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CONCENTRATION OF MAGNESITE FROM DELORO TOWNSHIP, ONTARIO, PROGRESS REPORT NO. 2: PILOT PLANT OPERATIONS (PROJECT MP-IM-6222)

by

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MINERAL PROCESSING DIVISION

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F.H. Hartman* and R.A. Wyman**

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SUMMARY OF RESULTS

138 lb of magnesite, analysing acid soluble - 99.20%, MgO in acid soluble - 46.16%, total Fe - 2.96% Fe_2O_3, soluble Fe - 2.89% Fe_2O_3, SiO_2 - 0.56% and CaO - 0.038% were produced for outside testing. This was done by floating talc and then silica and iron minerals from magnesite; the remaining magnesite concentrate was upgraded by passing it at 25 amps through the Jones Wet Magnetic Mineral Separator with high intensity plates, followed by screening out the plus 200 mesh fraction.

The metallurgy of a flowsheet, based on bench work done (Progress Report No. 1), was investigated. No important problems developed. Grade equivalent to that reached previously, with regards to silica, was not obtained. This could be accounted for by the fact that the runs were not of sufficient duration. Circuit sampling indicated good product grades.

Autogenous grinding was investigated. It appears practical for coarse but not fine comminution.

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INTRODUCTION

The results of bench scale tests, described in Progress Report No. 1 (MPI 63-61), were sufficiently encouraging that it was decided to carry out small pilot plant scale operations on the same magnesite ore from Deloro township. The objects were 1) to obtain enough high grade material—containing 0.50% SiO_2 and 3.00% Fe_2O_3, or less—to ship to refractory manufacturers for test work, and 2) to investigate the metallurgy of the proposed flowsheet. The work was done in the above order, giving priority to the magnesite concentrate; normal practice is to first work out the metallurgy. It was also hoped to develop information useful in the arranging of the mill circuit at Beaucage, Ont., where a full-scale pilot plant run was scheduled.

DESCRIPTION OF SAMPLE

A four ton sample of ore, in sixty bags, was received. It was of essentially the same composition as that described in Progress Report No. 1.

ANALYSIS

Chemical analyses of the acid soluble constituents, Mg as MgO in acid soluble, total iron, soluble iron and silica were determined. These were done under the supervision of G.A. Kent*.

X-ray diffraction analyses were run in the Ore Mineralogy Section by R.M. Buchanan**.

Semi-quantitative spectrographic analyses were made by the Mineral Sciences Division.

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*Senior Scientific Officer, Mineral Processing Division.
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TEST WORK

Forty-five bags of the material as received were crushed to minus 28 mesh by sledge and 10 x 7 inch jaw crusher; plus 28 mesh after jaw crushing was reduced to minus 28 mesh with a 10 inch cone crusher. During the crushing 500-600 pounds of 4 inch material was set aside for use as grinding media in autogenous milling tests.

Table 1 gives screen and chemical analyses of minus 28 mesh from the jaw crushing and from the cone crushing. X-ray diffraction analyses were run on the finest sizes to determine if talc could be concentrated by either of these two methods of reduction.

TABLE 1

Comparison of Two Crushing Methods

Fraction Mesh	Weight Per Cent of Feed		
	Cone Crusher	Jaw Crusher	Combined
-28 + 48	39.0	28.0	34.4
-48 + 65	13.9	12.6	13.7
-65 + 100	10.7	10.6	10.9
-100 + 150	9.9	10.6	10.2
-150 + 200	5.9	7.0	6.2
-200	20.6*	31.2*	24.6
Total	100.0	100.0	100.0

Analysis

Fraction	Acid Soluble %		Fe as Fe_2O_3 %		SiO_2 %
	Total	MgO	Total	Soluble	
Cone Crusher	57.04	26.23	4.94	2.11	34.64
Jaw Crusher	58.15	26.54	5.45	2.25	28.68
Combined	57.69	26.50	4.66	2.14	32.46

*X.R.D. analysis showed approximately the same proportions of talc present in both samples.

