MINING AND MILLING METHODS AND COSTS, VERMONT ASBESTOS MINES, THE RUBEROID CO., HYDE PARK, VT.

By H. L. Burmeister and I. E. Matthews
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MINING AND MILLING METHODS AND COSTS, VERMONT ASBESTOS MINES, THE RUBEROID CO., HYDE PARK, VT.¹

by

H. L. Burmeister² and I. E. Matthews³

INTRODUCTION AND SUMMARY

This is one of a series of publications by the Bureau of Mines dealing with mining methods and costs at representative operations in the United States. The report describes all phases of the mining methods for the open-pit operation and milling practices employed at the Vermont Asbestos Mines in Lamoille and Orleans counties, Vermont. A brief history of discovery and development of these asbestos deposits is given, and the ore deposits are described. Methods employed in exploration, sampling, and estimation of tonnage and grade are outlined. A breakdown of available cost figures is summarized in the last section.

All asbestos ore produced in this area has been won by the use of surface-mining methods. Two quarries, the Lowell and the "C" Area, are in operation. The quarries combined are producing and the mill is processing approximately 3,500 tons of ore per 3-shift day. The average 40,000 tons of chrysotile asbestos fiber produced at this plant annually accounted for 96 to 98 percent of the total fiber produced in the United States in 1958.

The mine is located (fig. 1) approximately 4 miles north of Eden Mills village on the southeastern flank of Belvidere Mountain (fig. 2).

ACKNOWLEDGMENTS

Acknowledgment is made to company executives for permission to publish this report and in particular to W. H. Page, assistant general superintendent, L. Jordan, exploration superintendent, R. K. White, mining engineer, J. K. Gilmore, research engineer, and D. R. Nichols, geologist.

Assistance received from A. H. Chidester and W. M. Cady, Geological Survey, in interpreting local geology, is hereby acknowledged.

¹Work on manuscript completed June 1960.
²Mine examination and exploration engineer, Division of Mineral Resources, Bureau of Mines, College Park, Md.
FIGURE 1. - Location Map.
Cryotile asbestos was discovered on Belvidere Mountain by a woodsman in 1892, but very little exploration or development work was done until 1900. In this year, a small mill was built at the Eden quarry, after which a number of companies conducted limited and intermittent mining and milling operations until 1928 when the operations were purchased by other interests and became a continuous and successful enterprise. The Ruberoid Co. purchased the Eden property and the adjoining, practically unexplored, Lowell property in 1936. From 1936 to 1943, the Lowell property was explored and developed for production. The Eden quarry was abandoned as uneconomic in 1943, after having produced approximately 2½ million tons of asbestos ore. The Eden mill continued to operate on ore from the newly developed Lowell quarry until 1950, when the present mill was completed at the Lowell site and the Eden mill was permanently abandoned. In 1953 mining was started at the "C" Area quarry, which adjoins the Lowell quarry on the south. Figure 2 shows Belvidere Mountain and the mining area.
GENERAL GEOLOGY

The rocks of the Belvidere Mountain area are in the east limb of the Green Mountain anticlinorium, the major structural feature of the region. The asbestos deposits are in folded lenticular bodies of ultramafic igneous rock on the southeast flank of Belvidere Mountain, about 7½ miles east of the axis of the anticlinorium. The bodies are part of a belt of ultramafic rocks which extends over 2,000 miles from Alabama to Newfoundland and which is also host to the important chrysotile asbestos deposits in the eastern townships of Quebec. In Belvidere Mountain the ultramafic rocks, originally banded peridotite and dunite, have been altered partly or completely to serpentine and locally further altered to talc-carbonate rock and steatite. The ultramafic lens, which is as much as 1,000 feet thick, is intrusive into metamorphosed sedimentary and volcanic rocks of the Cambrian Camels Hump Group, and generally occupies the stratigraphic position between crystalline schists, gneisses, and quartzites, and the overlying Belvidere Mountain amphibolite. The Camels Hump Group overlies Precambrian rocks unconformably and is overlain by the Upper Cambrian Ottauquechee formation which outcrops a few hundred feet east of the operating quarries (figs. 3 and 4). The Camels Hump Group is a heterogenous assemblage of schist, gneiss, and quartzite, which range widely in composition and grain size and exhibit marked changes in lithology along the strike. The Belvidere Mountain amphibolite is the uppermost formation of the Camels Hump Group; the amphibolite is from 700 to 1,000 feet thick and probably represents a metamorphosed waterlaid volcanic mafic detritus. It is locally divided into a coarse-grained, dark-green hornblende amphibolite and an overlying fine-grained, lighter green epidote amphibolite. Southward from Belvidere Mountain, the amphibolite grades into greenstone. The same rock units have been mapped and described in detail by Albee⁴ in the Hyde Park Quadrangle to the south of Belvidere Mountain.

The ultramafic rocks are probably of Ordovician age. Serpentine is the predominant rock type and is the principle host to the asbestos. Talc-carbonate rock is found in a few places in bands through the serpentine and also in some of the complexly folded lenses southeast of the quarries. Small, pod-shaped ultramafics which have been intruded, or possibly tectonically emplaced, into the wallrock on both sides of the Lowell ore body, contain talc-carbonate rock and steatite at the margins and cores of serpentine.

It is apparent that the alteration of the ultramafic rock was accomplished by aqueous solutions that converted the magnesium silicate olivine to the hydrous magnesium silicate serpentine. The growth of the chrysotile asbestos fiber proceeded along fractures and was accomplished by the alteration of the adjacent ultramafic rock to massive serpentine.

DESCRIPTION OF DEPOSIT

The old Eden quarry deposit and the "C" ore body are in the upper part of the easterly dipping serpentineite mass. The overlying Belvidere Mountain amphibolite constitutes the upper ore limit in both areas. The Lowell ore body occupies the northeast limb of a tightly folded syncline and has its northwesterly trending axis nearly perpendicular to the regional structure.

(figs. 3 and 4). Core drilling in the Lowell pit indicates that this limb is approximately vertical to a depth of at least 1,000 feet below the 1,050-foot level, and is from 300 to 600 feet thick. The few schist inclusions in the "C" and Eden ore bodies have presented no special mining problems, but in the Lowell quarry, amphibolite has been leafed apart from the gneisses and dis- tended to form a discontinuous septum diagonally across the ore body. The septum is an essentially vertical, tabular body that pinches and swells irregularly along its dip and strike. It is less than 10 feet thick in most quarry exposures, but it contributes considerable barren tonnage where it swells on and above the 1,300-foot level. A barren dunite zone has been intersected by all of the bench faces near the center of the Lowell quarry body and has been a major consideration in establishing a mining program for the Lowell ore body.

A comparison of drill core values with structural features indicates a systematic distribution of ore values with respect to geologic structures. Value distribution is zonal, with progressive increases in value as the centers of structural deformation are approached.

The fibers occur in veins in serpentinized rock and exhibit cross- and slip-fiber habits. Cross fibers are nearly perpendicular to the vein walls and occur as simple veins, stockworks of veins, or series of closely spaced, parallel ribbon veins. The stockwork type of occurrence (fig. 5) also demonstrates typical alteration of the dunite (light areas) with massive serpentine (dark areas) adjacent to the asbestos veins. In some veins the fibers extend unbroken from wall to wall; in others a central parting contains magnetite or serpentine similar to the vein walls. These veins are usually less than a quarter inch wide, but veins 1 inch wide are not uncommon. Slip fibers vary from oblique to approximately parallel to vein walls (fig. 6), and although they may be longer than the cross fibers, they generally have less tensile strength. Cross fibers predominate in the least altered, somewhat blocky rock (fig. 7) and are most abundant in the central part of the Lowell ore body. Slip fibers, however, are more generally distributed in shears, which may consist of a single fracture or of a wide zone of closely spaced fractures (fig. 8).

