BENEFICIATION of Hill-Trumbull Mine Ores

By
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Description of method used in beneficiating low-grade ores—Data covering a nine-year period of operation show averag percentage of tonnage recovery 64.45 and average percentag of iron unit recovery 88.17—Crude ore treated in this perio was approximately four and one-half million tons, whic produced nearly three million tons of concentrates.

THE beneficiation of iron ore on the Western Mesaba Range in general, and at the Hill-Trumbull mine in particular, is accomplished by a process known as "washing." This treatment is necessary because most of the ore in the western district is not of sufficiently high grade for furnace use in its natural state. However, the ore is of such character that the undesirable siliceous material can be eliminated by "washing."

Before entering into an explanation or description of the methods used in treating the Western Mesaba ores, it is desirable that some understanding should be had of what distinguishes wash ore from standard grade or merchantable ore.

The iron formation on the Mesaba Range extends for a distance of 125 miles, having an approximate average width of about 2 miles. While the actual ore areas are of considerable extent, they occupy only a small percentage of the total area. Investigations have shown that almost the entire iron formation has been developed through a process of leaching of a hydraulic iron silicate known as "Greenalite" by the circulation of underground water. Where the process of leaching and subsequent enrichment was most effective, the result is the high-grade merchantable ore, but where conditions for the circulation of underground water were not so favorable, the process of enrichment was carried out to a lesser degree. These varying conditions produced iron formation grading from Greenalite, on the one hand, to high-grade ore on the other.

The degree of concentration affecting different areas naturally divide the Mesaba Range into three sections, viz, the eastern section, the central section, and the western section. In the eastern section there exists a hard, lean iron formation practically barren of merchantable deposits of any size, together with some lean siliceous material. In the central section are to be found merchantable ore bodies of large size, occurring in a rich, largely altered formation, together with a considerable amount of low-grade merchantable and non-merchantable siliceous ore material. In the western section the same altered iron formation occurs as in the central section and in it similar large ore areas; but here, instead of the merchantable ores, the non-merchantable siliceous ores predominate, together with solid and decomposed taconite. The non-merchantable siliceous ores of the Western Mesaba, together with some of the decomposed taconite and ore, are what constitute the wash ore bodies.

Typical wash-ore bodies are composed of alternating layers of high-grade ore and a very fine sand. The mass is easily broken up in mining, making a mixture of small chunks of hard ore and sand. The decomposed taconite and ore may or may not be washable; actual tests are generally necessary to determine its washability. The washable variety co sists of chunks of fairly good ore wi fine sand and considerable granular ir ore. The sand is not as free nor in definite layers as in the typical wash o but the mass is a more homogeneo mixture of the ore and siliceous ma rial, often with the sandy particles a hering to the ore.

One of the characteristic features the Western Mesaba district is the currence in places of an unrelated lay of ore material, lying on top of t Mesaba ore formation. This layer known as cretaceous ore, and consi of a coarse conglomerate of iron pebbles, grading upward through a fi conglomerate into a very fine black sha The iron content is sometimes hi enough to make it merchantable, but t lower grade material will not "was The name of this layer was derived fr the fact that fossils of various kinds found within it, and these have been termined to belong to the cretaceous a of geological history.

After the ore areas of the West Mesaba had been explored and det mined, the physical structure of the ma rial suggested the possibility of mak it merchantable through a process of c centration. The first experiments alo these lines were conducted by Mr. Wal Barrows, Jr., Mr. Chas. A. Purdon associates in 1901 and 1902, when t shipped a carload of ore from Arcturus property, near Marble, Minn. a concentrating plant at Cedartown, The results of this test were so sa factory that a small concentrating pla consisting of conical screens and McLa han jigs, was installed at the Arctu Also, in 1903 and 1904, a small plant somewhat similar construction, but w

