Asbestos Mining and Milling in Quebec—II

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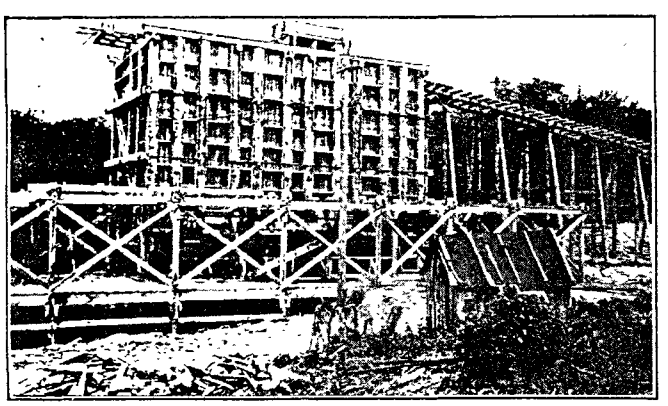
Asbestos Mining and Milling in Quebec—II

Modern Underground Mining Methods Now Being Introduced — No General Standardization of Milled Product—Simple Crushing, Screening and Suction Used To Separate and Grade Asbestos — Detailed Costs of the Various Operations

By Walter A. RuKeyser

THE SEARCH for crude asbestos and the operation of hand-cobbing begin immediately after the rock is block-holed. The first or rough cobbing rids the veins of asbestos of most of the adhering gangue. The final cobbing is done by girls, usually, in suitably designed sheds on the surface, and cleans the veins of any remaining rock particles and partially "opens" the asbestos. In one of the mines, the run-of-mine rock, with the refuse from the rough cobbing, is run over slowly moving conveyor belts for hand-picking. The product is sorted as to length and quality and bagged for shipment, the bags weighing 100 lb. net and the material running about 40 cu.ft. per ton of 2,000 lb.

After the sorting of the crude on the floor of the pit or benches, the rock which constitutes the mill feed is shoveled—usually by hand—into the boxes, or skips, of



Loading terminal for an aerial tramway

the cableways. It has been found impracticable to use mechanical means for loading these boxes, primarily because of the fact that a steam (or electric) shovel could not be kept busy enough—there being of necessity many working places, which may be on the benches of several levels. In the Thetford and Black Lake districts, at least, suitable grades for the egress of the shovels could not be maintained. In addition, there are the extremely irksome winter conditions, which would severely handicap movement of the shovel or loader. I know of no property in the district where a small loader or mucker such as is employed underground in metal mines has been used experimentally, although I think such a device might possibly find application under favorable conditions.

Cranes Effective in Handling Waste and Rock

Steam and electric cranes are used in two or three operations in the district to sort and handle the boxes of waste and mill rock. In this connection it must be remembered that the asbestos-bearing rock occurs in zones separated possibly by granite or, more often, by barren serpentine. This must all be mined. Thus a large proportion of "dead" rock results, usually about 25 per cent of the total and running as high as 40 to 60 per cent, which must be sent to the dump.

Usually both waste and mill feed are hoisted to the surface by means of cableways. However, at the Bell mine, a crane is used to load narrow-gage dump cars, and these are assembled into trains and hauled by means of a hoist through an inclined tunnel to the mill bins or waste-rock dump. This incline system has practically replaced the cable derricks. The lower third of this incline is situated in a pillar of rock left between two pits which are now connected by a main opening. The tunnel is about 1,200 ft. long and reaches the surface near the crusher house.

At Black Lake, the Black Lake Asbestos & Chrome Co. is using a crane to make up the trains of waste and mill rock on the floor of the company's main or No. 9 pit. Cableways are used to lower the boxes from the upper benches. This main pit is now connected by a 45-deg. raise to the floor of a smaller and more shallow working, Pit No. 6, and it is the intention to mill down from this pit, all of the rock being taken out through No. 9. A tunnel approximately 200 ft. long runs through the pillar, separating the two workings at the level of the tracks of the main pit. This is sufficiently large in cross-section to allow the crane to enter and to swing its boom when necessary to sort both classes of rock. Fifteen-ton steam locomotives run the trains to the wet-rock bin feeding the crushers and to the waste dump, both objectives being about 1,500 ft. from the face of the pit.

The topography of the Black Lake mine, coupled with the large amount of available surface area, has permitted the placing of the company's mill below the level of the pit floor.

Large Cableways Have Been Extensively Developed

Typical Thetford open-pit mining has probably been most highly developed at the King mine of the Asbestos Corporation of Canada, a reorganization of the old Amalgamated Asbestos Co. The operations at this mine disclose a high degree of progressiveness and show careful planning. The hydraulic stripping operations already described were begun by this company after an extensive diamond-drilling campaign, totaling 20,000 ft., that was awarded by contract to the Sudbury Diamond Drilling Co., which has had five drills in continuous operation since May, 1920. As much as 90 ft. of ⅞-in. core was recovered per day by one drill, and I am told that reserves of milling rock sufficient for thirty years' mill operation at the present rate of output have been blocked out.

The King mine, Lot 26, Range 5, Thetford, is the largest producer of the group, and the open pit has reached a depth of over 300 ft. At the surface it measures approximately 900 x 500 ft., and this width is increasing continually. Five powerful cable derricks now replace thirteen small ones by which the rock was formerly hoisted and conveyed to hoppers at the surface. These hoppers loaded into 36-in. gage cars, which were assembled into trains and hauled by steam locomotives to the bins or to the waste-rock dump, 4,000 ft.

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distant. The five large cableways have enabled the mine to more than double its daily hoisting capacity, which must be approximately 3,000 tons in twenty-four hours at a maximum.

