome; a single thread of fair tensile strength can now be made, weighing not more than an ounce per hundred yards.

The hardness of Canadian chrysotile is from 3 to 3·5 Moh's scale, and its specific gravity 2·2 to 2·3. It has a lustre sub-resinous to greasy, pearly, wavy, and silky. The colour is generally dark green to blackish-green. The asbestos in East Broughton, Quebec and Deloro township, Ontario, is grass green; while that from Templeton is yellow, some specimens having a pale green tint. Blue asbestos has been found in Canada in one place only, in a shaft 60 feet deep in Templeton township, Papineau county, Quebec; but this is an exceptional occurrence. In most cases the fibre, when drawn out in threads, is white, with silky lustre. Brown and discoloured asbestos is also found, but this colour is not original, and must be attributed to weathering, or to infiltration of other substances, mostly oxide of iron.

Temperatures of 2,000° to 3,000° F are easily withstood, while with some varieties a temperature of 5,000° F has apparently produced no visible effect. As to acid-resisting qualities, F. Schrader[1] states that hornblende (amphibole) asbestos is preferable in this respect to the chrysotile variety. He finds that asbestos fabrics, in order to resist such acids as are required in the chemical industry, should be made of hornblende asbestos, in which, the proportion of bases to silica is 1:1. Chrysotile asbestos, in which the proportion of bases to silica is 3:2, is attacked by very weak acids (like acetic acids), which dissolve the bases, and leave almost pure silica, without apparently destroying the fibrous condition. Boiling for four hours with dilute hydrochloric acid effects the same result.

[1] "Chemiker Zeitung", p. 285 (1897).

CHEMICAL COMPOSITION

In determining the value of asbestos, chemical analysis is a very important factor, since the chemical percentage composition of good spinning fibres varies but little. The following table is repeated from Cirkel.[1]

Locality	SiO_2	MgO	FeO, Fe_2O_3	Al_2O_3	H_2O+	Total	Authority
Thetford..................	39·05	40·07	2·41	3·67	14·48	99·68	Dr. J. T. Donald
Black Lake, British Canadian quarry............	39·36	42·15	3·31	....	14·50	....	Dr. M. L. Hersey.
Black Lake, Standard quarry.	40·42	41·85	2·60	0·82	14·37	....	Dr. M. L. Hersey.
Black Lake, Southwark pit.	39·22	40·27	2·26	3·64	14·37	....	Dr. J. T. Donald.
East Broughton...........	40·87	41·50	2·81	0·90	13·55	99·63	Dr. J. T. Donald.
East Broughton, Fraser pit.	41·90	42·50	0·69	0·89	14·05	....	Dr. J. T. Donald.
East Broughton, Frontenac	39·20	42·97	2·95	....	13·87	....	Dr. M L. Hersey.
Eastman, Benoit location	40·42	40·62	2·92	1·92	13·45	....	Dr. M. L. Hersey.
Danville..................	41·84	41·99	2·23	....	14·28	....	Dr. J. T. Donald.
Danville..................	42·64	39·54	3·66	....	14·31	....	Dr. J. T. Donald.
Laurentian, Templeton....	40·52	42·05	1·97	2·10	13·47	100·10	Dr. J. T. Donald.
Italy......................	40·30	43·37	0·87	2·27	13·72	100·53	Dr. J. T. Donald.
Western Australia.........	42·40	40·73	2·08	1·60	14·01	....	Dr. M. L.Hersey.

Specimens of crude fibre from several pits, and samples of milled fibre collected by the writer were analysed by E. A. Thompson, Chemist, Division of Chemistry, Mines Branch, with the following results:—

[1] Cirkel, F.: "Chrysotile-Asbestos"; Mines Branch, Dept. of Mines, Canada., p. 31 (1910).

Thetford	SiO_2	Al_2O_3	Fe_2O_3	FeO	CaO	MgO	H_2O+	Cr_2O_3	Total	Sp. Gr.	CO_2
Johnson's Company, depth 120 ft. S. side	40·40	0·10	2·55	0·74	Nil	42·70	13·50	Trace	99·99	2·56	....
Duplicate	40·45	0·70	1·45	0·90	"	43·12	13·42	"	100·04	2·72	....
Johnson's Company, depth 120 ft. N. side	40·45	0·26	1·52	0·60	"	43·70	13·56	"	100·09	2·47	....
Duplicate	40·38	0·44	1·35	0·59	"	43·90	13·45	"	100·11	2·52	....
Bell Asbestos Mines, depth 130 ft. N. side	40·36	0·21	1·35	0·66	"	43·86	13·45	"	99·89	2·55	....
Duplicate	39·26	1·62	1·99	0·75	"	42·61	13·58	"	99·81	2·56	....
Bell Asbestos Mines, depth 130 ft. NE	37·21	1·15	3·41	1·52	"	42·88	13·76	"	99·93	2·57	....
Duplicate	37·12	0·92	3·38	1·71	"	43·11	13·80	"	100·04	2·58	....
Bell Asbestos Mines, Milled Fibre "A"	38·96	1·32	1·47	1·56	"	42·88	13·68	"	99·87	2·56	....
Duplicate	40·31	0·48	1·88	0·72	"	43·10	13·52	Nil	100·01	2·56	....
King Pit, 500-ft. depth	38·70	0·66	3·07	2·05	"	41·93	13·53	"	99·84	2·56	....

Black Lake	SiO_2	Al_2O_3	Fe_2O_3	FeO	CaO	MgO	H_2O+	Cr_2O_3	Total	Sp. Gr.	CO_2
Johnson's Company, depth 150 ft. S. side	38·75	1·00	2·11	1·32	Nil	43·36	13·38	Nil	99·92	2·57	....
Duplicate	39·55	0·04	2·48	1·30	"	43·19	13·41	"	99·97	2·56	....
Johnson's Company, depth 150 ft. N. side	38·00	0·42	4·25	1·75	"	42·15	13·52	"	100·09	2·48	....
Duplicate	40·10	0·30	2·30	1·25	"	42·65	13·59	"	100·19	2·56	....
Vimy Ridge Mines	40·30	1·00	1·83	1·14	"	42·32	13·15	"	99·74	2·57	....
Quebec Asbestos Corporation, East Broughton, milled fibre	38·45	0·14	3·15	0·86	"	41·18	11·86	"	100·09	2·59	4·45
Arizona—Regal Mine	40·30	0·96	0·62	0·16	"	43·88	13·87	"	100·02	2·48	....
Duplicate	40·38	1·02	0·73	0·15	"	43·76	13·91	"	99·95	2·49	....
Arizona, harsh	39·80	0·53	0·40	0·24	"	43·44	14·81	"	99·84	2·44	0·62

Note: Before being analysed, all samples were dried at 105° C. for five hours. The figure shown in column H_2O represents the combined water.

Water of Crystallization

An interesting comparison is in the water content reported in these analyses and in those reported by Cirkel, and quoted above. In 1910, the Quebec pits had reached only a shallow depth, whereas the samples analysed in 1928 were taken from depths of from 50 feet to 500 feet. It would appear that the water content is not altogether a comparative measure of softness or harshness. Generally, fibre from Vimy Ridge is more harsh and brittle than that from Black Lake, which in turn is not so soft as that from Thetford, yet the water content grades as follows:—

	H_2O (+105° C.)
Vimy Ridge	13·15
Black Lake (average of 4 determinations)	13·47
Thetford (average of 11 determinations)	13·57

With these may be compared analyses of samples from other fields:—

	H_2O (+105° C.)
East Broughton	11·86
Arizona (average of 3 determinations)	13·89
Arizona (one determination)	14·19

Whereas Cirkel found the water content of Quebec fibre to be between 13·47 and 14·50 per cent, the present analyses of Quebec fibre, disregarding that of slip fibre from East Broughton, show a range from 13·38 to 13·80 per cent. The range of difference in each district is even more narrow, that of Black Lake being from 13·45 to 13·59 per cent, and that of Thetford from 13·42 to 13·80 per cent. It will be observed that these overlap.

Alumina

Compared on a basis of alumina content:—

Vimy Ridge		1·00
Arizona	(average)	0·83
Thetford, from 0·10 to 1·62	(average)	0·72
Black Lake, from 0·04 to 1·00	(average)	0·44

Judging from these figures the alumina content does not appear to afford a comparative measure of harshness.

Iron

Milling the fibre apparently lowers the iron content, especially in the spinning grades, indicating that a part of the iron is present as a contaminant uncombined with the fibre itself Analyses of crude fibre from one pit, on an average of four determinations, showed Fe_2O_3, 2·55 per cent and FeO, 1·16 per cent, combined 3·71 per cent. Analysis of a sample of spinning fibre taken the same day at the mill showed only 1·67 per cent Fe_2O_3 and 1·14 per cent FeO, combined 2·81 per cent.

At a property where analysis of a sample of crude fibre showed FeO, 2·05 per cent, and Fe_2O_3, 3·06 per cent, analysis of milled fibre showed the following:—

	FeO	Fe_2O_3
Long spinning fibre	1·40	3·77
Short spinning fibre	1·59	3·94
Shingle stock	1·56	4·21
Paper stock	1·42	3·92
Cement stock	1·69	4·73

Magnesia

On a basis of the magnesia (MgO) content, analyses of samples of fibres compare as follows:—

East Broughton		41·18
Vimy Ridge		42·32
Black Lake, from 42·15 to 43·36	(average)	42·84
Thetford, from 41·93 to 43·90	(average)	43·70
Danville		40·76
Arizona		43·69

Chrome Iron

Frequent mention is made in literature on asbestos of the presence of chrome iron, forming a parting in crude fibre. As only a trace was found in any of the samples, this mineral if present, probably occurs as a film on magnetite.

Silica

On the basis of silica content the analyses show the following:—

Vimy Ridge	40·30
East Broughton	38·45
Black Lake	39·10
Thetford	43·36
Arizona	40·16

Lime

No lime was found in any of the fibres, even where the serpentine from which they came occurred in a limestone formation.

Specific Gravity

Taking the specific gravity of pure asbestos as 2·22 (Dana) the various samples range as follows in comparison:

Vimy Ridge	2·57
East Broughton	2·59
Black Lake	2·54
Thetford	2·56
Arizona	2·47

The fact that the specific gravities reported for all samples are higher than for pure asbestos is due to the presence of impurities, as shown by the analyses.

A study of the tables of analyses leads to the conclusion that there is a close similarity in the percentage of chemical composition of fibres which show related physical characteristics of silkiness, flexibility, and strength. The percentage of combined water lies within a narrow range, the minimum for fibre of the Black Lake-Thetford district being about 13 per cent. Harsh, brittle fibres of the tremolite and actinolite, and also some of the hornblende group, contain little water—the amount varying between 1·1 and 5 per cent.

That the percentage of water present in a fibre has a bearing on its silkiness is shown in the physical change which it undergoes when heated to such a temperature that part of the water is driven off. The remaining substance is brittle and may be crumbled to ash. Experiments have shown that a high degree of heat will cause the asbestos fibre to become brittle, although it does not destroy its heat-resisting qualities.

No change in physical characteristics of fibre has been observed in samples from depth, at least to 1,200 feet.

21629—3

Analyses of Serpentine, Asbestos, and Associated Minerals

No.	Description	SiO_2	MgO	FeO	Al_2O_3	Fe_2O_3	CaO	H_2O	Na_2O	MnO	Fe	K_2O	Loss on ignition	Total	Authority
1	Actinolite, Elzevir tp., Ont.	61·82	23·98	6·55	1·12		1·63	5·45							Prof. Coleman, Toronto.
2	*Hornblende Minerals—*														
	Tremolite, Richville, Gouverneur, N.Y.	57·5	24·9	0·2	1·3	0·2	12·8	1·3	0·7		0·8			99·7	Dr. Pirsson.
	Actinolite, Greiner, Tyrol.	56·1	21·2	5·5	1·2	0·8	12·1	1·9	0·2		0·1			99·1	"
	Hornblende, Edenville, N.Y.	41·9	11·2	14·3	11·7	2·5	11·5	0·7	2·7		0·8			97·3	"
	Arfvedsonite, Greenland.	43·8	0·8	33·4	4·4	3·8	4·6	0·1	8·1					99·0	"
	Glaucophane, island of Syra, Greece.	55·6	7·8	6·8	15·1	3·1	2·4		9·3					100·1	"
3	Mountain cork	57·20	22·85			4·37	13·39	2·43						100·24	Quenstedt.
4	Crocidolite, South Africa.	49·6		19·80		22·00			8·60					100·00	
5	Crocidolite (locality unknown).	51·1	2·3	35·8				3·9	6·9					100·00	De Lapparent.
		51·22	2·48	34·08			0·03	4·50	7·07	0·10				99·48	
6	Picrolite, East Broughton	37·88	43·29	0·36	1·10	2·70	0·82	14·32							Dr. M. L. Hersey.
7	Soapstone (Canada), East Broughton.	61·50	33·03		0·89	0·11	0·16	4·25							Verger, Paris.
		62·80	33·10		0·20	0·25		3·60							"
		63·70	33·75	1·46	0·42			0·48					0·19		McCandles Jones
		56·20	32·65					2·64							Dr. M. L. Hersey.
8	*Soapstone, Foreign—*														
	Austrian	59·59	32·92	0·79	1·76		0·59	3·79				0·56			"Mineral Industry".
	French	50·91	24·86	2·58	13·19		1·82	6·64							"
	Italian	51·23	33·32	1·89	7·08		1·80	5·46				0·22			"
9	French chalk	62·80	33·50					3·70						100·00	"Asbestos" by McCandles Jones
		63·49	31·75					4·76						100·00	
10	*Serpentine—*														
	Laurentian	39·34	43·02			1·80		15·09						99·25	Geol. Surv., Canada, 1863, p. 472.
		41·20	43·52			0·80		15·40						100·92	
		44·10	40·05			1·15		14·70						100·00	
		29·80	38·40			7·92		13·80						99·92	
	Cambrian, Black Lake.	39·60	40·71	0·99	1·45	3·74		12·98							Dr. M. L. Hersey.
		41·20	40·96	0·99	0·53	3·75		13·73							"
		38·90	42·93	4·44	2·01	3·53		8·47							"
		39·20	44·02	4·02	0·99	2·97		8·85							"

Analyses of Serpentine, Asbestos, and Associated Minerals—*Concluded*

No.	Description	SiO_2	MgO	FeO	Al_2O_3	Fe_2O_3	CaO	H_2O	Na_2O	MnO	Fe	K_2O	Loss on ignition	Total	Authority
	Decomposed serpentine:														
	Lot 14, R. IX, Broughton.	34·70	32·10	4·20	2·95	6·50	......	3·96	......	......	......	21·03	....	....	Dr. M. L. Hersey
	Lime serpentine........	27·20	8·54	15·28	26·75	3·57	11·90	7·60	......	......	......	......	....	....	"
	"	41·15	12·77	10·82	13·21	2·52	16·78	3·40	......	......	......	......	....	....	"
	East Broughton (disassociated from asbestos).	41·10	42·39	0·99	1·02	2·58	......	12·10	......	......	......	......	....	....	"
	Richmond............	38·00	38·92	1·32	2·89	7·49	......	10·90	......	......	......	......	....	....	"
	Mansonville............	37·80	38·52	0·80	1·83	7·27	......	13·46	......	......	......	......	....	....	"
	Eastman..............	40·42	40·62	0·47	1·92	2·45	......	13·45	......	......	......	......	....	....	"
	Thetford..............	40·76	42·32	0·49	......	3·05	0·35	13·60	......	......	......	......	....	....	"
11	*Chrysotile Asbestos—*														
	Thetford..............	39·05	40·07	0·87	3·67	......	......	14·48	......	......	......	......	....	....	Dr. J. T. Donald.
	Black Lake, British Canadian quarries.	39·36	42·15	3·51	......	......	......	14·50	......	......	......	......	....	....	Dr. M. L. Hersey.
	Black Lake, Standard quarries.	40·42	41·85	2·60	0·82	......	......	14·37	......	......	......	......	....	....	"
	Black Lake, Southwark mine.	39·22	40·27	2·26	3·64	......	......	14·37	......	......	......	......	....	....	Dr. J. T. Donald.
	Locality not known....	39·60	41·99	1·62	......	2·58	......	14·44	......	......	......	......	....	....	Dr. M. L. Hersey.
	East Broughton, exact locality not given.	40·87	41·50	2·81	0·90	......	......	13·55	......	......	......	......	....	99·63	Dr. J. T. Donald.
	East Broughton, Glasgow and Montreal mine.	41·90	42·50	0·69	0·89	......	......	14·05	......	......	......	......	....	....	"
	East Broughton, Frontenac.	39·20	42·97	2·95	......	......	......	13·87	......	......	......	......	....	....	Dr. M. L. Hersey.
	East Broughton........	41·20	40·83	0·45	0·12	3·77	......	13·29	......	......	......	......	....	....	"
	Thetford, lot 2, R.V....	40·76	42·32	0·49	......	3·05	0·35	13·60	......	......	......	......	....	....	"
	Broughton, lot 14, R. XI.	46·60	11·87	12·35	3·44	2·70	15·80	2·92	......	......	......	......	....	....	"
	Eastman..............	40·42	40·62	2·92	1·92	......	......	13·45	......	......	......	......	....	....	"
	Danville..............	41·84	41·99	2·23	......	......	......	14·28	......	......	......	......	....	....	Dr. J. T. Donald.
		42·64	39·54	3·66	......	......	......	14·31	......	......	......	......	....	....	"
	Laurentian, Templeton.	40·52	42·05	1·97	2·10	......	......	13·47	......	......	......	......	....	100·10	"
	Italy..................	40·30	43·37	0·87	2·27	......	......	13·72	......	......	......	......	....	100·53	"
	Western Australia......	42·20	40·75	2·08	1·60	......	......	14·01	......	......	......	......	....	....	Dr. M. L. Hersey.

ORIGIN OF CHRYSOTILE ASBESTOS

Authorities who have studied this subject are not in agreement as to the origin of asbestos. An investigation now under way by the Geological Survey will, it is hoped, add further information to this controversial theme. The two main theories supported are: asbestos is considered by some to be a deep-seated alteration product of igneous rocks; others consider it to have been developed in fissures in serpentine. The latter school divide in opinion as to whether the fibres grew from the rock toward the centre of a fissure, or from the centre of the vein outward toward the rock. Whether either theory will hold for all deposits remains to be determined. The solution of this problem will go far to assist in prospecting for deposits, and in working them economically.

Some of the types of chrysotile deposits which differ, yet in which the fibre may have a common origin, are:

1. Thetford-Black Lake vein fibre, with which is associated slip fibre.
2. Pennington and Tanguay lots where zones of vein fibre cross the belt of slip fibre.
3. Coleraine, where, while the fibre may be readily freed from the enclosing serpentine on one side of the vein, yet on the other side it merges into or grows out from the rock.
4. Arizona asbestos, which occurs in serpentine bands and nodules in limestone.
5. Templeton and Buckingham fibre, in which the occurrence of serpentine resembles that of Arizona, but in which the accompanying limestone is crystalline.
6. Deloro township, Ontario, where the fibre is found in zones which resemble those worked in Arizona, yet the rock mass is serpentine.

Articles dealing with this subject are listed under "Bibliography" and are too extensive for detailed reference.

DEPTH OF ASBESTOS DEPOSITS

At Thetford asbestos is at present worked to a depth of 400 feet. Specimens from a depth of 500 feet, and from drill cores to a depth of 1,700 feet are equal in grade to the material produced nearer the surface.

A campaign of diamond drill testing now under way by the Asbestos Corporation, Limited, will yield further information on this point. At no time in the history of a Quebec quarry can it be said that there has been ore blocked out on which to base operations. So long as an operator had fibre in the face of a quarry he continued working and when country rock was encountered he directed his efforts elsewhere. While a pit in the main belt may have good rock at any depth it does not necessarily follow that recovery can be continued to an unlimited depth by quarrying, as the fibre-bearing zone may dip with the overlying rock, in a manner similar to that in the Broughton section. Depth of quarrying is also limited by the dimensions of the ore-body and necessity of maintaining walls at a safe angle.

Before planning extensive quarrying or mining operations it is advisable to test the ground thoroughly by diamond drilling in order to determine the extent and position of the ore. No evidence has yet been forth-coming to suggest that the character of the fibre, or amount of fibre in the rock, undergoes any change within the limits of economical mining, and certainly not within quarrying depth. The depth to which quarrying may be carried on is limited by the width of the zone. Walls must be maintained at a safe angle and with the known width of zone at Thetford the walls of a quarry would be too close together at a depth of about 500 to 600 feet to leave a floor for working. To such a depth it is evident that good fibre will be found.

In order to mine below this depth underground mining methods will have to be adopted, and, as in all underground mining, the amount of available ore should be ascertained to warrant the necessary expenditure of equipping and developing a mine. John A. Dresser[1] gives his opinion on the depth of asbestos deposits as follows:

> The question of the depth of asbestos deposits in the Eastern Townships depends in a large degree for its solution on the form taken by the eruptive rock from which the serpentine has been derived. This has not yet been satisfactorily determined. The form may have been a sheet or laccolith intruded between beds of older rock. In that case the sheet would be more or less nearly horizontal in position, and would not have reached the surface until it was uncovered by the erosion of the overlying beds.
>
> Or it may have been an intrusive mass of rock, which was brought to the surface and has since had its upper parts removed by erosion.
>
> In the former case the depth of the asbestos would necessarily be limited by the thickness of the intruded sheet, but in the latter case, the serpentine and consequently the asbestos, might continue to an indefinite depth.
>
> The other factors necessary to the occurrence of asbestos are the segregation of olivine in the original rock, and the alteration of the olivine to serpentine. Of the first it may be said that olivine is a mineral characteristic of the lowest known depths of the earth's crust; and of the second, that serpentinization is a deep-seated process, which, unlike weathering, does not depend on the action of the atmosphere to produce it.
>
> Therefore, except for the possibility of reaching the floor of a sheet, it seems safe to conclude that the asbestos deposits of the Eastern Townships will continue for as great a depth as they can be profitably mined.

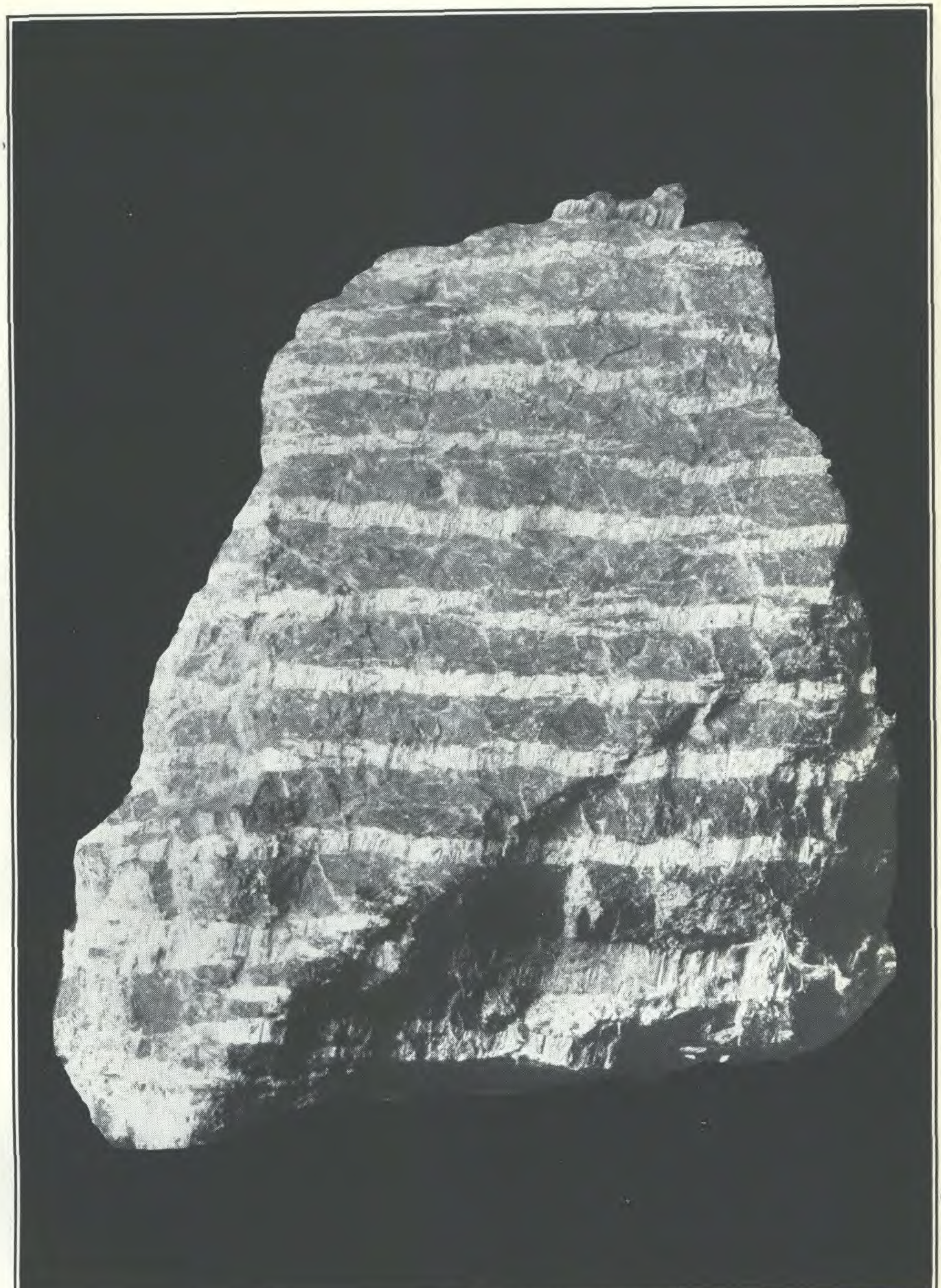
VEIN FIBRE AND SLIP FIBRE

The term "vein fibre" is applied to that asbestos which occurs in veins having the fibres at right angles to the enclosing walls. The veins range in width from a hair line up to 4 or 5 inches, and, rarely, even more. Almost the entire output of the Black Lake-Thetford and Danville pits is of this type.

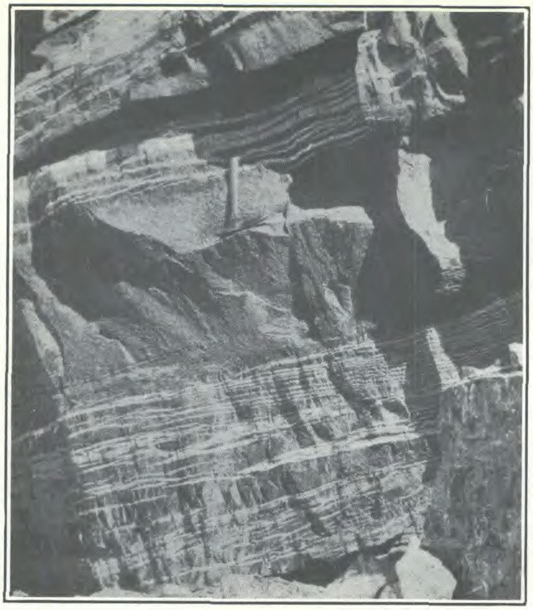
Sometimes fibre veins split up in several smaller veins, or coalesce and form a larger vein. At the Vimy Ridge and Imperial pits of the Asbestos Corporation, Limited, the veins assume a ribbon structure and are banded, having the appearance of being stratified.

Veins of long fibre are in many cases divided in the middle or near one margin by a seam of serpentine carrying magnetite. As a rule, at most of the pits, the asbestos can be easily separated from the rock, with the exception of some deposits of ribbon fibre. While the fibre, in these, can be separated readily from the rock at one side of the vein, at the other side it appears to merge into the rock or to be growing out from it. The

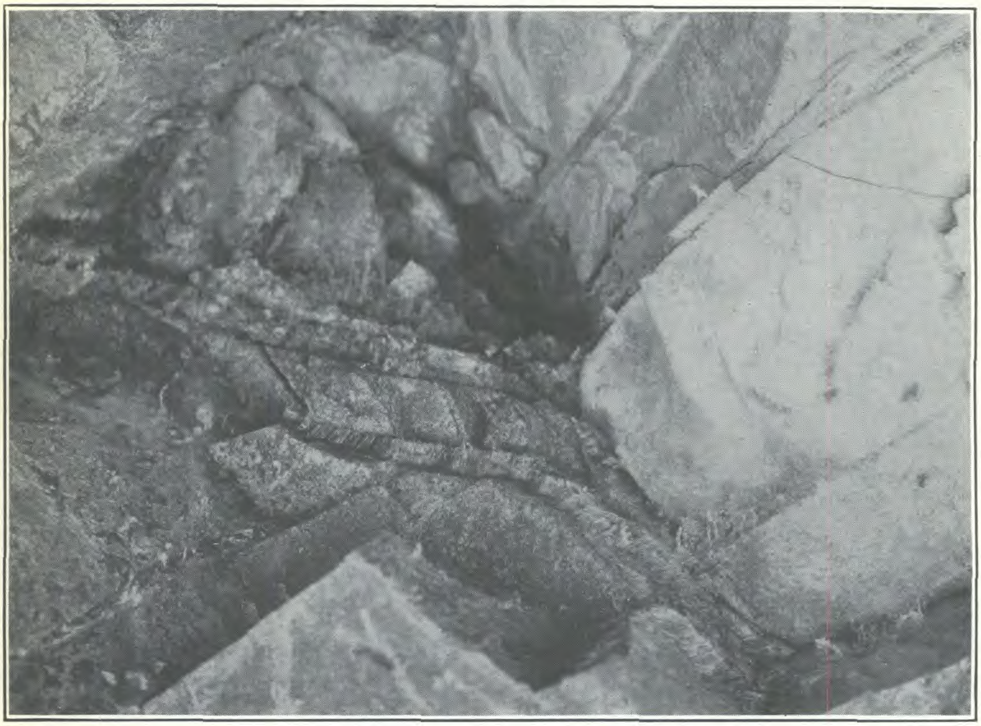
[1] Dresser, John A.: Trans. Can. Min. Inst., vol. XII, p. 203 (1909).



Ribbon fibre, Quebec.



A. Ribbon fibre, Quebec; Vimy mine, Asbestos Corporation, Limited.



B. Veins of crude asbestos in pit face, quarry of Canadian Johns-Manville Company, Limited, Asbestos, Quebec.

breaking necessary to separate such fibre from the rock is destructive of fibre. Fibre so " frozen " is usually coarse and brittle and hence more susceptible to damage from harsh milling treatment.

Most of the asbestos veins possessing commercial qualities are flanked by seamy partings of serpentine from 3 inches to 6 inches in width, the veins running, as a rule, parallel to the selvage planes. This feature is characteristic of the Thetford-Black Lake area. When freshly mined, these partings, which separate with ease from the adjacent rock, can hardly be detected; but when exposed for some time to atmospheric action they tarnish bluish white, and can readily be distinguished from the surrounding rock. The colour of vein fibre after being teased up in milling is white, although in situ it may be any shade of green, from light yellow in Thetford township to a dark greenish blue at Black Lake.

The principal qualities of the Canadian vein fibre are its great flexibility, silkiness, and tensile strength. The uniformity of these qualities throughout a considerable area has served to make " Canadian " fibre the standard, in comparison with which fibres from other fields are rated in value.

In some places the chrysotile lies along slip planes in the massive serpentine, and then the fibres, instead of being transverse, lie lengthwise in the fissure; such chrysotile termed " slip fibre " is, as a rule, not so valuable as the vein fibre, although differing but little in the main characteristics. Owing to the manner of occurrence, these fibres may appear to have considerable length, but this is due to the overlapping of the fibres which are all matted together, more or less in parallel position. This type is not so common in the Thetford-Black Lake area as it is farther northeast in East Broughton, where it forms the principal product of the quarries.

Slip fibre in situ is light green or white, and on being fluffed up is of a good white colour. For many purposes, slip fibre should be of equal value to vein fibre. On account of its mode of occurrence, however, and the necessary harsh milling to free it from the rock, the resultant product is more thoroughly fluffed up or " willowed " than is fibre from the vein formation, and hence not so desirable for use in the manufacture of certain articles.

The occurrence of the slip variety is principally confined to that part of the serpentine belt from range III, Broughton township, to lot 17, range IV, Thetford township, a distance of 14 miles.

At the Pennington pit, both vein and slip fibre occur, and from here westerly, vein fibre predominates. In all pits of vein fibre areas of slip fibre are encountered and quarried. The northerly margin of the main Thetford section is largely slip fibre, while at the Consolidated pit, on the southerly margin of the ore zone, is a considerable area of slickensided or " fish scale " serpentine, carrying practically no commercial fibre.

DISCOLORATION AND ALTERATION OF FIBRE

Discoloration of fibre by clay and oxide of iron in the early days of the industry was a cause of worry to the operator, and rejection, or allowance on price on the part of the manufacturer. With proper stripping of overburden, so that clay and surface water do not run into the pits, there is little trouble from discoloration, and where such occurs it is due largely to careless methods of working the pits.

Alteration of fibre, at one time, attributed to the effect of forest fires drying out the fibre near the surface is no longer a cause of worry in operations of the size now conducted. Harshness is more likely to be due to location. Fibre from the Black Lake area is more harsh than that from Thetford, yet this quality, if taken advantage of in the milling process, yields a more valuable shingle fibre. Fibre from two deposits in Ireland township is similar to Thetford fibre, while in an adjoining pit an unusually harsh fibre, difficult to mill, is found.

MINERALS ASSOCIATED WITH CANADIAN CHRYSOTILE ASBESTOS

This feature is fully covered by Poitevin and Graham[1].

There are only two metallic minerals occasionally associated with asbestos, magnetite and chromite. The former is found in some places as fine specks and grains accompanying the asbestos veins, and as partings which divide a vein into two sections. This admixture involves extra cobbing of the fibre to free it from the impurity. In milling, on account of its greater specific gravity, the magnetite can be partly eliminated. Milled fibre, on analysis, does not show as high an iron content as does the crude in situ. Chromite, when present in the fibre, forms a thin film on the magnetite. It also occurs as an ore in the serpentine, and shipments of commercial chrome ore have been made from one asbestos pit at Black Lake at a time of high prices.

[1] Geol. Surv., Canada, Mus. Bull. No. 27 (1918).

CHAPTER II

QUARRYING OF ASBESTOS

In order to extract the asbestos from the rock, either by hand cobbing or by milling, the fibre-bearing ground must be first stripped of overburden and quarried, or mined by underground methods.

As underground mining has been adopted at only two properties, the general practice may be described under the following heads:—

(1) Stripping of overburden.

(2) Quarrying, that is drilling and blasting the rock, picking the crude fibre, separating the barren rock from the fibre-bearing rock, hoisting all fibre and rock to the surface and transporting the crude fibre to the cobbing sheds, the barren rock to the dump, and the useful rock to the mill.

While open-pit quarrying is the method adopted at most of the pits, underground mining was found to be advisable on one property of limited surface area, and at another property to recover ore under the pit bottom. At one, favourably situated, the use of the glory-hole system has resulted in the production of rock at a low cost.

DEVELOPMENT OF OPEN-CAST SYSTEM

The present method of open-pit quarrying has been gradually evolved, and large equipment installed in the effort to secure an increased tonnage of rock. As in recovering many ores, the prospector first opened pits from which the rock could be shovelled and the valuable part picked out. As the pits deepened and widened, hoisting was done successively by means of the hand-windlass, horse-whim, boom-derrick, and overhead-cable-derrick; the size and capacity of the hoisting bucket being increased with each change until to-day the largest hoisting bucket has a capacity of 10 tons.

The width of the fibre-bearing zone, the extent of the property, location of milling plant and surface equipment, depth of overburden, location of dump ground, and contour of the surface, all have been factors in determining the size and shape of the pit and the methods of quarrying and hoisting employed.

The possibility of changing to an underground mining system in anticipation of the time, now rapidly approaching at some of the pits, when open-cast work will no longer be feasible, has been seriously studied by some of the companies. The expense of developing a hoisting shaft, underground haulage system, and stopes, together with the loss entailed in scrapping equipment now in use, have weighed against a change. Operators accustomed to a system, and workmen trained on certain lines hesitate to adopt methods to them unknown. By the open-cast system low costs have been attained, particularly where conditions were suitable for the use of cranes and steam shovels. Frequent slides of rock from the pit-faces and an increasing amount of lost time, due to bad weather and delay caused by shut-downs while the walls were being scaled of loose rock, are responsible for rising quarry costs. As the pits are deepened it becomes more difficult to obviate boundary troubles, as working too close to the walls in one pit is apt to draw down rock from neighbouring properties.

The advantages usually claimed for the open-pit method are:—

Easier supervision.
No trouble as regards ventilation.
No timbering is necessary.
But little wood, if any, is found in the finished fibre.
Possibility of complete extraction of all asbestos encountered in the rock; no loss in the form of pillars.

With the adoption of an underground mining system applicable to each piece of ground, some of the existing troubles might be overcome, fibre could be produced at a cost no greater than the present, and a steady output maintained.

Working with an underground mining system, particularly on a restricted area:—

1. Only fibre-bearing rock need be mined and hoisted, barren rock being left in pillars or used as stope filling.

2. Mining could be carried on continuously, with no lost time from inclement weather.

3. Pumping costs would not continue to increase, as they are proportionate to the drainage area of the pit.

4. A larger percentage of crude fibre should be recovered on picking-belts under close supervision of pickers than by the present method, especially in the winter when rock in the pits is often coated with snow and ice.

5. Drying costs should be reduced.

6. Fibre should be cleaner and of a better colour, as no clay overburden would become mixed with the rock.

7. Removal of overburden would be unnecessary.

8. A single hoisting crew would be required, and less power used than is now necessary to operate several cable derrick hoists.

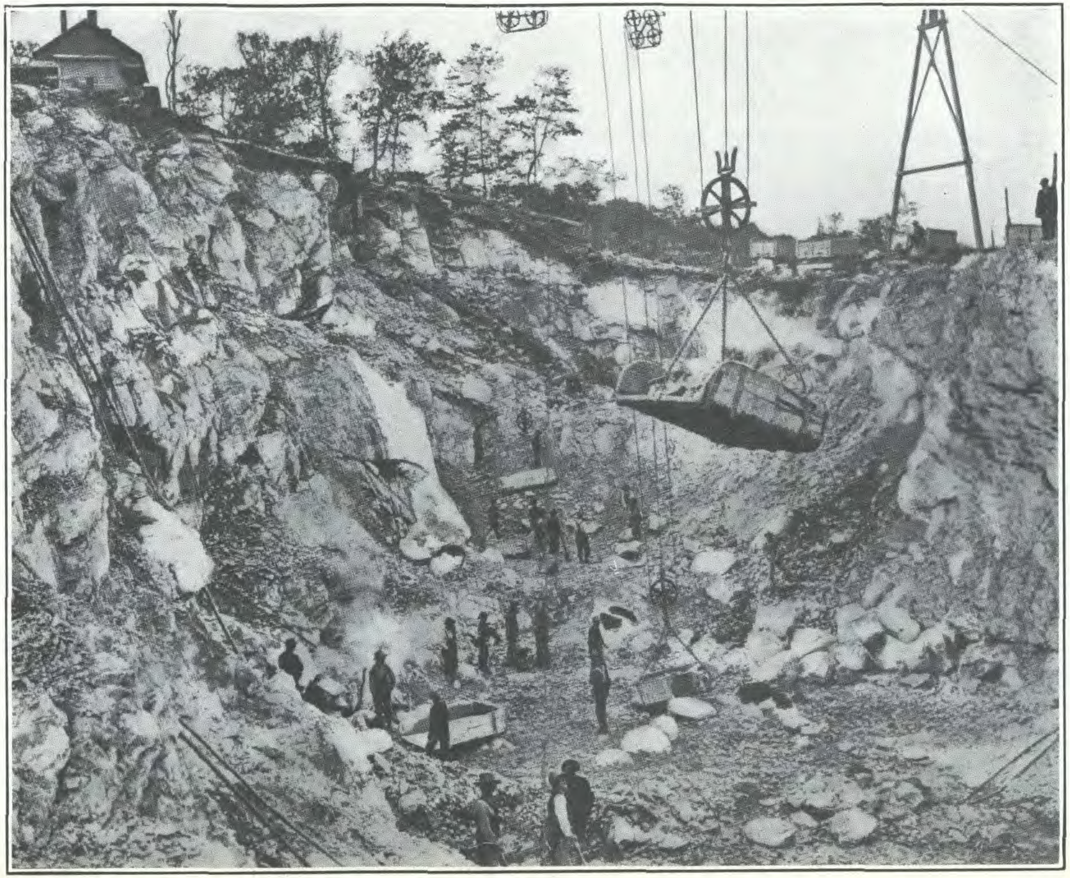
9. Better regulated feed would go to the mill by blending the feed from storage in several underground stopes.

10. Danger of floods would be lessened.

11. Less dumping room for barren rock would be necessary, and a saving on haulage of barren rock would be made.

Notwithstanding the apparent advantages of underground mining, careful study will be advisable in order to decide on the safest system as the many slickensided heads through the serpentine may be the cause of slides as they are in open-pit work.

The system practised for some years at one mine of carrying stopes comparatively narrow in width, has proved quite successful from a mining standpoint.



Canadian asbestos pit in an early stage of development.

Steam shovel stripping overburden, King pit, Asbestos Corporation, Limited, Thetford Mines, Quebec.

Whatever the disadvantages of underground mining may be, conditions are becoming such in the central part of the Thetford district, that in the course of a short time, underground mining will be the only one practicable by which the main fibre-bearing zone may be worked.

Since the above was written in 1928 exploration at the King pit of Asbestos Corporation, Limited, indicated that the ore-body lay underneath the pit bottom and the west wall of the pit. A system of underground mining has been developed, 3,000 feet of drifts and crosscuts driven, and seven stopes opened up. Costs of underground mining compare favourably with open-pit work, winter work is more steady, and the finished fibre contains less wood.

STRIPPING OF OVERBURDEN

To open a quarry it is first necessary to remove or strip off the overburden of soil or boulder clay which covers the larger part of the asbestos-bearing areas. The depth of overburden varies from a few inches to as much as eighty-six feet. Where the overburden is shallow it is loaded by pick and shovel into horse-drawn dump carts, or into boxes for hauling by cable derricks. Where the depth exceeds a few feet, steam shovels are employed by means of which trains of dump cars are loaded and the earth hauled to a dump ground one to two miles distant. Overburden has been stripped at one pit at the rate of 100,000 yards per year for a number of years. Efforts have been made to remove the overburden by hydraulic methods, but owing to the presence of numerous boulders in the clay this procedure did not prove economical.

In addition to the natural overburden, considerable expense is entailed in removing barren rock and clay which accumulated at the margins of the pits from earlier operations. It is necessary to keep a rim of rock around the pit free of overburden, to avoid clay falling into the pit and discolouring the fibre.

Some companies maintain a program of diamond drilling in order to ascertain the trend and width of the fibre-bearing zone. On the information thus gained, development is planned as much as possible, provided it does not interfere with existing installations of equipment. In the majority of cases, however, work on the face is continued until the percentage of fibre won proves unprofitable, when efforts are diverted elsewhere.

QUARRYING

As a rule the quarries are elongated and somewhat irregular in outline, the length being determined by the property boundary lines, and the width conforming to the width of the fibre-bearing zone. At times the width of the pit is greater than that of the zone, as low-grade or barren rock must be removed to maintain a safe working slope on the walls and enable the full width of profitable zone to be worked at the pit bottom.

All rock within the confines of the quarry is removed, no pillars nor barren rock being left. Worthless rock is also quarried and discarded in as large pieces as possible to save the cost of drilling and blasting.

A rough bench system of quarrying is usually followed but not on as definite lines as in limestone quarrying. The largest quarry, that of the

King pit, has a length of 1,200 feet, a width of 1,000 feet, and a depth of 465 feet to the deepest floor. To the east of the main pit a succession of terraces rises in heights of from 30 to 50 feet.

Drilling and Blasting

Two systems of drilling quarry faces are employed, one by short horizontal holes in the face, and the other by long vertical or inclined holes from bench floors.

The older method, and that still in use at most of the quarries, is to drill rows of holes, each to a depth of 10 to 16 feet along the face of a bench to be blasted, with air-hammer drills. Such drilling is often done by contract at a set rate per foot of hole drilled. The cost of drilling in this manner varies from 3 to 17 cents per ton of rock broken. As many as 300 to 500 holes may be connected up and fired in a single shot, bringing down sufficient rock for the loaders or shovels for several months. Care must be taken in so placing the holes that the rock is shattered into fragments of such size that an excessive amount of "block-holing" is not required.

Where possible face drilling is being superseded by "down" holes. These are drilled vertically or slightly inclined toward the face to depths of 32 to 40 feet. Vertical drilling is now the method used at the pits of the Canadian Johns-Manville Company at Asbestos, at the Bell and King pits at Thetford, and at the pits of the Quebec Asbestos Corporation at East Broughton. At the latter pits, however, holes are drilled to a depth of 75 feet.

A heavy type of air-hammer drill is mounted on a portable derrick so that holes may be drilled vertically or at a slight angle to the vertical. The weight of the drill together with the weight of a metal block is sufficient to hold the drill bit against the rock. The drill steel is fed automatically, the drill runner and two helpers are employed in changing steel, blowing out the hole, and moving the derrick; 1⅛-inch hollow round steel is used. The bit on the starter has a diameter of 3⅜ inches, and successive gauge changes are ½ inch each. From 4 to 6 steel are used per 40-foot hole depending on the hardness of the rock. Holes spaced 2 to 5 feet apart are set back from the face 10 to 25 feet. Some or all of the holes are inclined toward the toe of the quarry face at inclinations of 5 to 15 degrees. Horizontal toe holes up to 30 feet in depth may be drilled with the same machines and steel by using a special mounting.

In blasting the charge is from 30 to 50 pounds of explosive per hole. The bottom third of the hole is filled with 75 per cent gelatin dynamite in 2-inch by 16-inch cartridges. The balance of 40 per cent gelatin is placed next in the hole, and the remainder of the hole tamped with mill tailings sand. Two electric blasting caps with 30-foot and 20-foot wires are attached to a stick of dynamite in each hole, but not connected in the same series. Each cap is tested by means of a galvanometer before being used as a primer.