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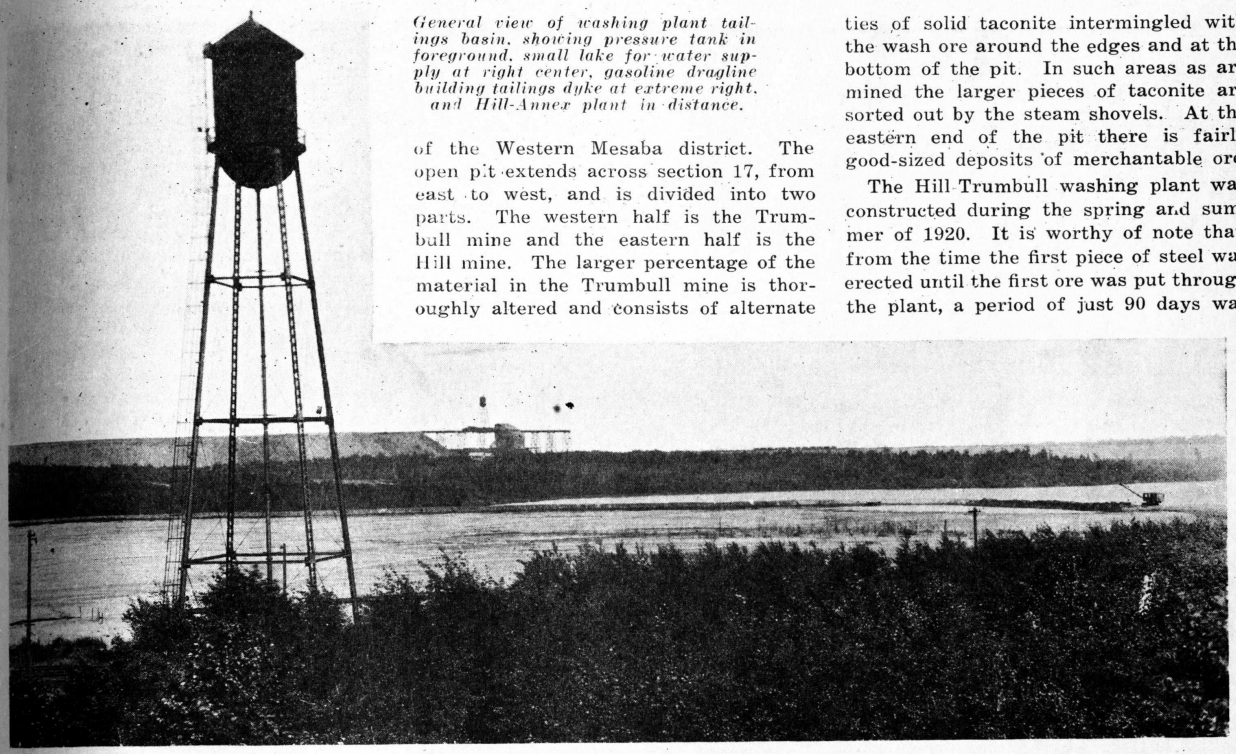


General view of washing plant tailings basin, showing pressure tank in foreground, small lake for water supply at right center, gasoline dragline building tailings dyke at extreme right, and Hill-Annex plant in distance.

out jigs, was installed and operated at the property, which is now the Holman-Cliffs mine, by Mr. Congdon and associates. The results obtained at these two experimental plants demonstrated the possibility of concentrating the Western Mesaba ores. The tests also showed that the screens and jigs would not meet the requirements of commercial operations, because of the varieties of materials to be treated, and also on account of the large quantities to be handled.