All the steam locomotives, both for the rock yard (which feeds the primary crushers) and for the dump, have been replaced by Canadian General Electric locomotives of the trolley type. The electrification involved one contract for equipment alone totaling over $110,000. It is said this step was taken primarily to eliminate the uncertainty of the coal supply, especially in winter, when railroad transportation from the United States may be seriously disrupted. However, a greater over-all efficiency and lowering of operating costs was probably the main reason for making the change, hydro-electric power being supplied to the mines of the district both by the Shawinigan Power Co. and the St. Francis Power Co., at rates averaging about $40 per horsepower-year on large new contracts. Fuel is now used only for the driers.

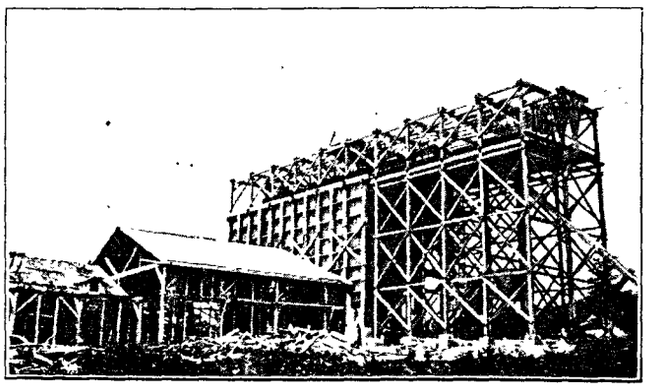
25,000-Ton Dry-Rock Bin

To facilitate continuous mill operation during the winter months, and to increase the flexibility of the system, a large concrete storage bin has been erected for the crushed and dried rock. The rock enters along a distributing conveyor from above and is drawn off to another conveyor through hand-operated arc gates at the bottom. This conveyor runs through a tunnel surrounded by "dead" ore. The sides of the bin are sloped at the angle of repose of the rock.

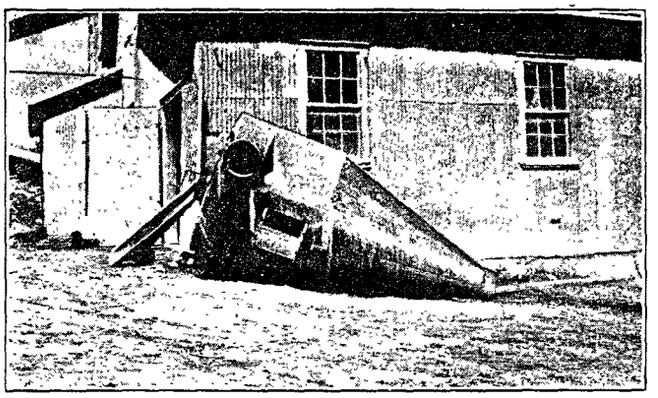
Although considerable underground exploratory work has been done in the district by several of the mines, only one property is really turning out its entire output by means of an underground mining system and shaft hoisting. This is the Thetford mine of the Consolidated Asbestos, Ltd., until 1920 the Jacobs Asbestos Mining Co. The property of this company consists of a long and comparatively narrow lot, surrounded by the workings of other companies. The open pit was about 225 ft. deep before underground mining was begun.

A triple-compartment shaft has been sunk to 515 ft. The first level was run at 188 ft., the main drift of which is 1,400 ft. long. From this main haulageway a series of crosscuts 75 ft. apart branched out, and raises were put up to the surface. The raises are vertical for the upper hundred feet or so, the lower parts being made into chutes inclined at 45 deg. From these chutes the glory holes discharge into the mine cars.

The haulage in the crosscuts is by means of horse-drawn steel cars. These are assembled in the main drift, where storage-battery locomotives take them to the loading pocket at the shaft station. The charging set for the locomotives is underground.



Discharge terminal for an aerial tramway



Collector used in many mills

A second level 175 ft. below the first has been driven, and by means of this the rock milled down from the former open pit is handled.

The shaft is vertical and timbered throughout, the headframe being of steel. The two skips are each of 2½-ton capacity and the hoisting plant has a capacity of 2,000 tons per day.

During 1920 a large loading pocket at the second level was completed and also a 160,000-gal. sump. The entire mine drains into this, drainage from the first level being effected through a series of 6-in. shot-drill holes. The cabled derricks are no longer used for hoisting rock, but only as accessories to fill the mine cars at the bottom of the pit for haulage through the first level. A part of the mine tonnage is hauled to the mill through a 20-deg. incline 1,015 ft. long from the surface to the bottom of the open pit. However, four-fifths of the total tonnage comes from the glory-hole operations and is shaft-hoisted. It is the intention eventually to use the incline only for a manway.

The rock after being hoisted to the surface is passed over a slow-moving picking belt for a further sorting out of the crude.

The "Combined" Method of Working as Practiced at Black Lake

The fact that the most productive asbestos-bearing ground rises steeply away from the railroad at Black Lake has permitted keeping the mine workings either at the level of the mill bins or above it. The topography thus lends itself to the driving of tunnels to the farthest-removed pits; or, as with the Asbestos Corporation's workings, has permitted the joining up of a scattered series of old workings by means of a main haulageway. These old pits were formerly under separate control, but, having been acquired by the corporation, are now consolidated into one extended system. The individual pits are being prepared for glory holing, and eventually the mine will be worked entirely by this method. A main haulageway, or tunnel, has been driven under the separate pits, thus connecting them underground. A branch tunnel has been driven to the south to a point under the Standard pit, a distance of 2,038 ft. At various points raises have been driven to the surface or to the bottom of old pits, so that the rock can be milled down for electric haulage to the mill in five-ton cars.

