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AUTOGENOUS GRINDING OF A SAMPLE OF 'E' ORE FROM KUKATUSH MINING COMPANY (1960) LIMITED

by

P. D. R. MALTBY

MINERAL PROCESSING DIVISION

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SUMMARY OF RESULTS

A sample of magnetic concentrate, which had been ground to 20 M in a rod mill, was fed to an autogenous pebble mill and ground at a rate of 300 lb/hr. By recirculating the spigot product of a cyclone treating the mill discharge, a grind of 87.6% minus 325 M was obtained in the cyclone overflow product. The circulating load on the mill was about 400% of the fresh feed rate. From calculation of the results the work required to grind a short ton of feed from 20 M to 90% minus 325 M was calculated to be 8.3 kwh.

Magnetic separation of the cyclone overflow product gave a concentrate assaying 61.75% Fe containing 90.5% of the iron contained in the rod mill feed or crude ore. Treating this concentrate on a Jeffrey-Steffensen laboratory separator and a Wade hydroseparator after regrinding gave a concentrate assaying 65.74% Fe. The concentrate sample was reground in a steel ball mill for 5 min to 95.5% minus 325 M.

Pebbles were made from 3 to 4 in. diameter lumps of crude ore. Consumption of pebbles was about 6% of the weight of feed. A screen test on the pebbles in the mill at the end of the test showed that there was very little build-up of pebbles at an intermediate size range.

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*Scientific Officer, Mineral Processing Division, Mines Branch, Department of Mines and Technical Surveys, Ottawa, Canada.

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Shipment

On completion of an investigation into the beneficiation of a sample of Kukatush 'E' ore* from Kukatush Mining Company (1960) Limited, several tons of the crude ore remained. About 4 tons of this ore was selected for the autogenous grinding tests described in this investigation report.

Location of Property

The property of Kukatush Mining Company is near Foleyet, Ontario, about 30 miles southwest of Timmins. The head office of the company is at 2100 Drummond Street, Montreal 25, Quebec.

Purpose of the Investigation

The purpose of the investigation was to determine the feasibility of grinding a sample of the ore autogenously from 20 M to 325 M. From this, a comparison of the results obtained by autogenous grinding and steel ball grinding can be made. The main factor in an autogenous grinding operation is the saving made in the cost of grinding media. Among other economic factors that should be considered are the grade and recovery of concentrate products, and the power used in grinding.

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* Mines Branch Investigation Report IR 61-103

Analysis

All chemical analysis of products was conducted by the Analytical Chemistry Sub-Division, Mineral Sciences Division, Mines Branch. Soluble iron assays were done using the HCl method.

GENERAL PROCEDURE

Two tests were done. After the results of Test 1 had been studied, a modified flowsheet was developed for Test 2. About 4 tons of crude 'E' ore was taken as feed for the pebble milling tests. The ore was crushed and ground to 20 M in a rod mill in closed circuit with a screen. The screen undersize was fed to a 2-drum Dings magnetic separator. The resulting cobbing concentrate was filtered and stored in drums. The recovery of iron from the original head sample up to this stage was 94.5%.

The mill used for the pebble milling tests was an overflow discharge type, 30 in. diameter by 48 in. long, driven by a 10 hp motor. Crude ore lumps ranging in size from 3 to 4 in. were selected from the ore pile and were used to make up the pebble charge. The mill was filled first with 900 lb of rock lumps, and the charge was ground for 1 hr. After this grind the lumps were well rounded, and were considered suitable for autogenous grinding pebble charge.

DETAILS OF INVESTIGATION

Test 1

In Test 1 the feed rate was 250 lb/hr. The minus 20 M cobbing concentrate was fed into a rake classifier, from which the sands were fed to the pebble mill. The pebble mill discharge was pumped back to the classifier, and the classifier overflow was pumped to a cyclone. The cyclone spigot product was returned to the classifier while the cyclone overflow product was stored in a collecting cone as the finished product. The test was run for 6 hr before the circuit was filled and a steady circulating load achieved. After an additional 1 hr running time, samples were taken at 30 min intervals for 2 hr with the results shown in Tables 1 and 2.