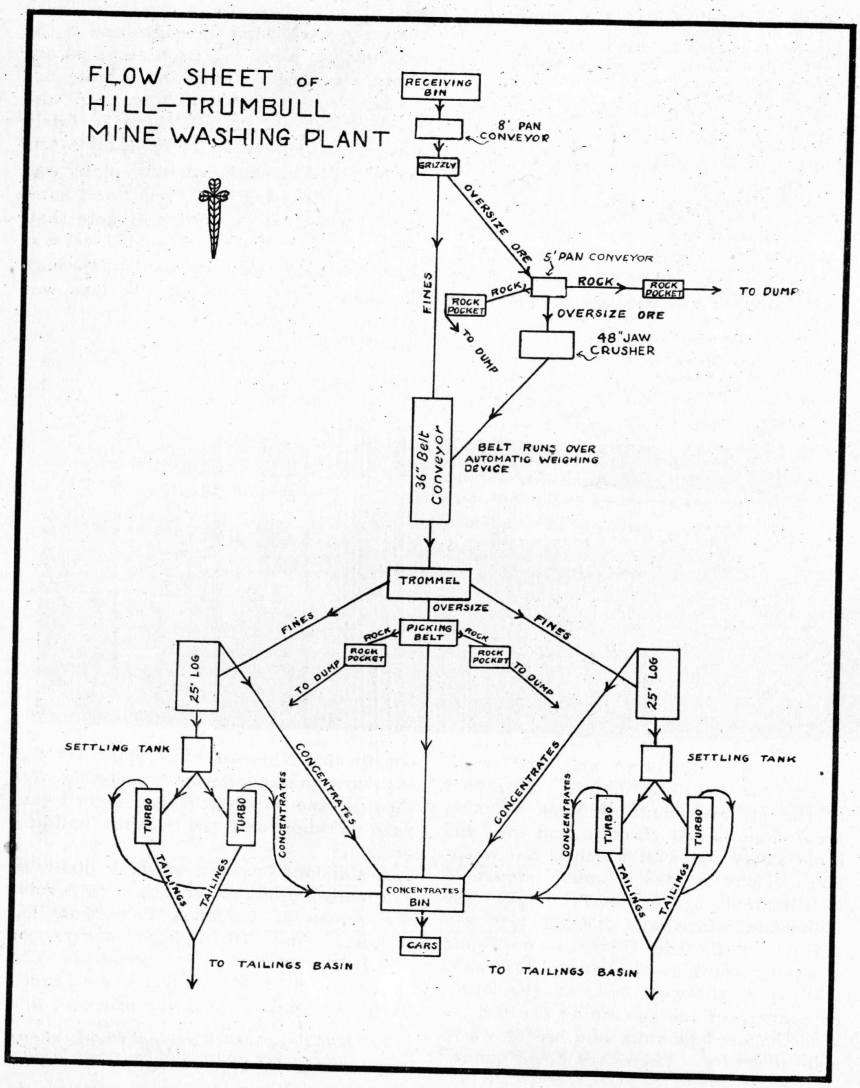
In 1905 the Oliver Iron Mining Company took up the investigation of the proper method for treating wash ores and, after considerable study and research work, erected an experimental plant in the vicinity of the Canisteo mine in 1906. During 1907 and 1908 experimental work was carried on in this plant with the machinery as originally planned, as well as with different concentrating machines which were suggested by manufacturers. As a result of these experiments, machines arranged in a series were designed and developed, which became standard for the Western Mesaba district. A standard five-unit washing plant was built by the Oliver Iron Mining Company, on Trout Lake, near Coleraine, Minn., in 1909 and 1910. During the last several years some departures from the original design have been introduced in the way of finer crushing and machines of the classifier type. Also jigging plants have been installed at several of the properties.

The Hill-Trumbull ore body is typical of the Western Mesaba district. The open pit extends across section 17, from east to west, and is divided into two parts. The western half is the Trumbull mine and the eastern half is the Hill mine. The larger percentage of the material in the Trumbull mine is thoroughly altered and consists of alternate layers of high-grade ore and sand, which is an ideal wash structure. This part of the pit also contains some taconite, some decomposed taconite and ore, and some sandy material which is not washable. There is also a small tonnage of merchantable ore in the Trumbull. The Hill mine, which was operated for several years by the Oliver Iron Mining Company, contains some high-grade sand and ore at the west end, but the larger percentage of the remaining ore body is a decomposed taconite and ore of washable structure. There are large quantities of solid taconite intermingled with the wash ore around the edges and at the bottom of the pit. In such areas as are mined the larger pieces of taconite are sorted out by the steam shovels. At the eastern end of the pit there is fairly good-sized deposits of merchantable ore.

The Hill Trumbull washing plant was constructed during the spring and summer of 1920. It is worthy of note that, from the time the first piece of steel was erected until the first ore was put through the plant, a period of just 90 days was consumed. This washing plant is of a standard one-unit design, consisting of a feeding and crusher house, a belt-conveyor bridge, and the washer building proper.