The rock is crushed by 36 x 42-in. jaw crusher to 5 in., being then further reduced to 2½ in. through three 15 x 20

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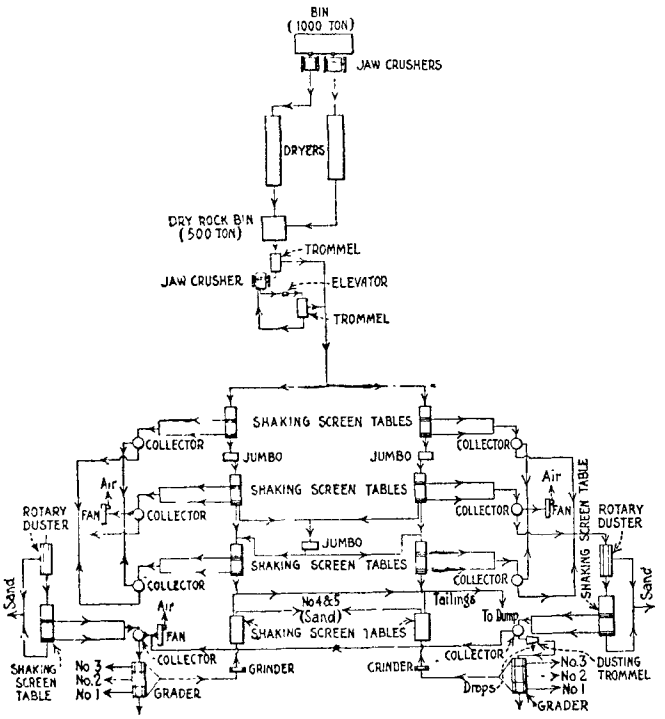
in. crushers of the same type. After drying, the rock is conveyed to a 25,000-ton bin similar to the one at the King mine.

The Canadian Johns-Manville Co., operating the Jeffrey mine, at Asbestos, near Danville, has now entirely eliminated cableways for rock hoisting. The country is of flat topography, and therefore the mine has been developed by means of four steam shovels operating on wide benches. The shovels load into standard-gage cars on the benches and in the bottom of the pit. Steam locomotives of 30 and 38 tons' weight haul the trains up maximum grades of 3 per cent to the mills, three in number, which have a combined capacity of 3,000 tons per day.

The problem at Danville differs from that at Thetford in that there is ample working space for the laying out of the grades and that the crude is more narrowly confined to high-grade zones.

Practically All Slip-Fiber Properties Worked By Steam Shovels

On the slip-fiber deposits steam shovels have found excellent application, owing to the fact that no crude has to be sorted before the rock goes to the mill. Thus, at East Broughton all the mines use this method, the



Typical flow sheet of a slip-fiber mill

shovels loading usually into 36-in. gage contractors' side-dump cars. The cars may be jogged back and forth between the working face and a crusher installation in the pit itself, as at the Quebec Asbestos Corporation mine, or hoisted out of the pit up an incline to the crusher bins, as at Asbestos Mines, Ltd., which has a 4,800-ft. aerial tramway of the Trenton-Bleichert type connecting the mine with the mill, having an hourly capacity of 50 tons. Its loading terminal bin has a rock capacity of 500 tons, the discharge bin holding 1,000. The loading terminal is 60 ft. above the discharge, and only 5 h.p. is required for the operation of the system.

At the Federal mine of the Consolidated Asbestos Co. the rock was formerly brought from the pit crushers to the surface on a 24-in. belt conveyor running through an 18 deg. inclined drift, but this method has been discontinued, and the cars are hoisted along an outside incline to the crushers installed on the surface. Much difficulty had been experienced with flooding and freezing, especially during spring thaws. The pit is about 300 ft. wide by 1,100 ft. long, and is worked in a single bench 125 to 150 ft. high. Both the foot and hanging walls dip at an angle of 67 deg. Two forty-ton shovels, both of the railroad type, supply the mill with its requirement of 1,000 tons per day.

Advantages of Caterpillar Shovel

At East Broughton the caterpillar shovel has been found most successful, being free from all track troubles and expense. One Harris shovel (Canadian made), usually with a 1¼-cu.yd. dipper, has been able to supply the mills from 600 to 1,000 tons per twenty hours. Hydro-electric power is used by nearly every mine in the district, and in almost every operation there is a direct railroad siding from the Quebec Central main line.

There is still considerable controversy in the district as to whether the advantages of underground mining systems outweigh the increased cost and disadvantages. The supporters of open-pit methods claim for their system that no skilled labor is required, no timber used, which some maintain contaminates the mill feed; no expensive shafts, stations, pockets and underground haulage must be driven and maintained, and a better separation of the crude is practicable. On the other hand, the supporters of underground methods maintain that twelve months' continuity of operations is possible in underground work; that a simplicity and centralization of hoisting is effected, eliminating signal boys and several hoistmen; that there is no waste of men's time in watching boxes overhead; and that a minimum of shoveling is necessary. However, in the Quebec district at least, the consensus of opinion is that open-pit methods are cheapest and best for shallow depths. The controversy starts only at that point.