In some areas of the Lowell quarry, closely spaced, parallel fractures form a foliation in the serpentine. Foliation is not consistent in direction; therefore, primary blasting is part of the time across foliation and part of the time parallel to foliation. Very little difference in fragmentation has been observed, but where the line of blast holes is parallel to foliation, a cleaner face results. The highest degree of fragmentation is obtained when blasting sheared zones rich in slip fiber.

In the Lowell quarry, a large number of small faults of minor displace- ment strike at nearly right angles to the contact walls of the deposit. These faults have no noticeable effect on rock fracture or breakage at the face. In the more blocky ore, rock breakage is augmented by the presence of cross-fiber seams, but breakage is not as complete as in areas containing slip fiber.
FIGURE 5. - Rock Alteration and Cross-Fiber Asbestos.
The barren dunite mass occurring in the Lowell quarry is blocky in nature, and primary blasting produces larger blocks than results from blasting serpentineite ore. In the Lowell quarry, wall rock schistosity is parallel to the serpentineite contact, and in many places the quarry walls are along planes of schistosity. Weathering of bedrock is usually confined to a few inches, except along occasional fractures, and therefore has no effect on rock breakage.
FIGURE 7. - Blocky Cross-Fiber Ore.
FIGURE 8. - Sheared Slip-Fiber Ore.
EXPLORATION

Geologic and Geophysical

The exploration department has been a very active unit of the Vermont Asbestos Mines for many years. Operations under this department have been most intensive on company-owned land, consisting of approximately 2,000 acres in Lowell Township, Orleans County, and 1,000 acres in Eden Township, Lamoille County. Investigations are conducted on both the main serpentine mass on Belvidere Mountain and along the serpentine belt extending northeasterly from Belvidere Mountain.

Geologic reconnaissance is largely confined to the summer months, due to the normally severe winter weather. These surveys are conducted by a geologist and a helper, who use a compass and tape for locating geologic features on topographic sheets and aerial photographs. Aerial magnetometer surveys have been conducted on the mine and much of the surrounding area to locate and coordinate magnetic anomalies. When geologic and aerial magnetic-survey data indicate the presence of an ultramafic body, with which asbestos deposits are frequently associated, detail ground magnetic and geologic surveys are conducted by company geologists. All detail exploration is laid out on grids controlled by triangulation stations, established from a 3,000-foot, true north-south base line. All mine surveys are referenced to this base line. If interpretation of data resulting from surveys is favorable and further exploration is warranted, a core-drilling project is considered.

Core Drilling

Exploration and development core drilling is usually accomplished by the use of two company-owned drills of different capacity. If a large drilling program is to be completed in a short time, or the area is at a distance from the mine, contract drilling is employed. AX-size drill tools are used in all instances.

The larger of the two drills is used when drilling holes to a maximum depth of 1,500 feet and the smaller when drilling to a maximum depth of 800 feet. One machine or the other, depending on the depth to be drilled, operates 3 shifts per day throughout the year. The second machine is held ready as a standby. Both drills are skid mounted and powered by gasoline engines. To reduce moving and setup time, each drill is equipped with a 12-foot, 3-inch-diameter, heavy-duty pipe mast, mounted on top of the swivel-head and shaft-assembly housing. The mast is hinged for rapid lowering when moving.

To pull the rods from an angle hole, a cable sheave is bolted to the mast support after the hydraulic head has been swung out (fig. 9). Time saved in moving and setting up more than compensates for the time lost in pulling 10-foot rather than 20-foot rod sections, particularly in short holes. Steel tripods with adjustable legs are used in drilling deep holes.

When the capacity of the standby drill is adequate for the next hole, a utility man bulldozes a road and hauls this drill to the next drill site, thus
reducing idle drill time. Water used in drilling is supplied from small streams by a high-pressure pump. In freezing weather, a water-tube heater is employed just ahead of the water swivel, but supply lines are usually not heated. The use of a small-diameter main-water-supply pipe increases velocity and retards freezing.

Approximately 18,000 feet of core drilling is done annually. Including all delay and moving time, an average advance of approximately 20 feet per drill shift is maintained. Penetration rate in all types of rock encountered averages 3.1 feet per hour of actual drilling. Actual drilling time in the first 6 months of 1959 accounted for 70.4 percent, moving 10.8 percent, and repairs and water shortages 18.8 percent of the total time expended in completing 8,115 feet of AX-size core hole.

In the first 6 months of 1959, core-drill operation and maintenance costs totaled $2.58 per foot drilled. This total included: labor $1.61, materials and supplies $0.58, and bits $0.39.

The Government participated in extensive exploration by core drilling under two Defense Minerals Exploration Administration contracts with the Ruberoid Company.

Core-Testing Laboratory

All exploration core is AX size and is brought to the laboratory where it is logged and divided into samples by a geologist.
Schist and barren serpentine cores are skeletonized by retaining only a 3- to 5-inch piece from each 10-foot section and cataloging it in the permanent core library. Percent of fiber and value per ton of ore is visually estimated in all fiber-bearing serpentine. Fiber properties, such as slip- or cross-fiber characteristics, strength, and length, are recorded. Degree of serpentinization, presence of magnetite, talc, and carbonates are recorded by coded number to insure uniformity in recording.

The fiber-bearing cores are usually divided into 40- to 60-foot samples for core-mill testing in the same laboratory. This length of core insures sufficient fiber to conduct a Quebec Standard Test, which is used to grade fiber recovered from the core sample. Highly sheared serpentine cores cannot be properly split, so the entire core is test-milled. After core-mill testing, the results are added to the original tracing of the log and kept with field books as a permanent record. The flowsheet of the core mill is shown in figure 10.

Wet core is thoroughly dried in a hot-air stream in order that fiber may be separated from the rock by air suction. Core is reduced to minus 3/16-inch by passing through laboratory jaw and gyratory crushers (fig. 11), which also frees a large percentage of contained fiber from the rock. The crushed rock and fiber is next passed through an air-swept hammer mill three times by hand feeding to open the bundles of fiber for air lifting by 3 water gage inches of vacuum, the maximum suction used in the core-testing mill.

Fiber is separated on screens and by aspiration. The first separation is made by passing the material through an adjustable vibrating feeder to a 20- by 53-inch, 12-mesh screen, the lower end of which is under a suction hood (fig. 12). A relatively strong vacuum is used which lifts some fiber not fully opened. The 12-mesh screen, as well as the following 26- and 40-mesh screens, is used separately, permitting a stronger suction on the coarser material, which if used on the fines would lift considerable rock and sand.

The same three screen sizes are used throughout test milling operations, thus resulting in comparative figures on fiber length. Use of a 40-mesh screen is necessary to obtain results comparable to production milling, where many closed circuits and heavily loaded screens permit very short fibers and dust to become attached to longer fibers. Material not aspirated is next fed to the air-swept, 1½- by 2-foot-diameter rodmill (fig. 13) operating at 25 r.p.m. with one 3-inch and one 5-inch rod load. The air enters one trunion, is directed downward by a baffle, across the fiber-bearing material, and out the other trunion. A sample is divided into batches, which are successively hand-fed to the mill. The initial batch weighs 15 pounds and is reduced to about 5 pounds in 1 hour. After each such period, an additional 5 pounds of feed is added until grinding and aspiration has been completed.