TABLE 1

Results of Test 1

Product	Weight* lb/hr	Solids %	Analysis % Sol Fe
Crude feed**	256	-	44.83
Pebble consumption	25	-	33.1
P.M. discharge	2896	73.1	53.31
Class. sands	1711	79.0	55.38
" overflow	1185	41.7	49.80
Cyclone spigot	915	75.8	51.5
" overflow	270	6.1	37.87

*adjusted **minus 20 M concentrate

TABLE 2

Results of Screen Tests of Test 1

Mesh	Crude Feed Wt %	P.M. Disch Wt %	Classifier O'flow Wt %	Classifier Sands Wt %	Cyclone O'flow Wt %	Cyclone Spigot Wt %	P.M. Feed* Wt %
+28	2.0	0.1	-	0.3	-	-	0.4
+35	6.3	0.2	0.2	0.9	-	0.1	1.1
+48	9.5	0.8	0.8	1.9	-	0.6	2.2
+65	11.2	2.3	2.0	3.6	-	2.0	3.8
+100	12.0	6.2	5.2	7.4	-	6.1	7.2
+150	9.8	10.8	10.1	11.0	0.2	11.5	9.0
+200	8.3	17.1	16.6	16.6	0.6	19.0	16.7
+325	9.1	23.2	22.7	20.9	5.0	28.0	34.8
-325	31.8	39.3	42.4	37.4	94.2	32.7	24.8
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0

* The pebble mill feed screen analysis was calculated from the combined classifier sands, cyclone spigot and crude feed products.

During the test, 15 lb of raw pebbles was added each hour. An hour before shutdown, the pebble charge seemed low, and an additional 100 lb of pebbles was added. After the test the pebbles were taken out of the mill, screened and weighed.

A size analysis of the final pebble charge is shown in Table 3.

TABLE 3

Size Distribution of Final Pebble Charge

Size	Weight lb	Weight %
+3 in.	20	2.3
-3 in. +2 in.	563	63.1
-2 in. +1½ in.	190	21.3
-1½ in. +1 in.	80.5	9.1
-1 in. +½ in.	35	3.9
-½ in. +¼ in.	2	0.2
-¼ in. +14 M	1	0.1
Total	891.5	100.0

The cyclone overflow product was treated by a 30 in. by 15 in. Dings 3-drum separator with the results shown in Table 4.

TABLE 4

Results of Dings Separation on Cyclone Overflow Product

Product	Weight %	Analysis % Sol Fe	Distn % Sol Fe
Dings conc	65.8	58.7	92.8
" tail	34.2	8.77	7.2
Feed*	100.0	41.63	100.0

*calculated

A 2000 g representative sample of Dings concentrate was treated by a laboratory Jeffrey-Steffensen separator and a Wade hydroseparator to give the results shown in Table 5. Jeffrey separator settings were: No. 1 drum, 2.2 amp, No. 2 drum, 1.2 amp, and No. 3 drum, 0.7 amp. Upflow rate in the hydroseparator was 70 ft/hr.

TABLE 5

Results of Treating Dings Concentrate

Product	Weight %	Analysis % Sol Fe	Distn % Sol Fe
Jeff midd	7.8	37.4	5.0
" tail	6.3	13.91	1.5
Wade overflow	1.7	42.73	1.2
" spigot☆☆	84.2	64.35	92.3
Feed☆	100.0	58.7	100.0

☆calculated

☆☆The recovery of Sol Fe in the Wade spigot calculated back to the crude ore before grinding in the rod mill is 81.0%.

Test 2

Test 1 showed that the ore could be ground autogenously but it was thought that better results would be obtained if the pebble mill discharge was cobbed magnetically before classification.

In Test 2 the pebbles from Test 1 were put back in the mill and raw rock lumps were added during the test at a rate of 20 lb/hr. Feed rate was kept at 300 lb/hr. The pebble mill discharge was fed to a Dings 3-drum separator and the concentrate was pumped to a cyclone. The cyclone spigot product was returned to the pebble mill and the cyclone overflow product was stored in a collecting cone. The flowsheet for Test 2 is shown in Figure 1.