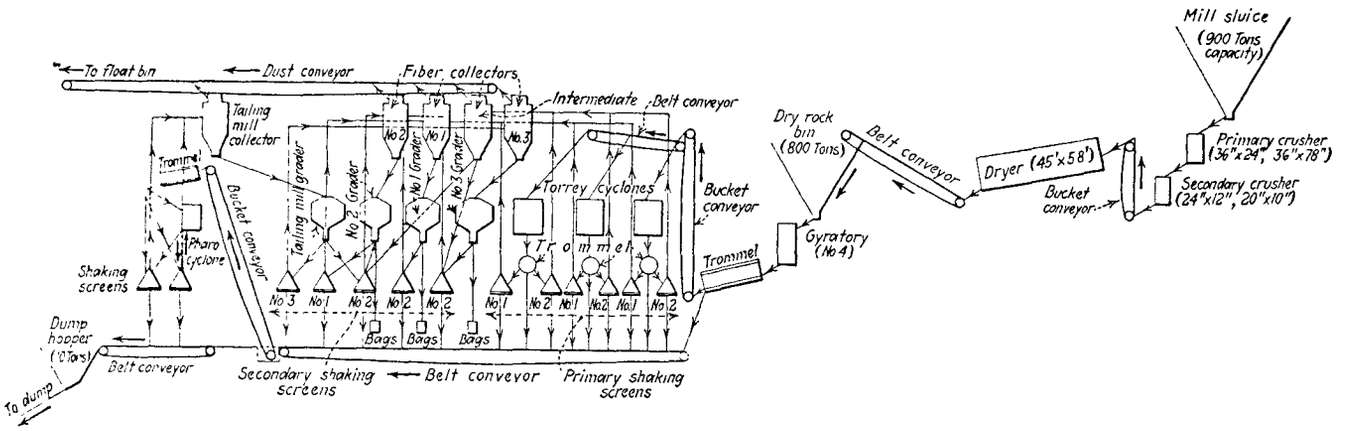
No Standardization in Grading Milled Product

Before describing the milling methods practiced in the Quebec industry it is necessary to explain the complexity of the grading problem. The various companies have arbitrarily adopted specific grades and designations for their products, the crude alone approaching a state of standardization. But even the two grades of crude vary in price according to the percentage of the longer fiber in each, which is particularly true of the milled fibers. Thus there are more than fifty classifications of the mill products.

The following method has been adopted throughout not only the Quebec mines but also by the manufacturers of finished product for testing asbestos. The standard testing machine is, as far as I know, made only by the two local foundries at Thetford. It is a shaking screen of four trays, fitting on top of each other, the screens being 24 x 14 x 4 in. The top or No. 1 tray is fitted with a screen bottom of 2 mesh, No. 11 wire; No. 2 screen is 4 mesh, No. 17 wire, and No. 3 is 10 mesh, No. 18 wire. The bottom forms a solid pan. The nest of screens is fastened to a frame and given a horizontal throw of 1½ in. The shaft, fitted with an eccentric, is made to revolve at 300 r.p.m.

To make a test, one pound (16 oz.) of fiber is placed on the top screen and run for exactly two minutes. The fiber retained on each screen is weighed separately,

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Typical flow sheet of a cross-fiber mill

and the number of ounces from each tray read in succession, the total, of course, adding up to make 16 oz. Thus, for example, if a sample of asbestos yielded a test reading 0-8-5-3, that grading would signify that 0 oz. had been retained on the top or 2 mesh screen, 8 oz. on the 4 mesh, 5 oz. on the 10, and the "drops" (or "pan"), that is, the minus 10-mesh screen, had reserved 3 oz.

The following table shows the average test of milled products for various purposes:

ASBESTOS TESTS

Purpose	Thetford	Black Lake	East Broughton	Peak Price per Ton
Long spinning fiber....	1½–9¼–4¼–1	3½–8½–2½–1½	1½–9–4½–1	$800
Medium spinning fiber .	0–8–6–2	0–8–6–2	0–8–6–2	350
Magnesia pipe covering and compressed sheet.....		0–7–5–4	0–5–8–3	200
Shingle stocks..... ..	0–1½–9½–5	0–4–8–4	0–1½–9½–5	125
	0–0–11–5	0–3–9–4		
Paper and millboard. . . .	0–0–10–6	.	0–0–11–5	80
			0–0–10–6	
Cement and roofing	0–0–5–11	.	0–0–5–11	40
"Sands," either of dark pulpy nature; short clean fiber or sandy. (For cement and flooring.)..... ..	(a)	(a)	(a)	... .

(a) No test.

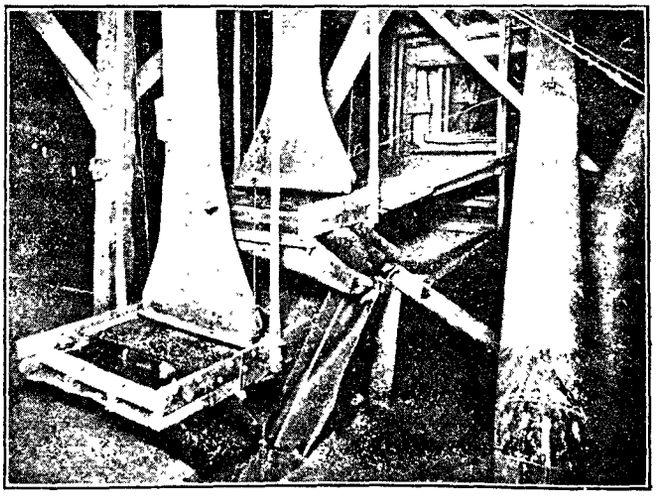
The problem of milling consists not only in recovering as much of the fiber from the rock as possible, but also with as great an average fiber length as is consistent with economy. Owing to the great difference in market price between the better mill grades and the poorer in general, the processes which have been evolved attempt to remove the fiber from the rock as early as possible during the treatment. Types of machines have been developed or applied with every attempt to spare the fiber from unnecessarily rough treatment, yet at the same time sufficiently breaking the rock which incloses it.