A number of flowsheets were tried based on the best results obtained from bench scale tests (Progress Report No. 1). These are described under sections and sub-sections. Section 1 deals with the work involved in providing samples of concentrate for refractory manufacture.

SECTION 1A

1) The -28 mesh heads were fed to a bank of six Faegergren cells, where pine oil was added to the pulp to float off talc. The rougher tails from the float went to a 2 ft x 3 ft Patterson ceramic lined mill, loaded with 4 in. ore as grinding media. This was in closed circuit with a small, double spiral classifier.

Using this arrangement it was difficult to adjust the cells for an even float. Samples taken showed little beneficiation. The method was not continued.

2) The -28 mesh material, after conditioning with 0.1 lb/t pine oil, was fed at 20% solids to a No. 7 Denver Unit Cell where talc was floated off. The sands from the bottom of the cell were discharged into a double spiral classifier, in closed circuit with the Patterson mill loaded with approximately 225 lb mixed grinding media (ore from +4 in. down). Classifier overflow material was filtered and stored damp for later flotation.

Trouble was experienced with building up of sands in the classifier. More grinding media was added to the mill; the slope of the classifier was adjusted. Results shown in Table 2 were obtained.

TABLE 2

Talc Flotation -28 Mesh: Autogenous Grinding

Fraction Mesh	Classifier O'flow, Wt %		
	Start of Run	Middle of Run	End of Run
+ 65	0	0	0
-65 + 100	0.1	4.0	0.5
-100 + 150	1.1	1.6	3.5
-150 + 200	3.6	6.1	12.5
-200 + 325	4.5	11.2	26.6
-325	90.7	77.1	56.9
Total	100.0	100.0	100.0
Acid Soluble %			
Class o'flow	61.29	63.20	66.56
Talc Conc	36.27	39.46	41.00

The data in Table 2 indicated a build-up of circulating sands with autogenous grinding. It was thought this was largely due to inadequate removal of fines during classification, thus allowing a cushioning effect in the mill. The ore grinding media in the mill was then replaced with flint pebbles. Accumulated sands from previous runs were ground to approximately 65% minus 325 mesh.

3) Classifier overflow, detalced at minus 28 mesh, was fed by hand scoop to a bank of six No. 5 Denver flotation cells arranged in series. Pulp density was 20%; Armac T and Aerofroth 73 were used as collector and frother.

Samples of the flotation froth indicated that, rather than silica, material high in talc was coming over.

4) Classifier overflow, detalced at minus 28 mesh, was fed to a No. 7 Denver Unit Cell for further treatment to remove talc. Pine oil was used as a collector.

Checks by laboratory flotation and Jones Separator with samples of the No. 7 cell product were upgraded to 99.19% acid soluble with a weight recovery of 31.8%.

5) Silica flotation with Armac T as collector, and using Aerofroth 73 as frother in some cases, was carried out in a bank of six No. 5 Denver cells, with the detalced and partially detalced material from 3 and 4 above. A number of passes through the bank of cells failed to produce maximum grade.

SECTION 1B

Work done in Section 1A indicated that the grind had not been controlled enough. The pulp contained coarse particles.

A new grinding circuit was set up. Minus 28 mesh head sample was fed to the Patterson mill loaded with 205 lb of graduated flint pebbles. The mill discharged onto an 18 in. Sweco screen with 65 and 100 mesh decks. Undersize was filtered and set aside for flotation. The minus 65 plus 100 mesh was recirculated; the small amount of plus 65, containing organic matter, etc., was discarded.

Approximately 500 lb of minus 100 mesh material was prepared in this way. A screen analysis is given in Table 3.

TABLE 3

Screen Analysis: -100 Mesh Product

Fraction Mesh	Weight %
+ 100	0
-100 + 150	1.8
-150 + 200	5.3
-200 + 325	19.1
-325	73.8
Total	100.0

Talc was removed from the minus 100 mesh material by feeding it to a bank of six No. 5 Denver cells. Pine oil was added to the head of the circuit.