A standard one-unit washing plant, as originally designed, consists of a revolving screen or trommel, two 25-ft. log washers, four 18-ft. log washers, or turbos, and 18 concentrating tables. The concentrating tables have become practically obsolete in wash-ore practice, and

Hill-Trumbull Washing Plant, showing crusher house and conveyor bridge.



in many plants the turbos and tables have been replaced by Dorr bowl classifiers. Also, during recent years, secondary crushing has been introduced into the cycle of washing operations. This crushing is applied to the oversize from the revolving screen, whereby the material is reduced to three-quarters or half-inch size, which results in the liberation of siliceous particles that adhere to the ore chunks. The product is then returned to the log washers. This treatment is largely applied to decomposed taconite and ore. The most recent development in the beneficiation of iron ore is the introduction of jigging units in connection with the washing plants. The jigs are used to concentrate a decomposed taconite and ore material, which is not treatable by the ordinary washing process.

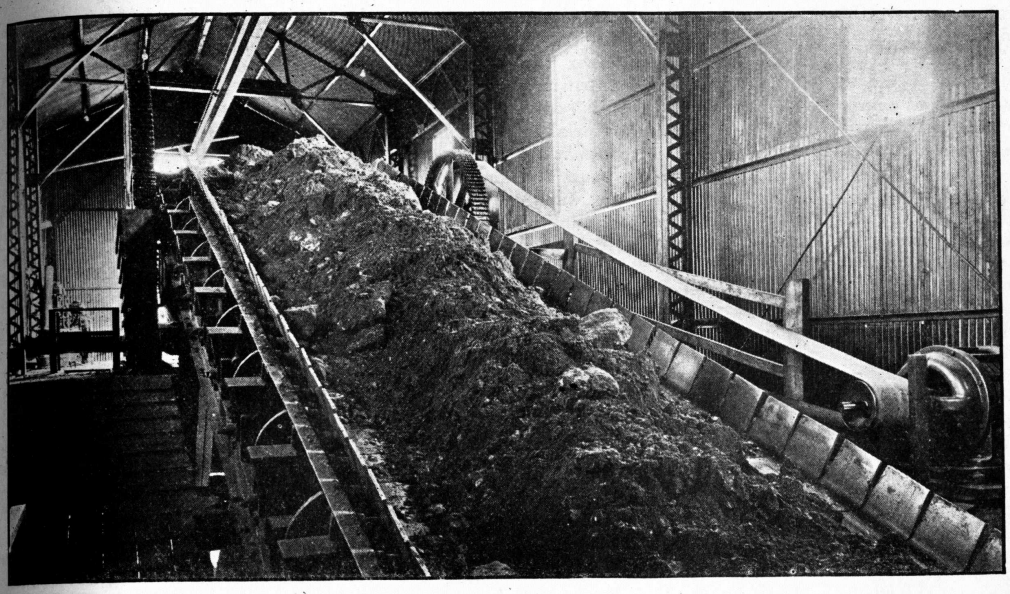
In connection with all washing plants there are receiving bins into which the crude ore is dumped, and machines for feeding the ore to the mill as well as crusher to reduce the large chunks to a suitable size.

The Hill-Trumbull washing plant is located about 2 miles southeast of the mine. The wash ore is delivered at the mill in trains of five 20-cu.-yd. air-dump cars. The material is discharged from the cars into a concrete receiving bin of six-car, or 210 tons, capacity. A train is shown at the receiving bin in the view on page 756. A machine known as an 8-ft. pan conveyor, which is 8 ft. wide and 62 ft. long, extends back under the receiving bin and forms the floor of it. The belt of this machine, consisting of a series of steel plates, 1 ft. wide, joined together with hinges and pins in the shape of an endless chain, runs over rollers on an inclined plane, 20 degrees from the horizontal, carrying the ore from the receiving bin and discharging it onto a set of grizzly bars spaced 4 in apart. The conveyor is driven by a variable speed motor, so that the feed to the mill can be regulated to a greater or lesser degree, depending on the quality of the ore being treated. When loaded to capacity, over its full length, the 8-ft pan conveyor carries approximately 7 tons. This machine, with a full load, is shown on page 755.