Crushing in Stages by Straight Impact

Concentration of asbestos by milling consists broadly in coarse crushing, drying, recrushing in stages, each step being followed by screening, during which air suction effects the separation of the fiber from the rock gangue; collection of the fiber, cleaning of adhering dust and rock particles by rescreening, grading, and, finally, bagging for shipment. This typical process is much the same today as when established in 1889 by Earle C. Bacon for the Scottish-Canadian Asbestos Co. (now defunct). The changes that have been made are essentially those of arrangement of the units in the flow sheet and of mechanical detail. The non-technical operator has always inclined in that district toward a *laissez-faire* attitude. Finally, it must be pointed out that the question of milling efficiency, per cent of recovery, and the like are largely indeterminate problems. Exact chemical determination of mill feed and tailings is not possible. There is no means of accurate analysis to check the results of the mill run. The matter has resolved itself to the present time in weighing the rock going to the mill and the production of fiber resulting. It is because of this last fact that modifications of practice throughout the district are the dictates of individual taste or judgment rather than conclusions based on accurate comparative data.

As the asbestos is deposited along lines of weakness in the rock, it follows that breaking by straight impact would be the ideal condition. The "squeeze" of the primary jaw or gyratory crusher is thus not harmful to the fiber, and the problem becomes of importance only in the later reduction. So it is that coarse crushers reduce the rock as much as possible, and the fiber liberated during this stage is separated from the rock before treatment by fine crushers.

In a typical milling operation, rock from the mine is dumped into a hopper or bin which feeds the primary crushers. Too often, the bin is of limited capacity, and any delay at the working face is reflected in mill operations. It must not be forgotten, however, that storage of wet serpentine is extremely difficult, if not impossible, under the Quebec winter conditions. For example, in January, 1920, the temperature at no time went above zero, and often hovered for days at 10 to 20 deg. below, reaching a minimum temperature of —48 deg. F. As



Courtesy of Asbestos, Crude & Fibre Corporation.

Shaking screen tables

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soon as the run-of-mine rock hit the plates of an unheated bin, the entire mass would freeze solid. Only by continual barring down, bulldozing with powder, and by never allowing the flow of the rock to cease could the bins be kept open. The frozen fines in particular would tend to form a cementing medium binding the large blocks. Under such conditions operators have considered it advisable to provide large dry-rock storage wherever feasible, and in an extreme instance (the Asbestos Corporation) 25,000 tons' storage has been provided. This is sufficient for a fortnight run of the mill.

Primary Crushing Usually by Jaw Type Machines

Coarse breaking is usually done by jaw crushers, because the better-sized product of the gyratory type machines is not a distinct advantage. The two primary machines at the King mine are 72 x 32-in. Blake type jaw crushers of a capacity of 100 tons per hour. At the Johns-Manville Co.'s mine the jaws of the primary crusher have an opening of 60 x 84 in. to take steam-shovel material direct. This is a Traylor crusher 19 ft. 7½ in. long, 11 ft. high, and 18 ft. 1½ in. wide, weighs 500,000 lb. and delivers 3,000 tons per eight-hour day of 10-in. product. Owing to the slippery nature of the serpentine, it was necessary to have an acute angle of nip—viz., 18 deg.

From the coarse crushers, of which there may be two, or even as many as three, series, possibly of jaw and gyratories combined, the rock is conveyed or elevated to the drier. Drying is an extremely important operation, the milling efficacy largely depending upon how well this is done. Too little drying hinders recovery and fiberization; too much injures the fiber. Hence, earlier operators used the indirect heat type of drier; for in that way it was thought that danger of "scorching" (partly dehydrating) the fiber was eliminated. The direct-heat drier, with its greater thermal efficiency, is now used almost everywhere; and one or two mines even employ the combined direct and indirect heat type in which the hottest gases pass around the shell of the drier and the last amount of heat is given up to the rock during the return of the gases of combustion through the shell. Although standard Vulcan, Ruggles-Cole and American Process driers are to be found, it is more usual in the district for shells to be made up by some Canadian foundry, and the castings and drives are purchased or made locally.

With the exception of the practice of the Asbestos Corporation, the horizontal rotary-shell drier, with a firebox at one end and a dust chamber at the other, is generally used. The speed at which the shell is revolved, its length and diameter, inclination from the horizontal, and whether or not a forced draft is to be used under the firebox are considerations which must be worked out for each individual application, depending upon the rock to be dried and the capacity required. The same factors determine whether or not there shall be baffles and whether the rock is to be passed concurrent or countercurrent to the gases of combustion. The Asbestos Corporation uses the stationary, vertical-tower drier patterned after the Edison type, in which the rock is dropped from the top and encounters a series of crossed-rod baffles in its downward passage against the uprising gases. From the drier discharge the rock is usually conveyed to dry-rock bins, where storage for at least two days' mill run is usual.

It is considered best practice to begin taking off the fiber immediately. The dried rock is therefore passed through trommels, and the fines, containing the liberated asbestos, are passed over shaking-screen tables. These may be 6 ft. in width by as much as 20 ft. long, and may consist of one, two or three decks covered with suitable screening, and shaken by means of an eccentric at, say, 300 r.p.m. Suction hoods made by the mill's tinsmith are suspended at the discharge end of the tables or of each plateau of the table. The hood runs the width of the screen and has an opening of about 4 in. It is connected by means of piping to conical-bottomed collectors, and the entire system is put under suction. Formerly, the material was made to pass directly through high-speed suction fans, this resulting in a needless tearing of the fiber. The shaking tables are not primarily for screening purposes. They rather serve as a means by which the feed can be spread out sufficiently for the suction to separate the asbestos from the heavier rock particles, and their oscillatory motion results in a "bedding" of the material. The particles which pass through the screen cloth (usually of from 8 to 12 mesh) are barren of commercial fiber and go to waste.

The regulation of the screening and suction affords one of the most interesting fields for experimentation in asbestos milling. I have never seen any record of accurate data showing the results of varying the inclination, the dimensions, the rate of vibration of the tables, nor the relation of rate of feed to them with a variation in the suction. Roughly speaking, the table as used in the average installation must have a capacity of twenty tons an hour, treating rock of average fiber content, and when a moderate suction (8 in. of water) is applied at the hoods.