A heavy froth was removed from cells 1, 2 and 3, a lesser amount from cells 4 and 5. Cell 6 acted as a scavenger. Results are given in Table 4.

TABLE 4

Talc Float: -100 Mesh Feed

Conditions: Feed rate: 1 lb/min
Pulp density: 20%
Reagents: 0.1 lb/t pine oil

Product	Weight %	Acid Soluble % Samples - 3 Runs			
		a	b	c	Average
Talc conc 1 (Cells 1-2-3)	29.5	25.51	18.51	21.71	
Talc conc 2 (Cells 4 5-6)		52.30	53.30	57.63	
Rougher tails	70.5	76.18	77.11	79.13	77.47
Total	100.0	-	-	-	
Recovery of Mag %					94.5

The rougher tails from the talc float, in a bench flotation test, upgraded to 99.27% acid soluble with a weight recovery of 20.2%.

On the other hand, pilot plant flotation of this material did not upgrade quite as well. Two banks of six Denver No. 5 cells connected in series were used. Feed was fed by hand to a mixer, using a scoop. The frother and the first of five additions of Armac T were also added to the mixer. The balance of the collector went to the second, fourth, seventh and ninth cells. Results are shown in Table 5.

TABLE 5

Silica Float: Detalced -100 Mesh Feed

Conditions: Feed rate: 1 lb/min
Pulp density: 20%
Reagents: Armac T - 0.49 lb/t
(5 stage additions)
Aerofroth 73 - 0.08 lb/t

Product	Weight %		Acid Soluble %	Recovery %
	Of Test	Of Feed		
Silica conc (Cells 1-6)	50.5	35.6	31.69	
Silica conc (Cells 7-12)			66.50	
Rougher tails	49.5	34.9	98.21	59.5
Total	100.0	70.5	-	

Cell conditions were similar to those of bench scale work, viz little froth produced by cell 1, a heavy froth from cells 2 to 5. Froth colour for cells 2 and 3 brownish, for 4 and 5 grey. Little froth was developed by cells 6 and 7, but cells 8 and 9 produced a dense grey froth. The last three cells produced little froth.

A summary of this run is given in Table 6.

TABLE 6

Talc and Silica Floats Combined: Overall Recovery
(Tables 4 and 5)

Fraction	Weight %	Acid Soluble	
		%	Recovery %
Heads	100.0	57.69	100.0
Talc float (R. tails) (Table 4)	70.5	77.47	94.5
Silica float (R. tails) (Table 5)	34.9	98.21	59.5

Maximum grade was not obtained in a reasonable number of silica flotation steps.

SECTION 1C

A number of samples from previous testing had accumulated. Each of these had been treated in a somewhat different way. The talc and most of the iron and silica had been removed.

All of these were passed through the Jones Wet Magnetic Mineral Separator at 5 amps. Some were combined previous to this step; others were treated separately. The non-mags fractions of the material that had been treated under Section 1A were wet screened on 100 mesh, and the oversize set aside. Products obtained are listed in Table 7.

TABLE 7

Jones Wet Magnetic Mineral Separator Products
(Non-mags: 5 amps)

No.	Weight lb	Mg as MgO in Acid Soluble	Total Fe as Fe_2O_3	Total Si as SiO_2
1 (a)	29.25	45.64	3.07	0.48
1 (b)	26.25	45.44	3.06	0.41*
2	118.5	45.81	3.20	0.64
3	12.5**	45.77	3.22	0.47*
4	6.7	45.60	3.07	0.57
5	50 (approx)	45.68	3.18	0.59

*Some of the sample sent to Harbison-Walker Refractories Company.

**Obtained by treating middlings in a 2000 g flotation cell.

None of these products was below the maximum iron content of 3.00% desired, and only some below the maximum silica content of 0.50%. Additional steps were therefore taken to see if further upgrading could be secured without resorting to flotation.