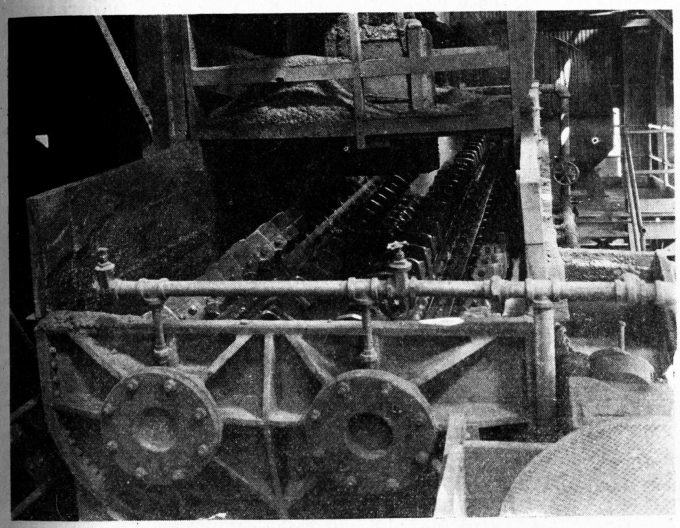
When the material passes over the grizzly, the large chunks of ore and taconite are separated from the mass and delivered onto a horizontal 5-ft. pan conveyor, which acts as a picking belt. Here the pieces of taconite are removed by means of an air-operated ram and deposited in rock pockets, from which it is drawn off into cars and hauled to the rock dump by an electric locomotive. The large chunks of ore are carried to a 48-in. jaw crusher, where they are reduced to 3-in. size and delivered onto a 36-in. rubber belt conveyor, which also receives the fine material which has passed through the grizzly. The discharge end of the 8-ft. pan conveyor, the grizzly, the 5-ft. pan conveyor, the jaw crusher and the air-ram are shown in the illustration at the bottom of page 755.

The 36-in. conveyor is an endless rubber belt, 192 ft. long from center to center of the end pulleys, and supported by rollers set at regular intervals, rising on an inclination of 20 degrees from the horizontal. This conveyor carries the wash ore from the grizzly and crusher to the top of the washing plant and discharges it into a revolving screen or trommel. At a point about midway along the length of the belt an automatic weighing device is installed, which constantly records the tonnage of crude ore being delivered to the mill.

The revolving screen or trommel is an inclined cylinder, 12 ft. long and 6 ft. in diameter, the surface of which consists of three sections of perforated steel plates. The openings in the plates at the receiving end are 1 in. in diameter, those in the plates of the middle section are 1½ in. in diameter, while those in the plates of the discharge end are 2 in. in diameter. As the trommel revolves, the ore is tumbled about on the interior of the machine, gradually working its way down to the discharge end. As the ore advances through this screening device, jets of water are played upon it from a perforated pipe. This water loosens up and removes all of the free sand and other fine material from the larger chunks of ore, which are delivered onto a rubber picking belt at the lower end of the screen. As the oversize material is discharged onto the belt it is carried forward to a chute through which it runs to the concentrate bin. As the screen product is moved along toward



Conveyor to Crusher



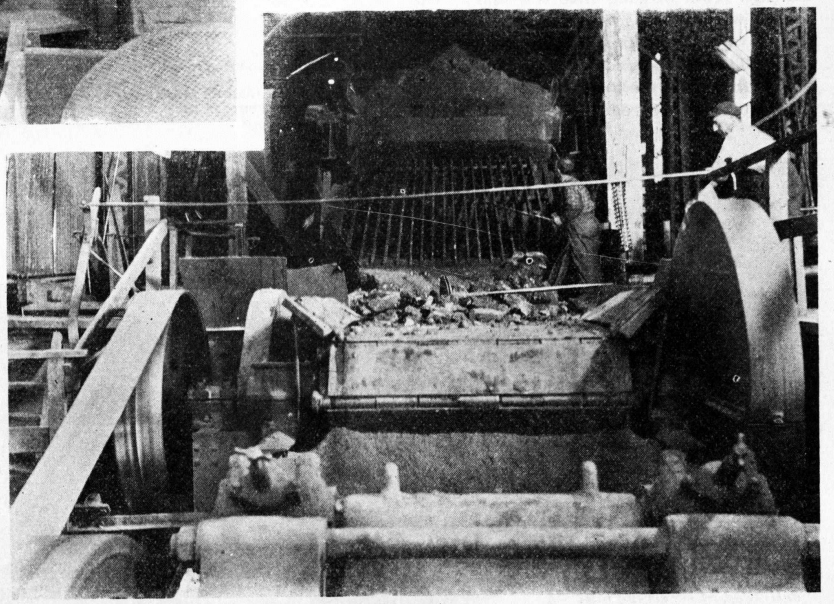
Looking into the tailings end of 25-foot log washer.