A second fiber separation is made on the 12-, 26-, and 40-mesh vibrating screens, but a reduced vacuum is used to remove the fiber now freed from rock by the rodmill. All plus 40-mesh material is reground to open any remaining spicules of fiber; and the reground product is passed only over the 40-mesh screen, and the fibers are aspirated. All of the fiber recovered in the three
FIGURE 10. - Core-Testing Mill Flowsheet.
FIGURE 11. - Core-Testing Crushers and Hammermill.

FIGURE 12. - Core-Testing 12-Mesh Screen With Aspirator Hood.
FIGURE 13. - Core-Testing Rod Mills.

stages of screening and aspiration is next cleaned on the 40-mesh screen without aspiration, combined, and passed through a high-speed centrifugal blower to bring the fibers to the same degree of opening as is achieved in the main mill.

All fiber recovered is then hand-mixed, and a representative 1-pound sample is tested in the Quebec Standard testing machine (fig. 14). This machine, consisting of a nest of 4 screens, ½-inch, 4-mesh, 10-mesh, and 35-mesh, and a pan, reciprocates 327 times per minute and is operated for exactly 1 minute and 50 seconds at a time. The fiber retained on each screen is weighed separately, and the screen fractions are used in calculating the value per ton of ore as represented by this sample. The evaluation of ore reserves, namely yield, value per ton of fiber, and value per ton of ore, is based on the results of laboratory tests.

Calculation of Ore Values

Evaluation of a potential block of ore is based on the weighted average value resulting from the use of data obtained in core testing samples from holes drilled in or near separate sections across the block. The standard sheet (table 1) contains a record of evaluation data obtained in the following manner:

Parallel cross sections are spaced at 50-foot intervals normal to the axis of the ore body. Holes in the section represented (table 1) were drilled vertically and at regularly spaced intervals in the section. Results of laboratory tests on core samples are plotted on the cross section nearest the core hole from which the sample was obtained. Each section is divided into possible mining levels, and these are further divided into blocks having a similar range of values. Areas are calculated by using a planimeter on the cross sections.

Core-mill test data on the section are given a full weight (wt) of one, while data from the two adjacent sections are given a half-weight value for their influence on the block. All ore in place is calculated at 12.5 cu. ft. per ton.

This method of calculation has proved reasonably accurate when compared with actual production.
TABLE 1. - Section-evaluation sheet

Section No. 12  
Block No. 3  
Volume 200,000 cu. ft.  
Level interval  
Tonnage 200,000 - 16,000 tons  
Calculated by  
Rock Ore  
Checked by  

<table>
<thead>
<tr>
<th>DDH</th>
<th>Cross section</th>
<th>Core section, feet</th>
<th>Wt</th>
<th>Ft.wt</th>
<th>Fiber, pct.</th>
<th>Fiber ft.wt</th>
<th>Test value, $/ton</th>
<th>$/ft.wt</th>
</tr>
</thead>
<tbody>
<tr>
<td>16-58</td>
<td>12</td>
<td>40</td>
<td>1.0</td>
<td>40</td>
<td>5.42</td>
<td>216.80</td>
<td>5.87</td>
<td>234.80</td>
</tr>
<tr>
<td>16-58</td>
<td>12</td>
<td>10</td>
<td>1.0</td>
<td>10</td>
<td>4.00</td>
<td>40.00</td>
<td>3.75</td>
<td>37.50</td>
</tr>
<tr>
<td>14-57</td>
<td>12</td>
<td>25</td>
<td>1.0</td>
<td>25</td>
<td>5.22</td>
<td>130.50</td>
<td>5.22</td>
<td>130.50</td>
</tr>
<tr>
<td>14-57</td>
<td>12</td>
<td>25</td>
<td>1.0</td>
<td>25</td>
<td>3.77</td>
<td>94.25</td>
<td>4.34</td>
<td>108.50</td>
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<tr>
<td>15-58</td>
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<td>50</td>
<td>1.0</td>
<td>50</td>
<td>4.62</td>
<td>231.00</td>
<td>4.99</td>
<td>249.50</td>
</tr>
<tr>
<td>9-57</td>
<td>11+50</td>
<td>50</td>
<td>.5</td>
<td>25</td>
<td>9.06</td>
<td>226.50</td>
<td>10.30</td>
<td>257.50</td>
</tr>
<tr>
<td>10-57</td>
<td>11+50</td>
<td>70</td>
<td>.5</td>
<td>35</td>
<td>7.42</td>
<td>259.70</td>
<td>9.34</td>
<td>326.90</td>
</tr>
<tr>
<td>3-58</td>
<td>11+50</td>
<td>40</td>
<td>.5</td>
<td>20</td>
<td>6.82</td>
<td>136.40</td>
<td>7.58</td>
<td>151.60</td>
</tr>
<tr>
<td>6-47</td>
<td>11+50</td>
<td>50</td>
<td>.5</td>
<td>25</td>
<td>1.91</td>
<td>47.75</td>
<td>2.74</td>
<td>68.50</td>
</tr>
<tr>
<td>4-47</td>
<td>12+50</td>
<td>50</td>
<td>.5</td>
<td>25</td>
<td>3.61</td>
<td>90.25</td>
<td>5.15</td>
<td>128.75</td>
</tr>
<tr>
<td>4-58</td>
<td>12+50</td>
<td>50</td>
<td>.5</td>
<td>25</td>
<td>1.98</td>
<td>49.50</td>
<td>2.20</td>
<td>55.00</td>
</tr>
<tr>
<td>5-58</td>
<td>12+50</td>
<td>64</td>
<td>.5</td>
<td>32</td>
<td>3.75</td>
<td>120.00</td>
<td>3.84</td>
<td>122.88</td>
</tr>
</tbody>
</table>

Totals 337 1,642.65 $1,871.93

Average grade of block, \( \frac{1,642.65}{337} = 4.87 \text{ pct.} \)

Average value of block, \( \frac{1,871.93}{337} = 5.55 \text{ per ton.} \)

Estimated fiber in block, 16,000 \cdot 0.0487 = 779.20 tons.

Estimated gross value, 16,000 \cdot 5.55 = 88,800.00.

FIBER RESEARCH AND QUALITY CONTROL

All research pertaining to fiber recovery and control of quality is conducted in the laboratory described in the section "Core-Testing Laboratory." Production and sale of 35 to 40 fiber grades necessitates accurate control of quality. Each grade is the result of combining fibers of different lengths in varying proportions. While bagging fiber, the operator takes a grab sample
from each of 50 bags in sequence. The composite of these samples is treated in the Quebec Standard fiber-testing machine to insure that the shipment meets the standards required for the grade ordered. Considerable emphasis is placed on quality control to meet demands of the trade. This is accomplished by employing additional highly specialized testing methods in conjunction with the Quebec Standard tests.

Quebec Standard tests require a 1-pound head sample and minimum weights of fiber to be retained on each standard screen. Table 2 shows the minimum weights allowed on each standard screen for the five most frequently ordered grades; the use and current price of these grades is found in Table 3.