Test 2 was run for $8\frac{1}{2}$ hr and timed samples were taken after steady conditions were reached. At the end of the test the pebbles were taken out of the mill, screened and weighed.

In both Test 1 and Test 2 the pebble mill discharge was checked to see if any large pieces of pebble were present. A few $\frac{1}{4}$ in. to $\frac{1}{2}$ in. diameter pieces were collected but the use of grates on the mill did not appear to be warranted. A screen was used to trap the oversize in the ball mill discharge before the pump to the next stage.

Flowsheet for Test 2

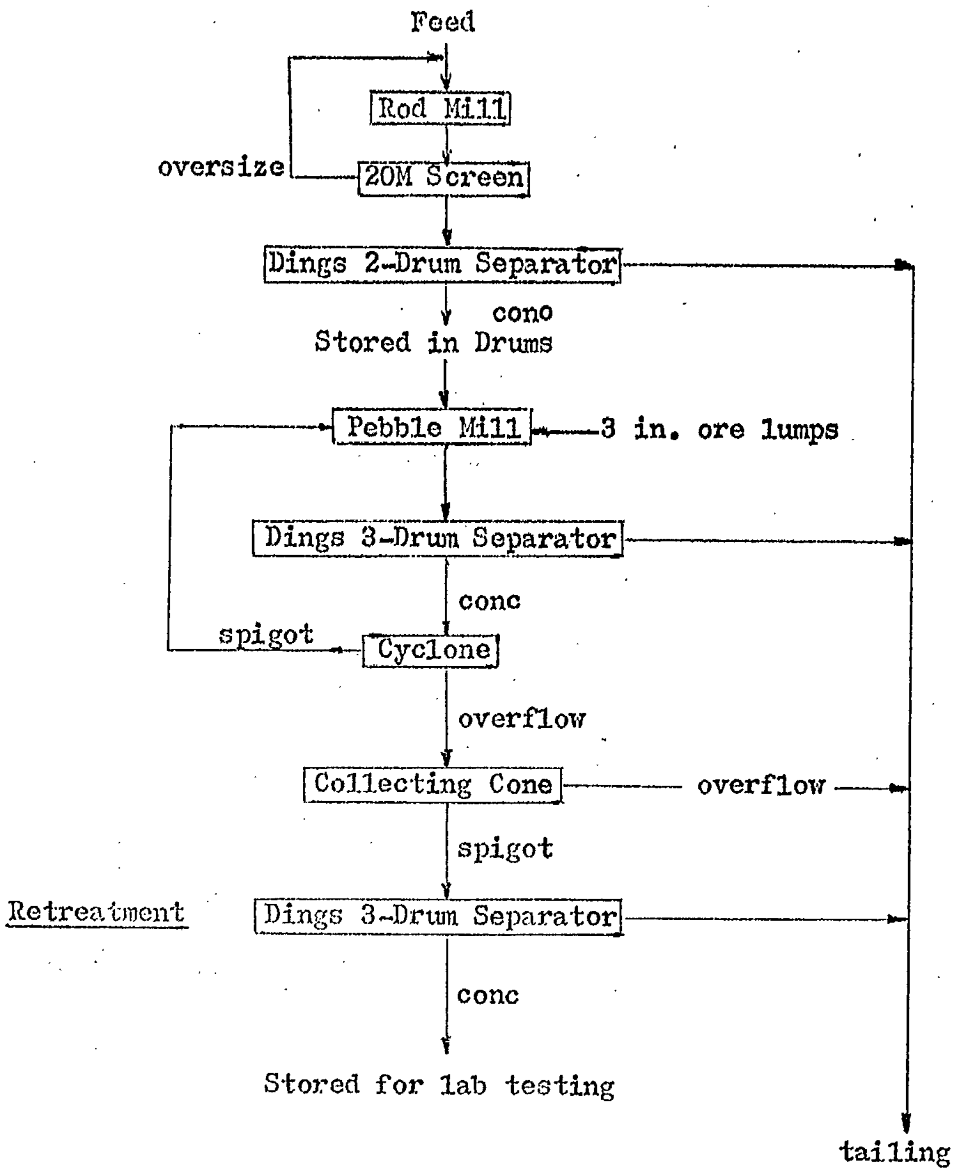

Figure 1

The balanced results of Test 2 are shown in Table 6.