A portion of Lot No. 5 (Table 7) was extracted and a screen analysis was performed. Results are shown in Table 8.

TABLE 8

Screen Analysis of Lot No. 5

Fraction	Weight %	Acid Soluble %
+ 100	0.1	-
-100 + 150	5.2	97.38
-150 + 200	10.1	98.48
-200 + 325	27.5	99.38
-325	57.1	99.06
	100.0	

It would appear that removal of the 15.4% +200 mesh would improve the grade of -200 mesh for silica.

A small amount of the sample of Lot No. 5 was then run through the Jones Separator, with salient pole plates at 25 amps, a higher intensity than previously used. The results of this test are shown in Table 9.

TABLE 9

Jones Separation at 25 Amps

Fraction	Weight %	Acid Soluble %	Fe as Fe_2O_3		SiO_2
			Soluble	Total	
Heads	100.0	99.10	3.05	3.18	0.59
Mags	15.6	99.39	4.58	4.76	0.35
Non-mags	84.4	99.17	2.88	2.92	0.72

A final test was made by running an additional small amount of the sample of Lot No. 5 through the Jones Separator, again at 25 amps, but this time with high-extraction plates. These results are given in Table 10.

TABLE 10

Jones Separation: High-Extraction Plates

Fraction	Weight %	Acid Soluble %	Fe as Fe_2O_3		SiO_2
			Soluble	Total	
Heads	100.0	99.10	3.05	3.18	0.59
Mags	37.2	99.45	3.88	3.89	0.35
Non-mags	62.8	99.04	2.86	2.83	0.79

This testing suggested that the remaining material, indicated in Table 7, should be combined, run through the Jones Separator at 25 amps with high-extraction plates, and then screened on 200 mesh.

Accordingly, Lots 1-5, as indicated in Table 7 were combined and extracted. The results of the Jones separation are given in Table 11.

TABLE 11

Further Jones Separation of Table 7 Material

Fraction	Weight		Acid Soluble %		Fe as Fe_2O_3		SiO_2	CaO
	lb	%	Total	MgO	Soluble	Total	%	%
Mags	34	14.5	99.29	45.07	4.29	4.58	0.34	0.024
Non-mags	201	85.5	99.17	45.88	2.91	2.98	0.63	0.038
	235	100.0						

To meet a shipping deadline the screening on 200 mesh was proceeded with as quickly as possible and without waiting for analysis. Screening efficiency as indicated by Table 12 was not all it should have been. Moreover, the final product, as shown in Table 13, was not as high in grade as had been expected.

TABLE 12

Screen Analyses of Sweco Products
(Figures on Weight %)

Fraction	+200 Mesh	-200 Mesh
-65 + 100	0.5	
-100 + 150	21.2	
-150 + 200	39.4	0.5
-200 + 325	38.9	33.1
-325		66.4
	100.0	100.0

TABLE 13

Analysis of Sweco Screen Products

Fraction	Weight		Acid Soluble %		Fe as Fe_2O_3		SiO_2	CaO
	lb	%	Total	MgO	Soluble	Total	%	%
+200 mesh	63	31.4	98.92	45.72	2.95	3.03	0.76	0.036
-200 mesh	138*	68.6	99.30	46.16	2.89	2.96	0.56	0.038
	201	100.0						

*Shipped to North American Refractories Company.

A semi-quantitative spectrographic analysis was performed on the two Sweco products and this is given as Table 14.

TABLE 14

Spectrographic Analysis of Table 13 Products*

Element	+200 Mesh	-200 Mesh
Si	0.22	0.05
Mn	0.08	0.05
Mg	P.C.	P.C.
Fe	0.58	0.41
Cr	0.02	0.01
Al	0.06	0.01
Cu	0.03	0.005
Ni	0.10	0.05
Zr	0.002	0.003
Co	0.005	0.003
Ca	Tr.	Tr.

* Analytical Chemistry Subdivision, Mineral Sciences Division Report No. SL-64-092.