After the holes are loaded and tamped by the blasting crew under the supervision of the head blaster and pit foreman, the wires are connected in parallel series with about 40 caps in each series. Throughout the pit are

Derrick drill, Canadian Johns-Manville Company, Limited, Asbestos, Quebec.

lead wires which are connected to a switch in one of the several blasting houses. Blasting is done at the end of each shift after the workmen have left the pit. To blast, the head blaster closes a firing switch and sends a 110-volt current through the circuit. The locked switch-box is so constructed that the door cannot be closed when the switch is in contact, and vice versa the switch cannot be operated when the door is closed. The box must be kept closed and locked by the head blaster at all times other than during the actual firing.

Blocks of rock which are too large to be hoisted conveniently are drilled or " block-holed " by means of plugger drills. For blasting these, 1-inch by 8-inch, 25 per cent nitroglycerine L.F. dynamite is used. Tailings sand, packed in paper bags, is employed for tamping. Block-holes are connected 50 in a series, the series being joined in parallel; as many as 500 holes have been fired in one shot.

In the quarry blasts 8 to 10 tons of rock is the average breakage per pound of explosive, and the cost per ton of rock quarried for explosives is from 4 to 7 cents.

The procedure of drilling vertical holes and blasting as practised at Asbestos has been described by Marvin.[1]

Separation and Removal of Ore and Rock

After the rock has been blasted, crude pickers gather up the loose long fibre, or long fibre with bits of rock adhering, into boxes. As the removal of the rock pile progresses, the crude is carefully sorted out. Large blocks of rock in which veins of crude are visible are drilled and blasted to free the fibre. Crude picking is the most important feature of the industry as practically no recovery of crude, as crude, is made in the mills or on picking-belts. The profits of the industry in the Thetford-Black Lake section are largely dependent on the recovery of crude. Spinning fibre is obtained from crude which has been passed over by the pickers or carried to the mill in pieces of rock. The mill, at pits where crude occurs, should be regarded as an adjunct to the recovery of crude, and not, as is sometimes the case, the main factor in the industry—a plant where a maximum number of tons of rock, regardless of fibre content, is to be treated daily. Where no crude or hand-cobbed fibre is produced all the rock containing fibre, together with the fines from the blasting is sent to the mill; but in quarries where the different grades of crudes are recovered, the broken material to be sorted comprises:—

1. The long asbestos fibre, and pieces of rock containing same.
2. The milling material, or rock, containing the shorter fibre.
3. Fine material resulting from blasting and breaking up the rock by means of sledge hammers.
4. Barren or dead rock.

The material specified in No. 1 is sent to the cobbing sheds, and the material indicated in Nos. 2 and 3 is sent to the primary crushing unit of the mill. The dead rock is loaded separately into boxes and transported to the dump.

[1] Marvin, Theodore: "The Explosives Engineer", February 1928, p. 50.

The methods of removing material from the pits depend on the pit location in some cases, and on the nature of the rock in others.

The various methods of removal may be listed as follows:—

1. Where no sorting is practised or advisable, loading is done by means of steam or electric shovels into cars. The cars may be hauled to a storage bin below pit level, from which the rock is transported on a conveyer belt to the primary crusher, or hauled direct on level or inclined tracks to the primary crusher.

2. Where sorting is advisable, ore and rock are shovelled by hand into separate boxes. The boxes are then hoisted by means of overhead cable derricks by which they may be dumped into cars at the surface or into bins, and thence into cars, and the ore hauled to the crusher, and rock to the dump.

3. The loaded boxes may be lifted by boom cranes and dumped into cars, the cars being hauled on a level or inclined track to the crusher, if of ore; or to the dump, if of rock.

The capacity of rock and ore cars varies from 5 to 15 tons.

At one quarry, electric power is used to operate the shovels, and the Lockwood system of controlling electrical haulage is being installed. Otherwise, haulage, either in the pits or on the surface, is by means of steam locomotives or electric locomotives, either trolley or battery driven.

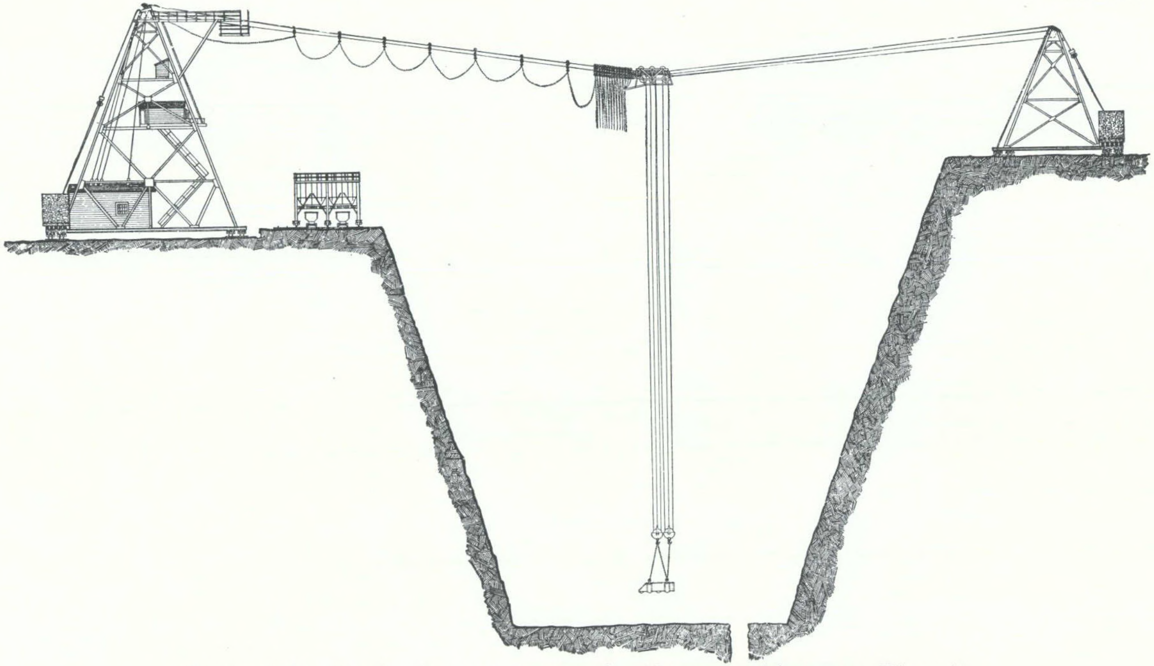
To indicate the growth in size of the cableway derrick from the earlier equipment, the following is a description of the installation at the King pit of Asbestos Corporation, Limited, by H. V. Haight, Designing Engineer of the Canadian Ingersoll-Rand Company:—

In order to supply their new mill, completed in 1924, the pits are being deepened at such a rate that it was decided to widen them by installing two larger cableways. These new cableways have spans of 1,400 feet and lift a net rock load of 10 tons. As the remainder of the pit is widened by these new cableways, the old ones of shorter span will be advanced and new ones of the larger span erected in their place. The new ones also operate at increased speed, as shown by the following table:

	Old Cableways	*New Cableways*
Span, centre to centre of towers.......	937 ft.	1,400 ft.
Maximum depth of pit from surface...	400 ft.	700 ft.
Capacity of ore box..................	132 cu. ft.	220 cu. ft.
Net weight of ore....................	12,000 lb.	20,000 lb.
Weight of ore box..................	2,700 lb.	4,400 lb.
Total suspended load at centre (including sheaves, ropes, and carriage)...	22,000 lb.	36,000 lb.
Rope speed (trolleying speed).........	1,000 ft. per min.	1,500 ft. per min.
Hoisting speed (3-part line)..........	333 ft. per min.	500 ft. per min.
Horse power of hoist motor..........	200 h.p.	450 h.p.
Diameter of hoisting ropes...........	¾ inch.	⅞ inch.
Diameter of main cable................	2¼ inch.	3 inch.
Stress in main cable.................	126,000 lb.	240,000 lb.

Plate IX shows the general arrangement of the new cableway. Plate X shows a "close-up" of one of the travelling head towers, with its counterweight of rubble masonry, and also the travelling ore bins, a cableway carriage, an ore box just about to be dumped, and the fall-rope carriers with their spacing chain.

The general method of operating the cableway requires very little explanation. The carriage is pulled back and forth on the main cables by an endless rope on the rear drum. The hoisting is done by the centre drum. The front drum carries the dumping rope, which does very little work except at the instant of dumping. The hoisting and dumping drums usually turn together, but when the box is to be dumped



Sectional drawing showing arrangement of cableway derrick towers, King pit.

A. Cableway derrick towers, King pit, Asbestos Corporation, Limited, Thetford Mines, Quebec.

B. Cableway derrick towers and rock bins.

the brake is set and the clutch released on the hoisting drum and then the dumping drum lifts the rear end of the ore box, letting the ore slide out the open end.

The hoist has special features that merit brief description. It is located in the base of the tower, but is arranged for remote control from the operator's cabin, higher up.

The motor is 450 h.p., 600 r.p.m., 2,200 volts, 3 phase, 30 cycles. It has full magnetic control, and all the electrical equipment is in the upper cabin, near the operator.

Each drum of the hoist has a cone clutch and a band brake. In addition, there is a main service brake on the pinion shaft. It is a graduated brake of the gravity-air type, set by weights and released by an air cylinder, the latter controlled by floating gear which is connected by rods to the operator's stand. The operator thus has instant, accurate, and easy control of the braking action. The brake blocks are of asbestos and the brake is very powerful, the brake drum being 24 inches in diameter with brake blocks 16½ inches wide.

The three-band brakes on the drums are also set by weights and released by air, but are of the "off and on" type, controlled by valves at the operator's stand.

The clutches are of the cone type. The clutch is set or released by a pair of toggles and a sliding sleeve, the sleeve being operated by an air cylinder, which is controlled by valves at the operator's stand. This type of clutch has many good features. Like the Lane band clutch, it is locked when engaged and has then no unbalanced end thrust on the bearings. It is, however, superior to the band clutch in several respects: it is in perfect running balance; it has no tendency to drag when released; the take-up for wear is very convenient; and it is very safe, the main parts being in compression.

The construction of the clutch on the endless rope drum is identical with that just described, but the drum itself is slightly different. After travelling across the face of the drum, the rope climbs the fillets in the corners of the drum and then crowds over, as on a spool. The fillets may be replaced when worn. Experience has shown that 5½ turns around the endless rope drum give sufficient friction.

The dumping drum was at first made with a toggle-cone clutch similar to those on the other two drums. This, however, did not work properly. Owing to the rather large fleet angle and the low strain on the dumping rope, it would sometimes climb to the next layer before reaching the end of the drum. The increased diameter then made the dumping rope wind faster than the hoisting rope, and it started to dump. To remedy this, the toggles were taken off and a screw thrust substituted. The thrust and counter-thrust are taken by bronze washers running between hardened steel plates. The bronze plates are grooved. These thrusts run in oil. The arm on the thrust screw is connected by rods to a hand lever at the operator's stand. With this arrangement, the operator sets the clutch on the dumping drum very lightly. and if the rope should start to climb the clutch will slip. When dumping, the operator can set the clutch harder if necessary.

The gears are all Falk cut steel herring-bone gears, and are enclosed in an oil-tight sheet steel gear case.

The whole hoist is mounted on a very substantial sectional cast-iron bed, the members being of box pattern. The motor is carried on an extension bolted to the main bed. The motor frame is of special design, having the feet nearer the centre-line than usual, in order to make the bottom of the bed under the motor of the same height as the main bed. This makes it convenient to attach the hoist to the base framing of the tower.

The general engineering of the cableways was handled by the staff of Asbestos Corporation, Limited. The span, the loads, and the rope speeds are unusually high.

The structural steel work was designed by Dominion Bridge Company; the main cables and hoisting ropes were made by the Dominion Wire Rope Company, Limited, of Montreal; the electrical equipment by the Canadian General Electric Company, Limited; and the hoists were designed and built by Canadian Ingersoll-Rand Company, Limited.

Drainage

The serpentine rock, as a rule, does not carry much water. Most of the water comes direct from rainfall or the run-off from the ground immediately adjoining the pit. Water collects in a sump on the bottom level or underneath it, and is pumped to the surface. At the largest pit only is the pumping a serious operation.

Power Used

According to the late J. J. Penhale, power was first applied to quarrying in the asbestos field in 1887 in the form of a steam plant by the late R. T. Hopper, at the property of the then Anglo-Canadian Asbestos Company at Black Lake (now Asbestos Corporation) of which Hopper was then manager. The equipment consisted of a single boiler hoist, and a small Rand compressor with rock drills. To-day, all hoisting is done by means of electric motors, and all air is supplied for drilling by electrically-operated air compressors.

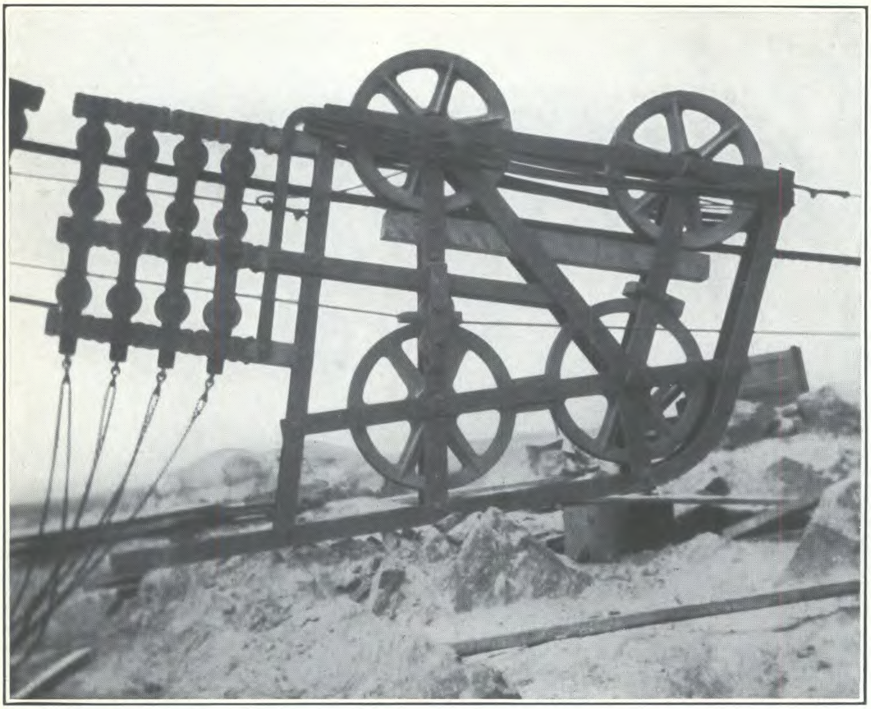
Cost of Quarrying

The cost of quarrying rock and delivering it to the mill depends on the amount of drilling and blasting required, the means of loading and method of hoisting, or tramming employed, and the amount of rock handled per hour.

Typical costs are:—

1. Soft rock, loaded by steam shovel, 17 to 40 cents per ton.
2. Hard rock, with glory-hole mining, 19 to 36 cents per ton.
3. Hard rock, with shovel or crane loading and tramming, 20 to 60 cents per ton.
4. Hard rock, with hand loading and cable-derrick hoisting, 30 to 60 cents per ton.
5. Underground mining, 35 to 60 cents per ton.

Cableway derrick towers, Johnson's Company, Thetford Mines, Quebec.



A. Cableway carriage.

B. Deadmen for anchoring cables.

CHAPTER III

THE DRESSING OF ASBESTOS FOR THE MARKET

Under the term " dressing " is generally understood the processes by which the miner converts his material into a saleable article, or by which he extracts a marketable article from the rock. In the case of asbestos, the processes are divided into (1) hand dressing, and (2) mechanical treatment.

HAND DRESSING

Hand dressing applies to the preparation only of fibres sold in the " crude " form, all other grades being produced mechanically. The standard grades of crude fibre comprise No. 1 crude, into which all fibre over $\frac{3}{4}$ inch in length is sorted; and No. 2 crude, fibre measuring from $\frac{5}{16}$ to $\frac{3}{4}$ inch. Occasionally, a No. 3 crude is produced. In this grade is put fibre which has the required length to be graded as a crude, but may be lacking in other characteristics. Fibre discoloured by iron oxide or clay, harsh fibre, long slip fibre, long head fibre, or even picrolite, may be sold as No. 3 crude, on sample.

When the fibre is cobbed clean of rock only, and not graded according to length, it is sold as run-of-mine crude.

Long fibre with adhering rock is brought from the pit to the cobbing shed and dumped on a horizontal coil of steam pipe to dry. After drying, it is parcelled out to cobbers, usually boys and girls, who work on a contract basis, being paid a stated rate per bag of 100 pounds of finished fibre, cleaned, inspected, and accepted. The cobbers work at benches in rows, as many as 60 being employed at one plant. Each cobber works in a separate compartment. A flat stone or iron plate, 10 to 12 inches square, is fitted into the bench. The fibre is flattened out and freed from rock particles by striking with a cobbing hammer from 3 to 7 pounds in weight. Each grade of fibre is placed in a separate box, and the refuse, rock, dust and short fibre, dropped in a receptacle under the bench. The No. 1 crude is screened on a flat shaking screen with $\frac{3}{8}$-inch holes; and the No. 2 crude on one with $\frac{3}{16}$-inch holes. The refuse from the screens and cobbing benches is sold as screenings, or added to the mill feed for the recovery of such fibre as it may contain. The output per cobber varies from 100 pounds to 300 pounds finished fibre per day.

The crude fibre ready for the market is put up in bags holding 100 pounds each. It still contains from 5 to 20 per cent of rock, dust, and short fibre, which material, useless to the spinner, is cleaned out when the fibre is opened at the factory in preparation for spinning.

Attempts have been made at several of the mills to prepare crude fibre by mechanical methods. The manufacturers, however, have so far been unwilling to accept such, or not at a price to compensate the miller for loss in weight occasioned by preparation.

MECHANICAL TREATMENT

History

The first attempt to solve the difficult problem of extracting the mineral from the rock by means of machinery was made in 1888, by the Scottish-Canadian Asbestos Company, now owned by the Asbestos Corporation. This plant consisted of a 50 horse-power engine, Blake crusher, travelling picking tables, a set of Cornish rolls, revolving screens, elevators, shakers, and two large blowers. This mill was erected by J. J. Penhale, according to the plans of Mr. Earle C. Bacon, Engineer, New York. In 1890, Mr. R. T. Hopper—at that time Managing Director of the Anglo-Canadian Asbestos Company— experimented with the ore in a small mill, consisting of a Blake crusher, rolls, shakers, and a fan, and succeeded in producing a fibre of marketable quality. In 1890 and 1891, the American Asbestos Company (Union Mines)—now owned by the Asbestos Corporation—began experiments with the ore. The main object of this company was to do away with the almost indistinguishable No. 3 grade. This, however, was difficult to realize, unless the fibre could be thoroughly loosened and freed from the rock. The method adopted was as follows: the rock first passed through a Blake crusher, falling upon an inclined shaking frame which separated all the loose fibre and dust from the larger pieces of the asbestos rock; the fibre going directly to a cleaning and grading machine, while the asbestos rock dropped on a revolving picking table. Here the barren rock was separated from the asbestos by hand. The latter was then dried in drying kilns, and sent to the fine roll crushers.

The crushed material went over cleaning and grading machines which consisted of a set of inclined sieves in rapid shaking motion, in connexion with blowers, fans, etc., the remaining unbroken stone and fibre going again through a set of still finer rolls.

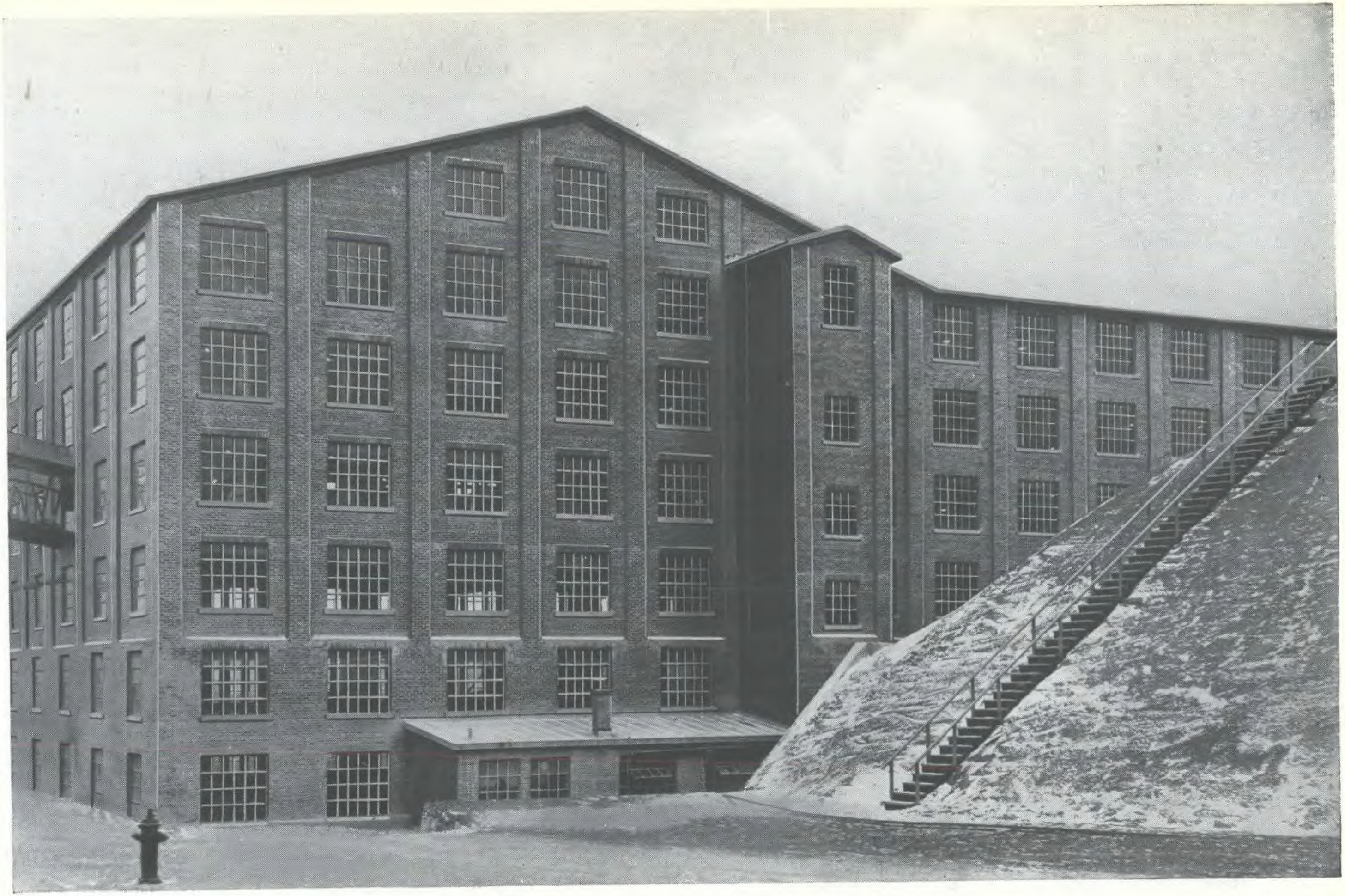
The results obtained in this mill were not satisfactory, as the fibre so produced still contained a large amount of rock particles and dust.

King Brothers, at Thetford, were the next to introduce machinery for the purpose of extracting small fibre from large pieces of rock in the dumps; which in the beginning of the industry did not warrant the expenditure for block-holing and further handling.

The plant consisted of a Blake crusher, from which the material was conveyed to a set of Cornish rolls; and a revolving screen then cleaned the fibre from dust. But this object was not fully accomplished owing to the failure of the rolls to crush the rock sufficiently. An additional blowing and screening apparatus was installed, which gave better satisfaction.

In 1893, F. Cirkel treated about 10 carloads of asbestos rock, containing small fibre, received from the Templeton Asbestos Mining Company, which was operating at that time the asbestos mines in Perkins to the north of Ottawa. The mill used was located at Buckingham, and had been previously employed in the grinding and screening of phosphate rock. It consisted of a system of Blake crushers, Cornish rolls, a pulverizer, and screens, and after many changes—especially in the screening devices—the method worked entirely satisfactorily in liberating the ore from the rock; but a complete extraction of the fibre was not effected, owing to the lack

King mill and plant, Asbestos Corporation, Limited. Thetford Mines, Quebec.



Beaver mill, Asbestos Corporation, Limited, Thetford Mines, Quebec.

of the necessary suction apparatus. When the latter was about to be installed, the mines shut down, and the experiments were consequently discontinued.

All the experiments carried on in the above mills conclusively demonstrated the great difficulty in freeing the fibre entirely from the dust and adhering rock particles. Owing, therefore, to the imperfect quality of the fibre so produced, the unwillingness of the manufacturer to buy prepared fibre at that time, and also owing to the trouble with the customs authorities of the foreign countries, who considered the fibred asbestos as a manufactured article, hence levied a duty thereon of 25 per cent ad valorem, the mechanical preparation appeared to come to a standstill.

In 1892, 1893, and 1894, several large shipments of prepared asbestos were made, and although the quality was not up to the expectations of the manufacturers, nevertheless, some of the latter realized the immense importance of the new innovation, having for its object the saving of the freight charges by the elimination of the rock in the different qualities of crude, which, in some cases, amounted to from about 15 to 20 per cent of the total weight. On the other hand, it was manifestly of the utmost importance for the mine owners to succeed in mechanical separation, since the large dumps resulting from the earlier operations contained a very large amount of short fibre, and did not warrant the comparatively large expenditure involved in extracting by hand-cobbing; and the saving of which would represent a valuable asset when the mechanical process of separation of the fibre became a success.

The Bell Asbestos Company, under the management of Mr. George R. Smith, commenced to experiment with the mineral in 1893, with the result that a mill was built in the following year, treating small quantities of asbestos rock with success. Other companies followed suit, and shipments of fiberized material commenced in earnest in 1895 and 1896. From the last-named year on, the process of extraction has been steadily improved. Mills of large capacity were built; the percentage of crude became insignificant compared with the large output of the fiberized article, and to-day every mine of importance is equipped with a complete milling and fiberizing plant.

In 1923, the present mill of the Asbestos Corporation at the King pit, designed by the writer and the engineers of the company, was completed. This mill embodied the best practice developed to that date in the camp, with additional features taken from milling practice in other fields. The mill building and equipment in appearance and performance compare favourably with similar installations in other mining fields. The capacity of this mill, 200 tons of rock per hour in two units, is considerably greater than that of any existing plant. Even this, however, has been superseded in size, though not in capacity, by mills constructed on the Beaver property of the same corporation and by Johnson's Company. In these two, however, only half the buildings has been equipped with machinery.

The more important improvements made in milling practice from time to time have been: application of electric power, development of cyclone grinders, less costly means of drying rock, installation of bins of large capacity for storage of dried rock, more definite methods of grading, cleaning of low-grade fibres, collection of dust and short fibre for sale as floats, and partial elimination of dust from the surrounding atmosphere.

MILLING PRACTICE

While the mining methods employed are merely variations of those in general use in getting out any rock, asbestos milling has developed some features of its own. It is becoming more generally recognized by the operators that the rock in each section requires to have a mill specially designed for its individual treatment. The hardness of the rock varies from place to place, as also does the quality, length, and percentage of the fibre. A mill which will recover fibre efficiently in one area may be so harsh in its treatment as to be destructive of length of fibre in another. A soft rock which will produce only short or low-grade fibre in big tonnage must be milled in a different manner from a hard rock containing a comparatively small amount of fibre but that of good quality and length.

It has taken considerable experience and the building of many mills to demonstrate this fact. The present tendency in mill design is to eliminate unnecessary machinery by lifting fibre after each crushing, unloading sand as soon as made, and keeping hard barren rock out of the mill.

Other than the suction systems and the cyclone, three varieties of which have been designed and developed in the Quebec district, all units in any asbestos mill are such as are used in other dry milling metallurgy.

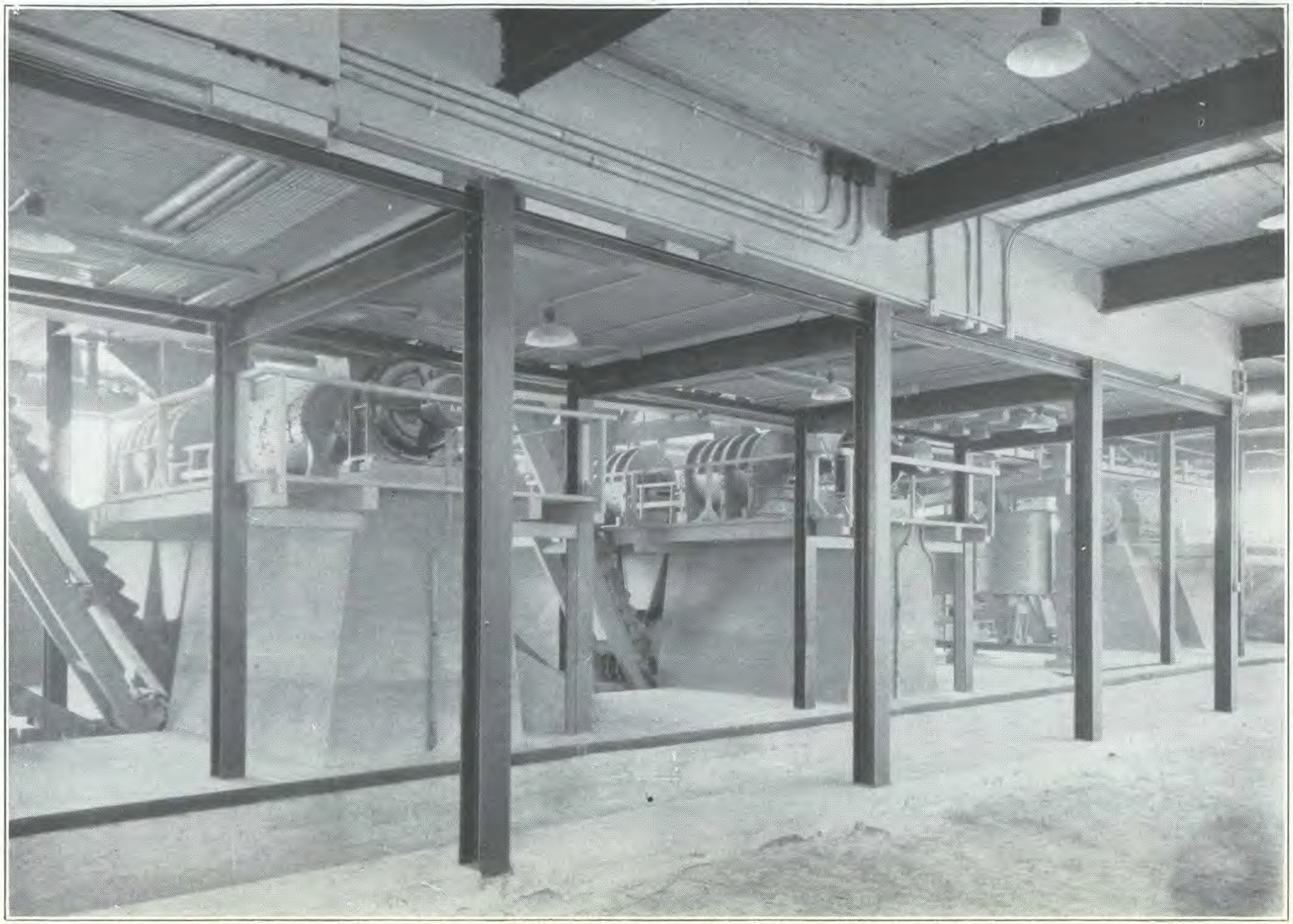
One of the most useful advances has been the building of large bins for the storage of the crushed rock after drying. This enables the mill-man to draw feed containing more uniform fibre content, so that the mill will not be loaded with fibre one day and be running on lean rock the next. Moreover, the rock in the bin cures to an even moisture content, so that hasty adjustments need not be made to accommodate a dry dusty fibre one hour and a damp tough fibre the next.

The necessity of ample screening area in the mill is being more generally recognized, although, with the type of flat shaking screen commonly in use, the screen cloth is cleaned only with difficulty and is often blinded and ineffective for the larger part of its surface.

Vibrating screens, both electrical and mechanical, are being found useful for removing sand, but they must be followed by flat shaking screens on which the rock and fibre will bed and from which the fibre may be lifted by suction. More attention is being given to cleaning the fibre thoroughly, and each year, less dust is left in the fibre by the better mills. The very fine fibre derived chiefly from the exhaust of the suction systems is collected in large dust bins and sold as "floats." In newer mills, fibre (other than floats) and sand are not allowed to pass through the suction fans, nor is opened fibre allowed to go into a crusher.

It too often happens that fibre, after being freed from rock, is allowed to enter the next crushing unit along with sand which should have been eliminated, and as a result it is unduly cut up.

With the control of the properties now in the hands of a small group of operators, instead of each property being operated as a separate unit as in the early days of the industry, the number of grades of fibre produced and marketed has been reduced from fifty to about thirty.



Crushing machinery, King mill, Asbestos Corporation, Limited, Thetford Mines, Quebec.

Collectors and fans, King mill, Asbestos Corporation, Limited, Thetford Mines, Quebec.

The design and equipment of a mill, in most instances, depends on the personal predilection of the operator of the moment, or on the persuasive ability of machinery salesmen.

In order to reduce costs, to increase percentage of fibre recovered, and to improve grades advantage has been taken, in some mills recently built, of the experience of the consulting engineer, and successful practice from other fields has been introduced. Notable improvements in milling and reductions in costs have resulted from such co-operation.

However, the competition of operators to mill a large tonnage of rock is still the cause of much barren rock being milled. This is ground into sand at a higher cost than that at which it could be picked out and discarded in lump form. The milling of such material also reduces the capacity of the mill, wears the machinery, and cuts up the fibre.

The structural geology of the area has not been worked out in detail, and at times mills are running on low-grade rock because the high-grade zones have not been delimited and it is more convenient to mine the low-grade.

With a fuller knowledge of the content of their ground, operators would be in a better position to produce the grades of fibre demanded by the market at any time, and secure a larger tonnage of fibre from the existing milling equipment.

A few typical flow-sheets will indicate the diversity of ideas for milling similar rock:

Mill A

Jaw crusher,
Rolls,
Hammer crusher,
Dryer,
Storage bin,
Screens with suction,
Hammer mill,
Screens with suction,
Cyclone,
Screens with suction,
Jumbo,
Screens with suction,
Jumbo for tailings,
Screens with suction,
Rotary graders and cleaning screens,
Floats bin.

Mill B

Jaw crusher,
Jaw crusher,
Grizzly screen,
Picking belts,
Dryer,
Disk crusher,
Screens with suction,
Jumbo,
Screens with suction,
Jumbo,
Screens with suction,
Grading and cleaning.

Mill C

Jaw crusher,
Dryer,
Storage,
Jaw crusher,
Hammer crusher,
Screens with suction,
Hammer crusher,
Screens with suction,
Cyclone for tailings,
Screens with suction,
Grading and cleaning screens,
Dust bin.

Mill D

Dryer,
Jaw crusher,
Jaw crusher,
Rolls,
Rolls,
Jumbo,
Screens with suction,
Jumbo,
Screens with suction,
Jumbo,
Screens with suction,
Jumbo,
Screens with suction,
Jumbo,
Screens with suction,
Jumbo,
Screens with suction,
Jumbo,
Screens with suction,
Flat grading screens.

Mill E

Grizzly,
Jaw crusher,
Jaw crusher,
Trommel screen,
Dryer,
Disk crusher,
Screens with suction,
Jumbo,
Screens with suction,
Rotary graders and cleaning screens,
Ball mill for tailings.

Mill F

Jaw crusher,
Dryer,
Storage bin,
Hammer mill,
Screens with suction,
Cyclone,
Screens with suction,
Grading and cleaning screens.

A study of the sequence of operations in the above flow-sheets shows that at times rock and freed fibre are recrushed together as many as four times before any fibre is separated. Such procedure cuts up and tears fibre unduly. Mill D has recently been rebuilt on the following design, in which it will be seen that an opportunity is afforded for lifting off the fibre each time the rock is broken, thus increasing the recovery of fibre in a longer form.

Mill D—Rebuilt

Grizzly in rock sluice,
Jaw crusher,
Dryer,
Grizzly, fines to screens fitted with suction,
Gyratory crusher,
Screens with suction,
Rolls,
Screens with suction,
Jumbo,
Screens with suction,
Jumbo,
Screens with suction,
Jumbo,
Screens with suction,
Jumbo,
Screens with suction,
Rotary graders and flat cleaning screens,
Floats bin,
Sand to dump.

The ball mill action of the rotary dryer opens some of the fibre so that it can be lifted before the rock enters the next crusher.

Primary Crushing. Rock as hauled from the pits is dumped into a sluice from which the primary crusher is fed. The sluice acts as a stabilizer on crusher feed, holding several cars of ore. In some cases, the sluice bottom is built of railroad rails to form a grizzly, and the fines by-passed. The cushioning effect of fines on the crusher is eliminated and the loosened fibre saved from being unnecessarily cut at this stage. The rate of feed of rock from the sluice to the crusher is controlled by finger-gates (suspended rails which may be moved up or down separately) operated by compressed air.

Various types and sizes of crushers have been tried at different mills, but the one which is becoming standard is the jaw crusher, usually with a 36-inch by 24-inch opening set with a 4-inch to 6-inch width of discharge. For increased crusher capacity, additional units are installed, or crushers up to 48-inch by 60-inch opening used.

Picking. The broken rock next passes over a picking belt and crude fibre, wood fragments, and pieces of iron are picked off. A second picking belt is sometimes used so that in dumping from one to the other the rock is turned over and material hidden on the first belt exposed to view on the second for picking. The ore may be further reduced by crushing, usually in rolls, hammer, gyratory, or cone crushers before going to the dryers.

Drying of the Mill Rock. The rock coming from the open pits and glory holes contains moisture and, in winter, even ice and snow. It is found advisable to dry rock from underground mining to assure even milling conditions. In the early days of limited output, and summer operation only, rock was spread in thin layers to dry in the sun. To expedite drying and lengthen the season of operation, coils of steam pipes were laid on the floor of a shed and the rock fines and fibre spread on them. This system is still used to dry rock containing crude fibre at the cobbing sheds.

Two types of dryer are in use:

1. The rotary dryer.
2. The stack dryer.

While the former is more costly to operate, it is preferred by some managers who claim that the ball mill action does milling work, freeing fibre from the rock and opening it up. On the other hand, careful experimental work tends to show that this same action is destructive of fibre, tearing and cutting it up.

The cost of drying in a rotary dryer varies from 4 to 18 cents per ton of rock, depending on the season, type of installation, and amount of rock handled.

The rotary dryer consists of a long cylinder made of strong boiler plate, and lined with sectional replaceable liners, bolted to the shell. This shell rests and turns on its ends on friction rollers. In order to allow the shell to expand when heated, and at the same time to prevent it from sliding, these friction rollers are flat at the upper end and grooved at the lower end of the cylinder. The length of the shell is from 40 to 60 feet; the diameter from 4 to 6 feet; and its inclination, 7 degrees. The drying is assisted by longitudinal blades, which lift the material and allow the same to fall through a current of hot air which circulates through the cylinder. The capacity of a dryer 60 feet long, by 5 feet diameter, is from 30 to 60 tons per hour, depending on moisture content of the rock, amount of fines present, and speed of rotation. The speed of the current of air passing through the cylinder is regulated either by blowers on the fire-box or suction on the stack, or by both. A suction fan on the stack draws off a certain amount of dirty fibre and dust which is trapped in a collector, milled, and cleaned.

The usual method of firing is to build a fire-box at the upper end of the cylinder and blow the hot gases of combustion into the shell along with the rock fed in. The shell is exposed and the loss of heat by radiation is considerable. The shell and moving parts, however, on this system are in view at all times and necessary repairs can readily be made.

A type of installation which is claimed to be more economical of heat is where the cylinder is enclosed in a brick chamber. The fire-box is installed under the feed end of the cylinder which is protected from direct contact with the hot gases by a firebrick arch. The heated current of air surrounds the shell and entering its lower end, passes through the falling material counter-current to its flow, being drawn off by a suction fan at the feed end.

The stack dryer which in its present form was developed by the Asbestos Corporation, is used by that company only. In principle it is similar to stack dryers or roasters employed in other metallurgical processes, but is especially adapted in construction for drying the material in hand. A square stack, some 50 feet in height by 7 feet across, is fitted with sets of grid bars of special shape. These interrupt the speed of fall of the material which meets a rising current of hot air from fire-boxes at the bottom. Speed of travel of the hot air is regulated by a suction fan which also draws off some fibre and dust which is caught in a collector, milled and cleaned. Having no moving parts, other than the bucket elevator for feeding, requiring no other power to operate, and with a low repair cost, this type of dryer is economical and efficient. The cost of drying in the stack or vertical dryer is from one-half to one-third that of a rotary dryer, handling an equal quantity of similar material. The design in use being the property of the Asbestos Corporation, it can be installed by other operators only by agreement with that company.

For fuel in both types of dryers, anthracite coal screenings and coke, either separately or mixed, are used. In one pair of rotary dryers pulverized coal is used as fuel.

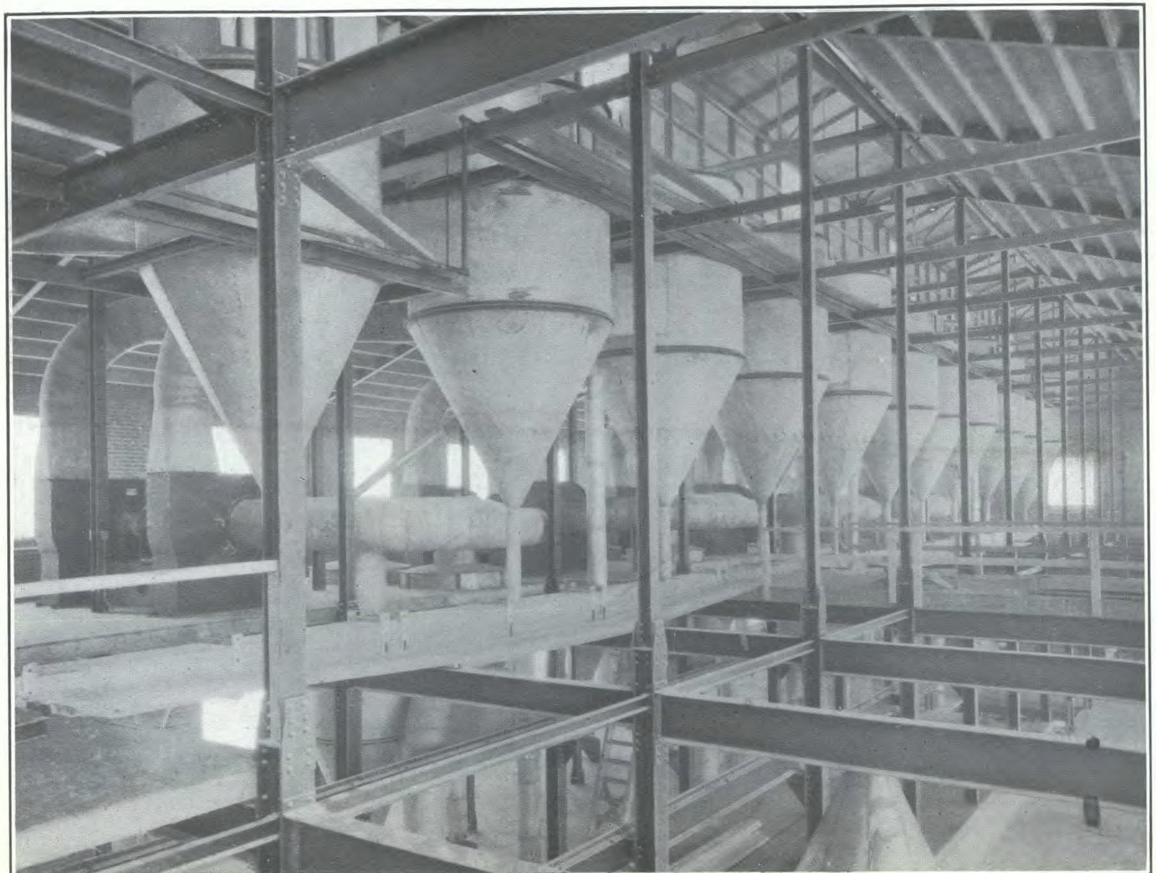
Storage Bins. From the dryer the rock is conveyed to a storage bin. With this unit in the flow-sheet, it is not necessary to completely dry the rock, as the heat contained in it continues the drying process.

An economical form of storage bin has been evolved, using waste sand from the mill for the construction of bottom and sides. A concrete tunnel, in which a conveyer belt travels, is banked on the sides by sand which forms the floor of a bin lying at the natural slope of the sand pile. On a framework overhead travels a feed conveyer belt. Incoming rock may be dumped in any section of the bin, so that lean and rich rock may be properly distributed and a feed of even fibre content secured for the mill. The bottom of the bin, or roof of the tunnel is fitted with gates through which rock may be fed to the conveyer belt running to the mill. By drawing from two or more gates at the same time, a correct proportion of coarse and fine rock may be fed to the belt, thus assuring a mill feed of comparatively regular fibre content. With the control available by the storage bin and its equipment, frequent adjustments of the milling are not necessary. The mill will not be running on coarse rock containing little fibre for one hour, and on fine rock with a high fibre content the next period. Nor will the fibre be dry and dusty for a time, followed by a feed of damp tough material. Bins of a capacity up to 25,000 tons of rock are in use. The roofing and walls are constructed of galvanized sheet iron, or corrugated asbestos sheets.