<table>
<thead>
<tr>
<th>Grade</th>
<th>Head, pounds</th>
<th>½-inch, ounces</th>
<th>4-mesh, ounces</th>
<th>10-mesh, ounces</th>
<th>35-mesh and pan, ounces</th>
</tr>
</thead>
<tbody>
<tr>
<td>3 R</td>
<td>1</td>
<td>2</td>
<td>8</td>
<td>4</td>
<td>2</td>
</tr>
<tr>
<td>4 T</td>
<td>1</td>
<td>0</td>
<td>2</td>
<td>10</td>
<td>4</td>
</tr>
<tr>
<td>5 R</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>10</td>
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</tr>
<tr>
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<td>1</td>
<td>0</td>
<td>0</td>
<td>7</td>
<td>9</td>
</tr>
<tr>
<td>7 R</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>16</td>
</tr>
</tbody>
</table>

Table 3 - Typical uses and prices of fiber

<table>
<thead>
<tr>
<th>Grade</th>
<th>Typical use of fiber</th>
<th>Approximate price per ton</th>
</tr>
</thead>
<tbody>
<tr>
<td>3 R</td>
<td>Spinning and packing fabrication</td>
<td>$428.00</td>
</tr>
<tr>
<td>4 T</td>
<td>Flat or corrugated siding sheets</td>
<td>181.00</td>
</tr>
<tr>
<td>5 R</td>
<td>Shingles, pipe wrapping, flexible sheets</td>
<td>120.00</td>
</tr>
<tr>
<td>6 D</td>
<td>Cement mix for shingles, asphalt mix for roofing</td>
<td>86.00</td>
</tr>
<tr>
<td></td>
<td>paper</td>
<td></td>
</tr>
<tr>
<td>7 R</td>
<td>Primarily in floor tile industry</td>
<td>43.00</td>
</tr>
</tbody>
</table>

Grades finer than 7 R are available for use in paints.

**OVERBURDEN STRIPING**

Overburden is removed by a contractor operating on a cost-plus-equipment-rental basis. Stripping is carried on only during the summer months and to the extent necessary for current quarry operations. Depth of overburden changes so frequently and rapidly from 0 to 40 feet that an average depth would be without meaning.

The contractor employs one or two small diesel shovels, depending on the quantity of overburden to be removed. A small backhoe is used for rough cleanup of bedrock, and hand tools are employed to remove roots from fissures in bedrock to prevent contamination of asbestos fiber (fig. 15). Very often the final cleaning is accomplished by the use of water under high pressure. Overburden is transported an average of approximately 300 yards by truck to locations removed from future mining operations.
FIGURE 15. - Stripping Overburden.

FIGURE 16. - Lowell Quarry and Secondary Crushing Plant.
MINING

A number of factors contribute to the selection of surface-mining methods used at this operation. The depth of overburden changes frequently and abruptly within the limits of 0 to 40 feet. After soil overburden is removed, the ore is exposed and ready for surface mining. Extent of the ore in length, width, and depth is sufficient to support the use of extensive benches, and the overall depth of quarry is rapidly increased by advancing the benches into the steep slope of the mountain. Downgrade truck transportation of ore and waste has been maintained since mining started and will be possible for a number of years in the future.

Quarry Operations

Two quarries, the Lowell and the "C" Area (figs. 2 and 16), are being operated simultaneously. The Lowell quarry has five working benches, designated as the 1,050-, 1,115-, 1,175-, 1,235-, and 1,300-foot levels. The quarry measures approximately 600 feet in width from rim to rim and is approximately 2,300 feet long. The "C" Area quarry operates on three benches, designated as the 1,180-, 1,230-, and 1,280-foot levels. This quarry measures approximately 500 feet in width from rim to rim and is approximately 1,700 feet long. "Level" numbers refer to elevation above sea level.

Activities of the mining department include primary and secondary drilling and blasting, material handling at the face, and truck transportation to primary crusher or waste dump, as well as primary and secondary crushing operations. This department employs 76 hourly wage men during a 24-hour period. Of this total, 40 are employed on the day shift, 22 on the afternoon shift, and 14 on the night shift.

From January 1 to June 30, 1959, inclusive, the quarries produced, after stripping, a total of 833,631 tons of material, of which 484,151 tons or 57.8 percent was ore and 349,480 tons or 42.2 percent was waste. This ratio of ore recovered to barren material removed is the result of a long-range mining program, calculated to produce the maximum tonnage of ore by use of surface-mining methods. As mining progresses in depth, the percentage of waste will decrease, until handling of barren material is confined to selective shoveling and not to removal of barren side walls. Loading and transporting this material requires the use of four power shovels, two bulldozers, and seven trucks. Two "down the hole" and two wagon drills are used for primary blast holes and one "travel drill" is used for secondary blast holes. A grader and two light trucks, not included above, are used for road construction and maintenance. Quarry responsibility is over upon delivery of crushed ore to a stockpile locally called wet storage.

Primary Blast-Hole Drilling

In both the Lowell and "C" Area quarries, primary blast holes are drilled in both the serpentine ore rock and the barren serpentine or schist. Any one of the holes may penetrate all of these rocks, and data are not classified in reference to material drilled. Drilling and blasting any rock in place is considered primary at this mine.
At present the "C" Area quarry is operating on three benches; each bench face is approximately 50 feet high. The Lowell quarry started operating with 125-foot bench faces, but in 1953, 60- to 65-foot bench intervals were adopted. The five benches presently in operation range from 75 to 100 feet in width. All 6-inch-diameter primary blast holes are drilled to a depth of 5 feet below the bench floor. The average burden (bottom of hole to toe on bench) is from 30 to 40 feet, depending on the material, and the spacing between holes ranges from 10 to 15 feet, depending on the burden. The distance from bench rim to the collar of drill hole ranges from 10 to 15 feet, depending on the previous breakback. Breakback or overbreak is usual and ranges from 10 to 25 feet, depending on whether ore or barren rock is blasted. Overbreak is considerably greater in ore than in barren rock. Usually very little toe is left after a blast.

From January 1 to June 30, 1959, inclusive, there were drilled 24,360 feet of 6-inch primary blast holes in 365 shifts or an average of 66.9 feet per shift. Actual drilling time was 1,918 hours at an average penetration speed of 12.7 feet per drilling hour. During this period, 13 tungsten-carbide, insert-type, 6-inch bits were used to discard, resulting in an average of 1,913.5 feet drilled per bit. Drill bits are dressed on a wheel an average of 16 times each before discard.

**Equipment and Operation**

All 6-inch primary blast holes are drilled by two "down the hole" crawler-mounted drills (fig. 17). Two-man crews operate one rig 3 shifts per day and the second rig 1 shift per day. The drills are identical except that one has a 20-foot mast and the other has a 25-foot mast. Drilling equipment operates on air at 100-p.s.i. pressure furnished by a diesel-driven, 600-c.f.m. rotary-type compressor.

This equipment is designed for drilling vertical holes to a depth of 70 feet, but at this mine no difficulty is encountered in drilling vertical holes to a depth of 185 feet. To meet the occasional need of inclined holes to compensate for previous breakback or to eliminate a toe, the company has designed and equipped both drills with a wedge-type adapter mounted at the base of the mast (fig. 18). At an inclination of 10 degrees from the vertical, holes are easily drilled to 150 feet, but at 15 degrees, cuttings fail to clear at 140 feet and plug the drill hole.