SECTION 2

The work reported under this section deals with the accumulation of metallurgical data.

A. Grinding

A new circuit was set up consisting of the Patterson mill, loaded with 205 lb of 1 in. -3 in. flint pebbles, in closed circuit with a commercial Tyler screen covered with 48 mesh cloth. The minus 48 mesh from the screen was filtered and the oversize returned to the mill.

Table 15 gives a comparison of the -48 mesh products from this circuit at 1 and 2 pounds per minute feed rates.

TABLE 15

Product Comparison: Two Feed Rates

Fraction Mesh	Weight %	
	1 lb/min	2 lb/min
-48 + 65	0.3	0.5
-65 + 100	3.1	3.1
-100 + 150	8.7	7.5
-150 + 200	9.2	8.0
-200 + 325	18.5	19.7
-325	60.2	61.2
Total	100.0	100.0

This grinding circuit was the best one tried. The screen had excess capacity and a uniform product was obtained.

B. Talc Flotation

The heads from Table 15 were fed by hand scoop to a small mixer and from there into twelve No. 5 Denver flotation cells in series. Excess pine oil was added to the mixer. Cell samples were cut and analysed. Table 16 shows the results.

TABLE 16

Talc Flotation: Cell Samples

Pine oil: 0.3-0.4 lb/t
Feed rate: 1 lb/min
Density: 20%

Cell No.	Weight %	Acid Soluble
1	38.2	18.42
2	10.9	24.54
3	3.4	27.62
4	3.1	39.67
5	7.2	55.05
6	5.1	59.19
7	4.8	62.24
8	7.8	61.43
9	0.9	58.99
10	1.5	61.10
11	0.4	-
12	0.5	-
Rougher tails	16.2	72.52

This data indicated that cell No. 4 was close to the cut-off point for the removal of talc. One Denver bank was set up to use the first four cells to float off talc. Approximately six hundred pounds of material was treated in this way. Results of a number of samples, taken over the entire run, are shown in Table 17.

TABLE 17

Talc Flotation

Pine oil: ± 0.1 lb/t
Feed rate: 1 lb/min
Density: 20%

Sample Cells	A		B		C		D		E		F	
	Wt %	Acid Sol %	Wt %	Acid Sol %	Wt %	Acid Sol %	Wt %	Acid Sol %	Wt %	Acid Sol %	Wt %	Acid Sol %
1											14.0	10.73
2	22.6	19.38	35.8	15.83	22.0	13.36	26.0	13.98	31.6	17.90	6.3	10.59
3											2.4	15.66
4	1.2	41.64	0.7	44.20	1.9	39.12	3.0	40.34	2.9	38.87	1.6	31.45
Rougher tails	76.2	74.58	63.5	76.14	76.1	78.49	71.0	79.42	65.5	79.77	75.7	77.80
Heads (calcd)	100.0	61.69	100.0	54.37	100.0	63.29	100.0	60.53	100.0	58.98	100.0	61.85

C. Silica and Iron Flotation

The detalced material was divided into two parts. One was floated "as is"; the second was reduced to minus 200 mesh by screening out the plus 200 mesh fraction and grinding it down in an Abbé mill.

A Mikro disc feeder was used for introducing feed to the mixer. This gave steadier conditions than hand feeding. Twelve cells were used in series. First run tails were re-run through the same cells to obtain further cleaning. Armac T and Aerofroth 73 were used as collector and frother respectively. Feed rate was 1 lb/min; pulp density was 20% solids.

Table 18 gives the results for the unground feed, and Table 19 for the all -200 mesh feed. The upper portion of each Table gives circuit sampling results from the various runs, and the lower portion indicates the overall results for the same run. "A" samples indicate an earlier period in each run than "B" samples.