Right—Discharge end of 8-foot pan conveyor. Grizzly, 5-foot pan conveyor and 48-inch jaw crusher in foreground. The small shaft and disk in the center of the picture is an air ram used for handling large chunks of rock.

the chute, any taconite or other undesirable material is picked off by men stationed on either side of the belt. All such taconite and other waste substances are delivered to a rock pocket by means of chutes, from which it is drawn off into 3-ton cars and hauled to the rock dump.

The finer material, which passes through the openings in the screen, drops into a hopper underneath, from which it goes to a cushion box, where it is divided into two equal parts. The divided feed is sent through launders to two 25-ft. log washers, located on the right and left sides of the floor below the screen. The log washers consist of a steel trough 25 ft. long, with rounded bottom, set at an inclination of 1¼ in. to the foot. Within the trough are two shafts, running the full length of the machine and supported by bearings at either end. Set at 90 degrees from each other, around the shafts, are four rows of paddles, placed at regular intervals. These paddles are set at an angle, so that the four rows virtually form a broken spiral from one end of the shaft to the other. The two shafts are set at the proper distance apart, so that when the machine is in operation the paddles of one shaft overlap those of the other. The view to the left, looking into the tailings end of the 25-ft. log washer, shows the general construction of the machine and the arrangement of the paddles.

The ore, together with the water from the trommel, is fed into the log washers from above, a short distance back of the center of the machine. Additional water is introduced at both the head and tail ends. The paddles on the rotating shafts, which make about 15 r. p. m., keep the ore in constant agitation, while their spiral position continually forces the coarser material up the incline toward the head end. The



large quantity of water flowing down the incline, through the mass, carries off the fine sand and finer ore, over the tail board, and this product is conducted to settling tanks by launders. The coarse concentrated ore is discharged from the logs at the head end and goes through chutes directly to the concentrate bin.

The overflow from the logs, after going through the settling tanks, is divided into four equal parts and then fed through launders to four 18-ft. log washers or turbos. These machines are constructed and operated practically the same as the 25-ft. log washers, the difference being that the paddle shafts make about 8 r. p. m. and hydraulic water is introduced through six hutches in the bottom. The coarser material is discharged at the head-end as concentrates and goes directly to the shipping ore bin. The fine material, which is now mostly sand and carrying very low iron value, is considered as waste and discharged through launders into the tailings basin.

As the washing plant was originally designed, it was intended that the overflow from the turbos should go to 18 concentrating tables for further treatment. It was found, however, that the quantity of material recovered on these machines was so small, and the grade of the product so poor, that it was not economical to operate them.

The tailings basin is a tract of low swamp land, approximately 3,500 ft. long and 1,000 ft. wide, lying between the washing plant on the west side and Little Penacie Lake on the east side. This area is not a naturally inclosed basin, therefore it has been necessary to cast a dike along the north, east, south and part of the west sides in order to prevent the tailings from flowing into the lake. The water within the basin is controlled by overflow pipes, which discharge into the lake. The intake ends of these pipes are adjustable as to height, so that the depth of water may be regulated, and the tailings allowed to settle down before the water flows off. The dike is constructed from the tailings after the water has drained out. This work is accomplished by means of a gasoline-driven dragline, which digs up the material from the floor of the basin and casts it up to form a bank. A view on page 753 shows the pressure tank at the washing plant in the foreground, the tailings basin in the center, Little Penacie Lake at the right center, the gasoline dragline on the dike at the extreme right, and the Hill-Annex washing plant of the Jones & Laughlin Company in the distance.

The water supply for the washing operations is provided by a pumping plant, which is located near the south end of the tailings basin. The equipment consists of one 2,000-gal., electrically-driven Worthington pole pump and one 2,000-gal. electrically-driven centrifugal pump as an auxiliary. The water is pumped out of Little Penacie Lake and is delivered to the washing plant through a 20-in. spiral-riveted pipe line.