Drill rods 4 inches in diameter are used in 18-, 20-, and 24-foot lengths. A geared, air turbine mechanism traveling on the mast rotates the rods at a usual speed of 70 r.p.m., and an air-actuated link roller chain both feeds the rods while drilling and pulls them when withdrawing. The 6-inch-diameter, tungsten-carbide insert bit is actuated by the "down the hole" percussion drill equipped with a butterfly valve. Cuttings are blown out of the hole by the drill exhaust and by a steady air jet through the bit. Fine cuttings are conveyed by flexible tube from the hole collar to a cyclone collector to eliminate dust. Coarse cuttings accumulate on the ground at the collar.
FIGURE 17. - Down-the-Hole Drill in Position for Inclined Drilling.
When a rib of rock remains as a toe after a bench is blasted, wagon drills are employed to drill blast holes for removal of the toe (fig. 19). Two wagon drills are available for this purpose; one, mounted on four rubber-tired wheels, drills with a 2-3/4-inch, tungsten-carbide insert bit, and one crawler-mounted machine uses a 3½-inch, tungsten-carbide insert bit. Which machine is chosen to drill a particular hole largely depends on the quantity of explosive necessary per foot of hole to break the rock. A portable, diesel-driven, 600-c.f.m. rotary compressor supplies air for this equipment.

Primary Charging and Blasting

The head loader and selected members of the quarry crew charge and fire the 6-inch primary blast holes.

Experience has governed selection of the following explosives as being well suited to the requirements: 75-percent-gelatin dynamite in 25-pound netted sticks, 75-percent-gelatin dynamite in 5-pound sticks, and 60-percent-gelatin dynamite in 25-pound netted sticks (table 4). Plastic, wire-countered detonating fuse, triggered by an electric cap, detonates the charge.

The primer is always placed in the bottom of a hole and consists of the bottom stick in a series of 5- by 24-inch sticks of 75-percent-gelatin dynamite. Dynamite cartridges are lowered by rope in the usual way (fig. 20). After charging with explosives, all holes are stemmed to the collar with dry mill tailings. Detonating fuse from each hole is connected to a trunk line which is ignited by a No. 0 electric detonator. The 440-volt blasting switch is in a concrete blasting house, located in a remote position. Some variance in charge is necessary in blasting ore-bearing serpentine, barren serpentine, and barren schist. Usually satisfactory fragmentation results from a blast, the ore-bearing serpentine being most easily fragmented. Figures 21 and 22
represent respectively a typical bench face in the Lowell quarry, before and after blasting.

Wagon-drill holes 2-3/4 inches in diameter are charged with 1 1/2- by 12-inch sticks of 40-percent-gelatin dynamite, and holes 3 1/2 inches in diameter are charged with 2-3/4- by 16-inch sticks of Ajax No. 2. All holes are fired by electric detonators. The burden on each hole determines the explosive charge.

**TABLE 4. - Types of dynamite used**

<table>
<thead>
<tr>
<th>Strength, percent</th>
<th>Stick size, inches</th>
<th>Weight, pounds</th>
<th>Designation</th>
</tr>
</thead>
<tbody>
<tr>
<td>30</td>
<td>1-1/4 x 8</td>
<td>-</td>
<td>Standard Gelatin.</td>
</tr>
<tr>
<td>40</td>
<td>1-1/2 x 12</td>
<td>-</td>
<td>Do.</td>
</tr>
<tr>
<td>45</td>
<td>2-3/4 x 16</td>
<td>4.5</td>
<td>Ajax No. 2.</td>
</tr>
<tr>
<td>60</td>
<td>5 x 30</td>
<td>25</td>
<td>Ajax No. 1.</td>
</tr>
<tr>
<td>60</td>
<td>5 x 24</td>
<td>25</td>
<td>Special Gelatin.</td>
</tr>
<tr>
<td>75</td>
<td>5 x 24</td>
<td>25</td>
<td>Giant Gelatin.</td>
</tr>
<tr>
<td>75</td>
<td>2-3/4 x 16</td>
<td>5</td>
<td>Special Gelatin.</td>
</tr>
<tr>
<td>75</td>
<td>5 x 24</td>
<td>25</td>
<td>Do.</td>
</tr>
<tr>
<td>75</td>
<td>5 x 24</td>
<td>25</td>
<td>Do.</td>
</tr>
<tr>
<td>75</td>
<td>5 x 24</td>
<td>25</td>
<td>Giant Gelatin.</td>
</tr>
</tbody>
</table>
Secondary Drilling and Blasting

Until 1954, drilling boulders and oversize from primary blasts was accomplished by the use of 6 jackhammer shifts per 24 hours. All jackhammer drilling has been replaced by the use of one "travel drill" operating 1½ shifts per day (fig. 23).

This self-contained drilling equipment is powered by a 75-h.p. diesel engine, which drives a 210-c.f.m. piston-type compressor. All functions of the equipment, including movement from place to place on rubber-tired wheels, are accomplished by the use of compressed air. A 35-foot, 6-inch-diameter tubular boom is attached to the front of the vehicle. An enclosed operator's cab and a drifter drill are moved as a unit by means of a traveling chain drive to any position along the boom. The automatic screw-feed dry drifter
FIGURE 21. - Bench Before Blast.

FIGURE 22. - Bench After Blast.
FIGURE 23. - Secondary Drilling.

may be swung in nearly any downward or horizontal direction. The boom moves in a vertical arc to 45 degrees above horizontal, and the bearing of the boom is controlled by movement of the swiveled single wheel supporting the rear end of the entire unit. Holes can be collared to a height of 33 feet above the quarry floor.

Movement of the machine to different stations or benches, as well as all operations of the drill, are under the control of one man in the enclosed cab, which in winter is heated by bottled gas.

Secondary blast holes are charged with 1\(\frac{1}{2}\) - by 8-inch sticks of 30-percent-gelatin dynamite and fired by No. 0 electric detonators connected in a series to a 440-volt power line.

**Truck Loading**

Four power shovels and two bulldozers are engaged in loading trucks with either broken ore or waste. All shovels are crawler mounted and electrically controlled and operated on 250-volt direct current, generated by motor generator sets operating on 2,300-volt alternating current.
A 7-cu.-yd., 450-h.p. shovel is the largest in use and is employed predominantly in loading barren rock to avoid breaking up large pieces (fig. 24). Maximum digging height and maximum truck-loading radius are both 34 feet. The dipper-bottom and tooth bases are manganese steel. High-carbon-steel tooth points are not built up but are used to discard. In well-broken material, this shovel loads 20 tons per minute in three passes, and on steady operation it requires the use of approximately 340 kw.-hr. Three smaller shovels are used largely to load ore, when and where required. Two of these shovels are driven by 150-h.p. motors and have 3-cu.-yd. ratings but are equipped with 2½-cu.-yd. dippers, and one shovel is driven by a 250-h.p. motor and is equipped with a 4-cu.-yd. dipper. A total of 4 shovel shifts operate in both quarries each 24-hour period. The three smaller shovels, strategically located, permit selection of ore from various areas to be blended in accordance with production requirements. The high-carbon-steel dipper tooth points, used on all shovels, have an average use life of 59,000 tons to discard without buildup.

One 180-h.p., diesel-driven, crawler-type bulldozer, equipped with an 11-foot blade, and one four-wheel, rubber-tired, 200-h.p., diesel-driven bulldozer, also equipped with an 11-foot blade, are used to clean up for the shovels and to trim waste dumps. A total of 3 bulldozer shifts are operated in a 24-hour period.

FIGURE 24. - Electric Shovel (7 cu. yd.).
Haulage

All ore and barren quarry rock is hauled in seven diesel-powered, rear-dump trucks. Two of the trucks are equipped with 200-h.p. engines and have both a rated capacity and an average duty of 15 tons. Five of the trucks are equipped with 300-h.p. engines and have a rated capacity of 22 tons, although their actual average load is 20 tons. All loads are carried either on the level or downgrade, and for this reason, trucks are equipped with oil retarders to save brakes. Three trucks serve each shovel, whether it is working with ore or barren rock. A total of 14 truck shifts are operated in a 3-shift, 24-hour period.