TABLE 18A

Silica Flotation: Unground Feed

Reagents: Armac T - 5 x 0.1 = 0.5 lb/t - Head of cells, No. 2, No. 4, No. 7 and No. 9 cells
Aerofroth 73 - 0.08 lb/t - Head of cells

Cell No.	A		B		A		B	
	Wt %	Acid Sol %	Wt %	Acid Sol %	Wt %	Acid Sol %	Wt %	Acid Sol %
1	0.9	22.48	0.8	21.16	0.6	25.85	0.4	26.97
2	6.0	28.74	2.1	28.60	4.7	33.34	3.6	32.21
3	1.9	38.05	0.7	32.09	1.2	35.62	1.1	38.34
4	12.2	28.39	1.9	24.94	6.0	34.80	5.9	32.33
5	3.1	47.03	1.3	43.45	2.8	54.63	1.9	45.82
6	0.9	38.33	0.8	46.39	0.8	46.89	0.7	44.78
7	3.7	16.91	1.7	24.00	2.6	24.61	1.6	23.54
8	1.0	26.76	2.7	39.95	2.1	35.96	1.4	44.22
9	3.7	18.64	7.9	26.60	4.9	31.81	4.7	28.36
10	3.5	30.84	4.2	29.83	3.7	28.35	2.4	35.24
11	1.7	25.19	1.4	36.07	2.0	37.09	1.2	48.38
12	1.4	30.76	0.7	36.35	0.6	33.55	0.3	48.01
R. tails	60.2	83.85	73.8	85.76	68.0	85.79	74.8	88.34
	100.0	-	100.0	-	100.0	-	100.0	-

Fraction	Weight %	Acid Soluble %	Weight %	Acid Soluble %
Silica conc 1 (Cells 1-6)	11.8	25.90	9.9	30.72
Silica conc 2 (Cells 7-12)	8.4	24.85	8.0	31.22
Rougher tails	79.8	79.20	82.1	85.11
	100.0	68.25	100.0	75.21

TABLE 18B

Reagents: Armac T - 5 x 0.1 = 0.5 lb/t - Head of cells, No. 14, No. 16, No. 19 and No. 21 cells
Aerofroth 73 - 0.40 lb/t - Head of cells

Cell No.	A		B	
	Weight %	Acid Soluble %	Weight %	Acid Soluble %
13	0.2	49.92	0.1	54.01
14	10.2	36.29	2.9	35.10
15	2.5	34.32	1.4	33.70
16	9.9	37.50	5.6	35.58
17	4.7	51.78	2.2	48.87
18	1.9	56.47	0.9	51.36
19	3.8	44.40	1.8	41.20
20	2.4	65.52	1.5	61.83
21	13.0	55.06	6.6	49.43
22	3.4	70.14	2.5	72.74
23	1.4	82.64	0.7	84.08
24	0.2	69.41	0.2	86.48
R. tails	46.4	96.59	73.6	98.28
	100.0	-	100.0	-

Fraction	Weight %	Acid Soluble %
Silica conc 1 (Cells 13-18)	58.0	33.06
Silica conc 2 (Cells 19-24)	7.4	51.14
Final tails	34.6	94.41
	100.0	55.70

TABLE 19A

Silica Flotation: -200 Mesh

Reagents: Armac T - 5 x 0.1 = 0.5 lb/t - Head of cells, No. 2, No. 4, No. 7 and No. 9 cells
Aerofroth 73 - 0.40 lb/t - Head of cells

Cell No.	A		B	
	Weight %	Acid Soluble %	Weight %	Acid Soluble %
1	0.1	-	-	-
2	0.3	26.18	0.2	27.49
3	0.1	29.20	0.1	28.37
4	1.0	33.34	0.8	23.73
5	0.7	38.71	0.7	32.27
6	0.2	32.04	0.4	28.57
7	0.5	30.32	1.0	21.84
8	0.6	35.87	0.9	25.60
9	1.1	25.96	0.6	24.44
10	1.6	26.12	1.1	21.68
11	1.0	29.60	0.6	27.87
12	0.3	26.79	0.5	26.76
R. tails	92.5	84.91	93.1	82.84
	100.0	-	100.0	-