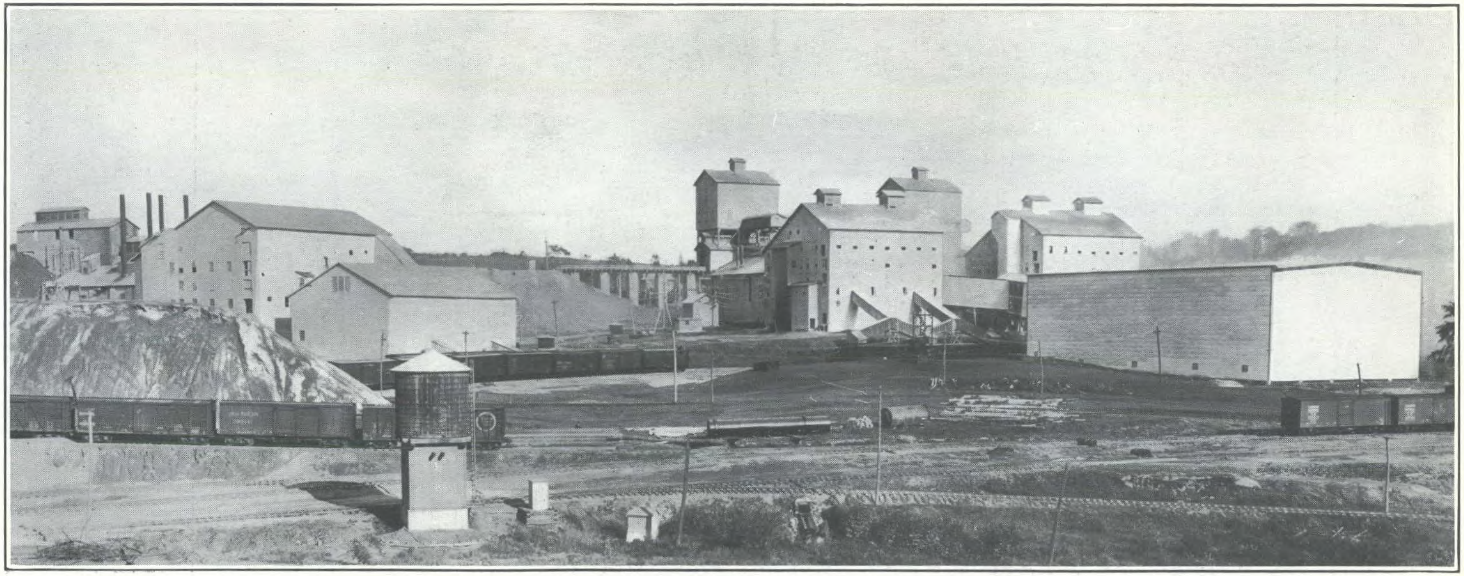
Milling

Up to the milling stage, the practice at the various mills differs but little except in tonnage handled and consequent size of units.

Rock coming from the storage bin is in fragments up to 2 or 2½ inches maximum diameter. The conveyer belt from the storage bin to the mill



Collector floor, King mill, Asbestos Corporation, Limited, Thetford Mines, Quebec.



Mill of the Canadian Johns-Manville Company, Asbestos, Quebec.

is equipped with an electric weightometer, so that an accurate record of the rate of feed and amount of rock going to the mill may be kept. No system has been devised for an assay of the percentage of fibre in the mill feed. Rock which on visual inspection appears to contain but little fibre may, on milling, yield a fair return. The percentage of fibre in the rock is judged by the output of fibre. This in turn depends on the system of milling employed. Two mills, differently equipped, may give a wide variation in the value of fibre recovered from rock taken from the same storage bin or pit.

Milling consists of reducing the rock in size by successive stages of crushing, at the same time opening or fluffing the fibre, screening out the fine sand, and lifting the freed and opened fibre after each crushing operation. The sand screened out goes to the waste dump, and the fibre is lifted by air suction to collectors, whence it passes to grading screens, each grade made being separately cleaned and bagged.

On first entering the mill, the rock is sized by screening so that free fibre and fines will not pass to the first coarse crusher which breaks the larger size rock.

This separation may be made in a trommel screen or on a double-decked screen of the vibratory type. The first mill breaking of rock may be done in one of several types of crusher, gyratory, hammer mill, roll, or jaw crusher.

The product of the crushers and the throughs from the sizing screens go either to screens or to fiberizers and thence to screens. As the hammer mills act as fiberizers, the product from them goes direct to screens. With the other types of crushers, however, it is advisable to open the fibre that it may be lifted by air suction. For this purpose, four types of fiberizers are in use, the Laurie cyclone, Pharo cyclone, Torrey cyclone, and the Jumbo.

Fiberizers. On account of the excessive wear of iron, high power consumption, and attrition of the fibre, the Laurie and Pharo cyclones are not used in the newer mills, and have gradually been discarded in the older mills. The Jumbo, which is made locally and is simple in operation, is apparently the most satisfactory implement for fiberizing, but there is room for improvement in design to endeavour to reduce the breakage of fibre. A Jumbo consists of a cylindrical shell set in a horizontal position, lined with sectional steel plates, and fitted with cast-iron ends. A horizontal shaft, on which are bolted chilled cast-iron beaters, revolves at a fixed speed depending on the size of material handled. The upper half of the casing is hinged to facilitate replacement of worn beaters. The beaters are made in two parts, a permanent arm bolted to the shaft, and a manganese steel hammer bolted to the end of the arm. The arms and hammers are turned at an angle to direct the material to the discharge end. Feed enters at one end above the shaft and is discharged either through an opening in the bottom at the opposite end, or through a longitudinal slot which in some cases extends the length of the bottom, and in others one-half or one-third of its length. The length of a Jumbo is 6 or 8 feet, and the interior diameter 24 or 30 inches. Beaters are set at 6- to 8-inch intervals on the shaft, and the end of the beater clears the shell by one-half to one inch.

The cyclones are vertical machines, the feed entering at the top or side, and discharging from one side.

In the Laurie cyclone two beaters of screw propeller type are driven at a speed of from 1,700 to 2,000 r.p.m., in opposite directions in a cast-iron chamber. The Pharo cyclone differs in that the beaters revolve in the same direction, and an arrangement of gates controls the rate of discharge.

The Torrey cyclone consists of a cylindrical steel shell set vertically. After passing one set of beater arms mounted on a vertical shaft, the material is directed by sloping plates to the centre and passes to a second set of beaters before being discharged. As in the Jumbo, the ends of the permanent arms are fitted with manganese steel hammers. An advantage of this type of cyclone is that the breaking is done by throwing the particles of rock against one another or against the shell with little grinding action. The attrition of fibre which occurs in the other types is minimized as the rock has a freer fall to the discharge. As the beaters do not carry a load of material the power required per ton is less. The usual speed of revolution is 800 r.p.m.

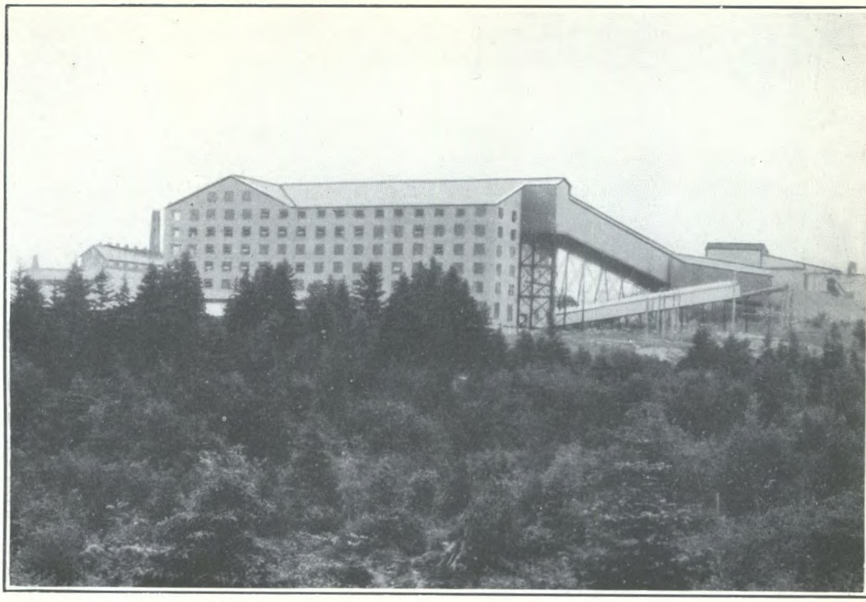
Oversize rock from the first screening is again reduced in size and more fibre freed. At this stage the crusher may be of the gyratory, jaw or hammer type, or a pair of rolls.

Following this reduction, the procedure is similar to that of the first stage of milling. If necessary, the material is passed through a fiberizer, or if already opened as is the fibre from a hammer mill, it goes direct to a screen. After the sand has been screened out and the fibre lifted, the rock is again broken. At this stage the maximum size of the rock is about ¼-inch, and further reduction is done in fine grinders, of which the Jumbo has proved to be the most satisfactory. In order that the fibre may not be cut up more than can be avoided, it is gradually reduced in a succession of crushings, two to four Jumbos being employed, the material being screened, and the fibre lifted off after each crushing. The load of the mill is gradually reduced by the amount of sand eliminated by each screening, and by the load of fibre lifted off each screen. Consequently, the amount of rock handled by the following crushers becomes successively less. Undersize from the last screen goes to the sand dump.

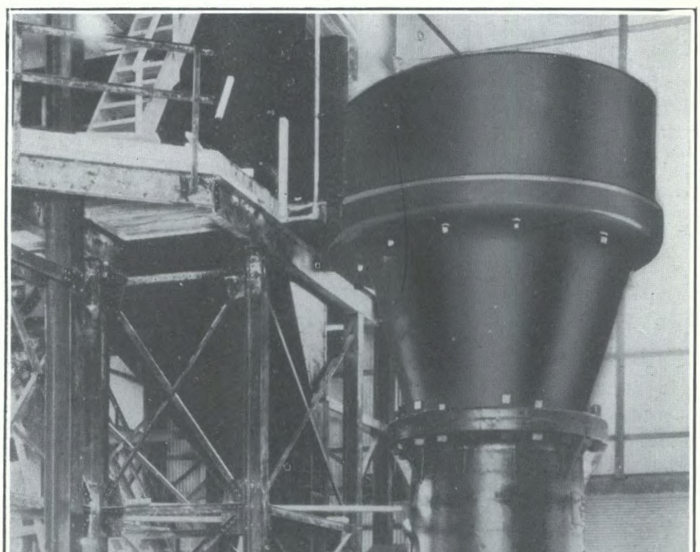
Rock Breakers. Crushing units such as rolls, gyratory and jaw crushers, are of standard makes and design, having capacities of either 30 or 60 tons per hour each. The hammer mill is a local adaptation of mills of the Williams type, the grid bars at the discharge being replaced by a slot running lengthwise of the semi-circular bottom of the mill to allow of free fall of the broken rock. When the rock has to be ground sufficiently fine, in mills fitted with grid bars, to pass through the spaces between the bars, much of the fibre is held in the mill and ground up. In the attempt to prevent this, an air suction was installed on the top of the machine. The combined suction and the centrifugal action of the beaters, however, caused a large amount of rock to accompany the fibre.

Screening

From each crusher the broken rock falls on, or is conveyed to, a screen where the sand is shaken out, the fibre lifted by suction at the lower end, and the overs passed to the next crusher.

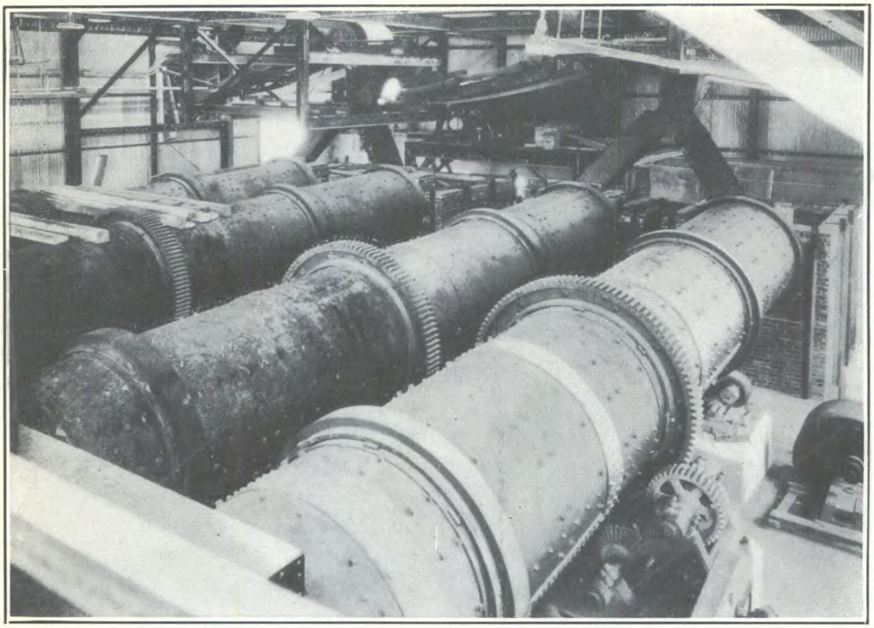


A. Johnson's mill, Thetford Mines, Quebec.

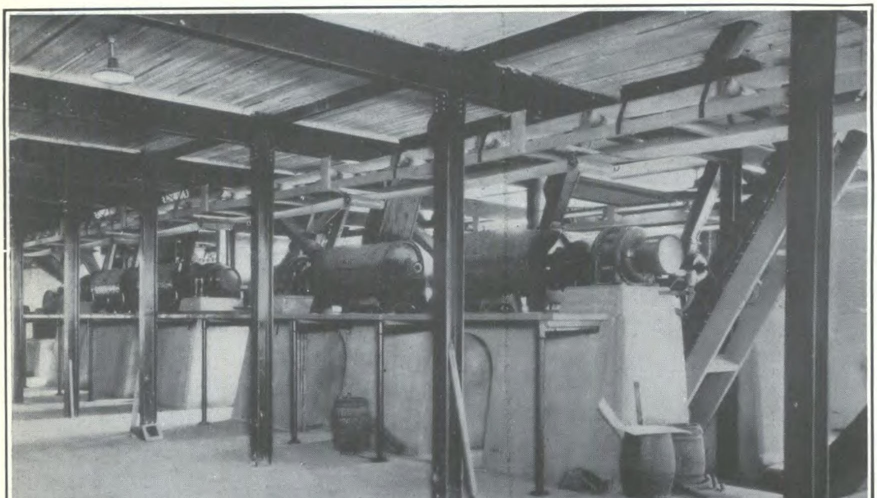


B. Primary gyratory crusher, capacity 500 tons per hour, Johnson's mill, Thetford Mines, Quebec.

(Photos by courtesy of Johnson's Company)



A. Drying drums, Johnson's mill, Thetford Mines, Quebec.



B. "Jumbos" for fine crushing of small sizes of asbestos rock, Johnson's mill, Thetford Mines, Quebec.
(Photos by courtesy of Johnson's Company)

Screens. The shaking screen is used throughout the mills. It consists of a wooden frame braced with cross bars in the form of a grid on which wire cloth or perforated metal plate is laid. The size of the screen varies, while those 5 by 10 feet, or 6 by 12 feet, are suitable in most places, others 3 by 10 feet, or even 6 by 18 feet may be used. Side and upper end boards 4 to 6 inches high direct the flow. The screen is suspended or mounted on flexible supports, and is set with an inclination to the discharge end. A shaking or bumping motion is imparted by means of an eccentric drive. In addition to screening out the sand, the motion moves the mass forward, and causes the fibre to rise through the rock fragments to the top layer from which it can be lifted by air suction. As the openings in the screen cloth or plate rapidly become clogged by minute particles of sand, various designs of tappers or beaters are operated on the cloth to keep it clean. At the best, however, only a small section of a screen is doing efficient work in eliminating sand at any one time, and much sand is carried to succeeding processes to the detriment of the fibre. This screen, being made in the mill, is inexpensive to build, and is operated at a low cost, especially when the driving mechanism is equipped with roller bearings. Screens are sometimes installed end to end, the feed being split, half going to each screen. In other installations, two or three screens may be mounted on the same framework, one above the other, the material falling from the first to the second, reversing its direction of flow, and again resuming the normal direction on the third screen. This arrangement has the disadvantage of hiding the screen cloth from observation and rendering it practically impossible to clean it. As screening is one of the most important operations in a mill—and as usually practised the least efficient—many attempts have been and are being made to improve it. It has been found that by placing certain types of vibrating screens ahead of the shaking screen that an important portion of the sand is shaken out, the stone and fibre being bedded on the shaking screen, and at the same time, more sand eliminated. The rapid motion and short length of travel on a vibrating screen does not permit of effective bedding to bring the loose fibre to the top of the rock. It should therefore be followed by a shaking screen, from the end of which the fibre may be lifted. Sand is discarded at 8, 10, 12, or 16 mesh at different mills.

Screens of the trommel type are used for three purposes, sizing rock, grading fibre, and cleaning fibre. For the first purpose, they are no more efficient than a properly designed grizzly; they are expensive in upkeep, limited in capacity, require considerable power to operate, and subject the fibre to rough usage. On the other hand, as in the case of the rotary dryer, they have a limited ball mill action in freeing and opening fibre.

Collecting of Fibre

Suspended at the discharge end of each screen, a few inches from the end, and just above the flow of material, is a hood made of galvanized iron. The sectional opening in length equals the width of the screen, and is itself 3 to 4 inches wide. At a height of 30 to 50 inches, depending on the width of screen, the hood converges to a pipe, 8, 12, 15, or 20 inches in diameter. This section of pipe in turn fits into a vertical pipe to which it is not attached. The hood is suspended on wires fitted with turn-buckles by means of which it may be raised or lowered or adjusted along the screen. The lower edges of the hood are equipped with flanges for directing the air current. In older mills, the pipe from the hood leads to an exhaust fan, which in operation lifts the fibre which passes through the fan and is blown into a room or chamber. However, this is no longer regarded as good practice. As many as 6 or 8 hoods may be suspended along the length of the screen, but usually each screen has one hood only.

In mills of modern design the pipe from the hood leads to a collector, a container made of galvanized iron. The upper section of the collector is 5 to 7 feet in height and 56, 60, 70, 80, or 90 inches in diameter. The lower half is cone-shaped, 5 to 7 feet in height, and at the bottom converges to a discharge pipe 10, 12, 15, or 20 inches in diameter. The outlet pipe from this type of collector, which is known as a " pull-through ", leads from the top to a fan, which for convenience of operation may be set at a distance from the collector. The fan, which is of a multi-blade Keith type, has a speed of from 750 to 900 r.p.m. and handles a volume of air from 25,000 to 45,000 c.f.m. A vacuum is created in the collector and the resultant suction lifts the fibre through the hoods and piping to the collector. The pressure is regulated to give a resistance at the hood of from $\frac{3}{4}$ to $2\frac{1}{2}$-inch water gauge as required. The direction of flow of fibre into the collector and an arrangement of internal baffles cause the fibre to drop when the speed of the air current is reduced, while the air, carrying dust and floats, passes on to the exhaust, either the atmosphere or a dust chamber.

The fibre from one screen only or from several may be carried to the same collector.

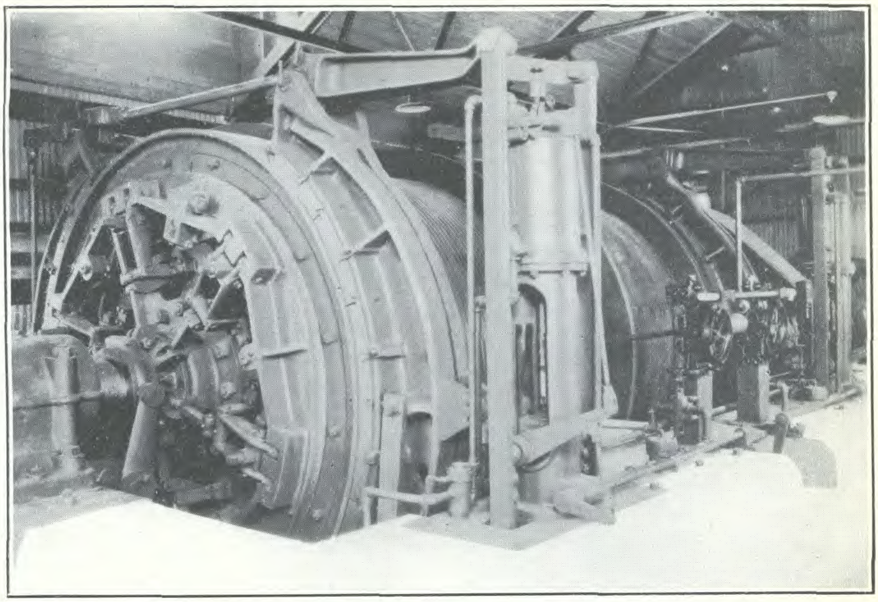
The fans may be driven either by belt drives from individual motors or from a line shaft, or by direct shaft connexion to the motor. At times, two fans are directly connected to the same motor.

The design of a collecting system is the work of a specialist. So many factors are involved that only an experienced engineer should undertake this feature of the mill design. Some of the advantages of the " pull-through " collecting system are that the fibre is cleaned of dust which is recovered as a separate valuable product, " floats ", and does not remain in the fibre to contaminate it as in the older system. As the fibre and sand do not pass through the fan blades, wear on them is reduced and their life increased.

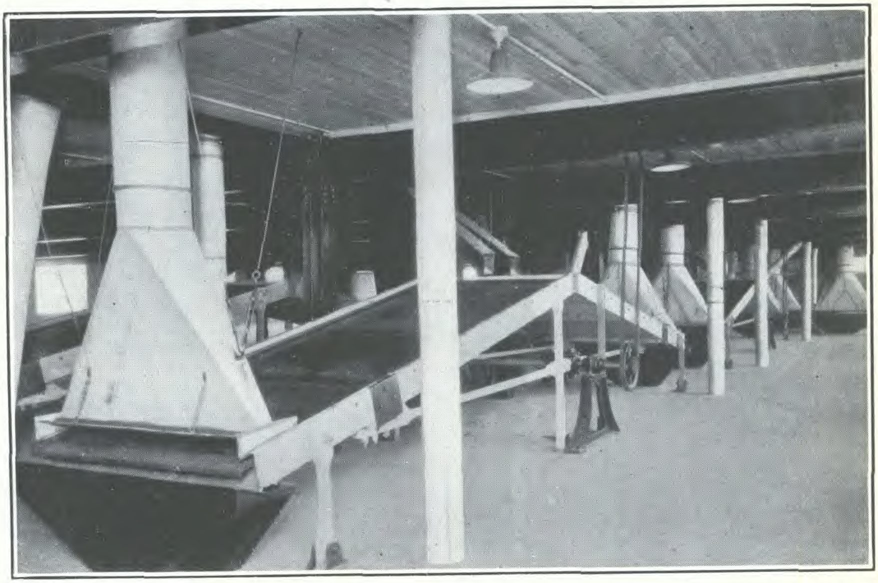
The dust-laden air from the fans is blown into chambers. To provide for the volume of air handled, these are necessarily large, often greater in cubic contents than the mill itself. By means of a system of burlap baffles the air is filtered before escaping to the atmosphere, the dust dropped, and collected in the hopper bottom of the chamber. A drag moves the dust or floats to a central point, from which it drops through a chute and is bagged. Even the floats are sometimes sized by screening before bagging.

GRADING AND CLEANING

Fibre is dropped from the collectors to the graders through lengths of pipe equipped with traps. Both flat and rotary screens are used for grading. Rotary screens may be operated at slow speed to handle a small quantity of fibre, or at high speed on a large production. Where

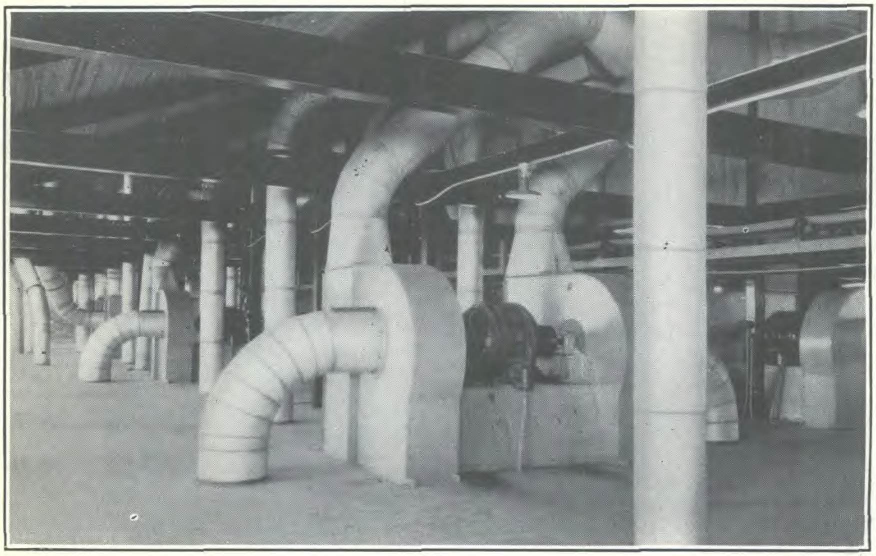


A. Electrical hoist, hoisting rate. 750 feet per minute, Johnson's mine, Thetford Mines, Quebec.

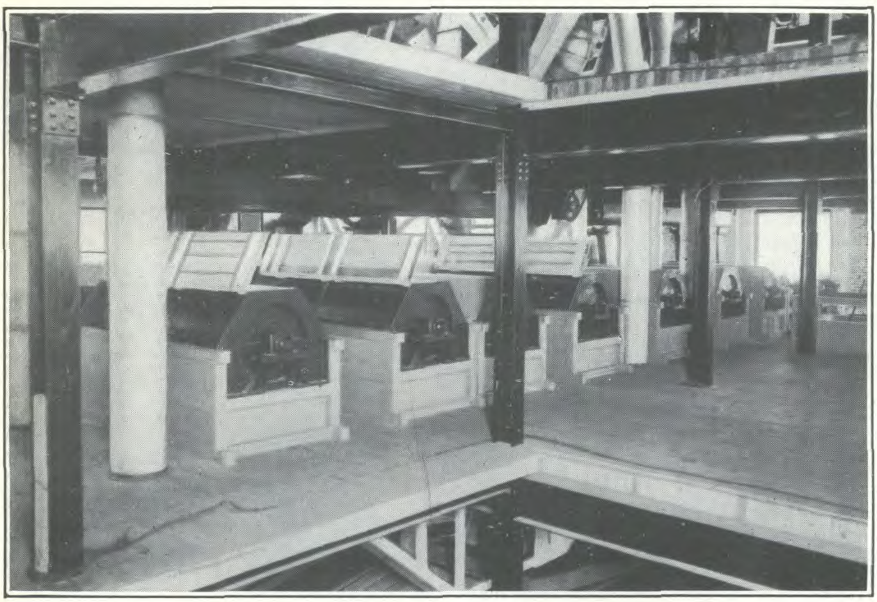


B. Shaking screens conveying asbestos fibre to suction apparatus, separating and sizing, Johnson's mill, Thetford mines, Quebec.

(Photcs by courtesy of Johnson's Company)



A. Aspirating system for lifting fibre from screens, Johnson's mill, Thetford Mines, Quebec.



B. Revolving machines used in separating or grading asbestos fibre, Johnson's mill, Thetford Mines, Quebec.

(Photos by courtesy of Johnson's Company)

three grades only are made, each half of the screen is covered with a wire cloth of a different mesh. Fibre is fed into one end of the screen, revolving paddles beat it up, force the short fibre through the screen of the first section, longer fibre through the screen cloth of the second section, and the longest fibre out at the end. Each grade falls on a flat cleaning screen where sand, dust, and unmilled splinters of fibre loosened in grading are cleaned out. Extra grades may be made by allowing portions from each screen section to combine; or any grade may be split into a number of grades in a second rotary screen or on a flat screen. From the ends of the cleaning screen, the fibre is lifted by suction, the unopened fibre and rock being allowed to fall from the end of the screen and be returned to a breaker and milled. The fibre, lifted to a collector, is dropped to a storeroom for bagging.

Testing

The method of testing as used in the industry, and adopted by the Quebec Bureau of Mines, is described by Mine Inspector Larochelle[1]:

To meet the demands of the market, a standard method of classifying fibre has been adopted by which the length of fibre is controlled. In spite of the different trade-names given the grades by the producers, there is no need of confusion for the purchaser who relies upon the standard test. The test is made on a machine known as the standard testing machine, a description of which follows.

The machine consists of a nest of four wooden boxes, measuring $24\frac{1}{2}$ by $14\frac{3}{4}$ inches and $3\frac{1}{2}$ inches in depth. The boxes, which are superposed one above the other, are numbered from the top down 1, 2, 3 and 4. The bottoms of boxes Nos. 1, 2 and 3 are made of metallic screen of the following specifications: Box No. 1: $\frac{1}{2}$-inch opening, diameter of wire, 0·105 inch. Box No. 2: 4-mesh wire, 0·063 inch. Box No. 3: 10-mesh wire, 0·047 inch. Box No. 4: is a receptacle for the fines which fall through the three other boxes. The nest of four boxes or trays rests on a table to which an eccentric with a throw of $\frac{25}{32}$-inch gives a movement of $1\frac{9}{16}$-inch travel.

To make a test, 16 ounces of asbestos is put on the top tray which is covered. The machine is run at the rate of 300 r.p.m. at the shaft of the eccentric, and by means of an automatic device, this is kept going for exactly two minutes, giving the nest a horizontal shaking movement. At the end of this time, the asbestos which remains on each tray is weighed. This gives the grades of the asbestos fibre; the longest fibre naturally stays on the top tray, whereas the shorter fibre, according to its length, remains on screens 2 and 3 or drops into the pan or lowest tray. The more fibre retained on the first screen and the less fibre in the pan, the higher the grade and therefore the greater its value. If for instance a customer buys spinning fibre of the specification 4-7-4-1, it means that in a sample of 16 ounces, representing the average of the lot shipped, 4 ounces will remain on the top screen, 7 on the second, 4 on the third and finally 1 ounce will go through all the screens into the pan. He will evidently pay more for this material than for paper stock testing 0-0-10-6. This indicates that out of 16 ounces tested, nothing is retained on the first two screens, 10 ounces remain on the third and 6 ounces go through the latter into the pan. It is evident that the figures of the test represent the proportion in ounces of the different lengths of fibre in a pound of asbestos.

During the mill-run, a sample of each grade is taken every half-hour, both at the grading screens and at the point of bagging. As exact uniformity of grading cannot be secured, owing to the variable nature of the material coming from the pit, an allowance is made in the requirements of the test,—the mill test showing a higher percentage in the upper test boxes than called for by market tests. As a general rule, the purchaser is delivered a fibre running higher on test than specified in his contract.

[1] Larochelle, Eugene: Rept. on "Mining Operations in the Province of Quebec, 1927," Bureau of Mines, Quebec, pp. 36, 37.

GRADES

Fibre from each mill is presently sold under a different series of designations, although similar marks may be employed at different mills for grades quite unequal in value. For instance, "C" marks a cement stock at one mill, and the same letter marks a spinning grade at another mill. Owing to characteristics imparted to the finished fibre by methods of milling or differences inherent to the fibre, a manufacturer may find a shingle stock from one mill suitable for his process, but will not buy one of equal test from another mill. Similarly with other grades.

All companies producing fibre in Quebec have recently agreed to a uniform classification of fibre grades; this conforms in groups to that adopted by Rhodesia, South Africa, Russia, and Italy. On account of the numerous grades made at different mills and from fibres of various characteristics each group has been subdivided into grades. This improvement will overcome the present difficulty of identifying grades up to now designated in a haphazard manner.

The following is the classification adopted by the Committee on Uniform Classification and Grading of Asbestos Mines Products of the Asbestos Producers of Quebec.

The asbestos mines products are divided into two classes: "Crude Asbestos" and "Milled Asbestos" respectively, defined as follows:—

"Crude Asbestos" consists of the hand-selected cross-vein material essentially in its native or unfiberized form.

"Milled Asbestos" consists of all grades produced by mechanical treatment of asbestos ore.

The "Crude Asbestos" and the "Milled Asbestos" are sub-divided into groups designated and defined here below.

Classification of the "Milled Asbestos" grades, unless otherwise specified, is based on the Quebec Standard Testing Machine, a description of which is given on pages 36 and 37 of "Report on Mining Operations in the Province of Quebec for the year 1927," and in the manner therein indicated. (*See* page 49, this report.)

Shipping Test.—The shipping test is the average for each carload or smaller shipment, of tests of representative samples, taken at the time of shipping.

Guaranteed Minimum Shipping Test.—The guaranteed minimum shipping test is that below which the actual shipping test shall not fall.

Crude Asbestos

Class	Standard designation of grade	Description
Group No. 1	Crude No. 1	Consists basically of crude ¾-inch staple and longer.
Group No. 2	Crude No. 2	Consists basically of crude ⅜-inch staple up to ¾-inch.
	Crude run-of-mine	Consists basically of unsorted crudes.
	Crudes sundry	Consists of crudes other than above specified.

Milled Asbestos

Group No. 3.......	Spinning or textile fibre.	Consists of fibre testing 0 - 8 - 6 - 2 and over.
Group No. 4.......	Shingle fibre..........	Consists of fibre testing below 0 - 8 - 6 - 2 to and including 0 - 1½ - 9½ - 5.
Group No. 5.......	Paper fibre...........	Consists of fibre testing below 0 - 1½ - 9½ - 5 to and including 0 - 0 - 8 - 8.
Group No. 6.......	Waste, stucco or plaster.	Consists of material testing below 0 - 0 - 8 - 8 to and including 0 - 0 - 5 - 11.
Group No. 7.......	Refuse or shorts......	Consists of material testing 0 - 0 - 5 - 11 and below, including material testing below 0 - 0 - 1 - 15 and specified as weighing 35 pounds or less per cubic foot, loose measure.
Group No. 8.......	Sand	Consists of such asbestos mill products as sand, weighing over 35 pounds per cubic foot, loose measure, and under 75 pounds per cubic foot, loose measure and containing a preponderance of rock.
Group No. 9.......	Gravel and stone	Consists of such asbestos mill products weighing 75 pounds and over, per cubic foot, loose measure.

Subdivision of the Groups of Milled Asbestos

Group No.	Standard designation of grades	Guaranteed minimum shipping test
No. 3: Textile and Spinning Fibres.......	3D	8 - 6 - 1 - 1
	3F	7 - 7 - 1½ - ½
	3K	4 - 7 - 4 - 1
	3M	2 - 9 - 4 - 1
	3R	2 - 8 - 4 - 2
	3T	1 - 9 - 4 - 2
	3Z	0 - 8 - 6 - 2
No. 4: Shingle Fibres....................	4D	0 - 5 - 10 - 1
	4F	0 - 3 - 12 - 1
	4K	0 - 4 - 9 - 3
	4M	0 - 4 - 8 - 4
	4R	0 - 3 - 9 - 4
	4T	0 - 2 - 10 - 4
	4Z	0 - 1½ - 9½ - 5
No. 5: Paper Fibre.......................	5D	0 - ½ - 10½ - 5
	5F	0 - ½ - 9½ - 6
	5K	0 - 0 - 12 - 4
	5M	0 - 0 - 11 - 5
	5R	0 - 0 - 10 - 6
	5T	0 - 0 - 9 - 7
	5Z	0 - 0 - 8 - 8
No. 6: Waste, Stucco, or Plaster..........	6D	0 - 0 - 7 - 9
	6F	0 - 0 - 6½ - 9½
No. 7: Refuse or Shorts.................	7D	0 - 0 - 5 - 11
	7F	0 - 0 - 4 - 12
	7H	0 - 0 - 3 - 13
	7K	0 - 0 - 2 - 14
	7M	0 - 0 - 1 - 15
	7-20	20 lb. per cubic foot, loose measure.
	7-25	25 " " "
	7-30	30 " " "
	7-35	35 " " "
No. 8: Sand.............................	8-40	40 lb. per cubic foot, loose measure.
	8-45	45 " " "
	8-55	55 " " "
	8-75	75 " " "
No. 9: Gravel and Stone................	9	75 lb. and over, per cubic foot, loose measure.

The fibre is packed in jute bags and marked with grade letter or number, and manufacturer's name, each holding 100 or 125 pounds of asbestos. Bags of different sizes are required for each grade, as the longer the fibre the more bulky it is.

Filling the bags is usually done by contract labour, and the fibre is packed in the bags by power devices, each company using one of its own design.

From the bagging room the bags are moved on conveyer belts to store sheds, each grade being stacked separately, ready for shipment.

GENERAL MILL EQUIPMENT

When the situation will permit, rock and sand are moved throughout the mill on conveyer belts. Bucket elevators, which are more costly in upkeep and power, and a frequent cause of stoppage of milling, are installed only when absolutely necessary.

From units on an upper floor to those on a lower, material is dropped through metal-lined chutes. The fibre does not come in contact with wood construction at any point as the presence of fragments of wood lowers the value of the fibre, or may be the cause of rejection by purchasers.

Most of the mills are designed on the two unit system. Each side of the mill is equipped with machinery of equal capacity. At times, both units may be run 24 hours a day; one unit may run two shifts while the other is under repair, or one may be run two shifts, and the other one shift, allowing each unit to remain idle one shift per day for repairs and adjustments.

Sand from screens is dropped on conveyer belts running lengthwise of the mill and elevated to sand bins. Such gravel and sand as may find a market is here screened out, and the balance loaded into cars and hauled to a dump for disposal. Cars of from 12 to 15 tons capacity, hauled by small steam locomotives on narrow gauge tracks, or by storage battery locomotives, or 40-ton cars hauled by a switching engine on a standard gauge track, serve to carry the sand. At one mill the sand conveyer belt is continued to a bin at a distance from the mill, and at others sand is carried on an inclined conveyer belt from the mill to the dump.

All hoisting and milling machinery is electrically operated. In the case of old mills the steam engine has been replaced by motors, the belt drives, line shafts, and counter shafts remaining. In new mills, however, all units of equipment are driven by separate motors, direct connected whenever possible. Motors are controlled from a central station, all being started and stopped from a single board.

At each mine is maintained a machine shop, usually rather elaborately equipped with tools and machinery not only for making repairs but for building important units for the mill, quarry, and yard.

A system of water mains with hydrants near the buildings, and hose and nozzle on each floor of the mill serves for fire protection. Water pumped from pits or reservoirs is stored in tanks.

GENERAL FEATURES OF THE MILLS OF THE DISTRICT

While the older buildings are of wood frame construction, those built in the last few years are of steel and brick with concrete foundations. Ground floors are laid in concrete and other floors are of wood construction, of a slow-burning type. The upper floors are surfaced with hardwood to facilitate cleaning. Storehouses are of wood frame construction, or of steel frames, covered with corrugated asbestos board.

The older mills, with a few exceptions, are located near the quarries; that is, within 800 feet. In the location of the newer mills, however, consideration has been given to possible enlargement of the pit and ground room for auxiliary buildings. The extra cost of laying and maintaining a few hundred feet of track and additional haulage expense are not serious items. When a side-hill location was available, the different sections of the plant have been constructed on terraces to take advantage of gravity in moving material down hill or to obviate the use of heavy and expensive elevators.

In the majority of installations, however, the plant is placed on flat ground, the different sections being located sufficiently far apart that rock may be transported on conveyer belts with suitable inclination. The maximum grade for conveyer belts handling asbestos rock is 22 degrees, but few are set at a steeper angle than 15 degrees.

Plants are usually constructed in three sections, primary crushing building, dryer building, and mill proper, with a storage bin after the dryer, and a dust bin outside the mill.

Crushers are set on concrete foundations on the ground floor, on which floor the bagging is also done. Screening and grading is carried on at the second and third floors, while the upper floors are used for fans and collectors. Under such a system, men in charge of crushers work on one floor only, and similarly with screen men and fan men. Each sweeper has one floor only to keep clean. The only men whose duties require them to climb from one floor to another are the superintendents, electricians, mechanics, and repair men.

Power

The total amount of electric power used in the quarries, mills, and auxiliary plants of the asbestos industry is 20,000 h.p. practically all supplied by the Shawinigan Water and Power Company or its subsidiaries. The first electric power used in the Thetford-Black Lake district was supplied by the St. Francis Hydraulic Power Company (now owned by the Shawinigan Water and Power Company) from a power station on the St. Francis river, 6 miles from Black Lake. The distance of the Shawinigan Power plant from Thetford is 90 miles. There are sub-stations at Asbestos, Thetford Mines, Black Lake, Coleraine, Robertson, and East Broughton. Power is delivered to consumers as a three-phase, alternating current, 2,200 volts, 60 cycles. The contracting rate varies with the amount of power taken, and length of the contract, from $32 to $42 h.p. year.

The horse-power required per ton of ore treated varies in the different mills with the quantity and kind of rock treated, with the apparatus employed, and with the size of material crushed at different stages, and the number of crushers. An average figure would be from one to two horsepower per ton of rock milled, about half of which is used in crushing and conveying, and the balance in screening, grading, and suction.

The number of men actually employed in the mill decreases with each new mill built, and the tonnage milled per man is now more than four times that of the older mills. The base rate for labour is 28 cents per hour, but most of the mill men, being mechanics, are paid higher rates.

Quality of Rock Mined

There is considerable variation in the quality of the rock quarried. While one quarry may yield a high percentage of crude fibre and have little milling fibre in the rock, another may not yield any crude whatever, but contain a rock rich in milling material. The quarries at Black Lake, Thetford, Coleraine, Asbestos, and Nicolet produce both crude and mill fibre, whereas mill stocks only are produced at East Broughton.

In the Broughton district, where slip fibre predominates, practically all the rock quarried, except barren wall rock which at times must be removed, goes through the mill. At some of the quarries in the other districts as much as 80 per cent of the rock quarried is milled, although at times, by careful sorting, so that only 50 per cent, or even 40 per cent, of that broken goes to the mill, more economical production of fibre results.

According to the report of the Bureau of Mines,[1] in 1929:—

> The quantity of rock mined and hoisted during the year totalled 6,208,970 tons; of this 1,323,947 tons or 21·32 per cent were sent direct to the dump as barren rock. The millrock amounted to 4,885,023 tons, from which was extracted a quantity of 309,746 tons of fibre valued at $13,758,661. Calculating, however, on the total rock hoisted, this corresponds to a yield of 4·988 per cent or 99·76 pounds of asbestos valued at $2·215 per ton of rock mined. This is calculated at the prices prevailing during the year and takes into account the stocks on hand at the beginning and end of the year.
>
> The quantity of asbestos rock mined and hoisted during the year 1928[2] amounted to 5,159,247 tons. Of this, 4,109,823 tons were sent to the mills, the balance, 1,049,224 tons or 20·34 per cent, was sent direct to the dump as barren rock. Calculating on the total rock hoisted we find it gave 266,227 tons of fibre, which, valued at ruling prices for the year, would represent a total value of $10,957,903, or a quantity of 103·2 pounds of asbestos, valued at $2.11 per ton of rock mined.

In reading these figures, it should be noted that in the Broughton district, and at quarries where loading is done by means of the steam shovel, or the rock quarried by the glory-hole method, practically all the rock broken goes to the mill. At some Thetford quarries only a low percentage of the rock broken goes to the mill. This is compensated for, partly, by the crude recovered, and percentage of yield in the higher mill grades. On an average, the milling rock furnished by these quarries may be taken as 30 to 60 per cent of all the rock broken.

The variation in the percentage of fibre in the milling rock is as great as the percentage of milling rock in the total rock mined. In the Thetford and Black Lake quarries an extraction of from 3 to 10 per cent is effected in most of the mills. There are exceptions of higher extraction, as one mill reported a recovery of from 11 to 15 per cent over a period

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[1] Quebec Bureau of Mines Report for 1929, p. 20.
[2] Quebec Bureau of Mines Report for 1928, p. 26.

of three months. In the Broughton, or slip fibre, quarries an extraction of from 7 to 20 per cent is made. A considerable quantity of the fibre produced is somewhat shorter than that produced in the Thetford-Black Lake quarries; but as previously stated all the rock broken passes, generally, through the mill.

The production of crude is gradually becoming less in amount per ton of rock broken year by year. This is due to the fact that in the effort to supply a mill of large capacity with rock from a single pit, under existing methods of quarrying, more rock is broken from the margins of the high-grade zone. While this may yield a percentage of mill fibre, crude-bearing rock occurs only in certain parts of the fiberized zone of serpentine.

The production of crude to all rock mined is given in Table I. The figures reported, however, are based on total rock, which includes that of slip fibre quarries, and of those in which although it may occur, crude is not sorted out. At the quarries producing crudes in the Thetford-Black Lake area, a fair average over a 10-year period would be from 0·20 to 0·40 per cent of the rock mined.

In Table I are given the amounts and percentages reported of crudes and mill fibres. While these are reported under two grades of crude and four grades of milled fibre, yet in one mill are made as many as eleven different grades, and in others from three to seven different grades. The proportion of No. 1 crude to No. 2 crude varies from pit to pit and from day to day in each pit. The percentage of spinning fibre is proportioned over the total fibre production; whereas at one mill only one per cent of the output may be in this grade, at another 25 per cent of all the fibre produced graded as spinning fibre, and for a short period, as much as 32 per cent was within spinning fibre test. In the Thetford district, where all the mills are operating on similar rock, so long as quarrying is confined to the main zone, the percentage of fibre secured in the longer grades depends largely on the design of mill and care in milling. At some mills the fibre is so cut up that only 4 to 6 per cent is of spinning grade after milling, while at others, from 17 to 24 per cent is the spinning fibre yield. Percentages of the different grades produced vary from time to time with market requirements.

COST OF MILL AND PIT EQUIPMENT

The cost of a mill depends largely on its capacity, design, and location. A mill to handle a large tonnage can be built at less cost per ton of capacity, in a similar situation, than one of smaller capacity. The operating cost per ton will also be less in the larger mill. The size of the mill, however, must be in accordance with the available milling rock, as any advantage gained in handling a large quantity of material may be more than offset in milling low-grade or barren rock. A mill designed to economize on labour and thus reduce operating costs may be more expensive to construct, but more profitable in operation. A side-hill mill requires a greater expenditure for foundations than one built on flat ground. Any saving made in elevating rock by reason of using gravity chutes in a mill constructed on a series of terraces may be counterbalanced by the interest on the extra cost of construction and by losses due to difficulties of supervision and operating. Where it is necessary for workmen to climb from floor to floor frequently to adjust machinery the more inaccessible sections are apt to be neglected, with consequent delays and losses. Construction in the winter season is more expensive than in summer. Building during a time of depression can be done for less than in a period of prosperity. A mill will also cost more when it must be constructed in a short time, rather than when reasonable time is allowed. The capacity of mills varies from 30 tons to 200 tons of rock per hour, and no general figure of cost per ton of capacity can be given.