Main-haulage roads from the end of mining benches to the primary crusher and to the waste dumps total 2 miles in length and have a minimum width of 35 feet and a maximum grade of 8 percent (fig. 25). Ore haulage from quarries to mill averages approximately 700 yards, and waste haulage from quarries to dumps averages about 500 yards. Two light dump trucks are used in summer to supply ½-inch mill tailings for road surfacing, and in winter to deliver the same material to insure traction. Roads are maintained by one diesel-driven grader equipped with a 13-foot blade. The grader is operated a single 8-hour shift.

FIGURE 25. - Truck Road and Grader.
in summer, but in winter snow removal may require 24-hour-per-day operation. No bituminous or other binder is used for road surfacing owing to the fact that such material would subsequently appear in the mill and contaminate the fiber.

Maintenance and overhaul of quarry equipment is conducted in shops at the plant, except for complete rebuilding of diesel motors which is done in commercial shops. Truck tires are recapped once, at a commercial shop.

Crushing

At this property, primary and secondary crushing operations are under direction of the mining department. In winter the crushers operate 3 shifts per day, and in summer they operate 2 shifts per day.

Mine-run ore is received in a 30-ton steel hopper, bottomed by a 5- by 16-foot pan feeder. In winter, the underside of the steel hopper is heated by oil flame to prevent freezing. The pan feeder serves a 48- by 60-inch jaw crusher, which has been fitted with curved jaw plates to facilitate breakage. A 200-h.p., squirrel-cage motor drives the crusher through 10 V belts. The manganese steel crusher plates are set at a 6-inch discharge opening, through which the ore falls to a 42-inch conveyor belt supported by rubber-cushion idler rolls. The belt delivers ore to a 1½-inch stationary bar grizzly, making an oversize product which is fed to a 5½-foot cone crusher set at a 1-5/16-inch discharge opening. The cone crusher product joins the grizzly undersize on a 30-inch belt, which conveys the final crushing-plant product to the previously described, wet-ore storage pile.

Figure 26 indicates the location of the primary crushing plant, the secondary crushing plant, the mill-waste dump, and the wet-ore stockpile, from which 100,000 tons of ore can be drawn through underground gates as mill head feed.

MILLING

The mill building is of steel-frame construction with corrugated asbestos cement siding. It was erected in 1949 and put into operation in 1950. Equipment for opening, screening, aspirating, and packaging fiber occupies the five floors of the 60- by 150- by 95-foot main section of the mill. The dust collector is located above the fifth floor. Ore drying and fine-crushing equipment is installed in a 58- by 130- by 30-foot attached section.

Milling equipment and general flow are of conventional design for the industry. The more than 450 motors operating in the mill represent a total of over 3,600 connected horsepower. Over one-third of the total power is required for the air system.

Material is transferred either by belt conveyor, gravity, or air. Air suction is used to separate the fibers and convey them to the top of the mill so that gravity movement may be used in the succeeding states of fiber flow (fig. 27).
FIGURE 27. - Mill Flowsheet.
The mill normally operates 3 shifts per day, 5 days per week except that the entire mill is shut down for 6 hours each Thursday for minor repairs and maintenance and is also down for a 2-week period each year for major overhaul. In a 24-hour, 3-shift period, there are employed in the mill a total of 104 hourly wage employees, of which 78 constitute the 3 actual operating crews of 26 men per shift. The additional men are engaged in maintenance and utility work.

**Ore Drying**

Wet ore flows by gravity to two steel, vibrating-chute feeders located in an underground passage below the wet-ore storage pile. Movement of the feeders is remotely controlled to regulate rock discharge from the chutes. Either one or the other vibrating chute discharges to a 24-inch, upward-inclined conveyor belt, delivering the ore to a single-deck rod screen with a 1-5/8-inch opening. When tests indicate that the screen oversize does not require drying, the oversize material bypasses the dryers and rejoins the undersize, which has passed through the dryer. If all the ore requires drying, the entire flow passes through a gate splitter, which directs the flow to either or to both dryers.

There are two 80-inch (inside diameter) by 60-foot duplicate steel-shell dryers of conventional rotary-type design (fig. 28). Twelve equally spaced, longitudinal rows of baffles are riveted to the inside of the shell. The baffles consist of 3½- by 12-inch channel iron, 2 to 3 feet long, the 3½-inch face abutting the steel shell. No refractory lining is used, but alloy-steel wear plates varying in size from ½- by 15- by 17 inches to 1/2- by 15- by 24 inches are riveted to the shell as a lining between baffles. The dryer rotates at a speed of 12 r.p.m. on two sets of trunnions and is driven by a 75-h.p. motor, through a speed reducer to the dryer ring gear. The dryers are inclined downward from the feed end at an angle of 4 degrees to insure the approximate 15-minute passage time required to heat the ore to an average temperature of 110° F. The firebox consists of a cylindrical, 15-foot-long 10½-foot-diameter, stationary steel shell, lined with 9 inches of hand-rammed plastic fire-clay refractory. Heat is supplied at the end of the firebox by a low-pressure fuel oil burner, which uses 1,500 gallons per 24 hours of operation in the summer and 3,000 or more gallons for the same period in winter.

Ore is fed by gravity to a narrow, stationary, cylindrical steel hopper located between the dryer and the firebox. Material from the hopper is picked up by angled steel plates in the feed end of the rotating shell and started on its passage through the dryer. To prevent pieces of steel from the quarry entering the fine crushers, the dry ore is passed under two electromagnets suspended above belts conveying the dryer discharge to a double-deck vibrating screen.

**Fine Crushing in Mill**

Dried ore is conveyed by belt to a double-deck vibrating screen equipped with 1-3/8-inch top and 5/8-inch bottom screens. The oversize passes through a 5½-foot, short head cone crusher in closed circuit with the screen. The
minus 1-3/8-inch plus 5/8-inch material is conveyed to duplicate 3-foot, short head cone crushers set for 3/16- to 1/4-inch discharge. The minus 5/8-inch material from the vibrating screen joins the product of the 3-foot, short head crusher on a traveling tripper conveyor belt which delivers the material to the 8,000-ton dry-ore bin. This bin is housed separately from the mill.

Recovery of Asbestos Fiber

Mill capacity is approximately 3,500 tons of ore per 3-shift day. Mill processing is divided into three circuits; namely, the rock circuit, the fiber-cleaning circuit, and the grading circuit. Classification of a circuit is determined by its primary function. However, while the functions mentioned are the primary ones of each circuit, each single function is not necessarily confined to one particular circuit. Suction or aspiration is measured in water gage inches and varies in each circuit. The rock circuit employs from 2 to 2½ inches, the cleaning circuit 1½ inches, and the grading circuit from 3/4 to 1 inch of vacuum. Two types of screens are used in the mill. Shaker screens measure 5 by 11 feet, have a standard reciprocating motion, and are in many cases supported from below or above by specially designed ash or maple staves (fig. 29) that give the screen the desired motion. Rotex screens
FIGURE 29. - Screen and Aspirator Hood.

FIGURE 30. - Ruberoid Fiberizer Open for Inspection.
measure 5 by 10 feet and have an oscillating head motion in the plane of the screen which progressively changes to a lengthwise reciprocating motion at the discharge end. Figure 27 includes only one of the two identical rock circuits and one of the two identical cleaning circuits.