Final Crushing Either by "Cyclones" or "Jumbos"

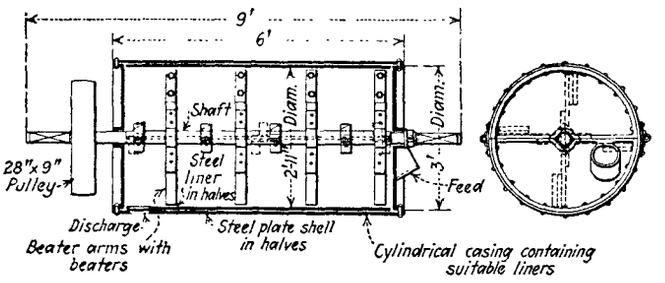
The secondary crusher may be in closed circuit with a rotary screen or trommel, the undersize from which goes to a second screen table. A further separation of fiber is effected in the same manner as before noted. The oversize is then passed to fine crushers, machines which have been specially developed in this district for asbestos milling, the older "Cyclone" and the recently more popular "Jumbo." Rolls have been tried and are occasionally used, but, owing to the matting of the resultant discharge, they have not found great favor in the asbestos mill. These machines are particularly inefficient on the talcose rock of the slip-fiber deposits.

As pointed out, the desired effect in the reduction of the asbestos-bearing rock is one of straight impact and disintegration permitting the freeing of the fiber and at the same time "fluffing" it. A minimum of grinding or shear action is desired. With this in mind the Laurie "Cyclone" was first evolved, with later modifications by Pharo at the Beaver mine and Torrey at Black Lake. The "Cyclone" consists essentially of two cast-steel impellers shaped like a ship's screw, weighing approximately 1,000 lb. each and made to revolve at a high speed (2,000-2,200 r.p.m.) in an inclosed chamber lined with manganese-steel plates to withstand the impact of the rock hurled against it. If a lesser action is desired the impellers may be made to revolve in the same direction, but in the usual practice they are rotated in opposite direction to each other. It is claimed by many that the "Cyclone" produces a great amount of attrition, injuring the fiber; is of low capacity, wasteful of power, and necessitates frequent and costly repairs.

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The impellers must often be changed every two days, owing to the high speed at which they are revolved, and must be balanced on their shafts with extreme care.

The above considerations led to the development of the "Jumbo," a machine, better mechanically, which has for some time replaced the "Cyclone" on the Broughton rock. Within the past two years much experimentation has been done using the "Jumbo" on the harder Thetford and Black Lake rocks, and the machine is finding



Sketch of "Jumbo"

a great deal of favor with some operators who have discarded the "Cyclone." The "Jumbo" is really a modification of the ordinary pulverizer, consisting primarily of a horizontal shaft fitted with a series of arms, these in turn carrying "beaters." The whole is caused to revolve at from 400 to 800 r.p.m. (as the nature of the rock dictates) in a cylindrical casing lined with suitable plates. The rock, fed from above at one end, is made to pass through the machine by a deflection of the beaters, and drops out at the other end. Here again is a great field for scientific test-work, as a variation in the speed, the length, number, spacing and type of beaters causes a great difference in the results obtained by the machine.

Fiber Is Carried by Suction to Collectors

From the succession of "Jumbos," "Cyclones," or combinations of both, the crushed serpentine and asbestos is spread over respective screen tables and the fiber again lifted from the rock gangue by suction. This is done as many times as necessary to effect the limit of economical separation from the rock. All the fiber is sent to collectors, which usually consist of galvanized sheet iron forming cylinders 6 ft. in diameter by 6 or 7 ft. high, terminated at the bottom by a truncated cone with a height also of 6 or 7 ft. These collectors are fitted with suitable baffles, which prevent the fiber from being exhausted into the atmosphere and thus lost.

From the collectors the fiber drops to a series of rotary or shaking-table screens, where all adhering dust and rock particles are removed from it. After this cleaning it passes through the graders. These consist of hexagonal or octagonal screens, which are slowly revolved, sometimes with a bumping motion, about a shaft which is slightly inclined to the horizontal. The graders are divided into sections fitted with screens closely approximating those used on the standard testing machine already described. The products from the graders go to their respective bins and are bagged in 100-lb. lots, either by hand or by semi-mechanical devices.

Waste serpentine is sent to a dump over belt conveyors, or, where this is not possible, by trams. Many of the dumps now contain three to five million tons.

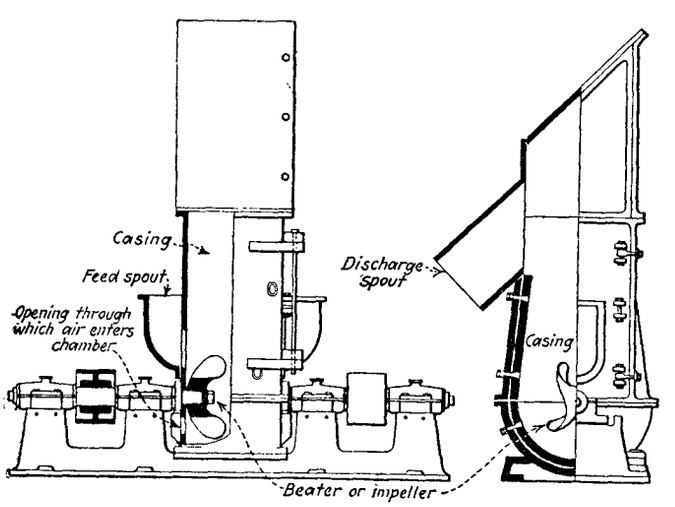
The accompanying flow sheets are typical, the one of cross-fiber milling at Thetford, the other of slip-fiber practice at Broughton.