WET MILLING OF ASBESTOS

Progress on the development of a wet method of treating asbestos ores is described by Freeman.[1]

A wet method of treating asbestos ores has been worked out by Selective Treatment Company, Limited, in a test plant at Thetford Mines. This invention relates to a process of treating asbestos ore in water to extract economically the fibre from the rock under such conditions of control that the character of the fibre, its length, texture, colour, cleanliness, and other qualities may be determined as required. Furthermore, it is claimed that the fibre so produced is free from rock dust which oftentimes constitutes a substantial percentage of the product obtained by the dry process, and that the amount of fibre recovered is in excess of that recovered by the dry process.

The process involves the following:—

(1) Ball milling under conditions to free fibre from attached rocky matter without completely fiberizing the asbestos.
(2) Maintaining high dilution in the ball mill to permit the fibre to be floated out of contact with the balls.
(3) Effecting a separation of coarse rock and fibre while wet.
(4) Collecting long fibre separately from short fibre.
(5) Compacting the fibre.
(6) Drying the compacted fibre.
(7) Fiberizing the dried fibre.

The foregoing claims and summary of the process are from patent specifications. Selective Treatment Company, Limited, erected a pilot experimental plant at Thetford Mines in 1923 after three years of laboratory research on the process. The plant operated during 1924 on shipments of asbestos rock from the principal mines such as the King pit of the Asbestos Corporation, The Bennett-Martin pit, the large pit and Imperial mine of the Black Lake Asbestos and Chrome Company, Vimy Ridge pit, and the Asbestos Mines pit at East Broughton. According to the reports of the company and of independent engineers the results were very encouraging and satisfactory, indicating that the process possessed a great deal of merit, warranting its consideration by the producing companies. The pilot plant operations of the Selective Treatment Company, Limited, were discontinued after the company's engineers had, in their opinion, done sufficient work on this scale to demonstrate that the process was an improvement over the dry methods, and to warrant the erection of a commercial plant.

A number of prospects have been opened up by the company on which a commercial mill might be built, but so far none of sufficient value has been found.

[1] Freeman, C. H.: Mines Branch, Dept. of Mines, Canada, "Invest. Min. Res. & the Min. Ind. 1926", pp. 75–76.

CHAPTER IV

COST OF EXTRACTION, MARKET, PRICES, STATISTICS, AND STATUS OF THE INDUSTRY

COST OF EXTRACTION

In the asbestos industry the cost of quarrying and milling is usually a deciding factor. A number of features affect this cost:—

(1) Size, shape, and location of ore-body.
(2) Method of loading ore, hand or power.
(3) Rock, ore, and fibre sorting in quarry or mine.
(4) Method of transportation—ore to mill, and rock and sand to dump.
(5) Amount of moisture to be dried.
(6) Type of dryer.
(7) Number of crushing steps employed.
(8) Design of plant.
(9) Number of grades of fibre made.
(10) Ability of individual superintendent.
(11) Proper maintenance of equipment to ensure running time.
(12) Percentage of fibre in ore.
(13) Character of ore milled, hard or soft.
(14) Amount of overburden to be removed for quarrying, or development to be done for underground mining.

Owing to variations in these factors the total production cost will differ from quarry to quarry, hence any generalization as to the comparative cost of quarrying and treatment per ton of asbestos recovered, would be of little value, being dependent on the nature of the rock, the percentage of fibre contained therein, the kind of plant employed, and the skill of the management.

In the Broughton district, where the rock is loaded by steam shovel, and practically all of it is milled, costs are low. Based on an extraction of from 8 to 12 per cent of fibre, the actual operating cost varies from $10 to $15 per ton of fibre.

In the Thetford and Black Lake quarries, where the rock is sorted by hand and shovelled into boxes which in turn are raised by cranes or cableway hoists, the operating costs vary from $20 to $60 per ton of fibre. Lower costs may be obtained where steam or electric shovel loading or glory-hole mining methods are employed. These costs are exclusive of expenses for management, offices, insurance, marketing, amortization, etc.

MARKET AND PRICES

The principal countries to which Canadian asbestos is exported are, in order of amounts marketed, the United States, Germany, United Kingdom, Japan, France, Belgium, Italy, Netherlands, Australia, Spain, and other countries.

A larger quantity of all grades of asbestos each year is being manufactured into articles of commerce in Canada, and goods manufactured from asbestos were exported in 1930, to a value of $199,783.

The principal market for paper stocks and lower grades is the United States, a small amount being consumed in Canada. Crude fibre, spinning and shingle stock, together with a limited tonnage of paper stocks, are exported to foreign countries. The proportion retained for Canadian manufacture is becoming greater each year.

The uses and consumption of asbestos are both increasing, but the Canadian production, particularly in long fibres, is not advancing in proportion to the demand. Canadian fibre is preferred by manufacturers for practically all purposes. To hold the market, however, prices must be satisfactory, as fibres from other fields can be used for many purposes, especially if mixed with the Canadian. For use in making magnesia block insulation an African fibre has practically supplanted Canadian as a longer grade of amosite can be obtained at a lower cost than Canadian.

A shortage of long fibre in Canada in 1928 and consequent high prices has encouraged production in other fields to such an extent that the industry has become firmly established abroad, and, with growth, improvements in milling and transportation have served to place it on a competitive basis. As production increased and costs became less, producers in Rhodesia have been able to market grades which formerly it did not pay to transport to Europe. Additional competition from this source, and from Russia, has a serious effect on the Canadian industry as a restricted outlet for low-grade fibres is likely to cause a reduction in total output. Rapidly increasing uses, however, may assist in correcting this situation.

Current market prices as quoted by the Engineering and Mining Journal, April, 1931, are:—

Crude No. 1	$400 to $450
Crude No. 2	$200 to $250
Spinning fibre	$125 to $175
Magnesia and compressed sheet fibres	$100 to $125
Shingle stock	$45 to $100
Paper stock	$27·50 to $35
Cement stock	$15 to $20
Floats	$10 to $12

Prices per ton f.o.b. Quebec mines, bags included.

The shipping points for Europe during the season of navigation on the St. Lawrence river are Quebec and Montreal, but by far the greater proportion is taken via the former port. During the winter season the traffic is handled via St. John, West St. John, or Halifax. Shipments from Thetford Mines and Black Lake to Quebec are made via the Quebec Central railway, and to St. John via Quebec Central railway and Canadian Pacific or Canadian National railways. Shipments from Asbestos and Nicolet to Quebec are via Canadian National railway.

Rates quoted by the Quebec Central Railway on asbestos for export from Thetford Mines, Black Lake, Coleraine, or East Broughton are:—

To Quebec—		
Crude	20½	cents per cwt.
Fibre	17½	"
Refuse or shorts	10½	"
To Montreal—		
Crude	39½	cents per cwt.
Fibre	31½	"
Refuse or shorts	16½	"
To St. John, West St. John, and Halifax—		
Crude	44	cents per cwt.
Fibre	35	"
Refuse or shorts	25	"

These rates include all terminal charges at the ports of shipment.

Ocean freight rates for the year 1931, quoted by the Canadian Pacific Railway, from Montreal and Quebec to London, are as follows:—

Asbestos, crude	60	cents per cwt.
Asbestos, fibre, spinning	50	"
Asbestos, fibre, n.o.s.	35	"
Asbestos, refuse (not exceeding in value $25.00 per ton at the mine)	30	"

In 1910 the through rates quoted from Thetford Mines to London, via Montreal, were:—

Crude asbestos, measurement 40 cubic feet per ton, 30·71 cents per 100 pounds, of which 20 cents represented inland and 10·71 cents ocean freight.

Asbestos fibre, measurement 70 cubic feet per ton, 28·40 cents per 100 pounds, of which 15 cents represented inland and 13·40 cents ocean freight.

Asbestos fibre, measurement 90 cubic feet per ton, 31·07 cents per 100 pounds, of which 15 cents represented inland and 16·07 cents ocean freight.

STATISTICS

The following tables of production and values since the year 1880 have been computed from the statistical returns published by the Department of Mines, Ottawa; the Dominion Bureau of Statistics; Annual Reports of the Quebec Department of Mines, and from the magazine "Asbestos." The preparation of the graphs and tables is the work of J. M. Casey, statistician of the Mineral Resources Division of the Mines Branch.

Explanation of Tables and Charts

Classification

The " output " and " shipments " of Canadian asbestos shown in the following tables are recorded in two classes:

(*a*) *Crude* long fibres, usually obtained from the asbestos-bearing rock by hand-cobbing; and

(*b*) *Milled* fibres, which, as implied, consist of long and short fibres obtained by the use of machinery in so-called asbestos mills.

Each of these classes is further arbitrarily arranged into groups or grades (numbered 1, 2, and 3), essentially based upon the *per-ton average prices received* by the operators for their raw fibres.

The value of asbestos depends chiefly upon the *length* of the fibre. While other qualities, such as colour, softness, smoothness, strength, etc., are also considered, in general the longer the fibre the greater its value.

During the earlier years, when crude fibres only were produced, asbestos was marketed as " firsts," " seconds," or " thirds." The advent of mechanical separation, about 1896, introduced a variety of specially prepared milled fibres, few at first, but gradually becoming more complex owing to the lack of standardization among the producers. Of late years, the fibres are classified according to the particular purposes for which they are to be used as basic material in the fabricated asbestos industries.

The following briefly explains the procedure followed in recording production and sales in official reports on mineral production: The first step consisted in finding the average prices received by the operator for each special stock of crude and of milled fibre reported sold and shipped during the year. These sometimes exceeded a dozen for each operator, and were reduced to three main groups: No. 1, including the higher average-priced stocks (tonnages and values); No. 2, including the medium-priced stocks (tonnages and values); and No. 3, including the balance. The quantity of any stock produced (" output ") was assigned to the same grade or group which its subsequent sale price indicated. The record of the high and low average prices realized by the operator for each numbered grade of crude and of milled fibre is shown in Table II (for the earlier years) and in Table XII (for 1903 and subsequent years).

Asbestic. This is a by-product from the milling of asbestos rock, and consists of a residue carrying very low percentages of short fibre.

Annual shipments have been recorded separately, as it is not especially valuable for purposes for which fibres are used. It has been found more desirable, however, than ordinary gravel as a roofing material, for which it is principally used.

Imports and Exports

Data on these features have been taken from " Trade of Canada " annual reports, and are for fiscal years ending March 31. Formerly, the fiscal year ended on June 30. Data given for the year 1907 cover a nine-month period only, viz., July 1, 1906, to March 31, 1907.

Regarding the *classification* used in these reports, it should be noted that these are as determined by Customs officials and are not comparable with the arbitrary grades used in the tables of *output* and *shipments*.

Exports of asbestos have been separately recorded in these reports since July 1, 1887, and the totals shown do not represent the total asbestos exported since the inception of mining operations.

The *imports* are shown as from July 1, 1885, and refer to manufactures of asbestos only. Imports of asbestos "packing" have been separately recorded since April, 1921.

LOCALITIES WORKED

Up to the present time, mining operations have been confined to the Eastern Townships region, with occasional shipments formerly reported from Argenteuil county, both in the province of Quebec. Some development work was also carried on during 1916 and 1917 in the Porcupine area, Ontario, resulting in a small shipment of crude fibre.

TABLE VII

Annual *Imports* of Asbestos Manufactures into Canada—By Countries—Fiscal Years

(Asbestos in any form other than Crude, and all Manufactures of)

Values: Fair market values in countries whence exported and at time of such export to Canada

Fiscal years	United States	United Kingdom	Germany	Belgium	France	Austria-Hungary	Nether-lands	Portugal (Azores)	Japan	Other countries b	Total imports
	$	$	$	$	$	$	$	$	$	$	$
1886	6,283	548	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	6,831
1887	7,537	12	287	"	"	"	"	"	"	"	7,836
1888	6,919	1,343	531	"	"	"	37	"	"	"	8,793
1889	7,923	975	1,008	"	"	"	Nil	"	"	"	9,943
1890	10,616	1,615	1,019	"	"	"	"	"	"	"	13,250
1891	12,592	158	360	"	"	"	188	"	"	"	13,298
1892	12,583	441	1,066	"	"	"	Nil	"	"	"	14,090
1893	16,584	807	1,790	"	"	"	"	"	"	"	19,181
1894	18,743	423	855	"	"	"	"	"	"	"	20,021
1895	24,355	375	1,364	"	"	"	"	"	"	"	26,904
1896	20,896	2,287	717	"	"	"	"	"	"	"	23,900
1897	18,068	707	257	"	"	"	"	"	"	"	19,032
1898	23,527	2,768	94	"	"	"	"	"	"	"	26,389
1899	30,813	1,275	379	"	140	"	"	"	"	"	32,607
1900	42,330	848	277	"	Nil	"	"	"	"	"	43,455
1901	48,080	1,908	841	"	"	"	"	"	"	"	50,829
1902	48,395	2,588	1,481	"	"	"	"	"	"	"	52,464
Total period	356,244	19,078	12,326	Nil	140	Nil	225	Nil	Nil	Nil	388,013
1903	71,731	2,081	1,653	Nil	Nil	Nil	Nil	Nil	Nil	Nil	75,465
1904	77,909	3,526	2,392	"	"	"	"	"	"	"	83,827
1905	109,824	6,190	822	"	"	"	"	"	"	"	116,836
1906	122,736	7,946	6,250	"	231	821	"	"	"	"	137,974
1907	113,158	10,190	3,168	"	672	321	"	"	"	"	127,509
1908	166,156	21,601	1,509	"	Nil	1,600	"	"	"	54	190,980
1909	160,211	17,783	483	"	"	2,121	"	"	"	Nil	180,598
1910	173,622	19,183	2,592	965	45	2,303	"	"	"	"	198,710
1911	211,621	33,313	4,143	692	2,488	1,997	"	"	"	77	254,331
1912	297,599	42,862	4,065	2,247	2,136	379	250	"	"	"	349,538
1913	443,495	43,907	3,480	3,456	340	1,960	522	"	"	"	497,160
Total period	1,948,052	208,582	30,557	7,360	5,912	11,562	772	Nil	Nil	131	2,212,928

1914...........................	415,338	49,805	5,599	2,674	537	546	Nil	Nil	Nil	Nil	474,499
1915...........................	188,178	33,505	3,064	1,734	Nil	Nil	33	1	"	"	226,515
1916...........................	150,931	40,921	Nil	Nil	34	"	Nil	Nil	"	"	191,886
1917...........................	316,253	77,910	202	"	Nil	"	"	174	"	1	394,540
1918...........................	463,230	64,233	520	"	"	"	"	71	"	Nil	528,054
1919...........................	600,108	49,522	Nil	"	"	"	"	52	"	12	649,694
1920...........................	658,570	75,566	"	"	"	"	"	159	7	Nil	734,302
1921...........................	814,824	162,151	"	"	45	"	"	Nil	140	"	977,160
Total period............	3,607,432	553,613	9,385	4,408	616	546	33	457	147	13	4,176,650
1922...........................	473,572	99,981	Nil	1,949	262	Nil	4	200	110	997	577,075
1923...........................	447,108	94,162	3	71	1,673	"	22	2	Nil	1	543,132
1924...........................	704,117	72,663	543	42	3,385	"	206	206	"	Nil	781,162
1925...........................	406,623	55,938	691	1,104	Nil	"	801	13	"	230	465,400
1926...........................	372,678	80,816	2,054	10,031	1,027	389	1,344	21	"	2	468,362
1927...........................	511,708	96,519	2,147	954	3,340	660	815	84	24	6,542	622,793
1928...........................	531,783	121,028	3,866	8,319	3,681	1,084	Nil	84	Nil	1,562	671,407
1929...........................	784,119	130,447	9,156	1,864	2,079	2,174	"	21	"	37	929,897
1930...........................	804,287	140,114	4,090	330	2,227	1,516	"	Nil	"	86	952,650
Total period............	5,035,995	891,668	22,550	24,664	17,764	5,823	3,192	631	134	9,457	6,011,878
*Grand total............	10,947,723	1,672,941	74,818	36,432	24,432	17,931	4,222	1,088	281	*b* 9,601	12,789,469

a Figures from 1922 include values of asbestos "packing", imports of which are given separately in the following table. *b* Italy; Switzerland; Sweden. * Total from July 1, 1885, to March 31, 1930.

TABLE VIII

Imports of Asbestos *Packing* into Canada, by Country of Origin

(From "*Trade of Canada*" annual reports—not separately classified prior to April 1, 1921)

Dutiable at the following rates: British preferential, 15 p.c.; Intermediate, 22½ p.c.; General, 25 p.c.

Twelve months ending March 31	United Kingdom			United States			Austria			Other Countries			Total packing			Per cent of yearly imports	Total imports
	Pounds	Value	Average per lb.	Pounds	Value	Average per lb.	Pounds	Value	Average per lb.	Pounds	Value	Average per lb.	Pounds	Value	Average per lb.		Value
		$	cts.		$	cts.		$	cts.		$	cts.		$	cts.		$
1922	61,323	37,889	62	77,237	46,611	60	3,997	1,363	34	s 2,046	997	49	140,606	85,597	61	15	577,075
1923	30,254	18,731	62	107,261	50,436	47	10,200	3,385	33	t 5	1	20	141,517	70,531	50	13	543,132
1924	41,376	19,942	48	105,145	51,332	49	....	....	....	n 313	205	65	157,034	74.854	48	10	781,162
1925	37,890	19,657	52	226,250	92,600	41	....	....	....	....	....	....	264,140	112,257	43	24	465,400
1926	49,161	24,787	50	142,304	66,733	47	....	....	....	....	....	....	191,465	91,520	48	20	468,362
1927	40,806	23,139	57	155,280	73,527	47	....	....	....	s 150	80	53	196,236	96,746	49	16	622,793
1928	82,861	44,106	53	142,901	67,019	47	22	32	145	s 270	534	189	226,054	111,691	49	17	671,407
1929	84,551	43,525	51	129,142	69,224	54	1,150	354	31	n 10	29	290	214,853	113,132	53	12	929,897
1930	62,700	31,543	50	137,362	68,569	49	0	0	....	0	0	....	200,062	100,112	50	11	952,650

s Switzerland. *t* Sweden. *n* Netherlands.

TABLE IX

Domestic Exports of Asbestos Products to Canada from United States

(Calendar Years)

(From annual reports of "*Foreign Commerce and Navigation of the U.S.*", Washington, D.C.)

—	Unmanufactured		Paper, millboard and rollboard		Pipe covering and cement		Textiles, yarn and packing		Brake and clutch lining		Other manufactures except roofing		Asbestos roofing		Total domestic exports	Exports of foreign asbestos to Canada	
	Short tons*	Value	Pounds	Value	Pounds	Value	Pounds	Value	Pounds	Value	Pounds	Value	Squares	Value	Value	Pounds	Value
		$		$		$		$				$		$	$		$
1922																	
Maritimes	......	......	10,386	617	84,424	6,648	1,862	1,329			14,966	4,511	10,006	490	13,595	....	.....
Quebec and Ontario	9	9268	1,599,415	70,343	706,996	52,809	139,112	71,235	Not separately		601,096	89,366	2,063,656	45,395	343,011	c 10,000	1,000
Prairie Provinces	1	18	40,757	2,345	236,599	17,324	8,771	5,764			81,747	13,415	163,756	3,509	42,375	....	.....
British Columbia and Yukon	1	48	91,111	5,376	122,748	11,254	28,330	12,576			90,091	12,574	212,620	5,365	47,193	....	.....
Total	11	334	1,741,669	78,681	1,150,767	88,035	178,075	90,904	classified prior		787,900	119,866	b2,450,038	54,759	446,174	10,000	1,000
1923																	
Maritimes	......	......	112,505	4,958	66,695	3,461	4,135	3,177			4,299	1,486	....	....	13,082	....	.....
Quebec and Ontario	59	1,219	2,533,994	115,138	1,801,616	139,769	238,393	127,037	to 1925		688,232	120,644	9,153	30,062	533,869	301	183
Prairie Provinces	1	51	170,127	6,828	963,169	78,850	8,821	5,589			353,436	29,546	521	2,376	123,240	285	39
British Columbia and Yukon	35	410	74,936	3,777	303,758	22,055	35,334	13,430			58,507	25,572	1,694	4,438	69,682	....	.....
Total	95	1,680	2,891,562	130,701	3,135,238	244,135	286,683	149,233			1,104,474	177,248	11,368	36,876	739,873	586	222
1924	35	1,919	1,494,696	77,401	1,276,637	94,017	286,408	145,461	....	....	916,429	158,388	1,336	9,207	486,393	138	56
1925	24	726	969,074	52,097	649,413	39,689	417,431	170,713	96,122	61,665	490,463	85,292	4,338	26,264	436,446	c 6,000	547
1926	66	1,552	676,586	47,568	767,594	44,115	525,772	217,415	181,796	117,130	854,550	98,799	2,072	18,000	544,579	....	.....
1927	....	11	784,021	38,399	976,692	57,041	536,938	234,700	197,577	114,461	1,126,577	120,813	3,572	42,092	607,517	58,547	1,466
1928	1	83	712,562	39,465	887,171	55,015	678,740	298,913	a1,420,842	202,393	1,270,848	181,912	4,091	39,688	817,469	Nil	Nil
1929	295	49,078	779,658	40,885	1,290,548	73,476	850,103	344,407	a1,118,831	183,954	2,515,844	271,471	11,853	117,023	1,080,294	"	"

* Gross tons in original, converted to short tons. *a* Lineal feet. *b* During 1922, "square feet". *c* Unmanufactured.

TABLE X

Imports of Unmanufactured and Manufactured Asbestos entered for Consumption in the United States

(Calendar Years)

(Annual Reports of "*Foreign Commerce and Navigation of the U.S.*", Washington, D.C.)

Asbestos imported	1925			1926			1927			1928			1929		
	Short tons*	Value	Average per ton	Short tons*	Value	Average per ton	Short tons*	Value	Average per ton	Short tons*	Value	Average per ton	Short tons*	Value	Average per ton
		$	$		$	$		$	$		$	$		$	$
†UNMANUFACTURED—															
Crude	22,428	2,475,966	110	14,886	2,465,890	165	12,497	2,724,038	218	13,890	3,050,566	220	16,976	4,334,060	255
Mill fibre	92,539	3,264,096	35	94,022	2,659,379	39	79,524	3,511,175	44	89,863	4,096,444	46	95,384	4,575,579	48
*a*Refuse sand	115,553	1,394,240	12	148,713	2,017,236	14	131,672	1,915,127	15	126,841	1,870,881	15	150,066	2,243,378	15
Total	230,520	7,134,302	31	257,621	8,142,505	32	223,693	8,150,340	36	230,594	9,017,891	39	262,426	11,153,017	43
From Canada	225,938	6,355,339	28	252,488	7,317,501	29	215,780	6,679,642	31	221,339	7,034,974	32	252,066	8,363,541	33
Per cent	98·0	89·1	......	98·0	89·9	......	96·5	82·0	......	96·0	78·1	......	96·0	75·0	......
‡MANUFACTURES OF—	Pounds			Pounds			Pounds			Pounds			Pounds		
Total imports	35,387,108	752,302	43	61,867,129	1,170,276	38	135,441,302	2,176,827	32	56,370,824	1,086,368	39	57,214,476	977,582	34
From Canada	999,000	30,010	61	511,207	21,191	83	450,156	16,976	75	407,744	25,261	124	315,863	16,353	104
Per cent	2·8	4·0	......	0·8	1·8	......	0·3	0·8	......	0·7	2·3	......	0·6	2·0	......
From Belgium and Netherlands	32,743,604	536,084	33	54,682,243	791,959	29	110,509,964	1,512,629	27	44,188,489	712,024	......	50,155,811	672,339	27
Per cent	92·5	71·3	......	88·3	67·7	......	82·6	69·5	......	78·3	65·5	......	88·0	69·0	......

* Gross tons in original, converted to short tons. † Enters duty free. ‡ Wholly or chiefly of asbestos, dutiable at following rates: yarn, 30%; woven fabrics (including brake and clutch linings and facings), 30%; packing, fabric (including expanding, block and cloth packing), 30%; packing, not fabric (including fibrs and sheet jointings and sheet joints), 25%; papers and millboards, 25%; shingles, slate, wood or lumber of asbestos (including cement, flat and corrugated sheets, corrugated ridges, ridge rolls, ridge tiles, and all material made of asbestos cement), 25%. The imports of these last in 1925 were 33,995,937 pounds valued at $582,676; in 1926, 61,305,807 pounds, valued at $892,269; and in 1928, 56,220,164 pounds valued at $887,879.

a Containing not over 15% of foreign matter.

TABLE XI

Imports of Unmanufactured Asbestos into United States, showing Country from which Imported

(Calendar Years)

(Annual Reports of "*Foreign Commerce and Navigation of the U.S.*," Washington, D.C.)

Received from	1925			1926			1927			1928			1929		
	Short tons*	Value	Average per ton	Short tons*	Value	Average per ton	Short tons*	Value	Average per ton	Short tons*	Value	Average per ton	Short tons*	Value	Average per ton
		$	$		$	$		$	$		$	$		$	$
*a*Africa, East and West (Br.)	185	12,462	67	10	2,106	211	......	......	......	......	......	......	......	......	......
*c*Africa, Union of South	421	37,888	90	2,405	317,816	132	3,479	497,430	143	3,220	518,975	161	3,680	585,240	159
*a*Africa, Portuguese	3,179	586,153	183	......	......	......	75	15,390	215	171	39,082	229	......	......	......
Australia	......	......	......	......	......	......	......	......	......	94	36,911	393	......	......	......
Austria	......	......	......	......	......	......	26	777	30	28	809	29	......	......	......
Belgium	......	......	......	......	......	......	205	33,581	164	748	99,007	132	348	55,125	158
CANADA	225,938	6,355,339	28	252,488	7,317,501	29	215,780	6,679,642	31	221,339	7,034,974	32	252,066	8,363,541	33
Colombia	......	......	......	36	472	13	......	......	......	......	......	......	......	......	......
Cyprus and Malta	......	......	......	......	......	......	......	......	......	1	84	84	......	......	......
France	......	......	......	1·1	24	21	......	......	......	109	15,885	146	......	......	......
*b*Germany	190	35,631	187	349	65,424	187	1,782	430,479	242	2,339	590,511	252	1,174	361,446	308
India	1·1	25	22	......	......	......	3	88	29	......	......	......	......	......	......
Italy	......	88	......	1·1	372	332	6	1,209	216	14	7,456	533	156	32,424	208
Japan	......	3	......	......	......	......	......	......	......	......	......	......	......	......	......
*a*Mozambique	......	......	......	1,754	328,849	187	2,051	441,803	215	2,147	594,979	277	4,524	1,578,514	338
Netherlands	......	......	......	28	1,050	39	......	......	......	91	18,038	198	......	......	......
Soviet Russia	......	......	......	......	......	......	......	......	......	......	......	......	252	111,290	442
*a*United Kingdom	606	106,713	176	549	108,891	198	286	49,941	175	293	61,180	209	226	65,437	290
Total	230,520	7,134,302	31	257,621	8,142,505	32	223,693	8,150,340	36	230,594	9,017,891	39	262,426	11,153,017	43

* Gross tons in original, converted to short tons. Probably originating in: *a* Rhodesia; *b* Russia; *c* May include some from Rhodesia.

TABLE XII

Price Range of Canadian Asbestos Fibres and Average Prices Received by Producers

(F.O.B. mines, Quebec. Dollars per short ton)

Average prices received by operators from 1879 to 1902 are shown in Table II.

Calendar Year	Crude No. 1 Range Max.	Crude No. 1 Range Min.	Crude No. 1 Average received	Crude No. 2 Range Max.	Crude No. 2 Range Min.	Crude No. 2 Average received	Crude No. 3 Range Max.	Crude No. 3 Range Min.	Crude No. 3 Average received	Mill Fibre No. 1 Range Max.	Mill Fibre No. 1 Range Min.	Mill Fibre No. 1 Average received	Mill Fibre No. 2 Range Max.	Mill Fibre No. 2 Range Min.	Mill Fibre No. 2 Average received	Mill Fibre No. 3 Range Max.	Mill Fibre No. 3 Range Min.	Mill Fibre No. 3 Average received	'Asbestic' Average received
	$	$	$	$	$	$	$	$	$	$	$	$	$	$	$	$	$	$	$
1903	200	150	157	110	45	96	......	......	......	60	35	38	30	15	20	14	10	12	1.31
1904	175	150	156	125	80	101	......	......	......	60	29	30	25	20	21	17	6	15	1.00
1905	200	150	174	130	90	99	......	......	......	80	50	46	30	18	21	18	6	14	0·96
1906	250	175	227	150	110	132	......	......	......	80	40	49	25	18	22	14	8	16	1.11
1907	300	225	264	200	100	157	......	......	......	163	57	82	50	18	28	15	8	10	0.72
1908	350	267	301	225	75	65	......	......	......	100	60	81	50	20	29	13	5	9	0.74
1909	300	200	270	175	100	152	......	......	......	100	45	53	40	25	25	10	6	9	0·72
1910	300	200	260	165	55	100	......	......	......	91	47	55	30	16½	23	15	6	8	0.71
1911	300	200	263	165	55	113	......	......	......	100	30	50	30	15	21	† 15	......	9	0.81
1912	300	200	263	200	25	102	......	......	......	100	30	44	30	15	20	† 15	......	10	0.80
1913	302	265	287	200	25	120	......	......	......	101	39	47	31	17	20	10	5	9	0.79
1914	330	275	301	191	25	132	......	......	......	101	33	48	28	15	20	10½	4	9	0.83
1915	352	200	276	196	25	122	......	......	......	103	31	53	25	18	20	13	5	9	0.85
1916	1,012	400	468	350	200	270	† 200	......	106	175	70	85	60	40	44	30	7	16	1.40
1917	1,200	550	753	450	250	393	200	75	180	270	90	89	85	45	52	40	8	24	2.59
1918	1,330	650	919	500	300	458	450	100	341	360	120	176	110	60	83	55	6	31	2.02
1919	1,300	900	1,255	850	500	744	450	200	291	500	150	224	120	60	76	55	6	35	2·93
1920	1,510	1,200	1,457	1,100	675	992	500	80	266	530	200	325	150	90	112	70	8	37	2.75

Calendar Year	Crude No. 1 Range	Crude No. 1 Average received	Crude No. 2 Range	Crude No. 2 Average received	Crude No. 3 Range	Crude No. 3 Average received	Spinning stock Range	Spinning stock Average received	Shingle stock Range	Shingle stock Average received	Paper stock and millboard, average received	Short fibres, average received	'Asbestic' Average received
1921	2,065*	1,230	1,351*	594	Not quoted in E. & M. J.	421	610*	256	125*	94	47	10	0.17
1922	867*	641	489*	331		196	252*	197	98*	55	32	8	0.96
1923	462*	456	262*	245		261	170*	124	67*	48	33	8	1.18
1924	349*	412	197*	200		170	114*	109	56*	47	32	9	0.60
1925	418*	365	259*	206		141	151*	106	60*	51	31	13	0.64
1926	523*	370	301*	230		207	190*	124	71*	59	34	13	0.65
1927	548*	424	346*	250		227	208*	129	83*	65	38	15	0.61
1928	623*	535	406*	297		128	209*	149	87*	74	39	16	0.59
1929	647*	558	454*	332		181	246*	177	85*	75	39	16	0.38

*Average prices as quoted by *Engineering & Mining Journal*, New York. †And under.

TABLE XIII

Average Prices quoted for Canadian Asbestos, per *Engineering & Mining Journal*, New York

(F.O.B. mines, Quebec. Dollars per short ton, including tax and bags)

Calendar Year	Crude No. 1			Crude No. 2			Magnesia and compressed short fibres			Spinning			Shingle stock			Paper stock			Short fibres, fillers, and sand			Cement stock			Rhodesian* asbestos** quotations (c.i.f. N.Y.)	
	High	Low	Aver-age	High	Low	Aver-age	High	Low	Aver-age	High	Low	Aver-age	High	Low	Aver-age	High	Low	Aver-age	High	Low	Aver-age	High	Low	Aver-age	Crude No. 1	Crude No. 2
	$	$	$	$	$	$	$	$	$	$	$	$	$	$	$	$	$	$	$	$	$	$	$	$	$	$
1921	3,500	1,000	2,065	2,000	600	1,351	500	150	347	1,000	225	610	150	90	125	75	45	65	15	7	11½	30	15	24	Not quoted	
1922	1,500	600	867	850	300	439	250	100	144	500	165	252	150	60	98	65	27½	40	15	6	9	25	12½	17	567	325
1923	550	325	462	350	225	262	175	60	118	250	100	170	90	50	67	45	30	34	20	6	10	25	15	20	362½	233½
1924	450	300	349	250	175	197	100	50	74	125	90	114	70	45	56	40	25	36	12	6	10	25	15	21	333½	206½
1925	475	325	......	300	175	......	125	65	95	200	90	159	75	45	59	45	35	39	30	8	11	25	8	18	290	220
1926	525	475	523	325	275	301	150	125	136	200	175	190	80	75	71	45	40	43	17½	10	15	25	25	25	324	250
1927	650	525	548	500	300	346	200	125	150	225	190	208	125	70	83	50	40	44	20	10	14	25	25	25	429	323
1928	650	600	633	500	375	406	175	160	167½	225	190	209	125	55	87	50	45	47½	20	10	15	25	25	25	450	350
1929	750	550	647	*a*575	375	454	225	160	196	*a*275	190	246	115	55	85	50	45	47½	20	10	15	25	25	25	450	350

*Prices quoted for *Rhodesian* fibres in October, 1922, were: Crude No. 1, $1,000–$700; Cruds No. 2, $500–$350; Spinning, $275–$200; Paper, $40–$35; Cement, $17½–$15.

**Rhodesian* fibres of inferior quality were also quoted during first quarter of 1923 at $200, all prices c.i.f. New York. *a* Marked shortage of Canadian Crude No. 2 and Spinning stock in Europe.

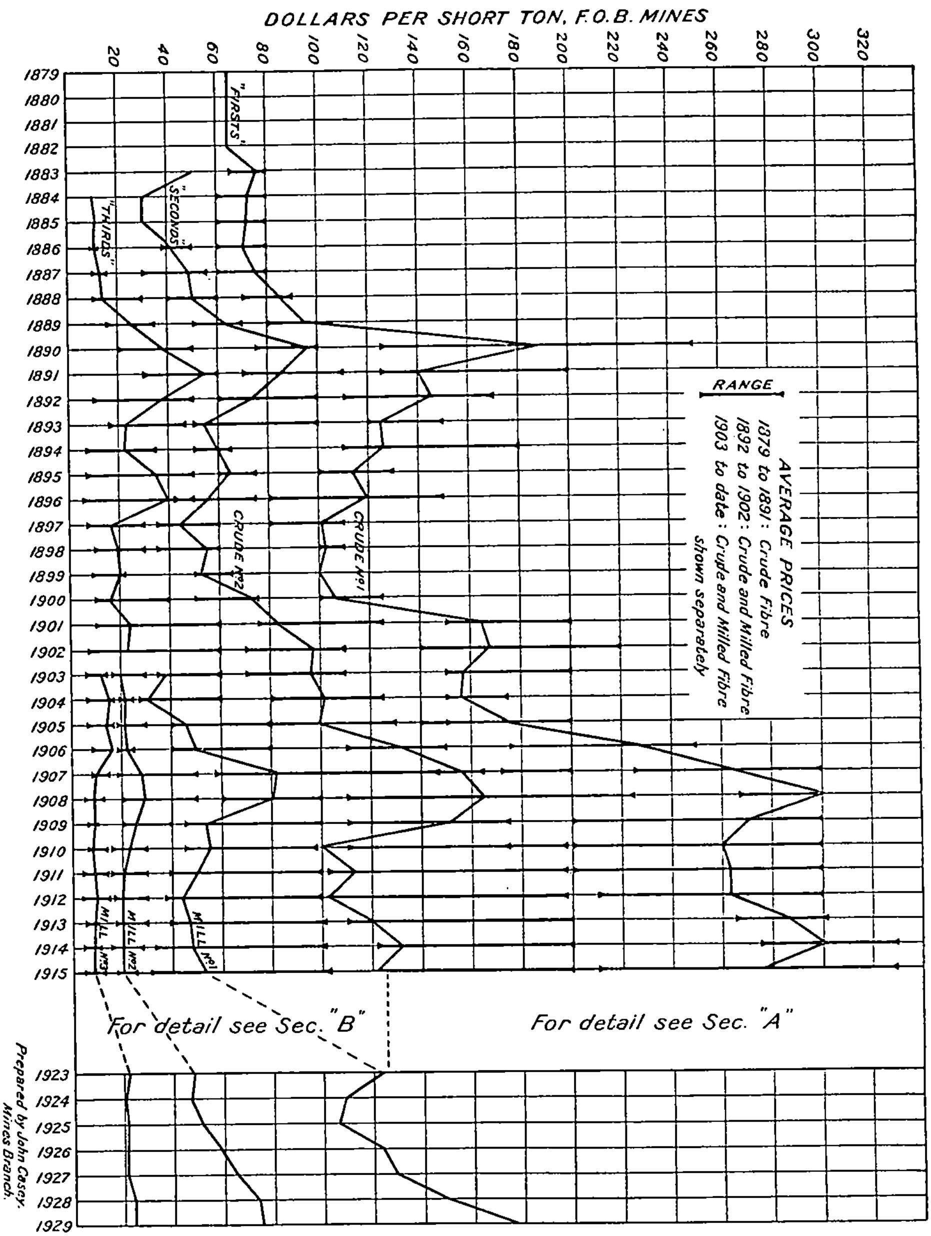


Chart II. Average prices received for Canadian asbestos fibres, f.o.b. mines, 1879-1929.

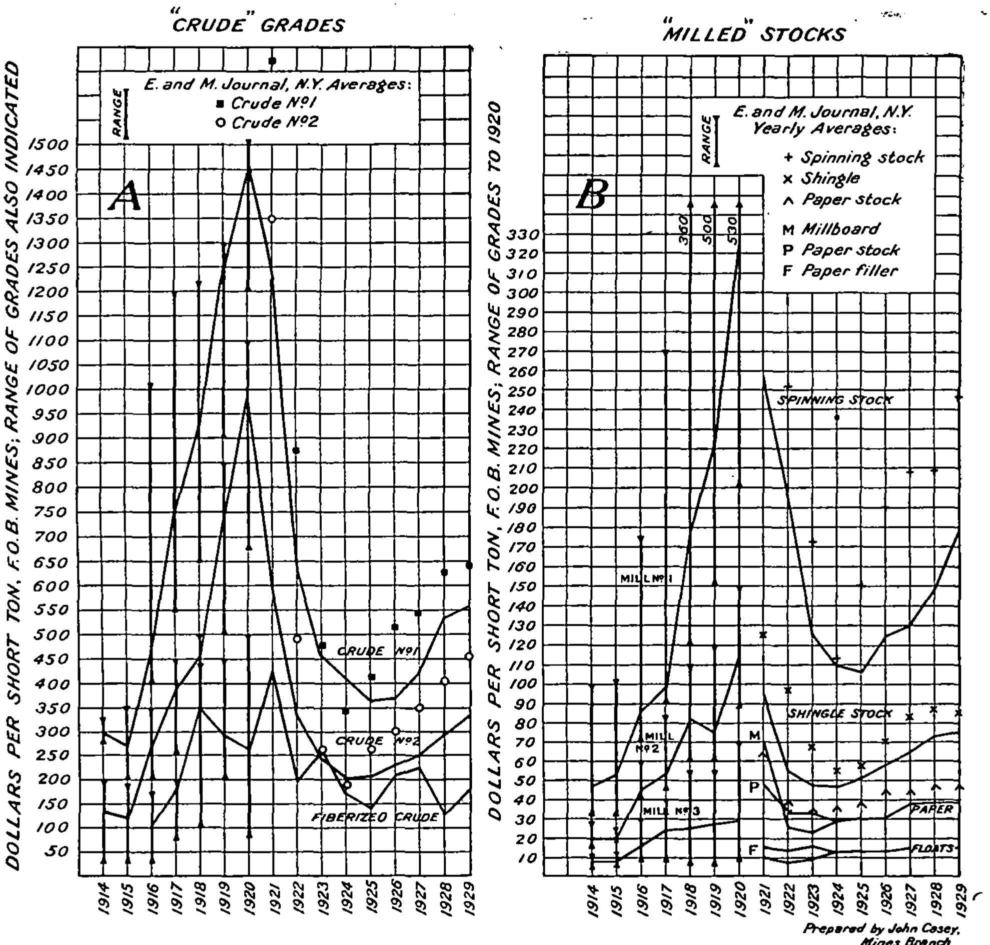


Chart III. Average prices for Canadian crude and milled fibres, f.o.b. mines, 1914-1929.

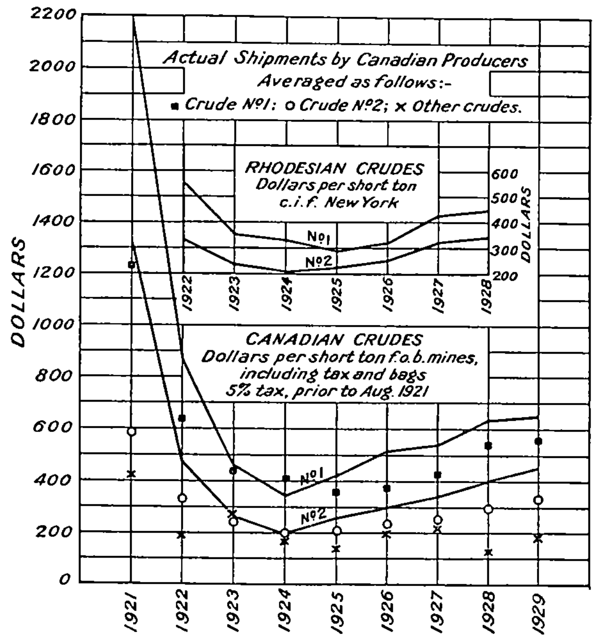


Chart IV. Average prices of crude asbestos.
(Quoted by Engineering and Mining Journal, New York)

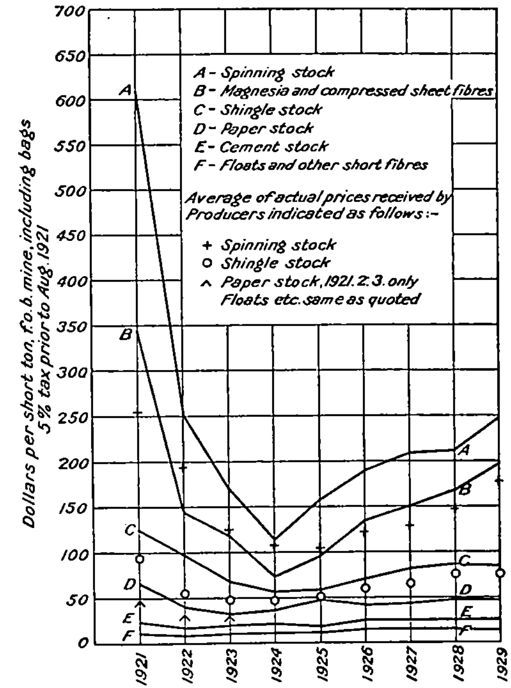


Chart V. Average prices of Canadian fibres.
(Quoted by Engineering and Mining Journal, New York.)

TABLE XIV

Summary Statistics of the Canadian Fabricated Asbestos Industry

(*Dominion Bureau of Statistics, Ottawa*)

Calendar year	Number of plants	Capital employed	Number of employees	Salaries and wages	Cost of materials	Selling value of products	Value added by manufacturing
		$		$	$	$	$
1891........	3	28,000	23	7,850	14,100	32,500	18,400
1901*.......	....	....	....	....	....	....	....
1911........	9	867,750	172	105,267	191,625	468,614	356,989
1916........	9	2,434,116	....	342,303	379,544	1,410,661	1,031,117
1919........	5	878,398	114	158,957	214,725	546,870	332,145
1920........	9	1,180,101	201	248,214	432,350	940,072	507,722
1921........	11	1,351,278	132	273,522	385,810	804,603	418,785
1922........	11	1,610,700	156	189,059	271,749	615,160	343,411
1923........	9	1,486,589	145	176,986	260,281	583,013	322,732
1924........	9	1,468,728	120	169,979	267,201	589,339	322,138
1925........	12	2,624,200	256	282,382	783,063	1,344,097	561,034
1926........	14	2,773,433	270	321,965	750,907	1,530,094	779,187
1927........	13	2,860,945	300	358,959	797,975	1,663,300	865,325
1928........	14	3,064,164	345	421,448	925,661	2,050,432	1,124,771
1929........	12	2,949,712	351	359,433	1,348,460	2,286,638	938,178

* Data for 1901 not available.

TABLE XV

Production of Fabricated Asbestos Products

(Compiled from data given in *Dominion Bureau of Statistics* publications)

Calendar year	Brake lining	Pipe and boiler covering	Packings	Building materials, shingles, millboard, and building lumber	Other products	Total production value
	$	$	$	$	$	$
1920.................		348,762		591,310	....	940,072
1921.................		275,780		528,823	....	804,603
1922.................		298,868		228,377	87,915	615,160
1923.................		367,037		215,976	....	583,013
1924.................	186,295	83,373	128,037	97,364	94,270	589,339
1925.................	272,217	179,717	187,916	567,379	136,768	1,344,097
1926.................	279,783	232,963	184,515	832,833		1,530,094
1927.................	326,072	277,339	204,376	855,513		1,663,300
1928.................	439,431	376,399	218,904	1,015,698		2,050,432
1929.................	555,739	406,395	234,595	a1,089,909		2,286,638

a Includes paper and corrugated sheathing, blackboards, tile, lumber, millboard, wallboard, etc.