Rock Circuit

The primary function of the rock circuit is the separation of fiber from the host rock. Compared with the other circuits, relatively strong suction is used at the hoods so that all possible fiber is removed and the remaining rock may be discarded to waste. At the same time a certain amount of grading, according to fiber length, is accomplished by the use of different screen openings on the various screens.

The rock circuit at the Lowell mill of the Ruberoid Co. consists of two identical units. The mill feed, regulated by remotely controlled vibrating feeders under the dry storage bin, is divided equally to these two units. In case of equipment breakdown in one of the units, the mill may be operated at partial capacity on the other.

Feed to a unit is first sized on a vibrating screen into plus and minus 3/8-inch. Oversize from this screen containing very little if any free fiber is passed on to the 800-r.p.m. Ruberoid fiberizers\(^5\) for liberation of still unreleased fiber. The movable part of these fiberizers (fig. 30) consists of a vertical shaft on which two stages of vanes are mounted by means of a spider, which serves as a distributing plate. The rock is fed by gravity to the top center against the shaft and thrown out by centrifugal force through the vanes and against a corrugated breaker plate, which serves as the liner of the mill. Impact breaks the coarse rock particles along the weaker, fiber-containing seams, developing only a minor quantity of rock powder. Air movement generated by the vanes keeps released or free fiber in motion and prevents destruction of fiber length. Undersize from the vibrating screens discharges to shaker screens equipped with suction hoods to remove the free fiber. The material passes over two ¼-inch perforated-plate shaker screens where long fibers are aspirated; the retained material then passes over two shaker screens equipped with 1/8-inch perforated plate where fibers of medium length are removed by aspiration. The fibers removed are separated from the air stream by cyclone collectors, which discharge to the fiber-cleaning circuit. Exhaust air from the cyclones passes to the main mill dust collectors. Undersize from the shaker screens passes on to additional shaker screens equipped with 1/16-inch perforated plate for removal of shorter fiber. Oversize from the shaker screens, consisting of rock and rock with unreleased fiber, passes on to an impact mill.

The impact mill, which operates at 900 r.p.m., is essentially a vertical-shaft, swing-hammer mill, which breaks the rock and releases the fiber by impact of the hammers against the particles and impact of the particles against a breaker plate.

\(^5\)Reference to specific makes or models of equipment is made to facilitate understanding and does not imply endorsement of such brands by the Bureau of Mines.
Following the Ruberoid fiberizers and the impact mill, the rock again passes over two shaker screens equipped with ½-inch and two screens equipped with 1/8-inch perforated plates, for removal of long and medium-length fibers. The plus ½-inch coarse rock is rejected to tailings; the minus ½- plus 1/8-inch material contains sufficient fiber to justify additional treatment and is passed to the next stage of impact milling.

The minus 1/8-inch material from all the previous shaker screens now passes over a shaker screen equipped with a 1/16-inch perforated plate for removal of short fibers already free. Undersize from this screen is rejected, and aspirated fiber goes to the cleaning circuit as before. The screen oversize that has not been aspirated is then treated in an impact mill (1,200 r.p.m.), to release additional fiber. Discharge of this mill feeds the two final shaker screens in the rock circuit, where the last short fibers are removed. Oversize and undersize products of these screens are rejected.

The rock circuit, then, consists of a series of shaker screens equipped with suction hoods, followed by fiberizers to release additional fiber. Basically the process is directed toward removing free fiber before any further milling action is taken which might shorten fiber length. A primary separation into long, medium, and short fibers is also made. All fiber aspirated goes to the cleaning circuit, with all exhaust air from the cyclone going to the dust-collecting unit. Cleaned rock is rejected to tailings.

Fiber-Cleaning Circuit

The function of this circuit is threefold. First, to further open fibers so that rock particles and relatively unopened material may readily be classified and removed at the suction hoods. Second, to classify and separate the rock particles and unopened material from the open fibers. Third, to further segregate fibers according to length.

These functions are accomplished on the long, medium, and short fibers from the rock circuit in a similar series of operations.

The fibers are first passed through standard graders consisting of fixed, horizontal, cylindrical screens of perforated plate. Beater arms and tips are attached to a rotating horizontal shaft, centered within the screen, and arranged in a spiral to form a three-quarter to one turn helix, which feeds the material through the grader, impells short fiber and sand through the screen plate, and opens the fibers. Depending upon operating requirements, spirals are varied and beater tips are angled to govern the rate at which material passes through the grader. Speed of the shaft and size of plate perforation are also varied according to location in the flow of material. Undersize removed from long and medium-length fibers is combined with short fibers from the rock circuit.

The long and medium-length fibers from the grading machines are discharged to shaker screens with suction hoods where open fibers are aspirated; then they are passed to cyclones which discharge to the grading circuit.
Oversize from these shaker screens, consisting largely of unopened fibers, passes through opening equipment and is returned in closed circuit to a previous point in the flow. Undersize from the shaker screens joins undersize from the graders and short fiber from the rock circuit. This latter product now passes over three Rotex screens equipped with suction hoods. Undersize from these screens is rejected to tailings, and screen oversize not aspirated is returned through opening equipment to previous points in the flow. Aspirated fiber goes to a grader where it is separated into short and very short fibers. The short fiber, which is the grader oversize, is treated by fiber-opening equipment and sent to the grading circuit. The grader undersize is passed over another Rotex screen and subsequent shaker screens. Undersize from these units is rejected. Unopened fibrous oversize is returned to the flow through opening equipment. Aspirated fiber is passed over a Rotex screen, through additional opening equipment, and delivered to the grading circuit.

Thus, in the cleaning circuit, fibers have been further opened, rock and unopened material have been removed by classification, and fibers have been segregated more completely into four main divisions: long, medium, short, and very short. All fibers aspirated go to the grading circuit, and all exhaust air from the cyclones goes to the main dust-collecting unit.

Grading Circuit

The primary function of the grading circuit is classification of fibers into lengths established for standard grades. In addition, further cleaning is accomplished by removal of fines and by classification with suction hoods. As previously noted, powerful suctions are used in the rock circuit, less strong in the cleaning circuit, and still less strong in the grading circuit. Special classification and opening equipment is used to obtain special grades for particular requirements. Fibers from both units of the rock circuit and both units of the cleaning circuit are combined and are treated in a single grading circuit.

Basically, the flow is through standard grading machines, where additional short fibers are removed from the long fibers and further fiber opening takes place. The fibers then pass over shaking screens, where additional fine sand and dust is removed and more unopened fibers are dropped out. The separate flows, according to fiber length, are, however, arranged so that various lengths may be blended to produce different grades and the length of particular grades being produced is controlled. A total of 35 to 40 different grades can be produced, and 5 to 8 different grades may be produced at one time.

Several different types of opening equipment are used in the cleaning and grading circuits. The particular equipment used depends upon fiber length and characteristics, longer fibers requiring milder treatment to preserve fiber length. In all cases, equipment is designed to apply the most work to the heavier unopened material and to selectively separate the opened fibers.

Shaking screens and Rotex screens in both the cleaning and grading circuits are equipped with rubber balls below the screens to prevent blinding; thereby their efficiency is increased.
Dust Collector

The dust collector is a vertical, pressure-bag-type air filter (fig. 31), divided into 8 compartments, each compartment made up of 336 bags, 8 inches in diameter and 17 feet high. Compartment intakes close in sequence to allow cleaning by automatic shaking of the bag tops. A full shaking cycle of all eight compartments is completed in 30 minutes. The unit handles air at the rate of 320,000 c.f.m., at 3 1/2 to 4-inch pressure loss.