One large mill in the district recently attempted to replace both "Cyclones" and "Jumbos" by reduction-type gyratory crushers breaking to about 1 in. However, the results could not have been successful, for the "Cyclones" have been put back into the flow sheet. Another plant at Black Lake has installed a swing-hammer mill manufactured by the K-B Pulverizer Co., with extremely satisfactory results. I understand that one of these machines is doing the work of three "Cyclones," with a great saving in repairs and power. The same plant has been experimenting with a new type of stationary screen, which requires no power and no replacement of any screen surface. This, too, has proved successful, and is based upon an entirely new principle.

The Asbestos Corporation has recently been running an extensive series of tests with the Mitchell vibrating screen, and one of these screens has likewise been installed by the Quebec Asbestos Corporation at East Broughton. To avoid duplification of data and to obtain comparative results, the Asbestos Mines, Ltd., installed a Tyler Hum-mer electric screen. It is still too early to state definite conclusions, but these machines will probably have their best, if not their only, application in the secondary process of cleaning the fiber and possibly in grading. For this purpose, tests so far made indicate that the vibrating screen, at least, has a capacity four or five times greater than the old shaking screen table.

Department of Mines at Ottawa Doing Extensive Testing

I have had the privilege for the last several months of consulting with the Department of Mines at Ottawa on some extensive asbestos milling test work which is being conducted under the direction of W. B. Timm. Several possible, and in some cases radically different, courses of action were laid out. The first involved dry milling, breaking as far as possible, say, to 1 in., in the jaw crushers; then sending the product to Hardinge



Sketch of Laurie "Cyclone"

mills. It was found that by applying suction direct to the mill the asbestos might be separated and removed without undue attrition. Mr. Timm has just completed a comprehensive and scientifically prepared report on this first test, but this is not yet generally available. The conical pebble mill has already been used in the district for regrinding the tailings for the preparation of a special product used for plaster and cement purposes.

Another interesting possibility in asbestos milling is by application of wet-grinding methods, even wet concentration by tables or flotation. The advantages, elimination of the dust evil, drying required only for the product, and not for the entire mill-feed; lesser cost of grinding, and protective action on the fiber, might prove so important in any successful method that they could easily revolutionize this phase of the industry.

It is the intention of the Department of Mines, Canada, to publish the results of all this work as soon as completed.

Six to Seven Per Cent Average Extraction for the District

Statistics prepared by the Department of Mines of Quebec show that before the Great War the value of the rock in the ground was below $1.50 per ton; recently it has been $4 per ton or over. The per cent of fiber extraction has averaged between 6 and 7. The average value per ton of the product increased from $35.90 in 1910 to $81.89 in 1920. The percentage of No. 1 crude decreased consistently from about 0.1 per cent in 1910 to about 0.033 per cent in 1920. That is, to obtain the same amount of crude, three times as much rock has had to be mined and hoisted. Thus, the 3,000,000 tons resulted in twice as much crude No. 2 and practically three times as much mill product. This shows that the rock mined in 1920 is not nearly as good as that handled in 1910, and that the mills therefore must have made considerable increase in recovery to maintain the proportion of mill stock. Rock mined was about 20 per cent greater than that milled in 1910; about 16 per cent in 1920. This average includes figures from East Broughton, where all the rock mined is milled. In 1920 there were reports of shipments by seventeen companies operating twenty-one mines. Prospecting and develoment was being conducted by nine other properties.

Costs

The following represent average results from an 800-ton per day mill working on slip-fiber rock mined by steam shovels from a pit 150 ft. deep. The figures are for the year 1919:

Value of ore milled, per ton	$2.60
Total expenses per ton mined and milled	$1.65
Recovery of fiber, excluding "asbestic" per cent	4.81
Average selling price of fiber, per ton	$60.00
Average operating expense (only), per ton	$38.00

The operating expenses include mining, milling, cost of bags and bagging, shipping, power and mine office charges, but not head office, sales, and other overhead. A typical report on cross-fiber operations gives the following:

Total tons mined (March, 1921), per shift	1,001
Rock to mill, per cent	65.5
Drier coal used per day, tons	10.470
Average cable-derricks used	9.6
Average payroll, per shift:	
Miscellaneous employees	13
Transportation	11
Teams	16
Machine shop and repairs	17
Mill, bagging and loading	37
Mining	108
Sorting crane	21
Total men	223

The figures show a production of about 4.5 tons per man for every man on the work and about 8¾ tons for every man in the mine.

The cost per ton delivered to mill or rock dump for derrick mining averages $1.017; the cost per ton, by crane handling, $0.576, and by crane and derrick, $0 850.

Underground development work produced rock at $1.895 per ton in crosscutting and $2.080 in tunneling. The total cost is proportioned as follows:

	Per cent.
Labor, mining	72.5
Supplies, mining	13.7
Labor, transportation	4.4
Supplies, transportation	2.5
Power	2.9
Insurance and miscellaneous	4.0
	100.0

At East Broughton, mining by steam shovel and milling is being done for $0.80 a ton.

At Black Lake a typical daily average might be expressed by the following:

Value fiber per ton of rock mined	$2.51
Value crude and fiber per ton mined	$3.43
Total operating and mine expenses per ton rock mined and milled	$1.48
Average value fiber per ton	$329.75
Expenses (mine) per ton fiber	$147.24

The cost of milling, bagging, loading, and mine overhead thus is about 45 to 50c. per ton milled and correspondingly less per ton mined. The above costs are for March, 1921, when operating conditions were perhaps at their worst and wages and supplies at the peak.

Exploration and Construction Costs

Diamond drilling in 1921 was contracted for at from $3 to $3.75 per ft., the latter being for a 1,000-ft. contract with 1¼-in. core recovery. Counting seven set-ups, the work averaged 25 ft. per day of twenty hours, all the holes being inclined. A maximum of 91 ft. was made in one day. The crew consisted of two runners at $6 per ten hours, two helpers at $4.50, and a foreman at $300 per month. Five and one-half carats of carbons were used.