TABLE XVI

Exports of Manufactures of Asbestos from Canada

(From "*Trade of Canada*" annual reports—Exports not separately classified prior to April 1913)

Fiscal years ending March 31	To British Empire	To United States	To France	Other countries	Total
	$	$	$	$	$
1914	52,535	14,754	450	30,525	98,274
1915	60,350	13,254	34	4,691	78,329
1916	111,139	4,226	Nil	2,922	118,287
1917	1,768	4,502	9	579	6,858
1918	40,621	13,288	Nil	2,098	56,007
1919	35,735	5,402	Nil	4,009	45,146
1920	12,715	10,119	206,497	2,985	232,316
1921	38,006	72,856	190,386	20,446	321,694
1922	7,043	93,823	45,513	7,451	153,820
1923	17,649	61,097	550	2,211	81,507
1924	9,517	52,645	2,081	219	64,462
1925	12,158	32,922	32	2,237	47,349
1926	20,279	32,102	205	3,918	56,504
1927	17,526	19,702	27	22,176	59,431
1928	15,279	17,241	143	15,499	48,162
1929	32,434	26,015	55	17,539	76,043
1930	88,465	16,317	Nil	33,051	137,833

TABLE XVII

Imports of Asbestos, other than Crude, by Countries—*See* TABLE VIII

TABLE XVIII

Estimated Consumption of Fabricated Asbestos

(Calendar Years)

Calendar year	Production	Imports (including packing)	Exports (including roofing)	Consumption
	$	$	$	$
1913	Not available	520,082	a73,446	....
1914	Not available	282,053	94,538	....
1915	Not available	168,894	125,003	....
1916	1,410,661	334,670	4,741	1,740,590
1917	Not available	537,431	55,666	....
1918	Not available	604,703	40,763	....
1919	546,870	656,037	232,501	970,406
1920	940,072	1,047,031	196,057	1,791,036
1921	804,603	634,587	261,274	1,177,916
1922	615,160	476,408	95,826	995,742
1923	583,013	775,328	72,498	1,285,843
1924	589,339	539,718	44,132	1,084,925
1925	1,344,097	448,769	55,572	1,737,294
1926	1,530,094	565,635	43,011	2,052,718
1927	1,663,300	671,882	66,334	2,268,848
1928	2,050,432	835,887	65,895	2,820,424
1929	2,286,638	1,013,436	113,952	3,186,122

a Not separately classified prior to April 1, 1913.

TABLE XIX

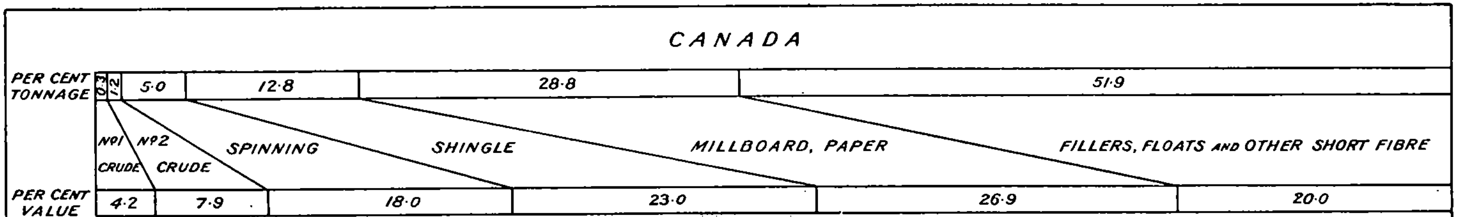
Status of Asbestos in Canadian Mineral Production

Percentages contributed annually by principal Canadian minerals.

Peak production year of each underlined—value basis.

Calendar year	Coal	Gold	Nickel	Copper	Silver	Cement	Lead	**Asbestos**	Natural Gas	Zinc	Total of these minerals	Total mineral production
	%	%	%	%	%	%	%	%	%	%	%	*a*
1910	28·9	9·6	10·5	6·6	16·5	6·0	1·1	**2·4**	1·3	0·1	83·0	$ 107
1911	25·6	9·5	9·9	6·7	16·8	7·4	0·8	**2·8**	1·9	0·1	81·5	103
1912	26·7	9·4	10·0	9·4	14·4	6·7	1·2	**2·3**	1·8	0·2	82·1	135
1913	25·6	11·4	10·2	8·1	13·1	7·6	1·2	**2·6**	2·3	0·1	82·2	146
1914	26·0	12·4	10·6	8·1	12·1	7·1	1·3	**2·2**	2·7	0·2	82·7	129
1915	23·4	13·6	15·0	12·7	9·7	5·1	1·9	**2·6**	2·7	0·4	87·3	137
1916	21·9	10·9	16·4	18·0	9·4	3·7	2·0	**2·9**	2·2	1·7	89·1	177
1917	22·8	8·1	17·8	15·7	9·5	4·1	1·9	**3·8**	2·7	1·4	87·8	190
1918	26·1	6·9	17·5	13·8	9·8	3·4	2·3	**4·2**	2·1	1·4	87·5	211
1919	30·8	9·0	10·1	7·9	10·1	5·6	1·7	**6·2**	2·4	1·3	85·1	177
1920	35·4	6·9	10·8	6·3	5·9	6·5	1·4	**6·5**	1·9	1·3	82·8	228
1921	42·1	11·1	3·9	3·5	4·9	8·3	2·2	**2·8**	2·7	1·4	82·9	172
1922	35·6	14·1	3·3	3·1	6·8	8·4	3·2	**3·1**	3·2	1·7	82·5	184
1923	33·7	11·9	8·6	5·9	5·6	7·0	2·7	**3·5**	2·6	1·9	84·4	214
1924	25·6	15·1	9·3	6·5	6·3	6·4	6·8	**3·2**	2·7	3·0	84·9	210
1925	21·8	15·9	7·1	6·9	6·2	6·2	10·2	**4·0**	3·0	3·7	85·0	227
1926	24·9	15·1	6·0	7·3	5·8	5·4	8·0	**4·2**	3·2	4·6	84·5	240
1927	25·0	15·5	6·2	7·0	5·2	4·8	6·7	**4·3**	3·3	4·1	83·1	247
1928	23·2	14·2	8·1	10·4	4·6	6·1	5·6	**4·1**	3·1	3·7	83·1	275
1929	20·5	13·0	8·8	14·1	4·0	6·3	5·4	**4·3**	3·2	3·4	83·0	311
Percentage for period	27·1	12·0	9·7	9·1	7·8	6·2	3·9	**3·8**	2·7	2·2	84·3	......
*a*Value	1,033	457	371	345	299	230	150	**144**	101	82	3,222	3,820

a Millions of dollars.



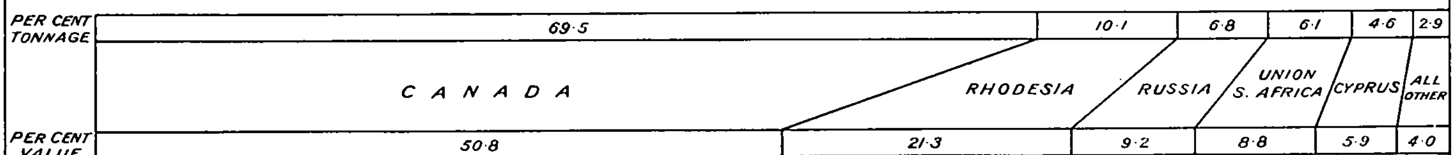
CANADIAN ASBESTOS SHIPMENTS 1928

	Short Tons	% of Total	Value	% of Total	Average per Ton
Crude Nº1	893	0·3	$ 477,640	4·2	$535
Crude Nº2	3,273	1·2	884,042	7·9	270
Spinning	13,570	5·0	2,017,884	18·0	149
Shingle	34,961	12·8	2,580,160	23·0	74
Millboard, paper	78,443	28·8	3,038,227	26·9	39
Fillers, floats and other short fibre	141,893	51·9	2,240,407	20·0	16
	273,033	100·0	11,238,360	100·0	41

ASBESTOS PRODUCTION 1928 - PRINCIPAL COUNTRIES

	Short Tons	% of Total	Value	% of Total	Average per Ton
Canada	273,033	69·5	$ 11,238,360	50·8	$ 41
Rhodesia	39,960	10·1	4,722,258	21·3	118
Russia	27,012	6·8	2,025,000	9·2	75
Union S. Africa	24,054	6·1	1,944,477	8·8	81
Cyprus	18,241	4·6	1,300,000	5·9	70
* All other	10,545	2·9	874,878	4·0	83
	392,845	100·0	22,104,973	100·0	56

* Australia, China, Finland, India, Italy and United States.



PRINCIPAL COUNTRIES

Prepared by John Casey, Mines Branch.

Chart VI. World asbestos production, 1928.

TABLE XX

Asbestos: World Production

World Production to end of Year 1929 (*Short tons*)

—	Canada	Cyprus	Italy	Rhodesia	Russia	Union of South Africa	United States	*a* All other	Total (short tons)
To end of 1909..	586,035	813	*b*	327	*b* 80,127	5,602	22,413	*b* 289	695,606
Calendar Year									
1910..........	77,508	487	......	332	12,985	1,482	3,693	3	96,490
1911..........	101,393	799	203	460	17,734	1,267	7,604	......	129,460
1912..........	111,561	861	205	nil	22,459	1,220	4,403	......	140,709
1913..........	136,951	1,308	193	290	24,797	962	1,100	......	165,601
1914..........	96,542	275	188	487	17,528	1,191	1,247	6	117,464
1915..........	111,142	1,230	179	2,010	11,212	2,138	1,731	1	129,643
1916..........	133,439	1,446	91	6,157	13,419	4,656	1,638	29	160,875
1917..........	135,502	1,197	94	9,562	6,908	6,220	1,958	892	162,333
1918..........	141,462	255	66	8,574	1,493	3,674	998	3,911	160,433
1919..........	136,765	1,491	108	9,799	740	3,932	1,161	1,634	155,639
1920..........	178,617	1,003	183	18,823	1,600	7,112	1,648	4,318	213,304
1921..........	80,634	1,004	463	19,529	10,832	5,122	831	3,262	121,407
1922..........	147,695	2,559	594	14,249	3,653	4,380	67	3,909	177,113
1923..........	215,311	2,409	1,695	20,364	5,995	8,393	227	2,424	256,818
1924..........	209,280	4,897	2,380	26,141	9,183	7,241	300	2,023	261,445
1925..........	273,524	3,588	2,320	34,349	11,023	10,167	1,258	5,518	341,747
1926..........	279,403	7,701	2,755	33,344	19,790	14,097	1,358	4,492	362,310
1927..........	274,778	12,746	5,006	33,176	23,700	22,133	2,986	4,146	378,671
1928..........	273,033	18,241	5,071	39,960	27,012	24,504	2,239	3,235	392,845
1929..........	306,055	15,803	3,968	42,634	*e* 39,000	33,037	3,155	*c* 286	434,938
Production to end of 1929........	4,006,360	79,283	25,762	320,567	352,199	168,089	62,015	40,376	5,054,851
Per cent........	79·2	1·6	0·5	6·4	7·0	3·3	1·2	0·8	100

World Production—On Basis of Production in 1914 (1914 production = 1)

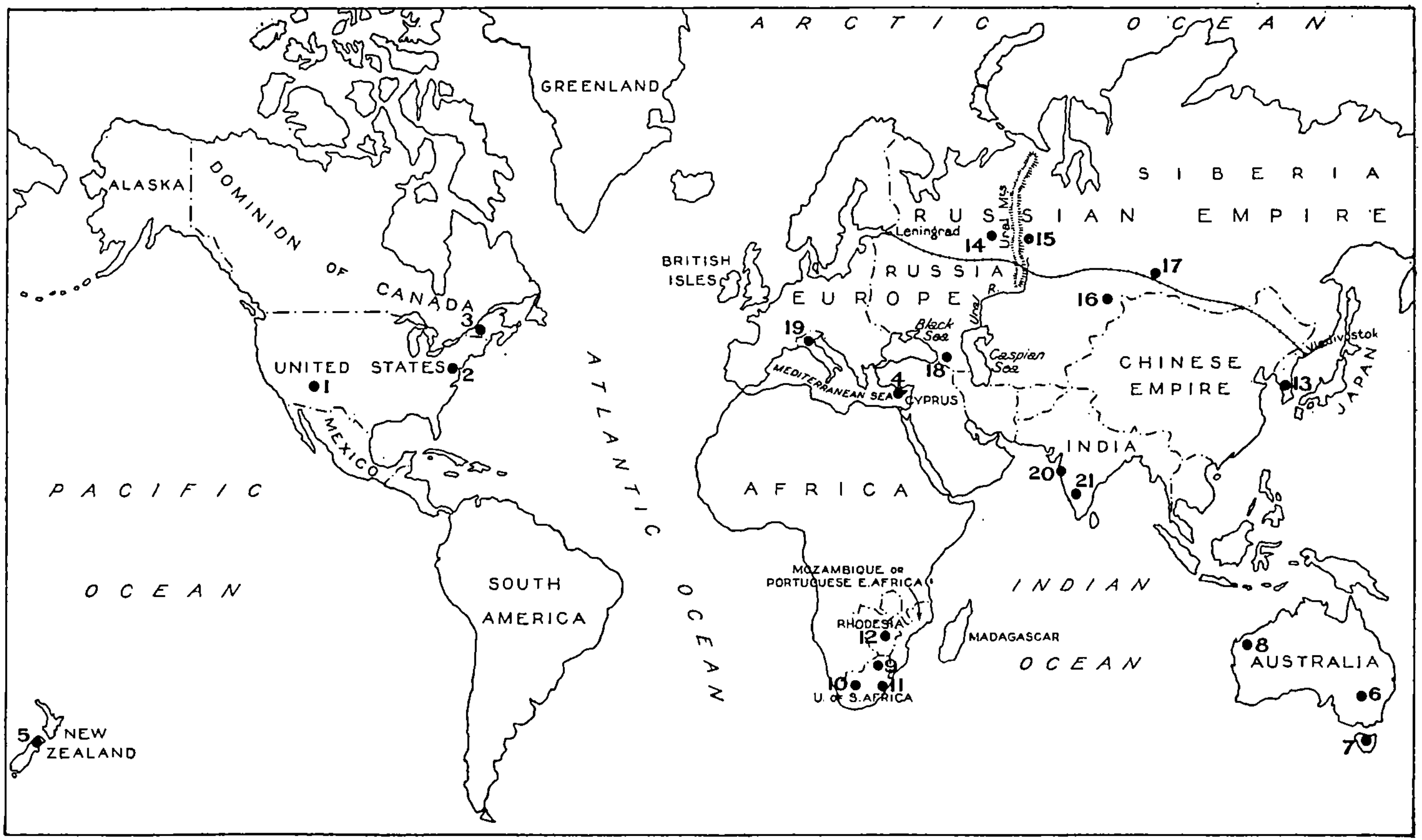
—	Canada	Cyprus	Italy	Rhodesia	Russia	Union of South Africa	United States	All other	Total
To end of 1909..	6·07	2·96	......	0·67	4·57	4·70	17·97	*d*	5·92
Calendar Year									
1910..........	0·80	1·77	......	0·68	0·74	1·24	1·96	......	0·82
1911..........	1·05	2·91	1·08	0·94	1·01	1·06	6·10	......	1·10
1912..........	1·16	3·13	1·09	nil	1·28	1·02	3·53	......	1·20
1913..........	1·42	4·76	1·03	0·60	1·41	0·81	0·88	......	1·41
1914..........	1·00	1·00	1·00	1·00	1·00	1·00	1·00	......	1·00
1915..........	1·15	4·47	0·95	4·13	0·64	1·80	1·39	......	1·10
1916..........	1·38	5·26	0·48	12·64	0·77	3·91	1·31	*d* 0·03	1·37
1917..........	1·40	4·35	0·50	19·63	0·39	5·22	1·57	1·00	1·38
1918..........	1·47	0·93	0·35	17·61	0·09	3·08	0·80	4·38	1·37
1919..........	1·42	5·42	0·57	20·12	0·04	3·30	0·93	1·83	1·32
1920..........	1·85	3·65	0·97	38·65	0·09	5·97	1·32	4·84	1·82
1921..........	0·85	3·65	2·46	40·10	0·62	4·45	0·67	3·66	1·04
1922..........	1·53	9·30	3·16	29·26	0·21	3·69	0·05	4·38	1·51
1923..........	2·23	8·76	9·02	41·82	0·34	7·05	0·18	2·72	2·19
1924..........	2·17	17·81	12·66	53·68	0·52	6·08	0·24	2·27	2·23
1925..........	2·83	13·05	12·34	70·53	0·63	8·54	1·00	6·19	2·91
1926..........	2·89	25·13	14·15	69·47	1·13	11·84	1·09	5·04	3·08
1927..........	2·85	46·35	26·63	68·12	1·35	18·58	2·39	4·65	3·22
1928..........	2·83	66·33	26·97	82·05	1·54	20·20	1·80	2·63	3·34
1929..........	3·17	57·47	21·11	97·54	1·71	27·74	2·53	......	3·70
Production to end of 1929........	....	....	......	....	....	....	....	......	......
Per cent........									

a Includes Australia, China, Finland, France, India, Japan, and smaller amounts from Argentina, Germany, the Philippines, and Spain, when data available.
b For Australia only, excluding tonnage from Italy and a portion from Russia. *c* Australia only. *d* Based on 1917 production. *e* Estimated tonnages for Russia, and are for fiscal years ended Sept. 30.

WORLD TRADE in raw or unmanufactured Asbestos, 1928.

Exports from *producing* countries: From Canada, 264,921; Cyprus, 12,968; Italy, 5,446; Rhodesia, 40,916; Russia, 12,288, including manufactures; Union of South Africa, 12,172; United States, 850; or a Total of 349,561 short tons, averaging over 6,700 per week.

Imports into *non-producing* countries: Into Austria, 4,921; Argentina, 55; Belgium, 20,005; Chili, 78; Czechoslovakia, 10,768; Denmark, 535; Dutch East Indies, 12; Egypt, 283; Esthonia, 77; Finland, 223; France, not available; Germany, 19,543; Hungary, 2,376; India, 2; Italy, 7,075; Japan, 11,419; Jugo-Slavia, 1,399; Latvia, 76; Lithuania 39; Netherlands, 3,117; Norway, 1,291; Poland, 1,497; Spain, 6,462; Sweden, 721; Switzerland, 1,182; United Kingdom, 30,404; United States, 230,594; or a Total *of 354,154 short tons.*



1. Gila county, Arizona.
2. Maryland, U.S.
3. Thetford, Que.
4. Cyprus.
5. Nelson, N.Z.
6. New South Wales (Barraba).
7. Tasmania.
8. Western Australia (Pilbarra).
9. Transvaal (Penge).
10. Cape (Prieska and Hay).
11. Natal.
12. Belingwe (Shabani), Mashaba and Lomagundi.
13. Chosen.

Ural Mountains

14. Baskenova.
15. Alpaievsk.

Altai Mountains

16. Minusinsk.
17. Irkutsk.

Caucasus Mountains

18. Kutais, Shusha.
19. Italy (Aosta).
20. Bombay.
21. Mysore.

Figure 1. Sketch map of the world showing asbestos-producing districts.

TABLE XXI

Summary of World Production to End of 1929

(Short tons)

Country	Production						Variety	Location	Remarks
	To end of 1909		1910 to end 1928		1929				
	Short tons	Value	Short tons	Value	Short tons	Value			
		$		$		$			
Australasia, etc.	289	10,302	7,567	475,992	286	71,448			
New South Wales	*17*	*Nil*	*2,853*	*238,383*	*Nil*	*Nil*	Amphibole	Barraba district	Opened up in 1909 for test shipments; worked at intervals between 1915 and 1923; now abandoned.
New Zealand	*Nil*	"	*2½*	*243*	"	"	Chrysotile	Takaka and Nelson districts.	Development work in 1920 and 1921.
South Australia	"	"	*43*	*3,003*	"	"	....	....	Worked irregularly between 1915 and 1924.
Tasmania	*224*	*1,766*	*3,557*	*31,896*	"	"	Chrysotile; amphibole	Near Beaconsfield	Opened in 1899; idle from 1900 to 1916, and since 1920.
West Australia	*48*	*8,536*	*1,112*	*202,467*	*286*	*71,448*	Chrysotile	Pilbarra district	Mining began 1908; idle from 1910 to 1918.
Canada	586,035	23,131,233	3,114,270	131,406,664	306,955	13,172,581	Chrysotile	Thetford, Black Lake and Danville areas, Quebec.	Mining in present area began 1879.
Per cent of total	85%	....	79%	....	70%	....	....	....	Totals exclude asbestic.
	(1,276)	*(9,471)*	*(2,469)*	*(24,944)*	*(30)*	*(375)*	Actinolite	Hastings county, Ontario	Small quantities since 1897.
China	*a*	....	*c* 2,488	*a, c*	*a*	....	Amphibole (brittle)	Manchuria, near Chinchu	Mining began about 1900 for export to Japan, and worked in small way since.
Cyprus	813	*a*	62,867	*a*	15,803	*a*	Chrysotile (short fibre)	Mount Troodas	Opened in 1906.
Finland	*a*	....	11,892	*a*	*a*	....	Amphibole	....	
France	*a*	....	*c* 6,570	*a*	*a*	....	....	....	
India, British	*a*	....	*c* 4,453	79,140	*a*	....	Amphibole	Mysore and Bombay districts.	Record not complete, being from 1914 to 1928.
Italy	*a, c*	....	21,794	*a*	3,968	*a*	Amphibole; chrysotile	At Mont Cenis and Aosta in Piedmont province.	Working on small scale many years prior to 1880; records obscure; noted for length and quality of fibres yielded.
Japan	*a, c*	....	*c* 6,304	*a*	*a*	....	....	Chosen (Korea)	
Rhodesia, Southern	327	15,933	277,606	35,281,594	42,634	5,774,918	Chrysotile	Belingwe (Shabani), Mashaba and Lomagundi areas.	Opened in 1908.
Russia	*c* 80,127	*a, c*	242,072	*a*	*e* 30,000	....	Chrysotile; amphibole	*Urals*: Perm district—(Baskenova, Sverdlovsk areas).	Discovered about 1710, worked several years and closed down indefinitely; re-opened and worked annually since 1883; record prior to 1909 includes only years between 1900 and 1909, and year 1893. In converting, the pood is valued at 36·1128 pounds; records obscure.
							Chrysotile	*Siberia:* The Altai region (Minusinsk, Irkutsk areas).	
							Amphibole	*Caucasus:* Kutais, Shusha.	
South Africa, Union of	5,602	594,045	129,630	10,005,307	33,037	2,420,646			
Transvaal	*Nil*	*Nil*	*74,165*	*5,342,286*	*26,984*	....	Chrysotile; some blue; amosite.	Penge district (Barberton)	Opened 1910; amosite (first produced), 1912; noted for length of fibre and resistance to acid.
Cape	*5,601*	*594,045*	*54,977*	*4,640,104*	*6,030*	....	Crocidolite (blue), chiefly.	Prieska and Hay districts	Mining began in 1893; record is from 1900.
Natal	*1*	*Nil*	*308*	*22,917*	*23*	....	Chrysotile	Natal	Samples in 1905; worked irregularly since 1910; idle late years.
United States	22,413	444,328	36,447	3,175,274	3,155	351,004	Chrysotile; amphibole	Gila county, Arizona; *near* Pylesville, Maryland.	Small annual production since 1882.
Miscellaneous	*Nil*	*Nil*	527	*a*	*a*	....	....	Spain, Philippines, Germany.	
Total	695,606	....	3,924,487	....	434,938	....			

a Not available. *c* Not complete. *e* Estimated.

CHAPTER V

ASBESTOS MINES AND PROSPECTS IN CANADA

QUEBEC

Asbestos Corporation, Limited

Localities: Thetford Mines, Black Lake, Coleraine, Robertson, and East Broughton, Quebec.

President and General Manager: Lieut.-Col. R. F. Massie, D.S.O.

Vice-President: Rt. Hon. Lord Shaughnessy.

Directors:

C. W. Colby, M.A., Ph.D.
George R. Cottrelle.
Kenneth T. Dawes.
Hon. Jacob Nicol, K.C.
Hon. Walter G. Mitchell, K.C.
Hon. Phillipe Paradis.
R. O. Sweezey.

Mines Manager: J. G. Ross.

Sales Manager: J. E. Triganne.

Secretary-Treasurer: J. T. McCallum.

Engineer: George Dick.

Head Office: Canada Cement Building, Montreal.

Mines Office: Thetford Mines.

Incorporated: Under the laws of the Dominion of Canada, 1926.

Mining Lands Held: Owned or under lease approximately 30,000 acres.

Capital: *Bonds*—Authorized $3,000,000; outstanding $2,467,300. First and refunding mortgage, 6 per cent, 15 years.

Bonds.—Authorized, $10,000,000; issued, $4,196,700. General mortgage, 6 per cent, 30 years.

Asbestos Corporation of Canada, Limited, Bonds.—Outstanding $288,600, assumed by Asbestos Corporation, Limited, 5 per cent, 30 years. First mortgage.

Bonds of Other Companies: $531,542.

Capital Stock: Common, authorized and issued 200,000 shares, no par value.

Preference stock, authorized $12,000,000, issued $7,456,400, par value $100, 7 per cent, non-cumulative.

This corporation, in 1926, succeeded the Asbestos Corporation of Canada, Limited, formerly the Amalgamated Asbestos Corporation, Limited, and brought under one control the properties then working under the following names: King mines, Beaver mines, British-Canadian mines, Fraser mines, Vimy Ridge mine, Consolidated mines, Federal mines,

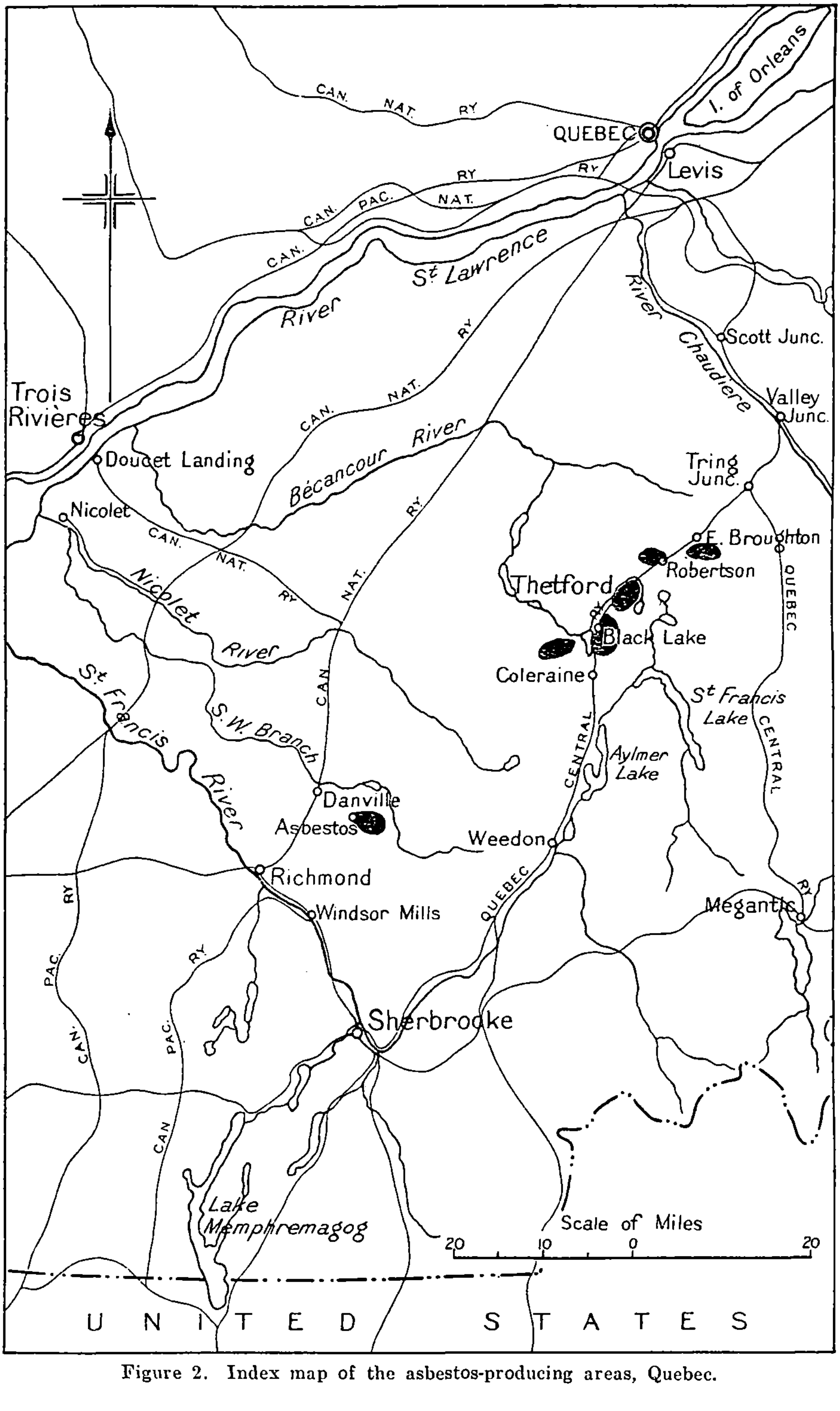


Figure 2. Index map of the asbestos-producing areas, Quebec.

Plate XXIII

AIR VIEW OF THETFORD AREA

1. Sand dump, Consolidated mine (Asbestos Corporation, Ltd.)
2. Sand dump, Johnson's Company.
3. Mill, Johnson's Company.
4. Pit, Johnson's Company.
5. Pit, Bell Asbestos Mines, Inc.
6. King pit, Asbestos Corporation, Ltd.
7. King mill, Asbestos Corporation, Ltd.
8. Beaver mill, Asbestos Corporation, Ltd.
9. Sand dump, Beaver mill, Asbestos Corporation, Ltd.
10. Beaver pit, Asbestos Corporation, Ltd.
11. Consolidated pit, Asbestos Corporation, Ltd.
12. Bennett-Martin pit, Asbestos Corporation, Ltd.
13. Bennett-Martin sand dump, Asbestos Corporation, Ltd.
14. Bennett-Martin mill, Asbestos Corporation, Ltd.
15. Mill, Bell Asbestos Mines, Inc.
16. Sand dump, Bell Asbestos Mines, Inc.
17. Sand dump, King pit, Asbestos Corporation, Ltd.
18. City of Thetford Mines.


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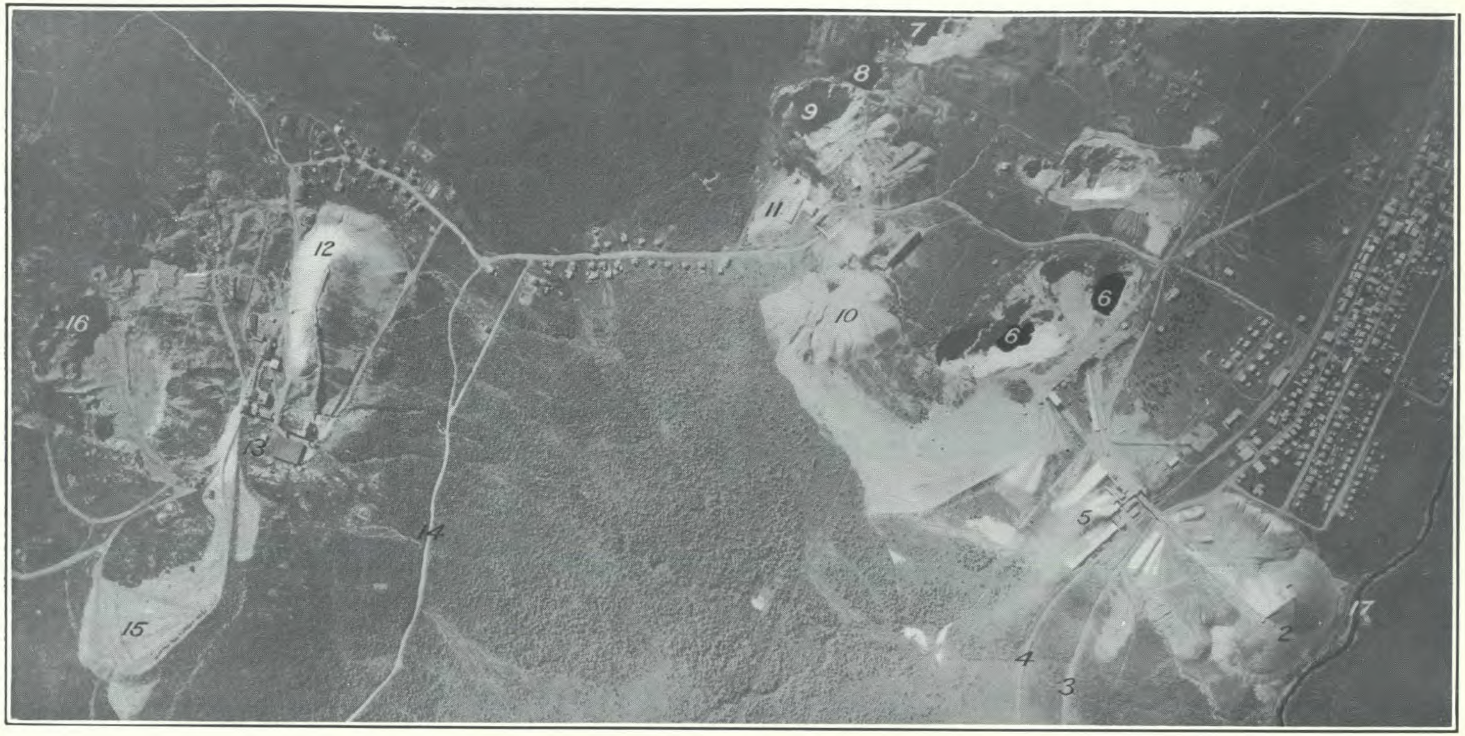
PLATE XXIV

AIR VIEW OF BLACK LAKE AREA

1. Black Lake village.
2. Sand dump, British Canadian mine, Asbestos Corporation, Ltd.
3. Highway to Thetford Mines.
4. Quebec Central railway to Thetford Mines.
5. Mill, British Canadian mine, Asbestos Corporation, Ltd.
6. Pits, British Canadian mine, Asbestos Corporation, Ltd.
7. } 8. } Glory holes, British Canadian mine, Asbestos Corporation, Ltd.
9. Pit, Johnson's Company.
10. Sand dump, Johnson's Company.
11. Mill, Johnson's Company.
12. Sand dump, Consolidated Black Lake pit, Asbestos Corporation, Ltd.
13. Mill, Consolidated Black Lake pit, Asbestos Corporation, Ltd.
14. Road to Thetford.
15. Rock dump, Consolidated Black Lake pit, Asbestos Corporation, Ltd.
16. Pit, Consolidated Black Lake, Asbestos Corporation, Ltd.
17. Bécancour river.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Belmina mines, Kitchener mines, Maple Leaf mines; Asbestos mines, Broughton mines, Asbestos Fibre mines, Black Lake; Black Lake Asbestos and Chrome mines, and Pennington mines.

Of these, the King, Beaver, British-Canadian, Maple Leaf, Vimy Ridge, and Asbestos mines are in active operation. A new mill recently built on the Beaver property will mill rock from the Beaver and Consolidated ground, replacing the mills at present on these two properties.

This company is the largest producer of raw asbestos in Canada, if not in the world, in one year the output having reached 120,000 tons.

The six active mills of the Asbestos Corporation have a total capacity of 500 tons of rock per hour. Together with seven inactive properties the holdings comprise approximately 30,000 acres along the Quebec Central railway, from Coleraine to East Broughton. At the King pit alone, 1,300,000 tons of rock is hoisted per year, of which 300,000 tons goes direct to the dump. Over 14,000 tons of rock and overburden have been handled in a single day. In normal times 1,500 men are employed and 16,000 h.p. (hydro-electric) is required for mining and milling. Besides hand-loading, two No. 50 B Bucyrus electric shovels of 2-yard capacity each and four steam shovels are used. For transportation, surface and underground, 12 electric locomotives, 8 steam locomotives, and 300 cars are in service.

The King Pit

Locality: Thetford Mines, Quebec. Operating principally on lot 26, ranges V and VI, Thetford township.

Superintendent: J. P. Wiser.

Engineer: L. V. Rainboth.

Men Employed: Average, 525.

Capacity of Mill: 200 tons of rock per hour.

The main pit, which is 1,200 feet long by 1,000 feet wide, and 400 feet deep, has been in operation for about fifty years; work having been begun in 1879, in a ridge near the southerly end of the present workings.

The output is about 4,000 to 7,000 tons rock per day.

Rock is hoisted by means of 8 cableway hoists, 2 with towers of steel construction, and 6 of wood frame construction. Five- and ten-ton skips, as hoisted, are dumped into bins, separate compartments in each holding ore and waste. Cars are loaded from the hopper bottoms of the bins, through gates controlled by compressed air, and hauled by electric locomotives to a sluice at the primary crushers. The primary crushing unit and stack dryers are in one building, from which the dried rock is conveyed to a storage bin which has a capacity of 25,000 tons. Rock is carried from the storage bin on a conveyer belt to a control bin in the mill. This building, of four floors, is 186 feet long by 68 feet wide, built of steel frame with brick walls. The equipment is laid out in two distinct units, each of which has a capacity of from 80 to 100 tons of rock per hour, giving a total capacity of 200 tons of rock per hour. Sand from the mill and waste rock from the pit are hauled in trains of 15-ton cars to the dump, three-quarters of a mile distant, across Bécancour river. The mill is situated on the main line of the Quebec Central railway, and is served by a through siding. Finished fibre is stored in sheds located on both sides of the railway track, and a large dust bin adjoins the mill. A machine shop is fully equipped for repair and construction work. Underground mining has been started, 5,000 feet of drifts and crosscuts having been driven, and 7 shrinkage stopes opened on the 300-foot level.

Beaver Pit

Locality: Thetford Mines, Quebec.
Superintendent: G. F. Jenkins.
Mill Superintendent: O. H. Adams.
Mining Lands: 500 acres, comprising lots 31 and 32, range C, Coleraine, and lot 36, range XI, Ireland. With this will now be worked the adjoining Consolidated lot, and Bennett-Martin lot.
Number of Men Employed: Average, 275.
Capacity of Mill: 100 tons of rock per hour.

The ground under exploitation comprises the southerly section of the main Thetford fiberized zone, so far as opened up. The new mill building is larger than that at the King pit, being 24 feet longer, 10 feet wider, and containing five floors. The crushing unit, which was built on the tailings pile from the old mill is in a well lighted building. The storage bin is located between the crushing and drying plant and the mill; the hauls by inclined conveyer belt being short. The construction of the mill is of steel and brick. It is located near the main line of the Quebec Central railway.

Loading by hand-shovelling and hoisting by cableway derricks has been replaced by loading with a 1½-yd. capacity, Bucyrus electric shovel into 10-ton steel cars.

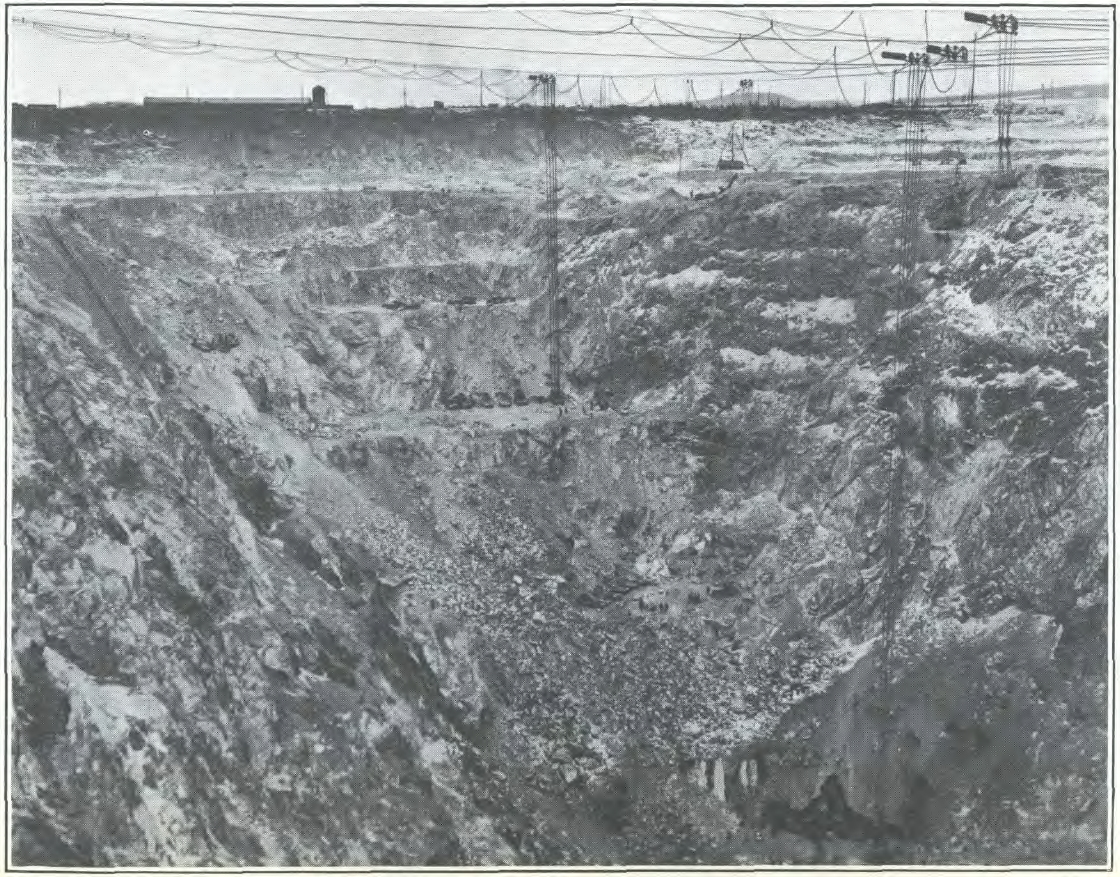
Cars are hauled from the pit to the bottom of an inclined track by electric trolley locomotives, from whence they are hauled up a double-compartment incline at an angle of 22 degrees for a distance of 1,100 feet.

Cars are dumped by electrically operated dumpers into sluices leading to a jaw crusher, 36 inches by 40 inches, in each unit. Each primary crusher is followed by a pair of 50-inch rolls, after which the rock passes through a King hammer crusher, thence by conveyer belt to a battery of three stack (each 50 feet in height and 7 feet by 7 feet in section) dryers, hand-fired

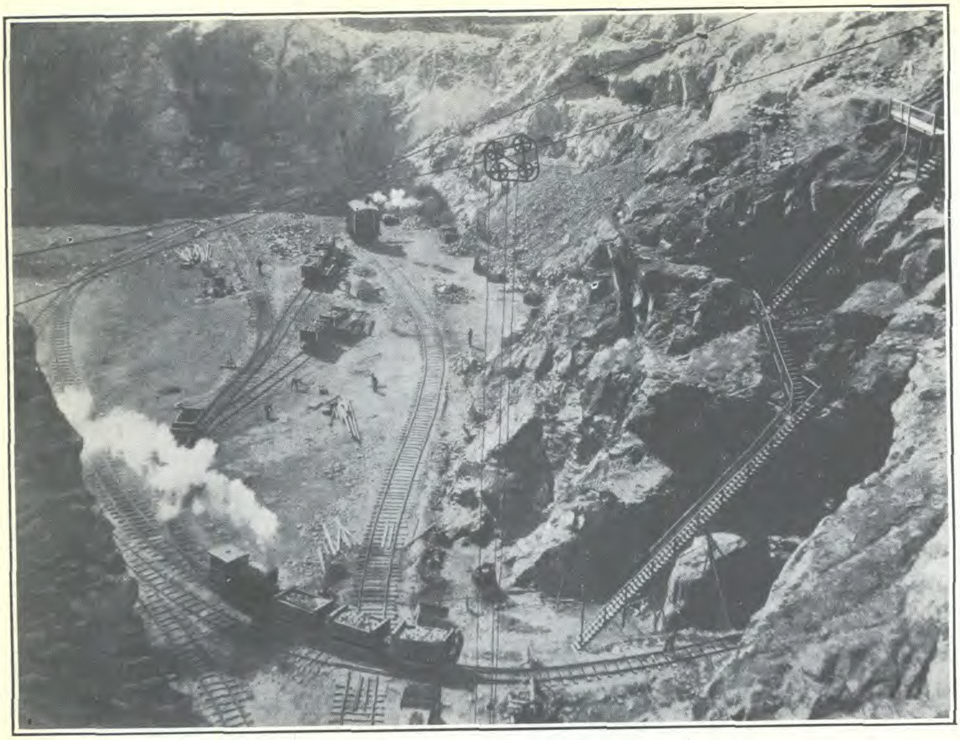
The dried rock is conveyed to a storage bin of a capacity of 25,000 tons from where it is drawn as required to the mill, being automatically weighed in transit on a conveyer belt.

In the mill only one unit is as yet installed. Incoming ore passes over a Niagara sizing screen, then to the crushing units, King hammer crusher, Williams hammer crusher, and two-stage Jumbo mills. After each crushing the fibre is lifted by suction supplied by Sheldon fans operating in pairs and direct-driven by motors. Fibre as lifted from the flat shaking screens which follow each crushing operation is caught in collectors, some of which are of the vertical type and some horizontal. From the collectors the fibre is taken on conveyer belts to the graders. After grading it is recleaned and bagged for shipment.

All crusher house motors are controlled from a single bank of manually controlled starters, as are all mill motors from another bank.



King pit, Asbestos Corporation, Limited, Thetford Mines, Que.



A. Pit of Bell Asbestos Company, Thetford Mines, Quebec.

B. Pit of Bell Asbestos Company, Thetford Mines; King pit of Asbestos Corporation, Ltd., in background; Johnson's Company pit to right.

Consolidated Pit

The Consolidated pit, formerly known as the Jacobs pit, is located on lot 28, range VI, Thetford township. As this pit had a narrow width on the fiberized zone, and part of the surface was covered by refuse from earlier operations, it was developed at depth by a vertical shaft 515 feet deep, from which a crosscut was run underneath the pit at the 385-foot level. A system of stopes up to 35 feet in width was developed, and as they were advanced upwards they became glory holes. The shaft was replaced as ore-hoisting medium by a double track, inclined tunnel 1,700 feet long. This ground will now be more economically handled in conjunction with the adjoining Beaver pit; the mill having been dismantled.

The British-Canadian Quarries

Locality: Black Lake, Quebec.

Superintendent: W. A. Clearihue.

Number of Men Employed: Average, 195.

Capacity of Mill: 90 tons of rock per hour.

This property in Block A, Coleraine township, was formerly operated by the British Canadian Asbestos Company, which succeeded the American Asbestos Company. Operated with it is the ground at one time worked by the Glasgow and Montreal, the United, the Manhattan, the Dominion, and the Standard companies.