Dust from the filters is collected in hoppers, which are continuously emptied through rotary valves. The discharged material is passed over screens, where any long fibers are recovered and heavy fines are rejected. The middle cut is further classified in mechanical air separators and other special equipment and marketed as standard grades of asbestos known as floats.

Control

Fibers from the grading circuit discharge to 6- by 8- by 12-foot bins. Fibers entering the bins are sampled and checked at regular intervals for length, cleanliness, and amount of unopened material. The Quebec Standard screen test is used to check length compliance with standard grade requirements.

After fiber has accumulated in the bins and has been passed by the tester, it is discharged to the bagging machines. As a further check on grade of shipments, a composite is made of samples taken from each of 50 bags in sequence, and the composite is tested for compliance with standard specifications.

Additional tests are made in the quality-control laboratory to check various characteristics of the many grades. These tests maintain control on the screens, opening equipment, and suction hoods through which the fibers are processed, to insure uniform products in accordance with established standards.

Bagging and Shipping

Three types of packaging machines are in use. Seventy-five to eighty-five percent of total production is packaged in 100-pound compressed paper packages (fig. 32). The fiber in these packages, or bales, is compressed from a loose density of 10 to 15 lb./cu. ft. to a density of 50 to 56 lb./cu. ft. The resulting package measures approximately 16 by 24 by 8 inches, but varies slightly depending upon the grade of fiber it contains. This compressing reduces shipping and storage space, and permits palletizing and mechanical handling of the packages. The remaining production is packaged in either jute or paper valve bags. To avoid compression and damage to fibers, the longest grades are packaged in jute bags (fig. 33). The shortest fibers are usually shipped in paper valve bags.

Compressed bags are shipped on nonreturnable, fork-lift pallets. All production is transported 18 miles by company-owned trucks to warehouse and railhead at Morrisville, Vt.
FIGURE 31. - Section of Dust Collector.
FIGURE 32. - Compression Packaging.

FIGURE 33. - Bagging Fiber.
PERSONNEL

This operation employs an average of 248 persons, 214 of whom are on an hourly wage and 34 on a salary basis. Salaried personnel include those engaged in administrative, technical, supervisory, and clerical activities. Operations are on a 3-shift, 5-day-per-week basis, the foremen and their crews changing shifts each week.

Satisfactory working conditions at this plant and the scarcity of other industry in the area, result in a very low labor turnover. Most skilled labor is obtained by training presently employed unskilled labor.

The company supplies 3 buses for transportation of approximately 75 percent of all hourly wage employees, who share bus-operating costs with the company. Personnel of all shifts are picked up and returned to eight centers and points along the bus routes, which cover a radius of 20 miles around the mine.

A labor contract has been in effect since 1953 with the United Cement, Lime and Gypsum Workers, International Union, AFL-CIO.

SAFETY AND FIRE PREVENTION

Safety is stressed in all departments at this plant. A complete plant safety inspection is conducted once each month by a four-member committee, consisting of one supervisor and three hourly wage employees selected from various departments. Departmental inspections are conducted on a semimonthly basis. Each month new committees are appointed to allow all personnel to participate. Committee reports are furnished to all supervisors for action and are also posted on bulletin boards. All safety committees have a meeting once each month to coordinate recommendations and action. First aid refresher meetings are held periodically under the direction of a qualified employee. A safety engineer, representing the company insurance carrier, makes a monthly inspection of the entire plant.

Personnel connected with the quarry or exploration departments wear hard hats at all times. All personnel are required to wear safety glasses, except when working in offices. Plain-lens glasses are furnished by the company, as are corrective lenses upon receipt of a prescription from an employee.

The safety record for the entire operation is excellent. Only four lost-time accidents occurred in the past 18 months of operation.

The plant has a well-trained and well-organized fire brigade on each shift. A dry pipe sprinkler system protects the mill and research building, stockroom, machine shop, bag storage, and several minor buildings. Four dual-outlet hydrants are located in hose houses at strategic points near major buildings. Each hose house is supplied with 300 feet of 2½-inch hose and other firefighting tools.
Water for fire control is supplied by a large spring-fed, man-made pond near the mill. A pump house adjacent to the pond is equipped with two vertical turbine pumps, either of which will supply 750 g.p.m. at a pressure of 125 p.s.i. One of the pumps is electrically operated and starts pumping automatically upon release of pressure in the sprinkler system or at a hydrant. The second pump is diesel driven. A 25-g.p.m. electrically operated pump keeps a constant 80-p.s.i. pressure on the system. Both nonfreezing and dry-chemical extinguishers are strategically placed throughout the plant. Fire detection is aided by watchmen, who check watch-clock stations.

COST DATA, 1958

The following tabulation lists all costs made available for this operation. Where possible, data have been expressed in units of work or of material, which are more useful than dollar values.

<table>
<thead>
<tr>
<th>Unit</th>
<th>Description</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Power, average rate per kilowatt-hour with 98.5 power factor, dollars</td>
<td>0.00953</td>
</tr>
<tr>
<td></td>
<td>Direct operating and maintenance labor per ton quarried (ore and waste)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Primary drilling and blasting</td>
<td>0.011</td>
</tr>
<tr>
<td></td>
<td>Secondary drilling and blasting</td>
<td>0.006</td>
</tr>
<tr>
<td></td>
<td>Power shovels</td>
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</tr>
<tr>
<td></td>
<td>Trucking</td>
<td>0.015</td>
</tr>
<tr>
<td></td>
<td>Bulldozing</td>
<td>0.002</td>
</tr>
<tr>
<td></td>
<td>Power, per ton quarried (loading ore and waste)</td>
<td>0.84</td>
</tr>
<tr>
<td></td>
<td>Powder per ton blasted (primary blasting)</td>
<td>0.298</td>
</tr>
<tr>
<td></td>
<td>Powder per primary ton blasted (secondary blasting)</td>
<td>0.070</td>
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<tr>
<td></td>
<td>Maintenance materials per total tons quarried</td>
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</tr>
<tr>
<td></td>
<td>Quarry-truck tires (approximate) per ton quarried</td>
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</tr>
<tr>
<td></td>
<td>Drilling 6-inch primary blast holes (overall per foot)</td>
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<tr>
<td></td>
<td>Primary and secondary crushing (per ton ore crushed)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Direct operating and maintenance labor</td>
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</tr>
<tr>
<td></td>
<td>Power</td>
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</tr>
<tr>
<td></td>
<td>Maintenance materials</td>
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<tr>
<td></td>
<td>Overburden stripping per cubic yard (by contract)</td>
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<tr>
<td></td>
<td>Core drilling total per foot (overburden NX-BX, rock AX)</td>
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</tr>
<tr>
<td></td>
<td>Ore drying (per ton dried)</td>
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<tr>
<td></td>
<td>Operating and maintenance labor</td>
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<td></td>
<td>Fuel oil</td>
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<tr>
<td></td>
<td>Power</td>
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</tr>
<tr>
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<td>Maintenance materials</td>
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<tr>
<td></td>
<td>Transportation of fiber to railroad warehouse in Morrisville, VT.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(per ton mile)</td>
<td>0.089</td>
</tr>
</tbody>
</table>

* U.S. GOVERNMENT PRINTING OFFICE : 1962 O — 634516