From time to time, as experience dictated, labor-saving devices have been introduced. The interior of the receiving bin was redesigned to eliminate square corners. The crude ore had a tendency to hang up and required poking to make it run. By rounding the corners this difficulty was overcome and the labor of two men was dispensed with. Large quantities of rock are removed from the ore as it passes over the 5-ft. pan conveyor and this work originally required two extra men. An air-operated ram was installed, at the side of the conveyor, which pushes and pulls the rock chunks off into pockets, with a subsequent saving in labor.

During the first several years operatio of the washing plant the railroad car which transport the concentrates, wer moved under the chutes by means pinch bars, and controlled by means hand-brakes. At the present time th cars are moved by an electric vertic drum winch, and controlled by com pressed air, conveyed to the brake cylin ders through a rubber hose. The brake are operated by a straight air valve lo cated on the loading platform at th concentrate bin. These installation again saved the labor of two men.

The results obtained at the Hill-Trum bull washing plant are best shown b the tables below, which covers a perio of nine years' operation.

While there are constant changes tak ing place in the methods and machine used in concentrating the low-grade or of the Western Mesaba district, none o these have been introduced into the Hil Trumbull washing plant. Tests hav been made to determine the advisabilit of making changes, but the ore in th Hill-Trumbull mine is of such characte that the method and machines in presen use have been proven to give as satisfac tory results as any of the new devices.

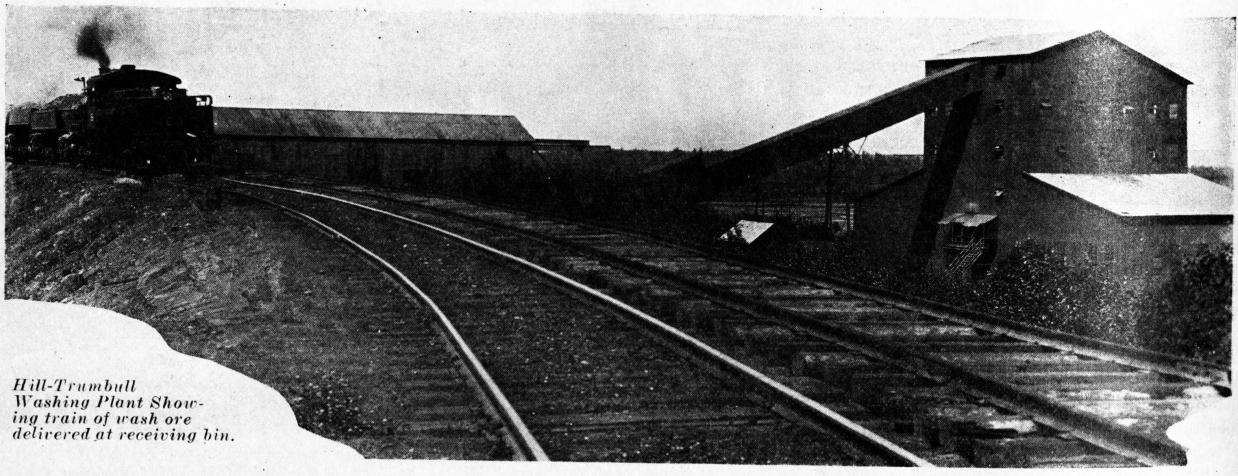
Average Analysis of the Products from the Var ou Machines in Producing 2,988,095 Tons of Concentrates

Machine	Average analysis Iron	Phos.	Silic
Screen	59.39	.060	7.6
Logs	59.82	.058	7.3
Turbos	55.01	.050	15.3
Tables*	59.39	.040	23.1
Tailings	15.75	....	....

* The tables were operated only during the pro duction of 1,024,104 tons of concentrates.

The flow sheet showing the cycle of operations i the mill is shown on page —.

	Total tons	Average analysis Iron	Phos.	Silici
Crude ore treated	4,636,237	48.70	.046	31.3
Concentrates produced	2,988,095	59.78	.059	7.4
Average percentage of tonnage recovery				64.4
Average percentage of iron unit recovery				88.1



Hill-Trumbull Washing Plant Showing train of wash ore delivered at receiving bin.