From the mill, which is located on the main line of the Quebec Central railway, a tunnel runs into a side hill. In its two main branches, the tunnel has a length of over 2 miles and is 12 by 14 feet in cross-section. Trains of 8-ton cars are hauled by electric locomotives. Near the upper end of the tunnels, glory holes 300 feet in depth are worked. Mining by this system affords the cheapest mill rock in the district. No picking of crude fibre, and little sorting of barren rock, is done. As at the King and Beaver pits, a large dried rock storage bin is in use. The capacity of the mill is 70 to 90 tons of rock per hour. Milling by cyclones is practised and a large part of the output is in shingle grades.

Maple Leaf Mine

Locality: Between Thetford and Black Lake, on lots 28 and 29, range VIII, Coleraine township.

Superintendent: S. Bateman.

Engineer: A. D. Porcheron.

Capacity of Mill: 50 tons per hour.

Number of Men Employed: Average, 75.

The pit is 700 feet by 600 feet, and 160 feet deep. Loading of rock is by steam shovel on caterpillars. The primary crusher is a jaw crusher, 36 inches by 42 inches, and milling is done by a jaw crusher, Torrey cyclone, and tailings mill.

Vimy Ridge Mine

Locality: Coleraine.

Superintendent: Telesphore Roy.

Number of Men Employed: 125.

Capacity of Mill: 60 tons of rock per hour.

Formerly operated by the Bennett-Martin Asbestos and Chrome Company, this quarry is situated 7 miles north of Coleraine, a station on the Quebec Central railway, with which it is connected by a standard gauge railway line owned by the company.

In 1927 the mill was remodelled and equipped with a system of rolls with the object of making shingle fibre, for which grade the fibre is peculiarly adapted. In 1930 the milling equipment was divided into two units.

The nature of the fiberized rock at this pit differs from that of Thetford pits, in that it is banded horizontally in ribbon fibre. Fibre up to 2 inches in length occurs, and in places as much as 20 per cent of the face of the quarry is asbestos. It is more harsh, and more difficult to mill than other fibres in the district. One mile to the east, in the Edith pit, on the south flank of Silver mountain, the fibre resembles that found at Thetford.

Asbestos Mines

Asbestos Mines, East Broughton, formerly the Boston Asbestos Company.

Locality: One-half mile from East Broughton, Quebec.

Superintendent: S. Bateman.

Number of Men Employed: 100.

Capacity of Mill: 50 tons of rock per hour.

Mining Lands: Broughton township, 25 acres east part of lot 13c, range IV; 100 acres, whole of lot 13b, 140 acres, whole of lot 14a, range V.

The pit has been opened on the northerly end of the East Broughton slip fibre belt. Rock is loaded by steam shovel into a car which is hauled up an inclined track, and after being broken and dried is conveyed in buckets by aerial tram a distance of 4,000 feet to the mill, which is built on the main line of the Quebec Central railway.

The rock contains fibre of the slip variety and on milling yields a high percentage of short fibres.

Operations at the other quarries owned by the corporation have been suspended.

Belmina Quarries

This property, formerly the Belmina Consolidated Asbestos Company, Limited, and at one time the Belmina Asbestic Company, and the Asbestos Mining and Manufacturing Company, now forms part of the holdings of the Asbestos Corporation, Limited. In 1919-20 a mill building was erected on lot 24, range I, at the easterly workings, and machinery brought on the ground by the Consolidated Asbestos Company, but installation was not completed.

The area comprises the northeast half of lot 25, range IV, about 100 acres; lots 23 and 24, range II, about 400 acres; and the southwest half of lot 23, range I, about 100 acres; all situated in the township of Wolfestown, Quebec. During 1907 and 1908, a mill of a capacity of 30 tons of rock per hour was operated on the westerly part of the property, on lot 23, range II. A wagon road was completed from Coleraine Station, and an electric power line run from Black Lake. Both the serpentine and asbestos fibre resemble in character those of Thetford Mines.

Pennington Pit

Locality: Four miles east of Thetford, Quebec.

Mining Lands: 1,025 acres, comprising lots 14, 21, and 28, range IV, 600 acres; lots 16 and 17, range IV, 400 acres; lot 15, range IV, 25 acres, all in the township of Thetford.

This ground was worked and a mill operated, up to 1923, by the Pennington Asbestos Company, successors of the Robertson Asbestos Company which built a mill in 1909 on lot 16, and is now a part of the holdings of the Asbestos Corporation, Limited. The serpentine is of the East Broughton type, with the difference, however, that the fibre is of both slip- and cross-vein varieties, thus yielding a certain amount of crude. On the other hand, in comparison with the Thetford fibre, which exhibits peculiar dark shades when in situ, the asbestos is green and yellowish green in colour. Two bands running diagonally across the main zone carry cross-fibre veins from which some crude was recovered. The mill when in operation had a capacity of 30 tons per hour. It is now dismantled.

The Kitchener Pit

Locality: Three miles northeast of Robertson Station. Acquired by the Asbestos Corporation along with the other holdings of the Consolidated Asbestos Company, who rebuilt the mill in 1919-20, at the same time changing the name from Berlin to Kitchener. The mill did not operate.

Area: 200 acres, covering east half of lot 11, range V, township of Thetford. The fibre is of the slip variety, and the fiberized zone has a width of 150 feet.

The Federal Pit

Locality: One mile north of Robertson Station, on the Quebec Central railway. Acquired by Asbestos Corporation, Limited, along with the other holdings of the Consolidated Company, and operated until 1927. The mill, which had a capacity of 50 tons rock per hour, has been dismantled. The ore-body forms a reserve from which slip fibre can be recovered.

Black Lake Consolidated Pit

Locality: Black Lake, Quebec. In 1924, operations were suspended on this property, and in 1926 it became a part of the holdings of the Asbestos Corporation, Limited.

Mining Lands—

The Union Asbestos pits, about	110 acres
The Southwark pits, about	117 "
The Imperial pits, about	158 "
The Black Lake Asbestos and Chrome quarries, about	5,000 "
Total	5,385 acres

In 1909, these lots were grouped under the name of the Black Lake Consolidated Asbestos Company, which later became the Black Lake Asbestos and Chrome Company, Limited. The main pits were side-hill workings on the Union ground, lots 27 and 28, range B, Coleraine township, on which the mill, now dismantled, was located.

When the mill was in operation in 1917-18 it was one of the most efficient in the district, with a milling capacity of 60 tons per hour of mill rock containing only 3 per cent fibre, the rock in situ carrying only 1¼ per cent fibre. Pit rock was loaded by hand and lifted by means of cranes of the railroad type to cars. One-half the pit rock was sent to the dump as barren. The system of milling practised gave a high yield in the more valuable grades. Twenty-five per cent of the fibre recovered in one year graded as spinning fibre. The shingle stock, which ran as high as 60 per cent of the fibre yield, was regarded as unusually valuable for the purpose. Fibre from the Southwark pit differed in character from that from the Union pit, being softer and shorter but of a higher percentage in the rock.

In 1930 the Union pits were worked by leasors for crude fibre.

Asbestos Fibre Pit

This property adjoins the Black Lake Consolidated pit. Before equipment of the mill was completed it was acquired by the Asbestos Corporation, Limited, in 1926, and operations were suspended.

Broughton Pit

The pit of the Broughton Asbestos Fibre Company (now part of the Fraser), situated three-quarters of a mile from East Broughton, between the Fraser pit of the Asbestos Corporation, Limited, and the pit of the Quebec Asbestos Corporation, Limited, has been idle and full of water for many years.

The holdings comprise 35 acres on lot 13, range VIII, Broughton township, Beauce county.

Bell Asbestos Mines, Inc.

Owned by the Keasbey and Mattison Company of Ambler, Pa.
Locality: Thetford Mines, Quebec.
Mining Lands: NE ½ lot 27, range V, Thetford township.
Manager: Orlando C. Smith.
Quarry Superintendent: George W. Smith.
Mill Superintendent: Herbert A. Smith.
Capacity of Mill: 75 tons of rock per hour.

The present members of the staff are sons of the late Hon. George R. Smith, for many years manager of the company, and closely identified with the development of the industry.

Formerly operated by an English company, this is one of the oldest and most successful companies in the district. The pit lies close to Thetford Mines Station on the Quebec Central railway, on lot 27, range V, Thetford township.

The average number of men employed is 400.

The depth of the pit is 220 to 240 feet, with a length of 1,200 feet and a width of 600 feet. It lies to the west of the King pit, and north of the Johnson pit, from which it is separated by a party wall. The King pit being much deeper, no wall intervenes. Drilling is done in vertical holes 40 feet in depth. In parts of the pit, sorting is done, the mill ore and barren rock being loaded separately, put into boxes which are lifted by cranes and dumped into cars. On other faces all rock is loaded by steam shovel. On the floor of the pit, tracks are laid on which cars are hauled by steam locomotives to the foot of an incline track. The haulage tunnel and general operations of the company are described by R. C. Rowe.[1] The haulage tunnel leaves the floor of the pit in the extreme northwest corner of the pit, runs under the lines of the Quebec Central railway, and Notre Dame street of Thetford Mines, and finally emerges about 500 feet from the mill, which is situated to the north of the pit. The tunnel is 1,100 feet long, and has a slope of from 9·86 to 11·22 per cent. It is concrete-lined for the greater part of its length, and its dimensions are 12 feet wide by 13 feet high. In operation, trains of cars are attached to a hoisting cable at the entrance to the tunnel. An electrically driven hoist raises the train to the crest of the track, 400 feet beyond the portal of the tunnel, at which point the cars are picked up by a steam locomotive and run to the crusher house or to the waste dump. The mill rock is dumped into twin crusher chutes, feeding two 36-inch by 24-inch jaw crushers, manufactured by the Canadian-Ingersoll-Rand Company. These reduce the rock to about 5-inch or 6-inch maximum size, and discharge on a 36-inch conveyer picking-belt. On a return belt, from which further picking is done, the material is turned over to uncover crude fibre and débris hidden by the rock on the first belt. The ore then goes to two rotary direct-heat dryers. These are 40 feet long by 66 inches in diameter, and are coke fired. After drying, the ore travels by conveyer belt to a rotary screen, where fines are removed, oversize going to a Symons cone crusher. The crusher discharge, and rotary screen undersize, are sent to a 6,000-ton mill storage bin, constructed of

[1]Rowe, R. C.: Can. Min. Jour., Feb. 17, 1928, pp. 146–151.

concrete, of a length of 225 feet. The ore is distributed over this length by a conveyer belt equipped with a movable tripper. The bottom of the bin is fitted with chutes and gates under which runs a conveyer belt. A travelling, automatic, vibratory feeder, discharging on the mill feed conveyer, can be placed under any desired chute. The vibrator is motor driven and the feed can be stopped from three different places in the mill. The mill feed conveyer, after emerging from beneath the storage bin, passes over an automatic weighing machine equipped with an indicator showing the rate of feed per hour. The capacity of the mill is 75 tons per hour, and operations are continued during two shifts per day of 11 and 13 hours.

The treatment plant is in two distinct and independent units. The primary breakers are of the William's hammer mill type, fitted with grid slot discharge of a special design developed by the engineering staff. The tailings grinders are cyclones. Slow speed, flat shaking screens are used for cleaning out sand and bedding the rock and fibre. Collectors of the pull-through type are used and grading and cleaning are carried out on flat shaking screens. A recovery of 8 per cent of fibre is made on the average, although much higher yields have been obtained over short periods. Eleven different grades are made, the largest single grade being shingle stock. Tailings are conveyed to a 1,600-ton steel storage bin from which they are drawn off into cars and hauled by a steam locomotive to the waste dump. The plant is entirely self-contained, even to engine shops for repairing locomotives. A complete machine shop is maintained, and also a saw-mill and wood-working shop.

The output of finished fibre is from 45,000 to 55,000 tons per year.

Johnson's Company

Locality: Thetford Mines and Black Lake, Quebec.
President: Harold Kennedy.
Vice-President: Dr. J. A. Johnson.
Managing Director: Andrew S. Johnson, Jr.
Directors: S. J. Johnson, Dr. M. J. Mooney.
Secretary: A. M. Robinson.
Head Office: Thetford Mines, Quebec.
Incorporated: Under the laws of the province of Quebec, in 1885.
Authorized Capital: $250,000 all paid up.
Mining Lands Held: Over 1,000 acres in Thetford Mines and Black Lake. The principal pit is on the northeast portion of lot 27, range VI, Thetford township.
Number of Men Employed: Thetford pit and mill, 300. Black Lake pit and mill, 200.

This company was the pioneer in the asbestos industry; their operations having commenced in 1878. Up to 1926 operations were carried on by the founder, the late Mr. A. S. Johnson. The present managing director, Mr. A. S. Johnson, Jr., has succeeded his father to the position. The secretary, Mr. A. M. Robinson, has been connected with the company for 43 years; and several of the employees have service records of from 40 to 50 years. At present this company produces a large proportion of the crude fibre exported from Canada. Operations are carried on at two plants, one at Thetford, and the other at Black Lake, the Thetford plant being the larger. One unit of a new mill erected on the Thetford property was put into operation in September, 1930. The Thetford pit is located along the northwesterly boundary line, and is separated from the Bell pit by a party wall. At the northeast corner it adjoins the King pit. In shape it is rectangular, having a length of 800 feet, a width of 500 feet and a depth of 220 feet.

Hoisting by six cableway derricks has been replaced by crane loading and hoisting on an incline track.

Rock is loaded in the pit by hand shovelling into 2½-ton steel boxes. These are lifted by two Orton electric cranes and dumped into 7½-ton steel cars which are hauled by a Vulcan gas-electric locomotive to the foot of an incline. Hauling through the incline is on a single track with by-pass for balanced hoisting, the lower part of a track being on a 3 per cent gradient and the upper seven hundred feet at an incline of 21 degrees. Cars in trains of two each are dumped at the top of the incline by an automatic trip rail. Hoisting is by means of a Canadian Ingersoll-Rand hoist with 7-foot diameter, double drums, driven by a 450 h.p. motor,—remote control operation. The hoist is installed in an isolated building.

Crusher House. Primary crushing equipment is housed in a steel frame building covered with corrugated asbestos sheathing. Ore cars dump on to a Polius slicing bar grizzly operated by a 15 h.p. motor, from which it is fed to a Kennedy-Van Saun No. 36 gyratory crusher of a capacity of 500 tons per hour from 36 inch to 5 inch.

Throughs from the grizzly go direct to the dryers and the product of the No. 36 crusher is recrushed in a pair of No. 38 Kennedy-Van Saun gyratories.

Dryer House. Four rotary dryers, each 5 feet in diameter by 40 feet in length, are driven by individual motors. Two are hand-fired and two fired with pulverized coal using a Kennedy-Van Saun pulverizer system. Dust and dirt are drawn off by induced draught, caught in collectors, dropped on a conveyer belt and sent to the dump.

Dry Rock Bin. Dry rock is transported on a rubber conveyer belt to a storage bin of the sand dump type, the walls of which are supported on tie crib work. The capacity of the bin is 35,000 tons. A concrete by-pass allows rock for test runs to go direct to the mill.

Mill. The mill building is of steel frame construction and brick walls with concrete foundations. Wooden floors are of slow-burning type of construction. Crushing machines on the ground floor are set on concrete foundations.

Equipment is installed in one unit of the mill only. Ore entering the mill on a conveyer belt from the dry rock bin is automatically weighed and dumped into trommel screens.

Throughs from the trommels fall to a pair of flat, shaking screens from which fibre is lifted, sand goes to the waste dump, and overs to the next crusher. Overs from the trommel go to a pair of No. 37 Kennedy-Van Saun gyratory crushers. Second-stage crushing is done in a Williams hammer mill followed by two-stage Jumbo crushing.

Fibre is lifted from all screens by means of Sheldon fans, direct-driven, to vertical collectors of the pull-through type.

Fibre is graded in high speed graders and mixed in screw conveyers. Bagging is done by bagging machines of the plunger type.

All crushing units and elevators are fitted with dust collecting hoods. Dust from collectors is exhausted to a dust bin, from which the fibre is brought back by a drag conveyer for scalping.

Electrical control apparatus is installed in a separate building, control being by manual operation.

The capacity of the installed unit of this mill is 100 tons of rock per hour.

Black Lake Pit

Superintendent: James Briggs.
Capacity of Mill: 30 tons of rock per hour.

The pit adjoins that of the British Canadian pit of Asbestos Corporation, Limited, near Black Lake station on the Quebec Central railway. Rock is hoisted from a pit 250 feet by 120 feet by 100 feet deep, by five cableway derricks, box loading being by hand-labour.

Hauled by steam locomotives to the sluice the rock is crushed in a jaw crusher, whence it goes to a pair of rotary dryers, thence to a small storage bin.

Milling is done by means of rolls and Jumbos. Fibre is trucked one mile to the railway for shipment.

Quebec Asbestos Corporation, Limited

Locality: Near East Broughton station.
General Manager: Ernest E. Spafford.
Head Office: East Broughton, Quebec. This company is controlled by the Philip Carey Manufacturing Company of Cincinnati, Ohio.
Capacity of Mill: 50 tons of rock per hour.
Mining Lands: The property of the company includes the former Ling Asbestos Company ground, on lots 12c, 13b, and 13c, range VI, Broughton township, Beauce county; the former Frontenac Asbestos Mining Company ground, 130 acres, covering the east half of lot 13a, range VI, Broughton township; the former Eastern Townships Asbestos Company ground, 90 acres on lot 13w, range VI, Broughton township; a two-mile section of the fiberized zone on lot 13, ranges VIII and IX, Broughton township. The mill is located on lot 13b, range VI, Broughton township, and quarrying is carried on at this lot, and the adjoining lots 13w and 13c. The mill on 13w lot, formerly operated as No. 2 mill, and for some years by the Eastern Townships Asbestos Company, has been taken down, and the pits on the three lots are now worked as one.

Quarry: The pit is 125 feet deep, 350 feet wide, and 1,100 feet long. The hanging-wall dips at an angle of 45 degrees to the southeast. An electric shovel with 1¾-yard dipper is used for stripping overburden which varies in depth from 6 to 14 feet. For blasting the rock, vertical holes are drilled to a depth of from 40 to 75 feet, with both piston and submarine hammer drills, using 2-inch steel as starters. Practically all rock, except that taken from the hanging-wall is milled. By means of an electric shovel with 1¾-yard dipper, a 15-ton car is loaded, and hauled on a standard gauge track, laid on the pit floor, by an electric locomotive to a bin beneath the pit floor. The car is dumped automatically into a circular steel bin 50 feet deep by 22½ feet in diameter. The bottom of the bin is made of steel bars and from it rock is dumped through a semi-circular gate, electrically operated, into a 15-ton car. Cable haulage up a 15-degree inclined track 500 feet in length raises the car to a chute where the load is dumped on a bumping bar grizzly. A semi-circular gate, electrically controlled, regulates the rate of rock feed to the primary crusher, which is of the the jaw type, 36 by 42 inches.

Mill. The throughs from the grizzly join the crushed rock on an inclined conveyer belt and go to the sizing trommel. The overs from the trommel go to a secondary jaw crusher 30 inches by 15 inches. Fines and crushed rock again join on a conveyer belt and the load is split into two equal parts, each lot going to a separate rotary dryer. The dryers are 40 feet long by 60 inches in diameter, and are direct-fired. Drying is more of a problem here than in the other districts, the slip fibre rock often carrying as much as 20 per cent moisture. A bucket elevator lifts the rock from each dryer to a gyratory crusher, thence it is conveyed to a storage bin of 500 tons capacity. The separation unit comprises two trommel screens, two Jumbos, flat shaking screens, covered with wire-mesh cloth, and fitted with suctions; five Jumbos followed by screens, the overs from which go to a second row of five Jumbos, after which the material is again screened. Fibre is lifted from all screens to pull-through collectors, graded and cleaned. Ballbearings are used throughout the mill.

Drainage. A through drainage of the pit is obtained by both surface and underground drainage. A ditch run parallel to the pit on the upper side empties into an underground drift which carries this surface water around the upper end of the pit and discharges into a small stream at the lower side of the property.

Underground workings directly underlie the pit and are connected with the pit floor by raises. These underground workings all discharge water into a sump which is equipped with an automatic vertical centrifugal pump, electrically driven, capable of discharging 1,800 gallons per minute. This pump lifts the water 180 feet through a 6-inch pipe discharging into the drift leading to the stream mentioned under surface drainage above.

The capacity of this drainage system is ample for all conditions and at no time have quarrying operations been delayed due to spring freshets or floods.

The underground workings also provide insurance against delays due to rock slides which might occur in the pit and would provide a means of handling such rock if necessary.

In 1930 a railway two miles in length was constructed to bring rock from the holdings in Broughton township, at which place a tunnel was driven through country rock to the ore zone. Rock thus brought will be stored in a bin in the bottom of the pit near the mill. This storage bin, now under construction, will have a capacity of 150,000 tons of rock.

Northern Asbestos Company

A mill is operated by Paul Hammerick at Thetford Mines to recover short fibre from the sand dump of the Johnson's Company.

Canadian Johns-Manville Company, Limited

The major productive activities of this company are located at Asbestos, Quebec, 5 miles from Danville, a station on the Canadian National railway, with which it is connected by a standard gauge railway. Its principal mining lands are located in Shipton township, Richmond county.

The officers of this company, Lewis H. Brown, President; C. H. Shoemaker, Vice-President and Manager; R. S. Gardner, General Superintendent; H. K. Sherry, Mine and Railway Superintendent; and S. L. Lamplough, Factory Superintendent, constitute a personnel well capable of handling an industry of this magnitude.

These operations constitute a regular source of income to a great number of people in the province of Quebec—employing over 1,000 hands in its mining, milling, and manufacturing and allied operations, and carrying an uninterrupted payroll for over thirty years.

Mining is carried on by the open-pit method, which has resulted at this time in an excavation approximately 3,000 feet in diameter by 200 feet deep. The serpentine formation in which the asbestos occurs is covered by an overburden of glacial drift which varies in depth from 20 feet to upwards of 125 feet. This surface material is removed by means of standard gauge, railroad-type steam shovels equipped with extra long booms and dipper sticks carrying 2½-cubic yard dippers, loading into air dump cars of a capacity of 16 or 20 cubic yards. Trains consisting of from ten to fourteen cars are hauled by steam locomotives and dumped on waste piles, which are located one or two miles from the pit mouth. It is planned to dispose of waste material at sufficient distance to provide against the possibility of its ever being moved again. These dumps vary in height from 10 to 90 feet, and are kept trimmed by a mechanical spreader, tracks being shifted and levelled by self-propelling track machines, which are actually able to lift or slide horizontally the very track on which they stand. The final clean-up, after stripping operation by the main shovels, is carried on by an auxiliary mobile type machine mounted on "caterpillar" treads and equipped with a "back digger" bucket of 1¼ cubic yards capacity, followed by hand work to assure against any appreciable amount of dirt later going with the underlying ore to the mills where it would not only interfere with the dressing operations but might contaminate the final product.

The removal of the asbestos-bearing rock or ore is done by the bench system, the benches having a vertical interval of 25 feet. This has been found to be the most practical height of working face to avoid rock slides and the attendant danger to equipment and, especially, to workmen.

A special system of rock drilling has been developed at this mine to suit the height of working face and to break to shovel size the maximum percentage of rock or ore in the primary blasting. The random direction

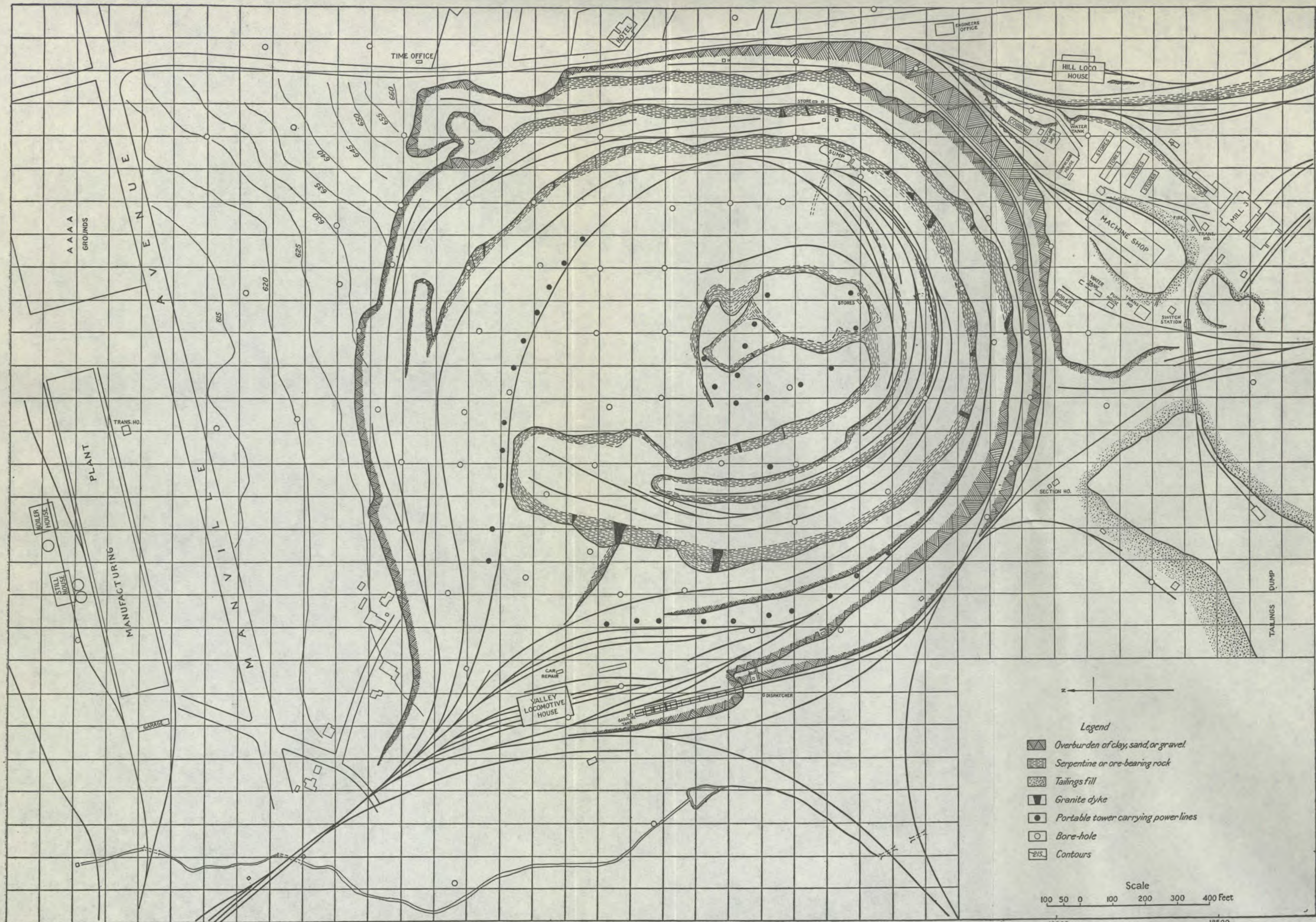
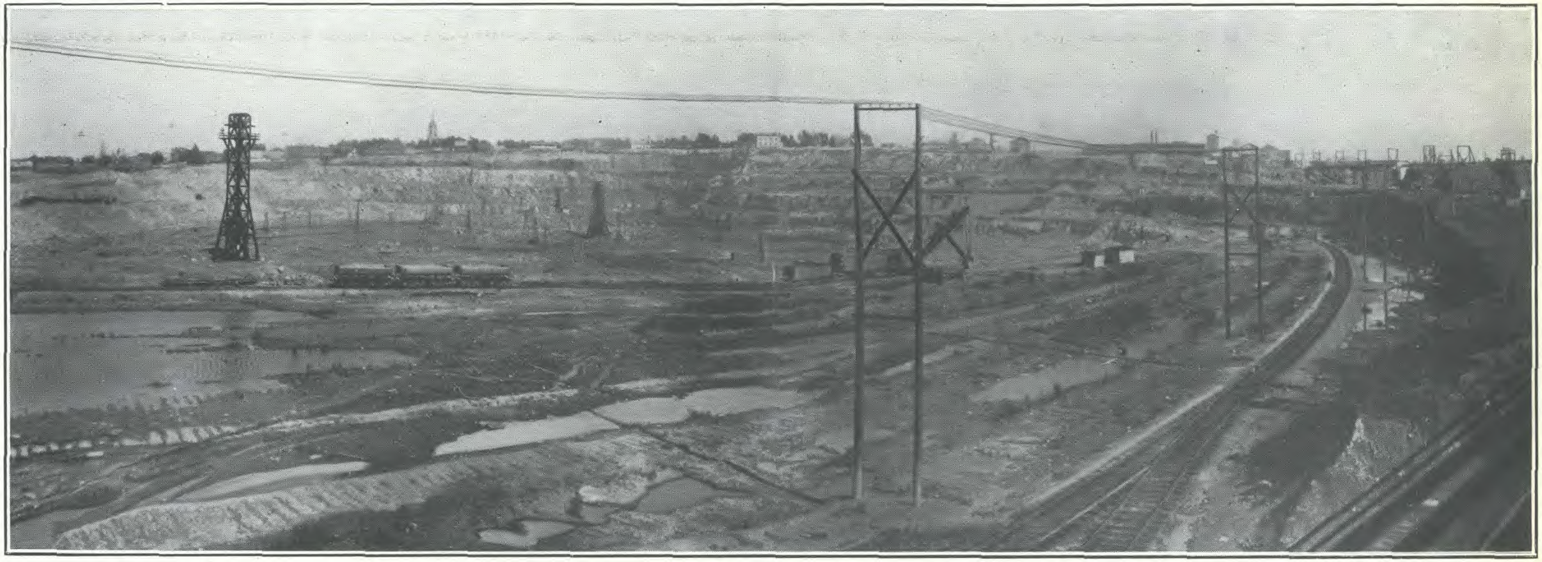


Figure 3. Pit map of the Canadian Johns-Manville Company, Asbestos, Quebec.



Panoramic view of Canadian Johns-Manville Company, Limited, Asbestos, Quebec.

and spacing of seams in the asbestos-bearing rock makes a larger number of holes necessary to effect the desired result. The semi-portable derrick-type of drill rig, carrying the largest pneumatic hammer-type machine, shown in Plate VIII, was first built and used at this mine. Its use has rapidly spread to other mining districts, where its adaptability has been found fairly universal. As applied at Asbestos, the system uses hollow drill rods up to 1½ inches in diameter and 40 feet in length. The manufacture as well as the shipping of these lengths of steel presented quite a problem, but has been successfully solved. The first supplies came from England, and later from the United States. There is now, however, at least one mill in Canada capable of rolling tool steel in the required diameter and lengths, at the same time maintaining a uniform hole throughout. The vibration to which this drill steel is subjected is terrific and requires steel of special composition and temper to stand the blows (1,200 per minute) from the power hammer above and maintain a cutting edge.

Three actively operating benches were in use at the time of inspection and, to facilitate steady work of shovels and the proper mixture of ore for the mills, a number of working faces are maintained on each bench.

Loading of ore is done by means of four steam shovels of the railroad type, with a dipper capacity of 2½ cubic yards each and one electric shovel with a dipper capacity of 4 cubic yards. For transportation 100 dump cars, air-operated, with safety chains to prevent accidental dumping are used. These cars have a capacity of 16 to 20 cubic yards. A squadron of 18 steam locomotives maintains service in and around the pit. These, however, are to be replaced by 60-ton electric locomotives in the near future, it being the intention to have, within a very few years, the whole plant operated almost entirely by hydro-electric power.

The pit is kept free of water by means of canals carefully located around the sides of the pit and on the different benches to prevent surface drainage from entering. A certain amount, however, especially in flood season, combines with ground water which constantly enters through rock crevices and finds its way to a central sump. From this it is pumped by two electrically driven centrifugal pumps which deliver it beyond the pit rim. Auxiliary pumps operate in a similar manner to empty catch basins higher up. Portable pumps which may be operated by steam or compressed air, are held in readiness for emergency service.

The material required to be handled by the above mining and railway equipment, totals approximately 15,000 tons per day of 20 hours. About 6,000 tons of this represents ore which goes to the mills, the balance consisting of waste rock and surface stripping which goes direct to the dumps.

Crude fibre is picked in the pit and cobbed by hand.

Hand-sorting of rock is not practised; the classifying into mill ore or waste rock (mostly lean serpentinized rock or granitic dyke rock) is performed with reasonable accuracy by the skilful shovel operators.

The railway traffic for the plant and the town, as well as for the surrounding country, is handled by a fully owned subsidiary, the Asbestos and Danville Railway Company. The main line, connecting with the Canadian National railway, is only 4 miles in length, but has over 20 miles of branches and auxiliary tracks. Including the mill tailings, which are also hauled to the waste dump in standard gauge automatic dump cars, the local railway system handles daily over 20,000 tons of freight, of which raw asbestos and manufactured goods represent but 2½ per cent; considerable other raw materials are shipped into the factory for combining with asbestos to make up the various products.

One can thus appreciate the vast amount of work required before the asbestos or articles made therefrom are ready for market.

The milling procedure is as follows: locomotives haul trains of cars over the crusher bins, where they are dumped into large receiving bins. The ore is fed from these bins, through power controlled gates, on to heavy cast steel apron feeders into the primary crushers. These latter will accommodate rock 48 inches by 60 inches. The 8-inch rock, the product of these crushers, is conveyed to trommels where it is sized, the fines, or material passing through the trommel openings, going direct to a battery of rotary dryers. Oversize from trommels is conveyed to secondary gyratory crushers, which crush material to 2 inches. This product combines with fines from the trommels and goes direct to the dryers. The horizontal rotary dryers are mechanically fired by means of automatic stokers. Ore from the dryers is passed through combined disintegrators and fiberizers, passing thence to sizing screens in closed circuit. The fibre is aspirated from the dry, broken down ore while passing over vibrating screens, the action being similar to that of a vacuum cleaner. It is further screened, cleaned and graded, and put up in 100-pound bags for shipment. The mills are electrically operated throughout. Tailings, or waste material, from the mill is so disposed on separate dumps as to make it economical to re-work this material if found necessary at some future date.

A section for Safety and Industrial Health is in charge of a safety engineer and an officially appointed medical officer. Regular plant inspections are conducted by these men and their staffs. All new employees are required to pass a physical examination, and every employee is granted an annual medical examination free of cost to himself.

A Safety Committee functions for every department, and one of the outstanding policies of this company is regard for the safety and welfare of its employees. Every means is used to improve conditions and to lessen the possibility of accidents. Each accident is the subject of a report by the safety inspector, while all serious cases are handled direct by the management. Helpful recommendations are made by the departmental Safety Committees, acting as advisors and inspectors, with this end in view. All mining accidents of other than a minor nature are reported to the Inspector of Mines for the province of Quebec, in accordance with Mining Law No. 149, and all serious factory accidents to the Inspector of Industrial Establishments, under the Quebec Industrial Establishments Act of 1925 (chapter 182 R.S.P.Q.). A special report is made to the Quebec Workmen's Compensation Committee on all compensatable accidents over the signature of the company doctor and safety engineer. All new employees are given instruction in the prevention of accidents by the employment bureau staff prior to starting work, and thereafter by their foreman. Competition between the departments in accident prevention is fostered and stimulated by the award of a Safety Flag, to be displayed in a prominent place by the department having the best accident record during the preceding month. Special employees are being trained in First Aid, and these have charge of the first aid stations located at different points about the plant.

A hospital is maintained and thoroughly equipped by the company, with an operating room and the latest scientific apparatus for X-ray, violet ray and diathermic treatment. The company doctor and two bilingual nurses are in charge of the patients, a 24-hour service being invariably maintained. These facilities are available to members of employees' families at moderate prices.

The Canadian Johns-Manville factory manufactures a full line of asbestos products, the principal ones being asbestos felt, paper, millboard, asbestos cement shingles, roll roofing of all kinds, pipe and furnace insulations, textiles, packing, cement, and paints. This factory utilizes a considerable part of the raw asbestos prepared at the mills and has a capacity sufficient at this time for the needs of the Canadian market, and in addition a foreign trade is being developed.

Nicolet Asbestos Mines, Limited

President: G. G. Gabrielson.

Manager: G. M. Boyd.

Sales Office: Nicolet Asbestos Mines, Limited, Inc., 25 Broad Street, New York. President: A. A. Martin.

Location: Lots 20 and 21, range VI, Tingwick township.

The pit and mill of the Nicolet Asbestos Mines, Ltd., are in Tingwick township, Arthabaska county, 7 miles east of Asbestos. The company's shipping point is at Tingwick Siding on the Canadian National railway, a distance of 10 miles, halfway between Warwick and Kingsey.

The company employs an average of 95 men.

The present size of the pit is 350 feet long, 200 feet wide, and 50 feet deep at the end.

The drilling equipment consists of a Canadian Ingersoll-Rand duplex air compressor (18 by 11 by 14), delivery 1,225 cubic feet of air per minute, driven by a direct-connected synchronous, separately excited, 200-h.p. motor; three jackhammers, one drifter, and one block hole drill. There is also a No. 4 Leyner drill sharpener.

The broken rock in the pit is loaded by a gasoline shovel into a 10-ton, end-dump car, and hauled by a single drum hoist driven by a 100 h.p. slip ring motor to the primary crusher bin. The cars dump automatically and return by gravity to be reloaded.

The crushing plant consists of a 28- by 36-inch Traylor Bulldog jaw crusher which is capable of crushing 105 tons per hour, from shovel size to 5 inches. The secondary crusher is a 4-foot Symons cone crusher fitted with a corrugated bowl which will crush 110 tons per hour from 5 inch to 1½ inch.

The drying equipment consists of two 5½- by 40-foot, rotary shell type dryers driven by two 40 h.p. induction motors. The hot gases from the furnaces pass directly through the dryer shells and out through 60-foot stacks supported by the steel dust bins at the discharge end of the dryers, the forced draught being supplied under the grate bars of the furnaces by a No. 8 Sheldon fan driven by a 10 h.p. motor. These dryers together have a capacity of about 50 tons per hour in wet weather. There is space provided for the installation of a third dryer which will be installed when required.

The capacity of the mill is slightly over 50 tons per hour, with provision for installing a second unit of the same capacity up to 100 tons per hour, which is the capacity of the crushing and rock handling equipment at present in dry weather.

In the milling methods there is no radical change from those employed in asbestos mills in other districts, Jumbos, shaking screens, fans, and collectors being used throughout. Of these machines, there are five Jumbos in groups of three and two, followed by five double shaking screens with two suction hoods on each. The fibre sucked up is graded on shaking screens and in rotary graders.

The grades being made are short spinning fibre, shingle fibre, paper stock, and cement stock.

The mill recovery is very satisfactory and is improving as the ore in the pit reaches the deeper areas away from the weathering influence.

OTHER LOCATIONS AND PROSPECTS

There are many asbestos locations and prospects throughout the asbestos district, from East Broughton to Colcraine, on some of which a limited amount of development work has been done. Further exploration would be required to determine their value, that is, if surface indications warranted any work. Commencing with the most northeasterly locations, and proceeding in a southwesterly direction, the principal locations are:

Dorchester County

Standon Township

Considerable serpentine outcrops on lots 10 and 11, range IX, and prospecting has been done by trenching in the overburden and by sinking test pits. One pit is 7 feet by 7 feet and 7 feet deep. A trench 140 feet long is 2 feet wide and 2 feet deep. The serpentine contains harsh fibrous picrolite, but no commercial asbestos. The areas are at the northeasterly limit of a series of serpentine outcrops extending across the southerly part of the province on the southwesterly part of which are situated the producing pits of East Broughton, Thetford, and Black Lake. The lots are 12 miles distant by highway from Ste. Germaine, a station on the Chaudiere division of the Quebec Central railway.

Cranbourne Township

In this township, on lots 19 and 20, range VI, the rock is exposed in two trenches, each 120 feet long, 2 feet wide and 2 to 3 feet deep. The rock resembles that mined at East Broughton, the fibre being of the slip variety. The rock varies in colour from a soft yellow to a hard grey. There are also some small cross-veins up to $\frac{3}{8}$ inch in length, showing in a prospecting shaft 8 feet by 8 feet in section, and 26 feet deep. The amount of vein fibre is very little and the slip fibre is harsh.

On lots 23 and 24, range V, considerable development was done, probably 20 or 30 years ago, one shaft having been sunk to a depth of 70 feet, and a drift run from it at a depth of 35 feet. In 1922, trenching and test-pitting was done in 18 places. The upper 30 feet of the shaft is in hard rock barren of fibre. In the lower part, however, the rock resembles that at East Broughton, and in addition to slip fibre, contains a few veins of cross-fibre of a light yellow colour and fair quality. These cross-veins run up to one inch in width. On lots 37, 38, and 39, range V, a band of serpentine about 600 feet in width runs along and across the Etchemin river. Prospecting has been done by trenching and sinking in 16 places. One pit, sunk near water level, reached a depth of 30 feet. Bands of slickensided serpentine carrying a little harsh slip fibre on the faces, alternate with hard massive serpentine in which thread-like veins of cross-fibre form a network. In only one or two places were veins as wide as $\frac{1}{8}$ inch observed.

Beauce County

Broughton Township

Southwest Half of Lot 13, Range III. The northeasterly terminus of the productive serpentine belt is found on the westerly part of this property, known as the "Cliche" property; no outcrops of value having been discovered farther east than this. The serpentine belt crosses the property at a distance of 800 feet south of the main road; its width appears to be at least 75 feet. The material on the dump at a series of five small pits shows fibre in fine fissures of dark green, much twisted and shattered serpentine.

Northeast Half of Lot 13, Range IV. This property known as the Miller mine, or Cowling lot, was opened in 1898, and about 1920 became a part of the Boston Asbestos Company holdings, now in the Asbestos Corporation, Limited.

Southwest Half of Lot 13, Range IV. This ground known as the Roy outcrops is now a part of the Asbestos Corporation, Limited, through its acquisition of the Boston Asbestos Company, Limited.

Northeast (East) Part of Lot 13, Range VII. Adjoining the holdings of the Quebec Asbestos Company, Limited, to the northeast, and the Broughton Asbestos Fibre Company to the southwest. A small mill was erected on it in 1921-22 by Joseph Poulin, but was in operation for only a short time.

Lot 14, Range VII. Known as the Fraser property, this lot has been owned by the Asbestos Corporation for some years. In 1921 the mill was equipped with a crusher and stack dryer. A trial run was made after which operations ceased. Mining prior to 1910 was confined to a crude vein which was developed on the southeast margin of the serpentine, close to the contact with the overlying schistose slates, which dip at this place to the southeast, at an angle of 65 degrees.

The asbestos vein, which in places assumes a thickness of 10 inches to 12 inches, follows a wall of soft talcose rock or soapstone from 12 inches to 14 inches thick. The quality of the asbestos is excellent; but the veins are irregular, splitting up sometimes into fine stringers disseminated through the serpentine, and at other places uniting and forming a continuous lead for a length of 100 feet. Some of the shorter fibre appears to be somewhat stiff and hard in texture. Whenever the vein assumed a large size the fibre was soft and silky. Three shafts were sunk to a depth of 60, 62, and 78 feet, respectively, following the dip of the soapstone. The main pit is now full of water.

Southwest Half of Lot 13, Range VII. This lot, known as the Tanguay lot, was purchased in 1928 by the Asbestos Corporation, Limited.

Southwest Half of Lot 13, Range VIII. At one time known as the Taschereau property, it was acquired by the Montreal Asbestos Company, and a mill was built on it by the Champlain Asbestos Company in 1909. After exploration of this lot and that adjoining it to the west, being the northwest half of lot 13, range IX, Broughton township, in 1928, by diamond drilling, both were acquired by the Quebec Corporation, Limited.

Lot 13, Range X. A hilly, wooded ridge crosses this property near the northeast boundary line, in a north-south direction. This ridge is composed mostly of a dark green, highly fissured and, at places, schistose serpentine. Along the middle line of the lot several excavations were made on a steep slope of the mountain, and a fibrous serpentine, similar to that at East Broughton, encountered.

Bras du Sud-Ouest. The outcrops on the Chaudiere river at the Bras du Sud-Ouest present different features from those in Thetford and Black Lake. Here, in many places, the rock is a serpentine breccia; being only partly serpentinized as an alteration apparently from a pyroxenite mass. Small veins of an impure asbestos of no economic importance may be seen.

Des Plantes River. Some asbestos has been found on the Des Plantes river, on the north side of the Chaudiere river, half a mile from the latter. Here black and grey altered slates and quartzites are in contact with a dark, slaty serpentine, which is cut by dykes of a white granite. Some small veins of asbestos can be seen on the outcrops.

Some encouraging features have been noticed on a property higher up the river, close to High falls. The serpentine here has a different character from that in the property above described, being compact, massive, and showing vein fibre.

Megantic County

Thetford Township

West Half of Lot 2, Range V. Several excavations in the easterly part of the property exhibit a fibrous serpentine rock similar to the rock found on the next lot to the east. The principal pit measures 8 feet by 10 feet, the bottom being in fibrous material.

Lot 5, Range V. This lot, on which slip fibre serpentine shows, became the property of the Asbestos Corporation, Limited, through its acquisition of the holdings of the Bennett-Martin Asbestos and Chrome Mines, Limited, as did also lots 10, 11, 12, 14, and 17.

Lot 13, Range V. Developed at one time by the Robertson Asbestos Company, this lot is now included in the holdings of the Asbestos Corporation, Limited.

Lots 27 and 28, Range V. On these lots the mill and pits of the former Bennett-Martin Asbestos and Chrome Mines, Limited, were located, since purchased along with the other holdings of the company by the Asbestos Corporation, Limited. The mill is idle and the ground is worked for the Beaver mill.

Other Locations. East of the railway, in Thetford township, serpentine is seen on lots 10 and 11, range VII; on lots 14, 15, and 16, range VIII; lots 14 and 15, range IX; and on lots 5, 7, 9, and 10, range X. The rocks in all these places do not belong to the productive variety.

Leeds Township

Near Kinncars Mills several outcrops of serpentine have been located, but, so far, not much asbestos has been found in them. In the concession of Ste. Catharine on the road east of St. Sylvestre, some exploration work was done, but nothing of importance was found.

Coleraine Township

Lot 26, Range A. In several large pits indications of veins are quite numerous; but the rock as a whole, appears to belong to the harder and drier variety, indicating an approach to the comparatively barren belt farther to the southeast. A number of short fibre veins occur in this area; but, generally, milling material predominates. On lot 25 a little work of an exploratory character has been done, and the rock here also appears to be of the harder variety.