TABLE 6

Balanced Results of Test 2

Product	lb/hr**	Weight %	Anal % Sol Fe	Distn % Sol Fe	Distn % of crude ore Sol Fe
Crude feed**	295	94.2	45.31	95.7	90.4
Pebble consumption	18	5.8	33.0	4.3	4.3
Pebble mill disch	1598	510.5	56.17	-	-
Dings 3-drum conc	1515	484.0	59.14	-	-
" " tail	83	26.5	6.18	3.7	3.5
Cyclone spigot	1285	410.5	59.16	-	-
" o'flow	230	73.5	58.41	96.3	91.2

*adjusted **minus 20 M concentrate

The size distribution of the final pebble charge, as compared to the initial charge, is shown in Table 7.

TABLE 7

Size Distribution of the Pebble Charge

Original Charge				Final Charge	
Size	lb	Weight %		lb	Weight %
+3 in.	20	2.3		4	0.4
-3 in. +2 in.	563	63.1		530	57.4
-2 in.+1½ in.	190	21.3		230	24.9
-1½ in.+1 in.	80.5	9.1		95	10.3
-1 in. +½ in.	35	3.9		52	5.6
-½ in. +¼ in.	2	0.2		11	1.2
-¼ in. +14 M	1	0.1		2	0.2
Total	891.5	100.0		924	100.0

From the results shown in Table 7 it appears that there is very little build-up of pebbles at an intermediate size. All the crude ore lumps added as pebbles during the test were greater than 3 in. in size.

The results of screen tests are shown in Table 8.

TABLE 8

Results of Screen Tests of Test 2

Mesh	Crude Feed Wt %	P.M. Discharge Wt %	Dings Conc Wt %	Cyclone	
				Spigot Wt %	O'flow Wt %
+35	2.3	-	-	-	-
+48	4.0	-	-	-	-
+65	6.6	1.2	1.2	1.5	-
+100	9.8	3.2	4.5	3.7	-
+150	9.2	7.1	9.9	8.7	0.6
+200	9.3	13.4	17.3	16.5	2.0
+325	12.8	27.3	25.5	32.6	9.8
-325	46.0	47.8	41.6	37.0	87.6
Total	100.0	100.0	100.0	100.0	100.0

A small sample of the cyclone overflow product was treated by a Jeffrey-Steffensen separator, followed by a Wade hydroseparator, at standard settings. The results of this test are shown in Table 9.

TABLE 9

Results of Treating Cyclone Overflow Product

Product	Weight %	Analysis % Sol Fe	Distn % Sol Fe	Distn % of crude ore Sol Fe
Jeff tail	7.6	18.39	2.4	2.2
" midd	7.8	36.20	4.8	4.4
Wade o'flow	2.0	40.70	1.4	1.2
" spigot	82.6	64.54	91.4	83.4
Feed*	100.0	58.3	100.0	91.2

*calculated

The Wade spigot product was found to be 94.1% minus 325 M.

A further test was done on the Wade spigot product. The product was demagnetized and rerun over the Jeffrey-Steffensen separator at reduced intensities on Nos 1 and 2 drums - respectively 1.5 and 1.0 amp. The results are shown in Table 10.

TABLE 10

Results of Retreatment of Wade Spigot Product

Product	Weight %	Analysis % Sol Fe	Distn % Sol Fe
Jeff tail	2.1	53.29	1.7
" midd	7.2	58.44	6.5
" conc	90.7	65.08	91.8
Feed*	100.0	64.36	100.0

*calculated

The cyclone overflow product which had been stored in a collecting cone was retreated by the Dings 3-drum separator with the results shown in Table 11.