Calyx shot drilling for a 4¾-in. hole averaged $0.94 per ft. on a 212-ft. hole inclined 15 deg. from the vertical. The average progress was 11 ft. 1 in. per shift. The average cost for seven holes, all inclined, totaling 1,426 ft., was $1.28 per ft. in 1919, including all moves, and $1.15 per ft. excluding moving. Twelve shot-bits were used, at an average cost of $0.0791 per ft.

Exploratory drifting in serpentine can be done as cheaply as $6 per ft.; shafts down to 150 ft. about $15 per ft., with stull timbering only. Permanent work of large cross-section requires timbering.

Approximate Cost of an 800-Ton Per Day Plant

The following is a recapitulation of the estimated cost of replacement of a complete plant to handle 800 tons per twenty hours for steam-shovel mining the slip-fiber deposits:

Construction	$85,000
Tramways and railroad	5,000
Machinery (complete)	135,000
Machine foundations	4,000
Motors	45,000
Chutes and spouting	1,500
Auxiliary cableway	10,000
Locomotives and cars	12,000
Steam shovels	60,000
Shafting, pulleys, belting	15,000
Steam, water and air pipe	7,000
Dust collector system	11,000
Lighting and power wiring	12,000
Office equipment	1,500
Teams, stable equipment	2,000
Tools and miscellaneous	10,000
Total	$326,000

This is at the rate of a trifle over $400 per ton daily capacity. Of this total amount, the mill and contents represents approximately $95,000, the driers, $22,000, the bins, $21,000 and the crushers, $21,000.

A 4,800-ft. Trenton-Bleichert fifty-ton per hour aërial tramway with two large bins, complete, installed, cost less than $50,000 at peak prices.

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In 1920, general pit labor cost from 35c. to 42½c. per hour, against 17½c. in 1915 and 12½c. in 1914. Mill and drier men received from 37½c. to 45c. per hour, and steam-shovel runners up to 55c. at the peak. Carpenters, blacksmiths, and the like commanded 45c. and 50c. An average wage of about 42½c. was the prevailing rate for all classes of labor in 1920.

In mentioning this phase of the subject it is necessary to point out that a condition exists in this district different possibly from that in any other in the world and comparable in a way only to Mexico. Unions, in the ordinary sense of the word, do not exist. The men are practically all French-Canadians, and, except in unusual instances, do not speak or understand English. The bringing in of skilled imported or foreign labor creates hostile feeling. The available resident help is for the most part unskilled men who leave the mines to farm in the spring and harvest, and who possibly leave for the "bush" to cut lumber or pulp wood in the winter.

The Church is necessarily all-powerful in the district, the local curé acting as labor leader, moral advisor, and mentor in general. Any attempt upon the part of the mine managements to vest in themselves these powers, in whole or in part, is not encouraged. In one or two instances which have come under my personal attention the village priest has asked that the company abolish a proposed plan of outside education and amusement. The men are extremely wary of any innovation, and to establish even such a benefit as group insurance, the curé was called upon to give his sanction and explain the move to the men. Often, high Church dignitaries visit the respective mines, establish shrines in the workings, and invoke the blessing of God on the operation.

The men are for the most part loyal, although committed to everything that is usual and customary to them. It is therefore extremely difficult to introduce new methods. It is usual for the lesser executives to be mustered from the French-Canadians, but the operating heads are almost without exception English, Canadian, or American. During the war many of the men enrolled under the American flag.

The individual nearly always owns his own home and farm; there is practically no floating population. These homes are nearly always scrupulously clean. The schools and hospitals are under the direction of the Church. The extensive size of the average family prevents any tendency toward a Red philosophy, and the men are consistent, if not too efficient, workers. Owing to the great number of religious and state holidays, and the all prevailing "high-wine" (a white whiskey with a 150 per cent "kick"), 250 working days is a high average for the year.

Great Progress Made With "Safety-First" Work

The above-stated facts have, of course, not affected the attempts of the various mine managements to promote the safety and welfare of the men wherever possible. The shaft and tunnel for the circulation of the men at the King mine is an example of this progressive attitude. All mines and mills take the usual, and in many instances unusual, precautions to promote safety. Thus, the Johns-Manville Co. has procured the services of an efficiency and safety engineer. Meetings are held and lectures on "Safety First" given. The company has organized a hospital in charge of a trained staff.

A further example of welfare work is the building of thirty-five modern cottages during the summer of 1920 by the Bennet-Martin Co. at the company's Vimy Ridge mine. This property is about six miles off the main line of the railway and has established a thoroughly up-to-date community. I understand that twenty-five more cottages were built during the past year. The houses, which are of extremely neat appearance, have a concrete foundation, and are of frame construction, with double sheathing, a layer of building paper covered over by asbestos board, and are roofed with asbestos shingles.

Many of the mines have well-run boarding houses, and all-in-all there is a well-established feeling of contentment among the labor of the district.

It has been the purpose of this article to show that the present technology of the Quebec asbestos deposits is the direct result of their geology coupled with a former lack of capital in the hands of small, individual owners who were themselves the operating heads. The modern and future tendency is constantly being based upon refinements of technique.

More especially in the milling department will there be a tendency toward the evolution of radically new methods, for the present state of the industry bespeaks possession of the means for experimentation and costly test work. The mining methods, although to a large degree dependent upon factors which permit of no change, will possibly in the future be laid out upon a more extensive scale, resulting from the further amalgamation of companies. Finally, there is being attracted yearly to the district a type of highly trained technical operator who is sure to effect the adoptation of the principles of best practice from outside fields.

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