Lot 27, Range A. This lot passed to the Asbestos Corporation, Limited, when it acquired the holdings of the Maple Leaf Asbestos Company, Limited.

Lot 26, Range B. On this lot a mill was erected by the Asbestos Fibre Company, Limited, the holdings of which were acquired by the Asbestos Corporation, Limited.

Lot 23, Range B. Several pits along the line between lots 23 and 24 show a number of veins of fibre of the Thetford variety.

Blocks A and B. At the Paré mine (formerly Lambly mine) a small mill was erected by the Canada Asbestos and Chrome Company, Limited. Two cableway derricks were used for hoisting ore and rock. Practically all the ore was milled, and a little crude fibre recovered. Operations ceased in 1927.

Frontenac County

In Adstock township several outcrops of serpentine can be found, but the rock seems to lack asbestos in paying quantities.

Wolfe County

Ham Township

Lot 13, Range VI, 2 Miles from St. Adrien Village. The distance from the nearest railway station, Weedon, on the Quebec Central railway, is 20 miles.

The length of the serpentine belt is 815 feet, and its width at least 105 feet. Small veins, $\frac{1}{8}$, $\frac{1}{4}$, and $\frac{3}{8}$ inch thick, occur in irregular fashion through a hard, dark green serpentine.

Asbestos has been found on one of the islands of Nicolet lake, township of South Ham. The serpentine rock which forms the large island rises abruptly out of the water to a height of 70 feet, and is apparently seamed throughout with fine asbestos veins. Picrolite is met with occasionally; this is generally brittle, and in places merges into mountain leather.

Richmond County

Shipton Township

Lot 12, Range V. In the northerly part of the lot serpentine occurs flanked by granite towards the west. Exploration was carried on at two different periods, in 1895 and in 1909. In a pit, 20 feet by 25 feet and 5 feet deep, a number of asbestos veins and stringers can be seen in a dark green serpentine.

Other Locations. On lot 9, range VIII, a number of small veins of asbestos occur, as well as on lot 12, range V, and on lots 9 and 10, range X.

Cleveland Township

The Richmond Location. Some prospecting has been done on the serpentine range located in the immediate vicinity of a flag station, Coris, on the main line of the Canadian National railway, between Montreal and Sherbrooke, 4 miles east of the town of Richmond. The area prospected covers 600 acres, more particularly the southwest half of lot 5, and of lot 6, range XIV; and the whole of lots 5 and 6, range XV.

Blasting has been done in several places along the eastern slope of the mountainous range on lot 6, ranges XIV and XV. The most westerly deposit is located at a distance of about 1,500 feet in a northeasterly direction from the railway track near the foot of the hill. The opening was blasted along the hillside in serpentine; the exposed rock face being 40 feet wide, and from 12 to 15 feet high. Asbestos veins occur along the rock face over a width of 3 feet; they are parallel to each other, and are from $\frac{1}{8}$ inch to $\frac{3}{8}$ inch thick. The deposit has the appearance of a lode with distinct cleavage planes striking north 70 degrees east, and having a dip to the north. Part of the serpentine has been quarried, and the dumps nearby contain some milling material.

Another opening was made near the dividing line, on lot 6, between ranges XIV and XV. It was blasted along the hillside, 50 feet wide, and from 10 to 15 feet high. A number of asbestos veins were uncovered, most of them $\frac{1}{8}$ inch to $\frac{3}{8}$ inch thick.

Brompton Township

Lot 26 and Half of Lot 25, Range IX. The property comprises in all 350 acres, on which some work was done in 1889 by the Brompton Asbestos Company. It is reported that some of the fibre is of good quality. The rock is associated with masses of diorite and slate containing white garnets and differs from that of Thetford and Black Lake. It is harder and darker in colour, and in places becomes talcose in appearance. The area, as a whole, has not been productive to any great extent.

Brome County

The Eastman Locations. A good deal of exploratory work was done in the years 1906, 1907, and 1908, around Eastman, a station on the Canadian Pacific railway, 28 miles from Sherbrooke and 78 miles from Montreal. The serpentine belt south of this locality was prospected, but so far no operations have been on a commercial scale.

Bolton Township

Lot 2, Range XI. Two bands of parallel asbestos stringers, $\frac{1}{8}$ inch up to $\frac{3}{8}$ inch thick, occur in a dark green massive serpentine on the side of a precipitous mountain, not far from Orford lake. Three prospect pits show two similar occurrences, in one of which fair milling material may be seen.

Lot 6, Range VII, called the Parker Lot. Prior to 1910, the Brome County Asbestos Development Company did some prospecting work on this lot and laid the foundations of a mill. In an open-cut a much fissured fibrous serpentine can be seen in which asbestos stringers are frequent.

Lot 10, Range VII, Benoit Lot. The serpentine formation outcrops west of Trousers lake in the shape of several parallel, rocky and steep ranges. On the western side of a ridge is an adit 15 feet high, 12 feet wide, and 20 feet deep. The serpentine is of a dark green and grey colour; is harder than the ordinary run of serpentine; and contains, occasionally, some small veins of asbestos. This property was also owned by the Brome County Asbestos Development Company in 1920.

Among the other asbestos outcrops in the vicinity is the John Carpenter deposit on cadastral lot 948, north of St. Etienne. About 80 feet of blasting has been done along the brow of a hill, in a dark green serpentine, which, on the surface, is in a crushed and foliated condition, but which becomes massive at a depth of a few feet. The exposed rock exhibits asbestos in a number of veins measuring from $\frac{1}{16}$ inch to $\frac{3}{8}$ inch thick. The asbestos, though in places silky, is to some extent brittle.

Asbestos has been discovered on cadastral lots 967, 744, 768, and 971; all located west of lake Nick, near Bolton Centre.

Potton Township

The Mansonville Locations. Near Mansonville, not far from the Vermont boundary, asbestos outcrops occur on a number of properties; but with few exceptions the veins are not of sufficient size to encourage actual development work.

Abitibi District

Lake Chibougamau

Reports on asbestos-bearing serpentine in the Chibougamau district of Quebec has been published by Dulieux[1] and the Chibougamau Commission[2], excerpts from the report of the latter being as follows:—

> Asbestos has been found in the serpentinized rocks of McKenzie bay, lake Chibogamau, Rapid river, (Faribault), lake Bourbeau and lake Asinitchibastat.

[1] Dulieux, E.: Ann. Rept. of the Dept. of Colonization, Mines and Fisheries, Quebec, 1908.
[2] Rept. of the Chibougamau Mining Commission of 1911, Dept. of Colonization, Mines and Fisheries, Quebec.

These serpentinized rocks are less pure than those of Thetford and Black Lake. Their asbestos-carrying properties appear to be somewhat localized by the presence of later intrusions, such as the grey dykes of Asbestos island in the western arm of McKenzie bay. Like the other mineral occurrences of this district, only a small area is uncovered, and the possibilities of these serpentine belts are not yet exhausted.

Considering, however, the prospects already discovered, the asbestos occurs in small veins, sometimes of normal silky fibre up to, in one case, an inch long, while a slip fibre as long as 1¼ inches was seen; also, there is a variety of picrolite, which weathers into tufts of harsh strong fibre. This, in depth, is so cemented with rock matter as to be of little value.

The silky fibre often occurs as short filaments or veinlets which have a reticulating or an astomising form not unlike varicose veins; the fibre varies in length from $\frac{1}{16}$ inch to ¼ inch, in most cases. Besides this, there are larger veins of ½ to ¾-inch fibre of several feet long. These are comparatively rare. Slip fibre is not very common; the rocks, unless completely sheared to a shale-like consistency, do not show much slickenside.

At no exposure, in this district, which we examined, is there an appreciable quantity of No. 1 fibre. The maximum good fibre is ¾ inch long; this is comparatively rare, and the whole product as mill fibre seems unlikely to run as high as five per cent of the rock mass when mined in large quantities.

This statement does not exclude the possibility of better fibre and higher percentages in other places, as yet obscured by moss and trees, for the purest serpentine, which seems most favourable, may occur at other points than those already developed.

When visited by the writer in 1921 and 1928, no further work has been done in the pits than that described in the reports referred to above. This district is about 170 miles north of lake St. John. The active prospecting campaign now under way by several companies, on other parts of the serpentine belt, may disclose additional areas containing a higher percentage of asbestos of as good quality.

Papineau County

Templeton Township

Lot II, Range VII. Chrysotile asbestos has been mined from time to time in this locality during the past sixty years. However, owing to the small extent and the pockety nature of the deposits such ventures have proved unprofitable. The serpentine occurs closely associated with crystalline limestone bands which cut the gneiss in a northeast southwest direction. The asbestos serpentine deposits in places assume the form of concretionary masses like rounded boulders; as disconnected pockets; as small irregular masses; and as deposits with elliptical sections having a diameter from 3 to 50 feet and with serpentine walls varying from 6 inches to 3 feet in width.

However the serpentine is not continuous, being broken up into pockets and the asbestos veins gradually disappear, at depth.

The asbestos contains very little iron and in some places fibre from ½ inch to 2 inches has been found.

Small showings have also been noted on lot 14, range VII, lot 2, range VIII, lot 16, range V.

Other Localities. Some work has been done on asbestos showings in lot 16, range V, Portland West township; Blanche lake; and at Gull lake, Mulgrave township; but the quantity of asbestos is too small to render extraction profitable.

A small quantity of asbestos was mined many years ago south of Silver lake—on lot 20, range IX, Wentworth township, Argenteuil county, also in Denholm township on the Gatineau river in Hull county where quite extensive operations were carried on at one time.

All of the foregoing deposits are in rocks of Precambrian age and seem to resemble the Arizona deposits in mode of occurrence.

ONTARIO

Cochrane District

Deloro Township

The property lies near the centre of Deloro township, one mile east of Mackay lake. The nearest station, 9 miles distant, is South Porcupine on the T. & N. O. railway, 478 miles north of Toronto. A good road connects the claims with the South Porcupine-Timmins highway, 4 miles to the north.

Claim P-8709, on which the principal outcrops occur, comprises about 40 acres. P-8415 has an area of about 60 acres, and P-9745 about 20 acres.

In 1926, the Porcupine Asbestos Company, Limited, installed a plant, including an electric power line and 4-drill air compressor, and excavated a pit 200 feet long, 60 feet wide, and 40 to 60 feet deep. Asbestos was won from a series of seven zones running in a north-south direction in a soft green serpentine. The zones are parallel to each other and dip at an angle of 45 degrees to the east. They are separated by intervening bands of barren serpentine from 4 to 7 feet wide. Each zone contains a vein of No. 1 crude, one of No. 2 crude, and from 3 to 8 veins of short fibre. At times a vein of No. 1 crude may have an even width of one inch for a distance of 100 feet. To a depth of 20 feet, the colour of the fibre is amber; below that depth it is bright green. The quality of the crude fibre is excellent. One car of crude was shipped before operations were discontinued.

Comparative analyses of asbestos from this property and from the Quebec field, made by Milton Hersey Company, Limited, of Montreal, showed:

—	Porcupine	Quebec
Silica	40·85	40·49
Alumina	0·60	1·27
Ferric oxide	1·02	2·53
Magnesia	41·40	41·41
Combined water	14·64	14·06

In 1918 a deposit was opened up by Messrs. Forbes and Slade, 2 miles to the east of the Porcupine Asbestos Company property, on the Campsell claims.

The fibre, which in places runs as high as 25 per cent of the rock mass, is unusually harsh and brittle. Frequently in the veins the cross-vein fibre is mixed with or replaced by calcite or quartz.

Munro Township

P. E. Hopkins[1] mentions the occurrence of asbestos in Munro township, Ontario.

In many places the greenstones are much altered to serpentine. They are found in many parts of Munro township and in northeast Beatty. In lot 10, concession II, Munro township, the serpentine contains numerous veinlets of fibrous asbestos and a little magnetite, some of the veinlets being over one-half inch in width. This area might be worthy of investigation as a source of asbestos.

Timiskaming District

Bannockburn Township

Prospecting has been carried on at the Rahn deposits on the west side of Bannockburn township, in the Montreal River area, for a number of years by the Empire Asbestos Mines, Limited. The best route, by road and water, is said to be 12 miles by road to Shiningtree lake, 4 miles along that lake, 6½ miles from Shiningtree lake to Duncan lake, 15 miles along that lake, then 9 miles by road to Fibre lake.

The country rock, according to a report by James McEvoy[2], is a hard quartzite in massive beds and through this the serpentine rock is present in dykes and large masses. The exact outline of these dykes could not be seen owing to the surface covering, but the bordering ridges of quartzite tilted up by the serpentine rock can be seen for considerable distances, in one case over a quarter of a mile. At four points beside such ridges the contact has been uncovered by blasting out openings 5 to 10 feet in depth. These openings show that near the contact the serpentine rock is rich in asbestos deposited in the irregular veins typical of that mineral. The veins are up to 1½ inches in width and show good fibre remarkably free from discoloration, although only a few feet from the surface.

In the first two feet of rock next to the contact the percentage may be stated at 20 per cent, and for a width of 4 feet, at 10 per cent. Beyond 4 feet distance there was little fibre to be seen.

The fibre resembles that found in Deloro township, Porcupine district, Ontario.

Analysis of a sample is reported as follows:—

Silica	41·00
Magnesia	42·00
Alumina	1·00
Ferric oxide	1·00
Lime	Nil
Organic matter	Nil
Combined water	14·50

OTHER AREAS IN CANADA

Samples of asbestos from Arrowhead, B.C., Sudbury, Ont., and Ville Marie, Que., have been examined. The exact locations from which these came have not been ascertained. None of them, however, were of high grade, being harsh and brittle.

[1] Hopkins, P. E.: Ont. Bureau of Mines, vol. XXIV, pt. I, p. 176 (1915).
[2] Unpublished report.

CHAPTER VI

MANUFACTURE OF ASBESTOS PRODUCTS

ASBESTOS FIBRE COMPARED WITH ORGANIC AND INORGANIC FIBRES

In comparing asbestos with any other fine fibre, differences in structure or surface cannot always be perceived by the eye or by the touch; under the microscope, however, certain differences may be readily seen.

Fine silk threads and crude Thetford asbestos fibre examined side by side appear to be identical, whereas the former is of organic, while the latter is of inorganic origin. Manufacturers of asbestos fabrics realized the totally different nature of these two fibres when they attempted to spin the asbestos. They found that special methods had to be employed and suitable machinery designed in order to make the very fine filaments of which the fibre is composed, adhere together, thus facilitating the manufacture of fine asbestos yarn to be used in spinning. Wool fibre, cotton fibre, silk threads, spun glass, quartz fibre, etc., all possess one feature in common with asbestos; they may be drawn out in fine threads to be used in spinning.

Figure 4. Fibre of raw silk.

A difference is apparent when wool, cotton, or silk is made up in garments, while in the single fibre identification is not readily made, except by microscopic examination. The sheep's wool fibre illustrated in Figure

5, magnified 600 diameters, has a peculiar, serrated and notched appearance, similar to some plants of the coniferous type. The outer surface is formed of irregularly shaped scaly bands, or plates, which overlap one another. Their peculiar projections act like teeth, and cause the fibres to cling together when twisted. It is said that the more numerous the scales are, the higher the price the wool commands. Fine Saxon wool is reported to have no less than 2,720 scaly bands, technically called imbrications, per lineal inch; whereas in Leicester wool they are said to number only 1,850.

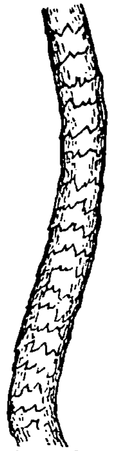


Figure 5. Fibre of sheep's wool, magnified 600 diameters.

Cotton fibre, especially the raw filaments, as seen under the lens has a twisted appearance, and its structural difference from asbestos fibre consists in the irregular and rough surfaces, which render it readily adaptable for spinning.

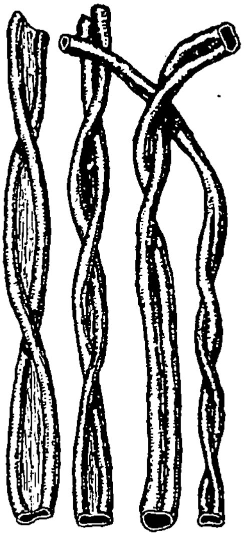


Figure 6. Filaments of raw cotton.

The usual method of determining the quality of cotton fibre, by feeling it with the fingers is necessarily a crude one; because—according to T. Gray (reference, Lecture before Franklin Institute)—the thickness of ordinary cotton fibre varies from 1/900 to 1/2000 of an inch. "Mississippi" delta fibre, considered one of the finest cottons, presents under the microscope a beautiful structure, and perfect development. The actual length of this fibre is 1/100 inch.

Figure 7. Spun glass.

According to the authority above quoted, from 300 to 800 twists of cylindrical tubes are in one lineal inch of cotton fibre.

Figure 8. Quartz fibre.

Mr. James Thompson[1] describes cotton fibre as follows:

The filaments of cotton are transparent glassy tubes, flattened and twisted round their own axes. A section of the filament resembles a figure of 8, the tube originally cylindrical, having collapsed most in the middle, forming semi-tubes on each side, which give to the fibre when viewed in certain lights the appearance of a flat ribbon with a hem or border on each edge. The twisted and corkscrew form of the filament of cotton distinguishes it from all other vegetable fibres.

Silk fibre possesses a multitude of peculiarities which, under the microscope, distinguish it readily from any other fibre, organic or inorganic. Each silk thread is composed of two separate filaments which are cemented together longitudinally. The surface resembles that of a fine glass rod; the line of junction of the two filaments is made perceptible by a fine groove.

C. V. Boys, in a paper before the Royal Institute in June, 1889, stated that two silk filaments when separated and washed, exhibited remarkable tensile strength; they were able to sustain a weight of 60 grains before breaking. This authority states that the carrying power is from 10 to 20 tons per square inch.

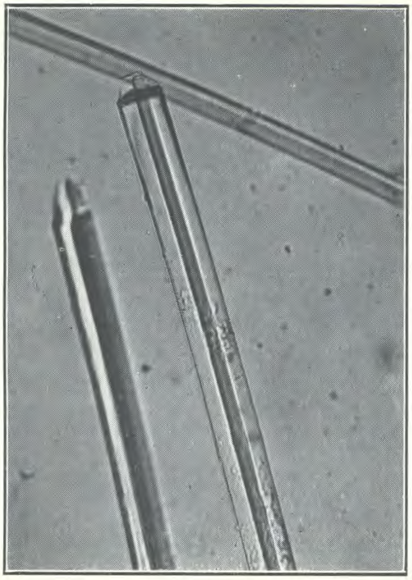
Cirkel had a number of photomicrographs of various Canadian and foreign asbestos fibres made to illustrate their characteristics and differences from other fibres. The illustrations show that asbestos fibre has one feature in common with other fibres, namely, that each apparently single fibre is in reality composed of a group of fine filaments. Under a more powerful microscope these filaments are seen to be formed of even finer filaments, and for micrometrical purposes fibres of 1/3000 of an inch in diameter have been successfully employed in the laboratory.

Asbestos fibre has no rough imbricated surface like wool fibre, but resembles a fine polished metal rod, free from any serrated surfaces; which explains the difficulty of the early manufacturers in their first attempts to spin it. The tensile strength of asbestos fibre in the mass is equal to that of silk. In attempts to measure the tensile strength of a single fibre it was found that the minute filaments slipped past each other, and no results were obtained. In the asbestos industry generally, tensile strength tests are made in the factories on asbestos yarn or rope, and although absolute accuracy cannot be claimed for these tests they are sufficiently accurate for all practical purposes.

Many difficulties were encountered in the attempt to study the character of the fibre under the microscope. When asbestos fibre is finely drawn out or separated into threads, their highly refractive qualities are at once apparent, and render irregularities in the structure of the filaments, or their special characteristics for purposes of identification, extremely difficult.

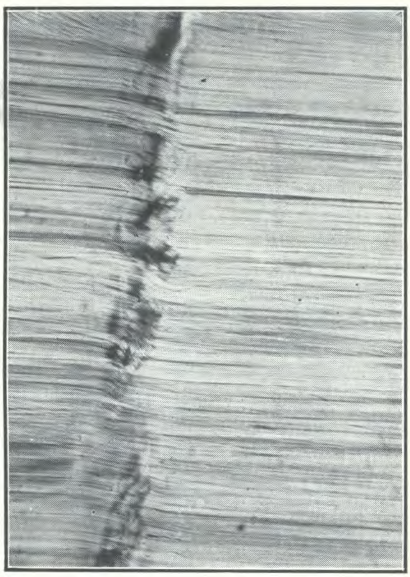
Optically all asbestos fibres show extinctions parallel with the axis of elongation; they are devoid of any pleochroic qualities. The outlines of the fibres, when examined under high microscopic powers, are round, prismatic, and polygonal; the majority being polygonal or round. All fibres exhibit, when examined under a common lens, the same characteristics of crowding, that is grouping together of numerous fine threads within what appears to be a single fibre. The actual size of the fibres of

[1] Thompson, James: "Mummy Clothes" (1891).



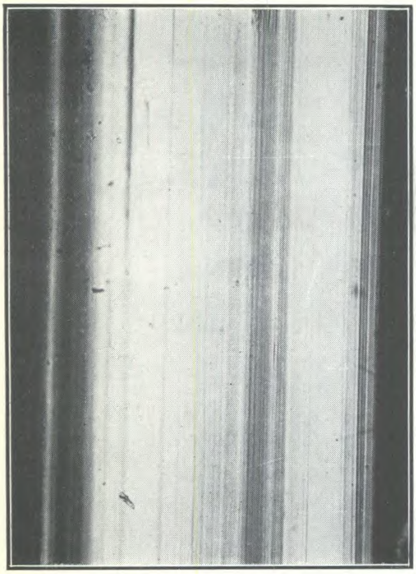
A. Spun glass. × 200.

B. Thetford fibre. × 250.

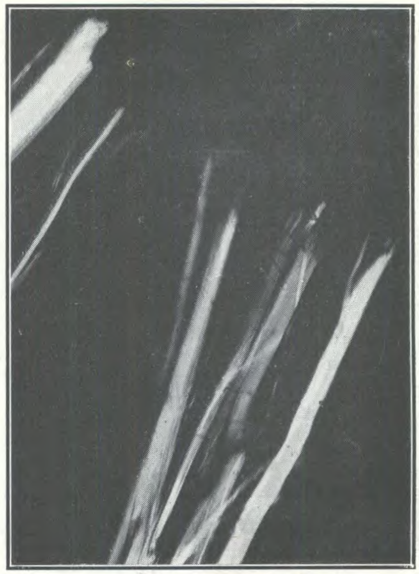


C. Black Lake fibre. × 350.

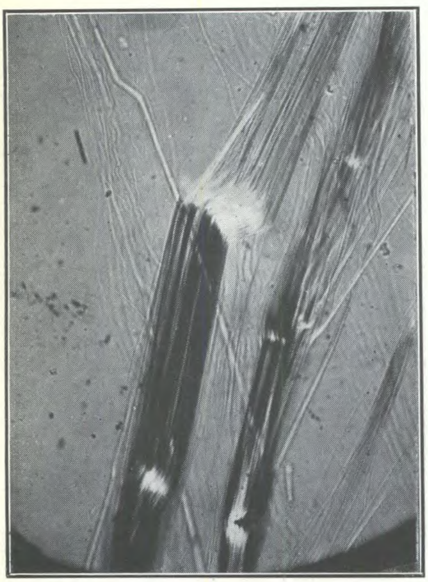
D. Black Lake fibre fracture. × 350.



A. Templeton asbestos fibre. × 350.



B. Thetford fibre ends. × 200.



C. Break in Thetford fibre. × 200.

D. Fibre from Urals, Russia. × 200.

all varieties—i.e. the diameter—is consequently indefinite, and although careful measurements have been made it can be demonstrated that even the finest filament measured is composed of fine threads, evidence that its division is infinitesimal.

The diameters of the smallest obtainable fibre of many asbestos varieties were determined by Dr. H. T. Barnes, Professor of Physics, McGill University, who furnished the following data:

—	Smallest diameter, millimetre	Number of fibres per lineal inch
Canada—		
Thetford	0·001	25,000
Black Lake	0·001	25,000
Broughton	0·0015	16,650
Templeton	0·0015	16,650
St. Adrien	0·002	12,500
Carded asbestos	0·001	25,000
United States—Grand Canyon, Arizona	0·00075	33,325
Casper mountain, Wyoming	0·00075	33,325
Russia, Ural mountains	0·00075	33,325
Siberia, Yenisei river	0·001	25,000
Africa, West Griqualand	0·009	27,775
Transvaal (Carolina district)	0·0015	16,650
Western Australia (Pilbarra district)	0·0015	16,650

Much difficulty was experienced in obtaining some of the photomicrographs of fibres, and it was necessary to use polarized light only, the single exposures being for six hours.

The following is a general description of the characteristics of each plate:—

In Plate XXVIIIA filaments of spun glass are shown. The rod-like nature is apparent; some of the threads are hollow in contradistinction to asbestos.

Plate XXVIIIB shows Thetford fibre. The two strings, respectively, marked a and b, although composed of thousands of individual fibres, have each all the characteristics of perfect crystals; the entire bundle exhibiting the optical qualities of a single fibre.

The Thetford fibres are beautiful in appearance; and when drawn out with the finger have an unctuous feel; in fact possess all the qualities of silk fibre. When in situ, they can be distinguished in most cases from any other asbestos fibre; but when drawn out, or subjected to mechanical treatment they lose their distinctiveness.

In the "micro" one bundle (*a*) is shown broken, and the fine ends can be readily seen. The two fibre bundles have been subjected to torsional movements and display immediately over their twisted points their numerous composite fine filaments, which appear in the "micro" as dark lines across the fibres.

Plates XXVIIIC and D are of Black Lake fibre, showing on one a fracture across the fibre, and in the other the broken end of a bundle of fibres. Of special interest in Plate XXVIIID is the infinitesimally fine fibres of which the bundle is composed.

Plate XXIXA illustrates a fine bundle of fibres from the Templeton deposits 20 miles north of Ottawa. Compared to Thetford and Black Lake fibre, its rod-like smooth surface resembles that of a polished metal. The nature of what is supposed to be single fibre threads is seen in Plate XXIXB. This shows that the fibres are not, as generally supposed, all like polished rods, but fine imbrications and apparently rough, undulating surfaces are plentiful.

The fibre resembles more a rough wooden stick with notches and many other irregularities; but it is clear that even if these detract from their smoothness, they add but little to their spinning qualities.

Plate XXIXC represents a break in a single fibre, the fracture being represented by the white portion in the centre of the photo. It illustrates again in a general way the extremely fine division of the fibre, especially noticeable above the fractures.

Plates XXIXD and XXXA are of fibres from Russia and Italy. No essential difference can be perceived between these and the Canadian fibre.

Plates XXXB and XXXC represent blue fibre from West Griqualand, South Africa. It exhibits a very coarse and fluffy appearance compared with the Canadian and Russian mineral, and a fracture in the fibre, as represented on Plate XXXC, shows distinctly the extremely minute filaments of which a single fibre is composed.

The other photomicrographs represent fibres from Carolina district, Transvaal; Pilbarra, West Australia; and Casper mountain, Wyoming, U.S. These fibres show the harsh rod-like structure, which to some extent differentiates them from the Canadian varieties.

The results of the microscopical investigations, covered above, may be summarized as follows:

1. The structure of asbestos fibre outwardly is almost identical with organic fibres, namely, that each apparently single fibre is composed of numerous, exceedingly fine filaments.

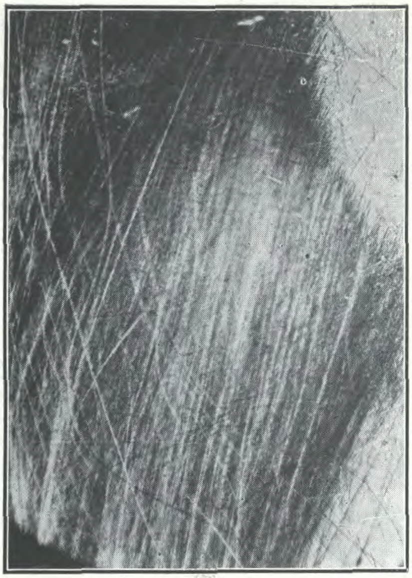
2. The difficulty of spinning asbestos fibre lies in the fact that, unlike silk, cotton, or wool, no imbrications or teeth-like obstructions are in evidence on the surfaces of any asbestos fibre.

3. The variations in outward structure of the fibres examined are not sufficiently marked to form a basis of reliable differentiation. One fact, however, seems to stand out, that is the glassy, or metallic, rod-like appearance of many asbestos fibres under high microscopic powers, with the exception of those from Thetford-Black Lake, Canada, and Russia.

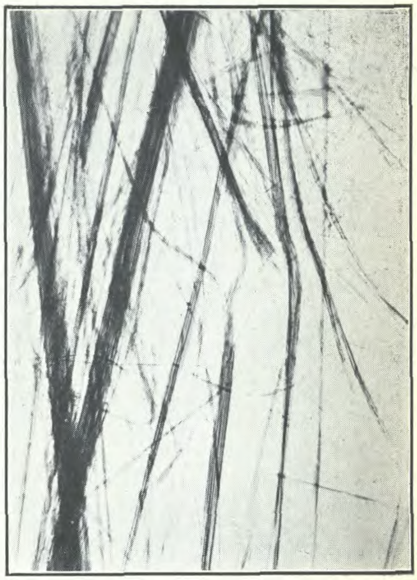
TEXTILES

The longer and better asbestos fibres, comprising No. 1 crude, No. 2 crude, and spinning grades, are the only ones used in the asbestos textile industry. Any of these, or combinations of these, in various proportions, with or without the addition of cotton, may be spun into yarns.

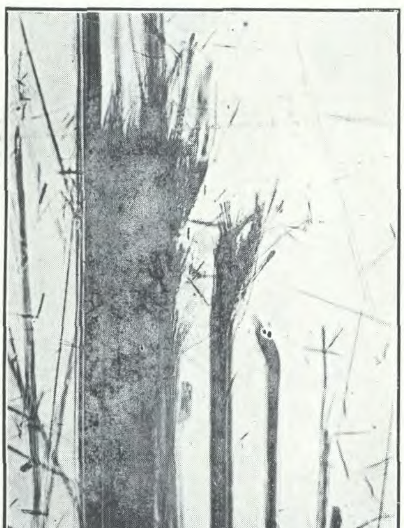
For a few purposes only No. 1 crude is suitable. Certain materials are made from No. 2 crude alone, whereas for other purposes both or either crude may be mixed with varying proportions of spinning fibres.



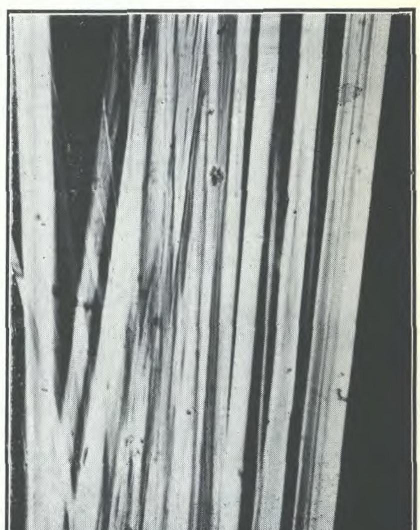
A. Fibre from Aosta valley, Italy. × 100.



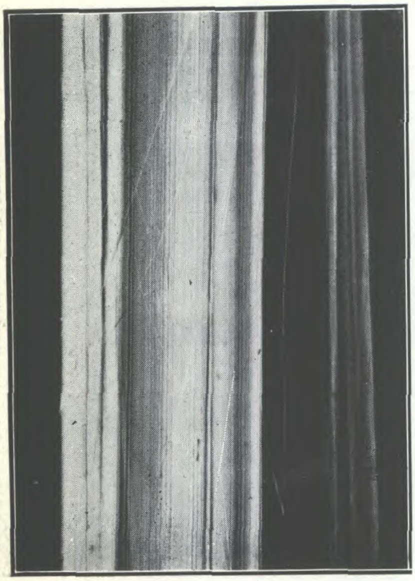
B. Asbestos fibre from West Griqualand, Africa. × 250.



C. Break in fibre from West Griqualand, Africa. × 350.

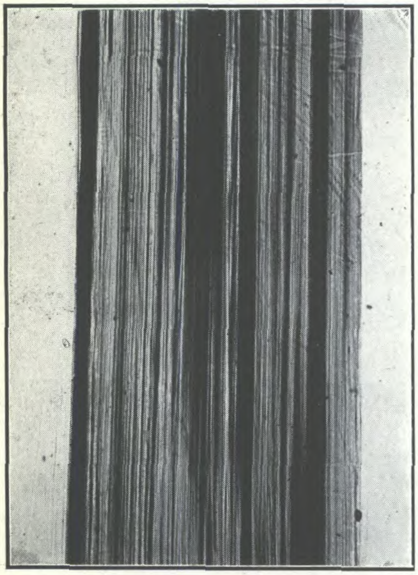


D. Fibre from Carolina district, Transvaal. × 200.

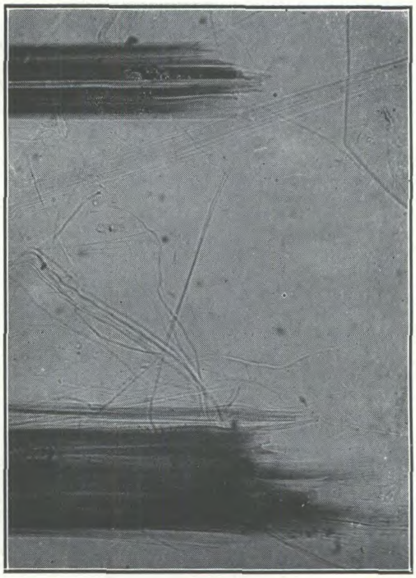


A. Fibre from Pilbarra district, Western Australia. × 200.

B. Break in fibre from Pilbarra district, Western Australia. × 150.



C. Fibre from Casper mountain, Wyoming. × 150.



D. Break in fibre from Casper mountain, Wyoming. × 150.

The grade of spinning fibre used may vary from one which tests 4 ounces out of 16 on the $\frac{1}{2}$-inch or top screen in the standard test machine to one as low as $\frac{1}{2}$ ounce on the top screen. The proportions of each fibre in the mixture are governed by price of fibre, availability of grades, and the type of finished article into which the yarn is to be manufactured. While it is true that a high-grade spinning fibre may contain a larger percentage of long fibre than No. 2 crude, yet the manufacturer is usually prepared to pay a considerably higher price, often double that of spinning fibre, for the crude in order that he may process it himself.

A manufacturer using a fibre from one source as a base may add to it fibres of various grades from one or more other sources, either to reduce the cost or change the quality of the finished yarn, or to supplement the available supply of the base fibre. At one time Canadian fibre and the better grades of Arizona fibre were considered indispensable in manufacturing the best yarns. High prices ruling in 1919 to 1921 and a scarcity of Canadian crude and spinning fibres caused manufacturers to experiment with the spinning of other fibres. In consequence, many other varieties are now employed, either alone or in combination with Canadian fibre, although in the opinion of practically all spinners interviewed no other fibre was found to be so satisfactory as that from Canada.

Asbestos from certain mines in Arizona on account of having a lower free iron content than Quebec fibre is regarded as being of special value for use in the manufacture of electrical insulation tape, especially where the highest strength is not a requisite. However, the supply of long Arizona fibre is limited, and much tape is made from Canadian fibre.

Preparation of Crude Fibre for Spinning

Crude fibre, as received from the mines or quarries, has undergone no treatment other than hand-cobbing. Masses of crude fibre with adhering rock are taken from the pits and dried on steam pipes. Boys and girls hammer the fibre free from the rock, flatten out the chunks of crude, and separate the cobbed fibre into two grades—No. 1 and No. 2 crude, according to length. Each grade is separately screened on a $\frac{3}{8}$- and $\frac{3}{16}$-inch mesh, respectively, shaking screen to remove rock, short fibre, and dust. The cleaned fibre is bagged, each bag holding 100 pounds of fibre. It still contains, however, a percentage of stone, short fibre, and dust.

Crude fibre is prepared for spinning by crushing to free it from rock, and to open it so that rock particles, short fibre, and dust may be cleaned out and the useful long fibre fluffed up or willowed.

Bags as received at the factory are dumped and the fibre shovelled in front of the mullers of a chaser mill, usually of the Chilian type. The mullers are edge-wheel rollers attached to a radial arm and revolving on a smooth surface. Some mills are fitted with splash boards and in others the sides are left open. The mullers vary in weight, diameter, and width, no size or type of mill having yet become standard, although the service required at all plants is practically the same. About 15 minutes are required to crush a batch of fibre, after which it is transferred to an opener or fiberizer, the latter usually being of the Saco-Lowell type. In some cases the operation in the Chilian mill is omitted, and the fibre opened and the stone particles shaken loose in a fiberizer fitted with beaters. Or, following the Chilian mill, the fibre may be passed through a set of stoner rolls for the removal of the rock. At another factory the fibre, after being opened, is blown into a long bin. Naturally the lighter fibre is carried to the farther end of the bin and remixing by hand is necessary.

Fibre from some sources after opening must be picked over by hand to eliminate bits of iron, wire, or wood. The presence of these foreign substances is a cause of constant complaint on the part of the manufacturers as serious damage may be done even by splinters of wood to delicate machinery.

The opened fibre is next passed over a shaking screen or through a trommel screen where it is cleaned of rock and dust, and lifted by air suction to storage bins. It is then ready for mixing with cotton. The proportion of cotton added depends on the type of fibre and on the purpose for which the finished material is to be employed. It rarely exceeds 20 per cent and may be as low as 8 per cent, or even 5 per cent. At this point African, Russian, or other fibres may be worked in; Canadian fibre being preferred as the base.

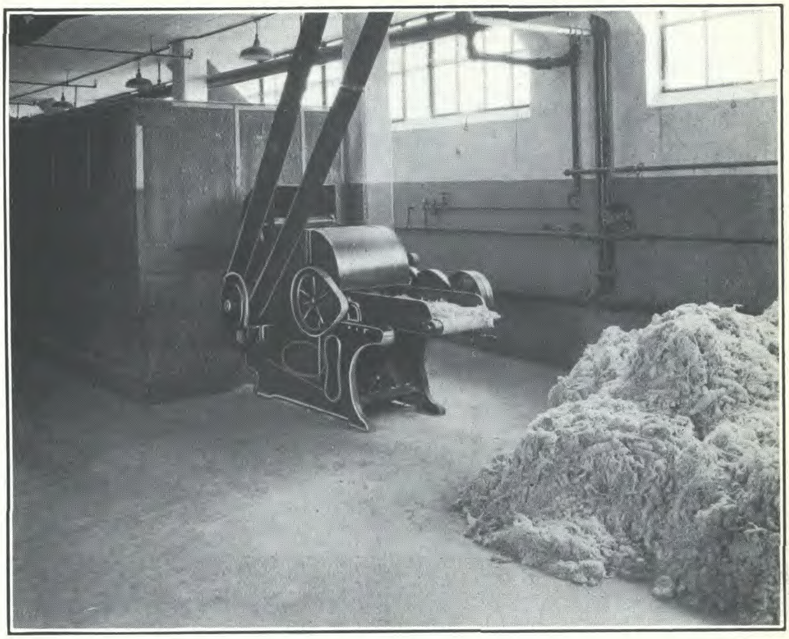
This mixing is accomplished in several ways, the more usual being to spread alternate layers of weighed quantities of fibre and cotton in a pile from which it is shovelled or blown into a mixer, a machine equipped with revolving beaters.

An improved method of adding cotton to the fibre is employed at one factory. A bolt of cotton unwraps at a fixed rate (by weight) on a travelling, slat-apron conveyer. On this sheet of cotton a determined weight of opened fibre is deposited in a layer, the whole going to a mixer and thence to storage bins.

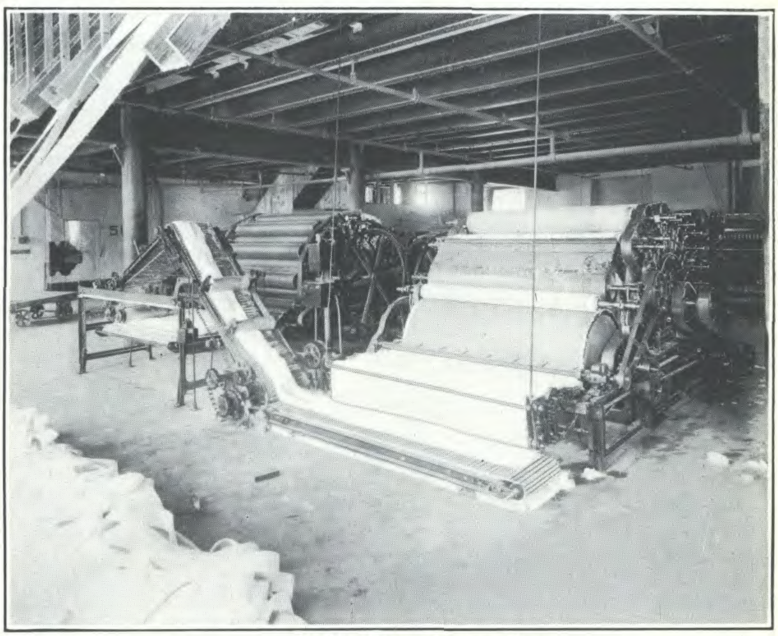
Carding

The mixture of asbestos and cotton is either carried to the carding machine in batches or blown in by an air blast as required. Carding consists in teasing the mixture on a series of revolving cylinders covered by strips of leather wound diagonally and fitted with close set, sharp, fine steel bristles. When dulled, the bristles may be re-sharpened, or a damaged section of a strip may be replaced. Carding combs the fibres parallel, and removes the remaining short fibre, bits of rock, and dust which may adhere to the fibre at this stage. The successive units in a card are known as picker rolls, cards, work rolls, fancy rolls, and doffer rolls. On emerging from the first carding machine in the form of a loose blanket the direction of flow is changed through 90 degrees. Passing over a camel-back it goes through a second carding machine. Double carding is said to increase the strength of the resulting yarn. From the last roll the fibre is stripped to a moving apron, where a set of reciprocating scrapers or rubbers condense it into rovings or unspun yarn, which is gathered in a roll on a Jack spool. A variation of this, however, is where the material passes from the condenser over a doffer roll and apron making a single-ply yarn without the intermediate stage of rovings, the yarn being wound on spindles.

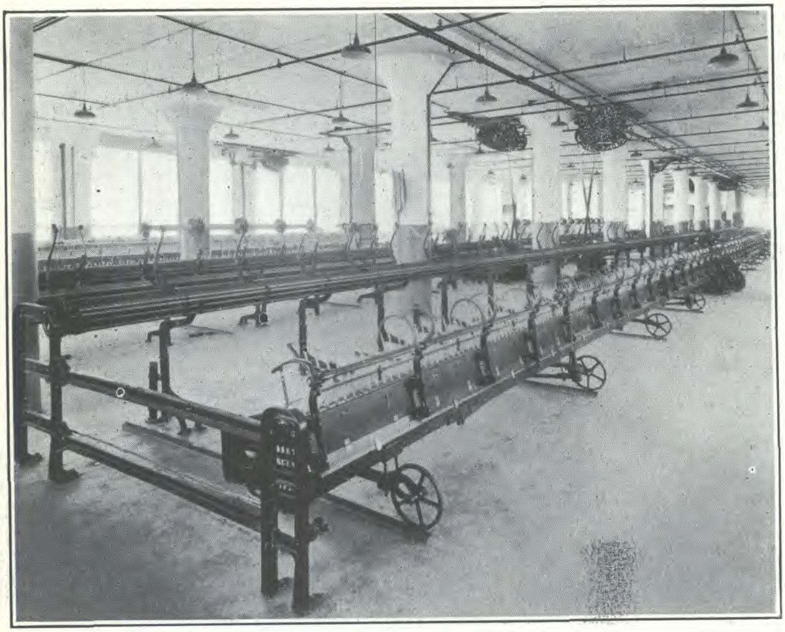
The card installation affords a measure of capacity of the plant. To keep one card running 10 hours per day requires about 5 tons of crude or spinning fibre per month. The total number of cards active in the



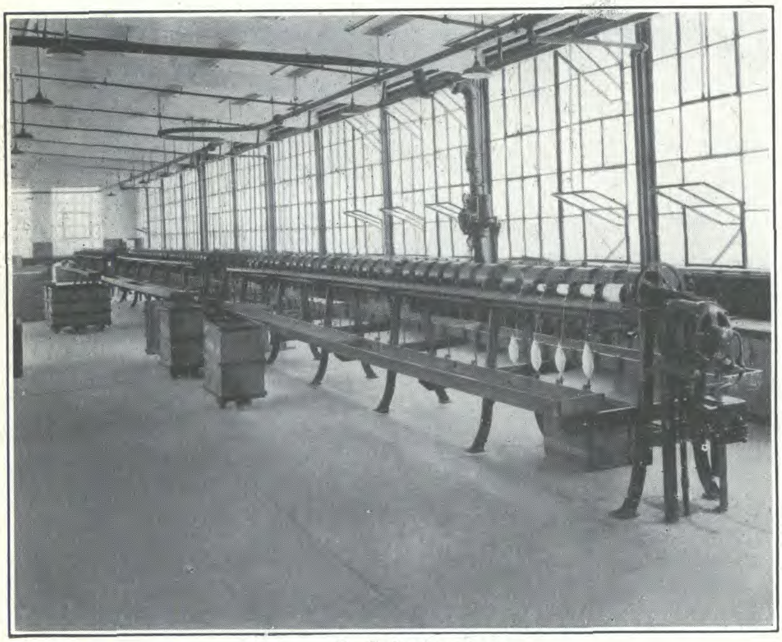
A. Mixing fibre.



B. Carding asbestos fibre.
(Photos by courtesy of Proctor and Schwartz.)



A. Winding yarn.



B. Spinning yarn.

(Photos by courtesy of Proctor and Schwartz.)

factories of the United States in 1928 was estimated at about 100, so that the fibre requirements of the existing installations in these grades is about 6,000 tons per year under normal conditions. With an increased demand for the products a larger output could be obtained by running the cards more hours per day.