TABLE 11

Retreatment of Cyclone Overflow Product by Dings Separator

Product	Weight %	Analysis % Sol Fe	Distn % Sol Fe	Distn % of crude ore Sol Fe
Dings conc	94.0	61.75	99.2	90.5
" tail	6.0	7.95	0.8	0.7
Feed*	100.0	58.50	100.0	91.2

*calculated

A 2000 g sample of Dings concentrate was ground in a laboratory steel mill for 5 min and passed over a Jeffrey-Steffensen separator and Wade hydroseparator at standard settings. The results are shown in Table 12. A screen test on the Wade spigot product showed it to be 95.5% minus 325 M.

TABLE 12

Further Treatment of Dings Concentrate

Product	Weight %	Analysis %		Distn % Sol Fe
		Sol Fe	SiO_2	
Jeff tail	5.4	20.54		1.8
" midd	11.2	54.02		9.8
Wade overflow	2.2	56.17		2.0
" spigot**	81.2	65.74	7.80	86.4
Feed*	100.0	61.78		100.0

*calculated

**Recovery of Sol Fe from crude ore is 78.2%.

Power Calculations

From the size distribution curves for Test 1 of pebble mill feed and discharge, the 80% passing size of the feed, F, is 118 μ. and the 80% passing size of the discharge, P, is 105 μ. The work index, Wi, for the feed was determined by laboratory tests to be 19.3.

Substituting in the formula:

$$W = Wi \left(\frac{10}{\sqrt{P}} - \frac{10}{\sqrt{F}} \right)^{*}$$

$$W = 19.3 \left(\frac{10}{\sqrt{105}} - \frac{10}{\sqrt{118}} \right) = 1.05 \text{ kwh/short ton of pebble mill feed}$$

Since the pebble mill feed was made up of 1 part crude feed to 10.4 parts of return classifier and cyclone sands, the power used in grinding crude feed was 12.0 kwh/short ton.

For Test 2, F = 98 and P = 84

and $W = 19.3 \left(\frac{10}{\sqrt{84}} - \frac{10}{\sqrt{98}} \right) = 1.55$ kwh/short ton.

Since the feed was made up of 1 part crude feed to 4.36 parts of cyclone spigot product, the power used in grinding crude feed was 8.3 kwh/short ton.

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* Bond, F. C., "Third Theory of Comminution"

CONCLUSIONS

From the results of this investigation, the use of autogenous grinding for this ore appears feasible. Apart from the savings effected by use of pebbles, other important economic factors of autogenous grinding can only be determined with more testing. The limited tests here described yielded the following information:

1. The power needed to grind the ore autogenously from 20 M to 90% minus 325 M was calculated to be 8.3 kwh/short ton using the product size distributions. When the same ore was ground through the same size range in a pilot plant test with steel balls, the power used was 6.7 kwh/short ton in actual practice and 5.9 kwh/short ton by calculation, using the product size distributions*.

2. Compared to tests made on the ore with steel grinding balls, the grade of concentrate produced at a comparable mesh size was lower when using autogenous grinding. For example, at 94.1% minus 325 M the best concentrate from autogenous grinding assayed 65.08% Fe. With steel grinding balls, concentrates assaying 67.0% Fe were obtained at 93.5% minus 325 M.

3. Recovery of iron in the concentrate appears comparable in each case. This should be checked, however, with further testwork.

4. The tonnage of crude feed that can be ground in a pebble mill is less than the tonnage that can be ground in the same mill using steel balls. A comparative test might have to be run to determine the effect this would have on capital costs.

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* Mineral Processing Division Test Report MPT 61-89.

Two concentrates were examined by microscope, both being about 92% minus 325 M. One concentrate, produced from autogenous grinding, contained larger middling particles than the other, produced from grinding with steel balls. This may be due to the closeness in specific gravity between the ore and the pebbles and would explain the reason for lower concentrate grades with autogenous grinding. In order to produce a final concentrate with 6% silica or less, a finishing grind using steel balls may be necessary. Although a sample of concentrate was ground to 95% minus 325 M in a laboratory steel mill, the final concentrate assayed only 65.74% Fe with 7.8% SiO_2. Finer grinding may be required to produce the desired grade.

PDRM:EBM