Spinning

The Jack spools of rovings from the cards are mounted on a mule and yarn spun which is wound on spindles, either of wood or paper.

Handling in the mule is one of the most severe operations. The travel backward and forward to draw out and spin the thread covers a distance of 53 inches. During half the travel the yarn is taut and under tension. One or two men are employed constantly repairing broken threads. At some plants humidifiers have been installed to maintain a uniform moisture content in the atmosphere. Each mule has a bank of 350 spindles, so that the capacity of a plant can be readily gauged from the total spindle equipment.

Carding machines, if not properly covered, allow a great deal of fluff to escape and float in the air. Likewise if the spinning floor is not kept clean the air becomes loaded with fluff. While this condition may not actually be harmful to the workmen, the dust in the atmosphere reduces their efficiency. Some operators refuse to use odd lots of blue or yellow fibre, or harsh fibre, as remnants remaining in the building are liable to be carried on air currents into yarn subsequently spun. Material woven from such contaminated yarn is apt to show blue, yellow, or hard spots, and be inferior to that spun from clean Canadian fibre.

The spindles of single-ply yarn are transferred to twister machines and twisted into two-ply or three-ply yarn which is assembled on spools. Spools of twisted yarn in turn are carried in baskets and mounted on creels for weaving, on end winders for filling bobbins, or on braiding machines.

When yarn is to be used for making articles such as brake-lining or packing it is desirable to reinforce it with fine copper, brass, or lead wire; brake lining is now made in England without metallic wire reinforcing. Three strands of single-ply yarn and two strands of brass wire of gauge Nos. 0·006, 0·007, or 0·008 are twisted together for weaving to form brake-lining. For yarn to be used in weaving packings, a single, fine lead wire or one to three strands of brass wire are twisted with two or three strands of asbestos yarn.

The creels are moved to looms; and cloth, tape, brake-lining, or packings are woven in a manner similar to that employed in weaving wool, cotton, or silk.

At any stage manufacture in a factory may be regarded as complete, and rovings, yarn, thread, cloth, braid, brake-linings, or packings sold, some for further processing or as the base of manufacture for a large variety of articles.

Yarn

Methods of manufacturing asbestos yarn are given by J. W. Weaver[1]:

Asbestos yarn is produced in a variety of sizes and in various qualities. The asbestos textile industry uses the term "cut" as a unit of measure for classifying the size or yardage per pound of asbestos yarn. Sizes for commercial requirements run from 1-cut to 30-cut, though sizes under 5-cut are rarely called for. Five-cut yarn measures 500 yards to the pound with a tolerance of 50 yards under and 50 yards over; 30-cut runs 3,000 yards to the pound with a tolerance of 100 yards minus and 100 yards plus.

Asbestos yarns are made by spinning selected grades of asbestos fibre into single strands. The yarn is given additional strength by twisting two or more plies together, producing thereby a product known as 2-ply, 3-ply, etc. For still greater strength, and for particular purposes, asbestos yarn may be spun with copper, brass or other fine wire, producing "metallic yarn."

The individual asbestos fibre is unlike any other fibre used in the textile industry in that it has the same diameter throughout its entire length; it is smoother than any other fibre, having no nodules, twists or any irregularities on its surface that will cause one fibre to cling to another. Asbestos fibres slip past each other so easily that the production of 100 per cent asbestos yarn is slow and expensive. To produce asbestos textile commodities at the speed and in quantities required for commercial purposes, it is necessary to mix with asbestos fibre some other kind of fibre that will act as a vehicle to carry the asbestos through the manufacturing processes.

Cotton is used almost exclusively for the purpose. Experience has shown that a cotton content of approximately 20 per cent in the finished yarn forms a yarn that is satisfactory for most purposes. Long Sea Island or Peruvian cottons are generally used in order to secure a strong spinnable yarn.

Methods of Testing

Cotton Content Determination.—The cotton content of metallic asbestos yarn shall be determined after all the wire has been removed from the test specimen. The asbestos yarn shall be washed thoroughly with chloroform or ether to remove all grease, fats, and oily matter and shall be dried to constant weight at from 100 to 105° C.

A test specimen of about one gram of the extracted and dried yarn shall be weighed and placed in a combustion boat and the boat placed in a combustion furnace. The drying and absorption train shall be attached and a gentle current of thoroughly dried and purified oxygen shall be started through the apparatus. Heat shall then be applied until the combustion tube becomes dull red and the tube shall be subjected to this temperature for 15 or 20 minutes. The flow of oxygen shall then be continued for an additional 15 minutes to remove the products of combustion from the apparatus. The water from the products of combustion shall be removed by passing them through bulbs containing sulphuric acid, and then through tubes containing calcium chloride. The carbon dioxide shall be removed by absorption by passing through caustic potash (KOH) in a Vanier or other absorption bulb. The weight of the bulb being known, any increase in weight indicates the amount of carbon dioxide absorbed.

Calculation: The percentage of cellulose shall be calculated from the following formula:

$$\text{Percentage of cellulose } (C_6H_{10}O_5) = \frac{\text{Weight of } CO_2 \times 0{\cdot}6137}{\text{Weight of sample}} \times 100.$$

[1]Weaver, J. W.: in "Textile World", vol. 72 p. 2485+, Oct. 29, 1927, "Asbestology". March and April, 1928; and in "Asbestos", April, 1927.

A. Twisting yarn.

B. Weaving asbestos cloth.
(Photos by courtesy of Proctor and Schwartz.)

Asbestos Thread

Asbestos yarn is transformed into asbestos thread. The yarn for the production of thread is especially hard twisted, and is put through processes that reduce it to fairly uniform diameter and smoothness. Thread is furnished in various sizes as follows:

2-ply,	12-cut	600	yards to the pound
2 "	14 "	700	" " "
2 "	26 "	1,300	" " "
3 "	12 "	400	" " "
4 "	12 "	300	" " "

It is furnished to the trade in one-pound or five-pound paper tubes put up on universal winders.

Asbestos thread is used in the production of asbestos gas mantles and for sewing asbestos theatre curtains and asbestos garments.

Asbestos Tape

Single-ply asbestos yarn is woven into tape. Several strands of the tape are woven on a loom at the same time. When the tape is to be used for electrical insulation, the fibre from which it is made must not carry any free iron minerals. Electrical tape on test must not show over 7 per cent carbon; the maximum amount of cotton allowable in the yarn from which it is made being 14 per cent.

Asbestos Cloth[1]

Yarn is wound on large spools for the warp of the cloth and on bobbins or "cops" for the weft. Warps of the required number of ends are put on beams, and carried through the loom harnesses and reeds. Bobbins are placed in the shuttles which in action pass backward and forward across the loom, following successive lifts of the threads by the harnesses, leaving the weft between the warp threads. The reed, which moves to and fro from the face of the loom compacts the threads tightly in place forming cloth. Finished cloth often does not contain more than 65 per cent asbestos.

Asbestos cloth is made in several weights and textures. The term " plain asbestos cloth" designates cloth made of plain asbestos yarn. "Metallic cloth" means that the cloth has been woven of asbestos metallic yarn.

Asbestos fibres are much finer in diameter than cotton fibres. In a yarn containing 20 per cent cotton there may be hundreds of asbestos fibres to each cotton fibre. The cotton fibres are so thoroughly surrounded and protected by the asbestos fibres that the term " Commercially Pure " or " C.P." is in general use in the asbestos industry for yarn containing 15 to 20 per cent cotton. For most purposes asbestos yarn containing 15 to 20 per cent cotton is superior to one having a smaller percentage.

Absolutely pure yarn is required only for the weaving of cloth to be used as diaphragms in the electrolytic production of oxygen and hydrogen or chlorine.

Specifications for Asbestos Yarns

Tentative specifications for Tolerances and Test Methods for Asbestos Yarns were published in the 1928 volume of The American Society for Testing Materials, Serial Designation D 229—28 T.

These specifications cover the tolerances and methods of testing for plain asbestos yarn and metallic asbestos yarn.

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[1] Weaver, J. W.: "Asbestology", March 1928.

Definitions

(*a*) *Asbestos Yarn:* Asbestos yarn is yarn consisting of: (1) Asbestos Fibre, or (2) Asbestos and Cotton Fibres, or (3) Asbestos and Cotton Fibres and Wire.

(*b*) *Plain Asbestos Yarn:* Plain asbestos yarn is yarn consisting of: (1) Asbestos Fibre, or (2) Asbestos and Cotton fibres.

(*c*) *Metallic Asbestos Yarn:* Metallic asbestos yarn is yarn consisting of plain asbestos yarn twisted with brass, copper or other fine wire.

(*d*) *Cut:* The term 'cut' indicates the size of asbestos yarn. The word 'cut' preceded by a number indicates, in multiples of 100 yards, the yardage per pound of single-ply yarn. For example: '5-cut' indicates that a pound of single-ply yarn so designated measures approximately 500 yards; '10-cut' indicates a yarn that measures approximately 1,000 yards per pound.

(*e*) *Ply:* The term 'ply', applied to asbestos yarn, indicates the number of strands of single yarn twisted together to form a heavier yarn. For example: '2-ply 10-cut' indicates that each of the two strands forming the 2-ply shall be 10-cut.

Tolerances

Yardage: The yardage of plain, single-ply asbestos yarn shall conform to the following requirements:—

—	Nominal yardage per pound	Permissible range of variation in yardage
5-cut	500	450 to 549
6-cut	600	550 to 649
7-cut	700	650 to 749
8-cut	800	750 to 849
9-cut	900	850 to 949
10-cut	1,000	950 to 1,049
12-cut	1,200	1,150 to 1,249
14-cut	1,400	1,300 to 1,499
16-cut	1,600	1,500 to 1,699
18-cut	1,800	1,700 to 1,899
20-cut	2,000	1,900 to 2,099
24-cut	2,400	2,300 to 2,499
26-cut	2,600	2,500 to 2,699
28-cut	2,800	2,700 to 2,899
30-cut	3,000	2,900 to 3,099

Size of Wire. The diameter of the wire used in metallic asbestos yarn shall not vary from the size specified more than plus or minus 0·001 inch.

Cotton Content. (*a*) The cotton content of both plain asbestos yarn and of metallic asbestos yarn shall conform to the following requirements:—

Grade A	15 to 20 per cent
Grade AA	8 to 20 "
Grade AAA	4 to 5 "
Grade AAAA	None.

Different manufacturers use different designations for asbestos cloth, there being no uniform standard nomenclature. The product of Keasbey and Mattison Company is designated as follows:—

—	Designation	Weight per sq. yard	Grade
		lbs.	
No. 10	Plain asbestos cloth	3	A
No. 9	" "	2·5	A
No. 8	" "	2·25	A
No. 8-A	" "	1·90	A
No. 8-AA	" "	1·65	A
3/6 in	" "	5·00	A
Special extra heavy grade cloth, monel wire reinforcement		4·9	AAA
(The foregoing cloths are made in the basket weave.)			
No. 13-C	Metallic asbestos cloth	3	A and AAA
No. 66	" "	2·75	A
1/32 in	" "	2·10	A
Asbestos twill weave diaphragm cloth			AAAA

All cloth is made in standard width of 40 inches, but other widths are woven to order.

Asbestos Packing

Asbestos yarn is used in the manufacture of various forms of asbestos packing for valves, steam engines, and pipe-lines, air pumps and gasoline pumps. In fact, asbestos packing is suitable for almost every purpose where packing is required. The yarn is worked up into twisted or braided valve stem packing, into braided forms that are compressed into rings or into cloth that is subsequently coated with rubber compound and folded or wound into various forms of packing for high pressure steam work and also transformed into gaskets for boiler tubes, handholes and manholes of boilers, and for pipe flanges. An inexpensive form of asbestos packing is made in wick and rope form.

Rhodesian and Russian fibres are at times used in making packing yarn, but are not so satisfactory as Canadian. Cloth is cut into strips, and shaped into packing or gaskets. These in turn are impregnated with rubber compound or wound around metal cores or asbestos rope. Various sizes are made in square, round, oval, ring, cup and other shapes. Seamless cloth is cut into sections, shaped to gasket form and coated with rubber compound and filler. In braiding yarn into packings, one or more strands may be impregnated with rubber compound before assembling, or a small braid so made, or asbestos rope may be used as the core of a large braid. Braided packings are often tubular with a hollow core. Woven cloth is formed by hand into gaskets 3 inches wide and as much as 72 inches in diameter.

Gaskets for certain purposes after being formed are dipped in oil and rolled in lubricating flake graphite. Metallic yarn, that is yarn made up of 2 or 3 strands of fine copper, lead, or brass wire and 3 to 7 strands of asbestos, is largely used for making packings. Woven packing after being shaped may be dipped in water-soluble lubricant, or may be moulded and vulcanized.

Asbestos fibre in packing (especially in high pressure steam packing) adds strength and resiliency. Its faculty of absorbing water in expansion of the packing justifies the additional cost. An extra strong packing is made by cutting the cloth in a special manner and resheeting before shaping. Asbestos fibre is combined with rubber other than in textile form to make sheet packing. Sheets which may be built up in several thicknesses are branded and sold as sheet packing, or cut up, shaped, moulded, and vulcanized.

Brake Lining and Clutch Facing

Brake lining, which contains about 16 per cent cotton, is woven from metallic asbestos yarn in a similar manner to cloth and in widths of from 1 inch to 42 inches. Standard widths for automobile brake linings are 1 inch, $1\frac{1}{8}$ inches, $1\frac{1}{4}$ inches, increasing by $\frac{1}{4}$ inch each to 5 inches, $5\frac{1}{2}$ inches, and 6 inches. Standard thicknesses are from $\frac{1}{8}$ inch to $\frac{3}{8}$ inch, with variations of $\frac{1}{32}$ inch between thicknesses. Ordinary basket weave may be employed, or a special means to form cone-shaped bands.

Bolts of cloth may be cut into strips, the strip folded over to form a band and stitched with one centre and two outside threads. Another type is formed by a double fold of the cloth with the join in the centre. Bands made by any of these methods are dyed for uniformity of colour. They are then calendered and processed by having a compound of high-grade rubber or other ingredient and filler rolled in. The bands are then treated under pressure and vacuumed in order to secure thorough impregnation. After drying in an oven they are coated with talc, stamped with a brand and coiled for shipment. Lining is tested for strength regularly, and daily service tests are made.

A woven brake lining is now made of asbestos yarn only, no metal wire being included.

Brake linings and clutch facings are also made of asbestos board, which is cut to size, impregnated, calendered, and finished. Extra clean and uniform paper stock fibre is required in the manufacture of these.

For hoisting-engine brake lining several layers of cloth may be built up and pressed together to form a band up to 3 inches thick, and 12 inches wide.

MANUFACTURE OF SHINGLES

Asbestos shingles were first successfully made by Ludwig Hatschek, in Austria, over 25 years ago, and the process invented by him, or variations of it, is still used in all countries. Two general methods of combining the ingredients going to make a shingle are practised; mixing in the dry state, or mixing with water. The materials in an asbestos shingle are Portland cement, to which is added 15 per cent of shingle grade of asbestos, and if desired, colouring material. After the shingle has been formed a coating of slate granules may be sprinkled on and rolled in. The granules in colour may be red, green, grey, or mixtures of any of these colours to produce a mottled effect.

Dry Process

Cement, asbestos fibre, and colouring material are dumped into a cylindrical mixer in which paddles revolve rapidly. To ensure thorough mixing the operation is repeated in a second similar machine. The material is elevated and spread evenly on a travelling conveyer belt 18 inches in width. Immediately before the dry powdered stock drops on the belt, a spray of water wets the belt to prevent the powder from sticking. The powder is levelled to a uniform thickness and water sprayed on at a temperature of 180° F. to ensure complete penetration at the speed of travel. A roller compresses the material, as it travels, to the required thickness. By means of a rotary cutter the strip is cut to shingle lengths. If desired, slate granules may then be sprinkled on and lightly rolled in. At the end of the belt the shingles are lifted off and piled in stacks. Between each shingle is placed a steel pallet. The shingle pile is built up on a car on the top of a vertical hydraulic piston, so that as each shingle is added the pile sinks. Thus, a man is always piling at a convenient height. The capacity of a single machine is 17,000 shingles per day. A stack of shingles three feet in height is moved on a truck under a hydraulic press, where a pressure of 20,000 pounds per square inch is exerted, and the excess water squeezed out in 20 seconds. The stack of shingles is then wheeled to a curing kiln where the heat, generated by the setting of the cement, creates a draught which carries off the balance of the moisture.

From the kilns the stacks of shingles are taken to a magnetic lift, tipped to a horizontal position and the pallets lifted out, dipped in oil and cleaned. The shingles are then sheared to size, the corners trimmed off and the nail holes punched. Scrap from these operations is returned to the mixer.

Asbestos shingles are made in the French or Diamond shape to be laid one thickness over the roof, and in the American or Rectangular shape to be laid like slate two or more thicknesses over the roof.

They are made in various sizes and thicknesses, and in six (6) standard colours—red, green, grey, blue-black, brown, and purple, and these colours can be produced in various shades and tones to suit the individual wishes of the customer.

They are manufactured by the Philip Carey Manufacturing Company, Johns-Manville Corporation, Keasbey-Mattison Company, and others.

Tapered shingles are made by using a tapered roll. One-half a shingle may be roughened by rolling into its surface, during the process of manufacture, a coating of coarse salt, which on completion of manufacture is dissolved out.

In a manner similar to that of making shingles, board or sheets up to 3 inches in thickness and 42 inches in width may be made, using the appropriate grade of fibre. Such heavier objects must be subjected to pressure for a longer time to squeeze out the water, and a longer period must be allowed for curing in the tunnel kilns. The handling of large sheets, and the intervening pallets, is done by means of an air suction frame. Ridge pieces for roofs are made from a shingle mixture, moulded to form. Corrugated sheet is made by crimping a flat sheet. Heavy board, under various trade names, as manufactured by the Philip Carey Manufacturing Company, the Johns-Manville Corporation, and others, is built into round-house flues, in the same manner as wooden boards. The structure is stiffened by 2 × 2-inch strips of the same material and the sections bolted together. After erection, bolt heads and nuts are covered with asbestos cement so that the whole is fume proof.

Wet Method

Cement, shingle fibre, and colouring matter are dumped into a large amount of water in a beater, similar to that used in a paper mill, and stirred to form a thin slurry. If it is desired to make sheets, the fibre used is compressed sheet stock, sometimes with a paper stock fibre added. In making either sheets or shingles, the process is the same. The slurry is pumped to a paper machine equipped with three rolls, and a sheet built up in successive laminations to the required thickness. From the end of the machine it is transferred to a roll from which it is cut off in two sheets. These are passed under a shearer or trimmer and six shingles cut out at one time. The shingles are then processed in the same manner as described above under " Dry Method."

Shingles are cut to shape to be laid on the American, English, or French system. In imparting a green colour, the colouring agent is not mixed in as in the case of other colours, but the colour is obtained by a veneer of chromium oxide.

Sheets may be sawn to any required size, and polished for finish.

The Keasbey-Mattison Company, Limited and the Philip Carey Manufacturing Company both manufacture a tiling for covering walls of bathrooms and for similar purposes. Thin sheets, instead of being cut to shingle size, are cut into larger pieces. These are sprayed with Duco or Pyroxalin. The sheet is then scored by grinding to resemble wall tile and polished. After nailing on a prepared wall base the nail heads are counter-sunk in the scored grooves and covered with asbestos cement.

Standard asbestos millboard is made 42 by 48 inches, and in four thicknesses, $\frac{1}{16}$, $\frac{1}{8}$, $\frac{1}{4}$, and $\frac{1}{2}$ inch. Thicker boards are known as lumber and may be made in any thickness specified up to 3 inches.

ASBESTOS PAPER

Asbestos fibre of paper stock grade is mixed with a large amount of water to the consistency of a thin slurry in a beater of the type used in making paper from rags. A wooden drum 5 feet long, set on the periphery with longitudinal iron strips $\frac{1}{4}$ inch thick and $\frac{1}{2}$ inch apart, revolves over a floor section set with similar slats. The drum is placed on one side of an iron tank open at the top. Between the end of the drum and the opposite side of the tank is a clear passage. As the drum is revolved rapidly the slurry is drawn through an aperture, $\frac{1}{8}$ to $\frac{1}{16}$ inch wide, between the drum and bottom slats and thoroughly pulped. The current circulates around the end of the drum and is repassed until the required consistency is obtained. The slurry is pumped to a paper machine, similar to that used in the manufacture of paper from rags or wood-pulp. White water containing starch, flour or size, and sodium silicate from the overflow squeezed out of the paper in later stages of the operation, is added to the slurry fed by a pump to each roll, adding successive layers of asbestos fibre. The layers are pressed by felt couch rolls at the wet end of the machine. The sheet thus formed goes to the dry end, a series of steam-heated rolls. After passing these, the sheet is wound on a drum. The drum is raised to the top of a stand and direction of travel reversed over several dry rolls. When 2-ply paper is desired, one side of the sheet is covered with a light coat of sodium silicate as an adhesive and two sheets run together over several hot rolls. The paper is cut to size, dried, trimmed and piled for shipment, or used for further manufacture in other departments. The following are standard sizes of asbestos paper.

Weight of rolls	Width of rolls	Weight per 100 sq. feet	Thickness
	inches	pounds	inch
100 pounds	36	8-10-12-14-16	1/16 - 1/8
50 "	24	8-10-12-14-16	1/16
50 "	18	8-10-12-14-16	1/16

Paper to be used in insulating may be scored before drying, or crimped by rolls for air cell insulation. The crimped paper may be built up to 2-ply by coating with adhesive, subjecting to light pressure, heating on a gas flame, and drying over hot plates. Cut to sheets, the air cell paper may be marketed as an insulator or rolled, 2-ply or even 8-ply, into pipe covering. When made into rolls, the paper is covered by thin muslin, or asbestos paper, the ends trimmed and the tube split longitudinally. Single-ply paper may be stamped out to form asbestos sheet packing and the pieces punched out repunched to make spark plug gaskets. All scrap is returned to the beaters and added to the raw material.

MAGNESIA INSULATION

A mixture of 15 per cent of asbestos fibre testing 0-6-6-4 or 0-5-8-3 and 85 per cent of magnesium carbonate is moulded into blocks for insulators, or the blocks may be shaped into tubes for pipe covering. At the plant of the Philip Carey Manufacturing Company at Plymouth Meeting, Pa., magnesium carbonate is made from dolomite, in California it is recovered from the bittern at salt works, and in Canada it is proposed to make it from Austrian magnesite and waste carbon dioxide gas from an industrial alcohol plant.

The process as developed at Plymouth Meeting, Pa., is elaborate and interesting. Dolomite containing 46 per cent magnesium carbonate is quarried close to the plant. A steel end-dump car in which a properly proportioned charge of coke has been placed is lowered down an incline into the pit, where it is filled with lumps of rock. The mixed load is raised and dumped into the charge top of a continuous-operating vertical kiln. From this kiln carbon dioxide produced by the combustion of the coke and the burning of the dolomite is drawn off by a compressor, passing first through vertical tank scrubbers to remove dust and cinders and to cool the gases. The burned lime is removed from the bottom of the kiln, and unburned rock and coke are picked out. The lime is cooled, weighed, added to an excess amount of water and the whole is agitated in a machine of the concrete mixer type. The milk of dolomite lime produced, which contains both calcium and magnesium hydrates, is decanted and delivered to a saturator; the ashes and unburned stone go to waste. Carbon dioxide from the compressor is forced through the milk of lime in the saturator. Calcium carbonate is formed and remains in suspension, while magnesia remains in solution as the bicarbonate. The calcium carbonate is separated from the solution of magnesium bicarbonate in filter presses, and goes to waste; this product is sometimes used as precipitated chalk. The liquor containing the magnesium bicarbonate is warmed in special tanks, carbon dioxide gas is liberated and returned to the circuit, while magnesium carbonate separates out in suspension. This solution containing magnesium carbonate is then pumped to settling-tanks, the upper half of each being walled by muslin; after settlement of the precipitate the clear water goes to waste. The white flocculent precipitate containing sufficient water to make a creamy fluid flows by gravity to a mixer where 15 per cent asbestos fibre of the grades noted above is added. At some plants fiberized blue crude or amosite from South Africa, or Shabani fibre from Rhodesia, testing 0-8-6-2, is used instead of Canadian fibre. The method of preparing these fibres is said to render them suitable for this purpose, and on a price basis African fibre of a higher test can be used, although at equal prices Canadian is preferred.

The mixture may be kept for some time in storage tanks without agitation, since the asbestos fibre will not settle out in less than twelve hours. Before use it is regularly tested for fibre content. When required it is pumped to a second storage tank and thence to a Kewanee tank under air pressure to equalize the feed to a filter press. The water content is reduced in the filter press to 90 per cent in eight minutes. The moulded cake from the filters is dumped into wire trays, piled on trucks, each holding 8 tons, and run into dry kilns heated by steam pipes. Air is circulated by blower fans for three days. Larger pieces are handled in curved, cast aluminium moulds with two, three, or four moulds per cast. After drying the blocks are trimmed, cut to lengths, and ground or bored out; this operation is performed by grooved cutting wheels provided with both internal and external cutting teeth. The grooved sections of magnesia insulation, which are manufactured in seventeen standard sizes, are rolled in glued canvas jackets, in pairs, the grooves in half cylinders of equal size facing each other to form tubes. The walls are up to 2½ inches thick. For extra insulation several sizes of tubes may be inserted one within the other. They are also packed this way for crating and shipment. Strength tests are carried out on the finished products from time to time as an aid in regulating the mixture.

COLD-MOULDED ARTICLES

A growing industry is the manufacture of electrical fittings and household appliances from short fibre. Stock for this purpose must be clean of grit and closely sized. A mixture made of gilsonite, asbestos fibre, cement, and oil is thoroughly ground together. Weighed quantities are fed to moulds and compressed. The moulded articles are cured by baking. Finishing is done by polishing to remove the flash and roughness, after which a lacquer may be sprayed on. The gilsonite imparts a brown colour. If only a grey colour is required, a mixture is made of fibre, cement, and water, and the moulded article cured by setting. All forms of electrical fittings, such as wall sockets, cord ends, and panels are made, as well as radiator knobs and similar articles. The further development of this trade will afford a market for the shortest fibre, much of which now goes to the sand dump.

ASBESTOS-PROTECTED METAL

This material is made by coating sheet metal, usually corrugated, with a mixture of asbestos fibre and asphalt. It is of special value as a covering for buildings exposed to acid fumes at smelters and acid plants.

PRODUCTS MANUFACTURED FROM ASBESTOS IN CANADA

Asbestos fibres of various grades are constituent components of many manufactured products. The longer fibres are used chiefly for spinning yarns, cords, and the production of woven fabrics. In recent years some manufacturers have found it feasible to introduce a small quantity of stock, shorter than those usually classed as spinning fibres, into the mixtures prepared for carding. Very short stock naturally tends to weaken the yarns and the amount introduced must be carefully adjusted to avoid weakening the yarns too much. The short and very short fibres and a limited amount of residual sands are used with other constituents principally to produce a long line of building products and moulded articles.

Canada is primarily a producer of asbestos products for export to other manufacturing countries, especially the United States. There are, however, a number of products made in this country from domestic supplies of graded asbestos. It should also be noted that for various reasons some manufacturers find it more profitable to import some foreign crudes for certain purposes; in other cases a limited domestic market makes it profitable to import yarns or semi-manufactured products for conversion into higher grade products in this country. This applies especially to the manufacture of certain woven fabrics and of insulating products.

The following list covers the principal articles containing asbestos fibres that are at present being manufactured in Canada:

1. Moulded products.
2. Refractory cements, putties, fireproof, and waterproof products, and acid-proof coatings.
3. Building lumber, shingles, and other roofing materials, including rock and gravel.
4. Heat insulating products, including sheets, blocks, etc.
5. Packings, gaskets, and similar goods.
6. Papers, sheeting, wallboards, blackboards, and switchboards.
7. Decorative panels, imitation marbles.
8. Yarns and ropes of certain grades, including metallic yarns.
9. Woven fabrics, including brake linings, clutch facings, tape, webbing, wick, tubing, theatre curtains, electrical safety blankets, etc.
10. Moulded brake lining and clutch facings.
11. Flexible brake lining.
12. Asbestos clothing including aprons, gloves, caps, helmets, leggings, etc.

The following is a list of the principal firms in Canada manufacturing and marketing goods which contain asbestos products.[1]

Canadian Manufacturers of Asbestos Products

Ontario

Canadian Gasket Company, Bridgeburg.
Canadian Raybestos Company, Ltd., 280 Perry St., Peterborough.
Robertson, H. H., Company, Ltd., 309 Front St. N., Sarnia; 506 Metropolitan Bldg., Toronto 2.
Sterne, G. F., & Sons, 126 Bruce St., Brantford.
The Arco Company, Ltd., Clouston Ave., Toronto.

Quebec

Anchor Packing Company, 997 Aqueduct St., Montreal.
Asbestonos Corporation, Ltd., Waterman St., St. Lambert.
Asbestos Manufacturing Company, 754 Victoria Square, Montreal.
Atlas Asbestos Company, 142 St. Peter St., Montreal.
Canadian Asbestos Company, 322 Youville St., Montreal.
Canadian Johns-Manville Company, Ltd., 904 St. James St. W., Montreal.
Commercial Alcohols, Limited, 3196 Notre Dame St. E., Montreal.
Russel Manufacturing Co., St. Johns, Que.

Nova Scotia

Guildfords, Ltd., 649 Barrington St., Halifax.

[1] The Mines Branch, Department of Mines, Ottawa, maintains a current list of foreign manufacturers of asbestos products, which is available for consultation to Canadian firms requiring information on this subject.

CHAPTER VII

COMMERCIAL APPLICATIONS OF ASBESTOS

The manufacture of asbestos goods forms at present a very important industry both in Europe and on the North American continent. Up to 1878, goods manufactured of asbestos were few, owing to the difficulty of spinning. The only kind of asbestos of commercial value known at that time was the Italian variety. According to Cirkel, asbestos was first used in the United States in the year 1868-9, in connexion with the manufacture of roofing felt and cement. In Great Britain a company was formed in 1871, called the Patent Asbestos Manufacturing Company (Ltd.); works were established in Glasgow and operations commenced. In 1880 the various Italian companies were amalgamated by the formation of the United Asbestos Company (Ltd.).

To learn of the various uses for which asbestos is employed it would be necessary to study the trade catalogues of manufacturers.

Some of the principal uses are enumerated to give an idea as to the widespread employment of this material.

Crude asbestos and high-grade spinning fibres are used either alone or mixed with cotton in spinning textiles, brake lining, yarns, rope, thread, string, packings, conveyer belts, table mats, insulation for electrical wires, filters, etc.

Mill fibre of compressed sheet grade is used in making sheets, and mixed with magnesia for making insulation, and with rubber for rubber sheet packings.

Shingle stock, mixed with Portland cement, is made into shingles, tiles, flooring, boards and lumber.

Paper stock is used in making asbestos millboard and paper, which in turn are manufactured into packings, brake linings, clutch facings, and various types of insulating materials.

Short mill fibres are employed in making cements, paints, and cold-moulded objects for electrical fittings, door knobs, radiator valve handles, etc.; and are mixed with cement for covering walls, especially for acoustic work.

The great number of articles into the manufacture of which asbestos enters is not generally realized, as in many, asbestos does not show. In such materials as asbestos roll roofing or even asbestos cement shingles, the presence of asbestos is not readily noticeable. Asbestos paper can hardly be told by the average man from heavy wrapping paper. In phonograph records, electrical and radio parts and telephone mouthpieces, the asbestos can only be detected by chemical analysis. In the automobile, the steam engine, or other pieces of machinery or apparatus, the asbestos is used in "hidden" places, sometimes seen only when the machine is taken down for repair. In some materials the asbestos, while used in the manufacture, is not in the material at all when finally placed on the market. Pottery manufacturers, according to an article in "Asbestos", for instance, mix asbestos with their clay, finding it useful to hold articles in shape while baking, but the temperature destroys all trace of the short asbestos fibres used.

TEXTILES

Asbestos Cloth

Asbestos yarn, composed of asbestos fibre of the highest quality, is woven into cloth of varying construction, weight, and thickness, which in turn is made into safety drop curtains for theatres, or for wall lining.

Asbestos cloth is also manufactured into suits of clothes for firemen, into gloves, mittens, and leggings.

Asbestos cloth, coated with rubber, is used in the manufacture of gaskets, sheet packings, etc.

One of the largest uses of asbestos cloth is in making of automobile brake lining. Strips of cloth are folded, stitched, and impregnated with a special compound under heat and pressure.

New uses are being constantly developed with a consequently increasing demand for crude and spinning fibre.

Asbestos Rope and Yarn

Fireproof asbestos ropes in use in fire departments are generally of two kinds; one entirely of asbestos, the other with a core of steel wire which adds to its strength.

One of the principal causes of the high prices ruling for crude fibre during the late war was the large amount of asbestos rope used in making mats for use on the decks of war vessels, and the cloth and high-grade asbestos insulating material used in the construction of such vessels.

Asbestos Cord and Twine

These are strong and hard finished. They are fire- and acid-proof.

Sewing twine is very fine, strong, hard finished twine used for sewing asbestos cloth and for binding materials exposed to the action of fire or acid, also for chemical apparatus and for insulating electric wires.

Brake Lining

Asbestos fibre of the highest quality is woven into brake lining, internal and external, and into cone and disk clutch facings for automobiles, as well as transmission lining. A yearly data book is issued by manufacturers of brake lining showing the various sizes of linings required for American motor vehicles. Brake linings vary in thickness from $\frac{5}{32}$ inch to $\frac{1}{4}$ inch, and in width from $1\frac{1}{4}$ inches to 8 inches, the most common size for automobiles being $\frac{3}{16}$ inch in thickness by 2 inches in width. Brake linings, as well as being woven to width in tubular form and shaped, are made by folding strips of cloth.

Moulded brake lining is used for internal brakes, especially for the front wheels of cars equipped with four-wheel brakes. Asbestos of short shingle grade, or scrap yarn twisted with wire is cut up and mixed with a preparation, the ingredients of which vary at each factory. The mixture is moulded under heat and pressure to the form of a segment of a band. This is finished by trimming and punching for rivet holes.

Tests are in progress as to the advantages of the two types of brake lining, woven and moulded. It is the opinion of some automotive engineers that a combination lining, woven material, impregnated with a composition and moulded may be found most satisfactory, especially for internal brake lining. Asbestos board is also treated and made into brake linings and cluth facings, and sold under the name of flexible lining.

Packing

The earliest modern application of asbestos to engineering purposes was in the manufacture of an improved gland packing. At first this was used mostly in the form of millboard; but the various modifications of this special manufacture are now exceedingly numerous.

The most common form of asbestos packing is made either by twisting or braiding asbestos wick or yarn together into a rope; but a large number of other kinds of asbestos packings are on the market. Wire is sometimes used to increase the durability and strength of the packing; while to increase the elasticity india-rubber is sometimes added. To improve the lubricating property of asbestos packing it is often manufactured with a filling of soapstone or graphite. A superior kind of asbestos packing consists of asbestos cloth rolled into any desired thickness with rubber between the layers. In a similar manner, by uniting layers of asbestos cloth, a flat packing—generally called asbestos and rubber sheeting—is made, which can be cut into rings of any shape and form to serve as a flat joint packing, instead of millboard or paper. Asbestos paper is used as a manifold packing in motor cars, the sections stamped out being punched and used as spark plug gaskets. Some of the varieties of asbestos packing manufactured are: oval, round, or square folded asbestos gaskets, high pressure folded asbestos gaskets, high pressure wire insertion asbestos sheet packing, high pressure wire inserted asbestos gaskets, asbestos tubular gasketing, asbestos tape, compressed asbestos fibre sheet packing, graphited compressed asbestos fibre sheet packing, compressed asbestos fibre gaskets, graphited compressed asbestos fibre gaskets, oil-resisting compressed asbestos fibre gaskets, asbestos cups for reverse gear pistons, locomotive packings.

ASBESTOS AS AN INSULATING MATERIAL

Non-heat-conducting coverings for application to steam pipes, boilers, and all heated surfaces, from which it is desired to prevent radiation, are manufactured to the extent of millions of feet each year. These are composed either entirely or in part of asbestos fibre of varying degrees of quality. The principal insulating material is made of magnesia bonded with 10 to 15 per cent of asbestos fibre. Asbestos paper assembled in various forms as air cell covering is also widely used. Asbestos fibre alone in the form of tape, wick, or rope, is wound on steam pipes as an insulator. Numerous varieties of pipe and boiler coverings are on the market in which asbestos is a component part. "Fibre felts" as they are technically called, are composed of pure asbestos fibre, and among other purposes are used in large quantities for insulating the heat radiating parts of automobiles; they are also employed for wrapping around small pipes; for the insulation of electric service wires, and in the manufacture of electric irons, toasters, and similar appliances.

One of the common ways of preventing radiation of heat from pipes, boilers, etc., is to mix loose asbestos fibre with other materials which serve to increase the non-conducting qualities of asbestos or to make the composition adhere more firmly to the surface of the pipes. Such a mixture made into a uniform paste with water, is laid on smoothly by means of a trowel as a thin covering around the pipe. Several layers are usually put on, allowing each to dry thoroughly before the next is applied. The whole is then covered with canvas, which prevents the coating from falling off, should it become cracked in the course of time.

Another mode of using asbestos for covering pipes is effected by forming it into sectional pieces, which are placed on the pipes and fastened by means of metal bands or canvas wrapping. An asbestos covering is made of successive layers of plain and corrugated asbestos felt, which, on account of the numerous air cells thus produced, effectually prevents radiation.

Where it is necessary to uncover boilers from time to time for inspection or repairs, insulation is obtained by sectional mattresses of asbestos cloth stuffed with asbestos fibres.

ASBESTOS MILLBOARD

Manufactured into millboard, asbestos finds a variety of uses. The millboard serves as a joint packing for steam pipes, cylinder covers, steam chest covers, and is appreciated for its durability, economy, and cleanliness. It will adapt itself to uneven surfaces and forms a perfectly tight joint, which with very little care, can be removed and replaced without injury. For special purposes—particularly when there is much water in the steam pipes—asbestos millboard can, by special treatment, be made waterproof. It is used for many purposes; for lining safes and filing cabinets to make them fireproof, in the construction of booths for moving picture projectors, for gas flues, and for lining refrigerators.

LINING OF FURNACES

Asbestos being one of the most refractory of substances, it is of value in a variety of ways for the lining of furnaces and in the manufacture of firebrick.

GENERAL USES

The principal uses as listed by " Asbestos " in 1925, with additions to date are as follows:—

Raw material (crudes, fibre, and sand):
- Yarn.
- 85 per cent magnesia pipe covering; blocks and locomotive lagging.
- Compressed sheet packing (12-1922-10).[1]

[1] Reference Nos. after uses refer to the month, year, and page number of "Asbestos" describing that particular use. Thus 5-1920-33 means the May 1920 number, p. 33.

Raw material (crudes, fibre, and sand):—*Concluded*
- Wick packing.
- Rope packing.
- Filling for asbestos mattress insulation (12-1921-5).

Asbestos cement products:
- Shingles (12-1920-5).
- Flat sheathing.
- Corrugated sheathing (1-1924-6).
- Water pipes (4-1925-4).
- Wall tile.
- Decorative panels.
- Pulleys (8-1920-50).
- Chimneys (5-1920-25).
- Boiler plugs.

Moulded composition.
Insulation of batteries (loose fibre).
Insulation of walls (loose fibre) and floors.
On gas logs.
Snow for Christmas trees.
Snow used in motion pictures.
Asbestos whiskers (for Santa Claus).
Paper (plain and corrugated).
Fibre used as filter in acid manufacturing plants.
Asbestos paint.
Grease filler.
Millboard.
Rollboard.
Wallboard.
Mulch paper.
Asbestos cement for:
- Insulating boilers, etc. (6-1925-12).
- Waterproofing.
- Glazing and pointing.
- Roofing cement (10-1922-11).
- Furnace cement (4-1923-14).

High-temperature insulation (Prasco) (6-1925-16).
Plaster—replacing hair.
Stucco.
Paints, varnishes, and fillers (7-1920-5).
In pottery to keep shape intact until baked.
Matches.
Filter fibres (principally amphibole) (2-1920-10).
Filter pads in Gooch filters.
Wadding in cartridges.
Timing device in bombs.
Block of asbestos rock for "Dutch" oven in steam-generating plant.
Packing for expansion joint in furnace walls (8-1924-30).
Paste from which to mould puppets on marionettes stage (9-1924-41).
In making an asbestos felt for acoustic work.
Acoustic plaster.
Door knobs.
Plugs for electric fixtures.

Asbestos Yarn

Cloth (9-1921-5).
Tape (1-1922-5).
Brake lining.
Clutch lining.
Valve stem packing.
Braided packing.
Metallic asbestos gaskets.
Asbestos rope (obsolete—once used for firemen's rope).
As a seating for glass in glazing bars.

For spark plug gaskets.
Electrical insulation.
Tying gas mantles.
Twine.
Sewing asbestos mattresses, theatre curtains, clothing, etc.
Non-frayable edges for stretchless hair belting (6-1925-41).
Facing for dryer felt (6-1924-19).

Asbestos Cloth

Packings (6-1920-5).
Sheet packing, high pressure, folded or wound.
Brake lining.
Clutch facing.
Gaskets.
Clothing, viz:—
 Gloves and mittens.
 Helmets.
 Aprons.
 Leggings.
 Suits.
 Mailbags.
In acoustic treatment (10-1923-22).
Filtering.
In acetylene welding.
Theatre curtains.
Portable motion picture booths.
Rugs.
Floor lining in theatres.
Theatre scenery.
Gun grips.
Tapestry (European).
Asbestos blankets for use in electrolyzer cells.
Also bags and diaphragms for same purpose in oxygen-producing plants (5-1920-5).
Asbestos-faced wipers in commutators.
Asbestos mattresses (for insulation) (12-1921-5).
Clothing for puppets on marionette stage (9-1924-41).
Lining for wooden boxes in which to raise meal worms for Japanese nightingales (6-1925-36).
Asbestos blankets for smothering fires.
In laundries, for mangles.
Protectors for gas bags in balloons.
Insulation in ovens (12-1923-18).
Padding in prison cells (3-1924-38).
Lining of foot-board of automobile to decrease heat (7-1924-41).

Obsolete Uses of Cloth

Napkins.
Tablecloths.
Cremation cloths.
Ruffles on sleeves (Chinese).

Asbestos Tape (Woven from Yarn)

Pull strings to pull pans from large ovens
Insulating locomotive steam pipes at bends, etc.
Winding coils
Insulating armatures
Winding bus bars
Insulating underground cable
Laboratory uses, viz.: Insulation of flasks, test tubes, retorts
Tie straps in diffusing materials

In glass manufacture for:
- Wrapping tines of forks to take bottles from ovens (1-1922-15)
- Reinforcing paddles for stirring molten glass

Protection of glass bowls on train lighting system

Wick Packing

As packing
For piping wire or armour plate

Asbestos Composition Material

Phonograph records
Buttons
Electric wire insulation (11-1923-7)
Heater cord insulation
Insulation compounds
Condensite Celoron for gears (4-1915-20)
Sealing of percussion caps in large cells
Lamp sockets
Rheostat backings
Switch parts
Arc deflectors
Mountings for heating elements
Resistance mountings
Radiator caps for automobiles
Imitation marble (European)
Porous filler in acetylene composed of asbestos, charcoal, kieselguhr, and cement (5-1920-14)
Composition of soapstone and asbestos used for body of electric stove (8-1920-23)
Pipe heel
Underground insulation
Flooring composition
Moulded brake lining
Brake blocks for hoisting engines
Fox traps
Bird houses

Asbestos Paper

Air cell and other coverings made of asbestos paper
Asbestos felt roofing
Asbestos built-up roofs (4-1921-10)
Asbestos-protected metal roofing (10-1922-10)
Many electrical and heat insulations in various ways and in various places, for instance, the electric percolator, toaster, grill, iron, and other heating devices are lined with asbestos to prevent the escape of heat
Tubes in electrical industry
Filing cabinet lining
Filtration purposes
Baking sheets
Lining table pads
Table mats
Lining of stoves and heaters
Insulation of ovens and dry kilns
Inner casing in pipeless heaters (8-1920-44)
Gaskets
Asbestos metallic gaskets
Disks and linings in cartridges and other explosives
In acetylene welding to protect from extreme heat
In chemistry and physics in many and various ways
Wicks in oil stoves

Lining of soldiers' helmets
Annealing (crumbled paper) (5-1920-7)
In burning carbon deposits, in auto cylinders to protect exposed parts
Wall covering
Carpet lining
Soldering pads (8-1920-44)
Baking sheets
Lining of mufflers on automobiles
Lining drum controllers in sulphate mills (2-1922-5)
Lining auto radiator covers
Cigarette wrappers (?) (10-1922-62)
Insulation (with magnesia) in ovens (12-1923-18)
Around soldering iron just above the tip (7-1924-41)

Asbestos Millboard

Lining of stoves and heaters
Fireproof wallboard
Asbestos table pads and mats
Lining of safes and insulation of ovens and dry kilns
Stove mats
Fire protection of ceiling over boilers and smoke stacks
In metal-clad doors the millboard being placed on both sides of the wood, underneath the sheet of metal
In copper gaskets
Glass mills cover their paddles with it, the paddles being used to take out the bottles from the furnaces
Lining of garages and moving picture booths
Lining of electric switch boxes
In gas range oven, ¼" in bottom prevents burning of pies, cakes, etc.
Washers in electric irons
Guards for stoves and ovens in restaurants (5-1925-34)
Lining for dry cleaning machines to protect from fire in using gasoline spray (5-1925-24)
Tent shields and stovepipe rings
Lining garbage incinerator (7-1924-31)
Lining for hoods of automobiles
Chimney pots

Asbestos Flat Sheathing (Lumber)

Insulators between phases and on arc deflectors
Manufacture of cabinets and panel box work
Switchboards
Prevention short circuits in trolley cars
Laboratory table tops
Exterior sheathing (half-timber effect) on houses or other buildings
Interior sheathing of factories, etc.
Portable houses or school buildings, traffic police shelters, etc.
Semi-portable motion picture booths
Mounting of test instruments and gauges in sulphite mills

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