Fraction	Weight %	Acid Soluble %
Silica conc 1 (Cells 1-6)	4.8	31.30
Silica conc 2 (Cells 7-12)	6.5	32.49
Rougher tails	88.7	84.77
	100.0	78.60

TABLE 19B

Reagents: Armac T - 5 x 0.1 = 0.5 lb/t - Head of cells, No. 14, No. 16, No. 19 and No. 21 cells
Aerofroth 73 - 0.40 lb/t - Head of cells

Cell No.	A		B	
	Weight %	Acid Soluble %	Weight %	Acid Soluble %
13	4.5	34.31	1.6	32.78
14	15.3	47.41	7.7	33.49
15	5.7	51.98	3.4	38.57
16	9.6	77.70	5.8	59.59
17	5.2	89.71	3.0	82.92
18	1.0	83.28	1.0	82.23
19	3.4	88.30	1.0	76.63
20	1.2	88.22	1.0	88.53
21	3.8	92.15	3.3	90.19
22	0.6	89.69	1.0	92.54
23	1.0	90.69	0.7	93.05
24	0.6	72.30	0.6	91.42
R. tails	48.1	98.45	69.9	99.27
	100.0	-	100.0	-

Fraction	Weight %	Acid Soluble %
Silica conc 1 (Cells 13-18)	55.2	46.96
Silica conc 2 (Cells 19-24)	6.4	67.04
Final tails	38.4	95.88
	100.0	66.90

D. Treatment of Middlings

With small scale tests, using a 500 g and a 2000 g Denver flotation cell, and Armac T plus Aerofroth 73 as reagents, no trouble was experienced in upgrading 85 to 95% acid soluble middlings to 99.10 to 99.60% acid soluble products. A preliminary grind before flotation seemed to be helpful.

On a larger scale, the rougher tails shown in Table 19 (95.88% acid soluble) were divided in half. One part was passed through twelve No. 5 Denver flotation cells in series, using similar conditions to those carried out with the material referred to in Tables 18 and 19. Results are tabulated in Table 20.

The other half of the above rougher tails was mixed with a silica concentrate (middlings assaying 67.04% acid soluble) so that the weight was increased by 30-35%. This combined material was then treated in the same way as the first half (Table 20) with the possible exception that the cells were pulled slightly harder. Results are given in Table 21. In these tables the upper portion again is circuit sampling and the lower portion overall sampling.

TABLE 20

Silica Flotation: No Recirculation of Middlings

Reagents: Armac T - 5 x 0.1 = 0.5 lb/t - Head of cells, No. 2, No. 4, No. 7 and No. 9 cells
Aerofroth 73 - 0.40 lb/t - Head of cells

Cell No.	A			B		
	Weight %	Acid Sol %	Sol Fe_2O_3 %	Weight %	Acid Sol %	Sol Fe_2O_3 %
1	0.9	87.60	3.32	2.7	90.27	3.46
2	7.6	91.90	3.44	20.2	93.37	3.52
3	8.7	96.03	3.52	15.7	96.74	3.51
4	2.4	95.85	3.45	1.1	95.50	3.80
5	4.5	97.08	3.33	4.3	96.59	3.61
6	2.8	97.06	3.31	1.1	96.80	3.56
7	6.1	98.51	3.29	13.0	99.25	3.44
8	0.6	94.93	3.43	2.8	98.57	3.48
9	6.4	98.17	3.37	15.4	99.21	3.11
10	1.7	93.15	3.76	0.5	98.41	3.22
11	1.1	96.96	3.46	2.0	98.18	3.29
12	1.1	98.27	3.40	0.3	90.94	3.46
Tails	56.1	98.31	3.32	20.9	98.50	3.10
	100.0	-	-	100.0	-	-

Fraction	Weight %	Acid Sol %	Fe as Fe_2O_3	
			Soluble	Total
Silica conc 1 (Cells 1-6)	31.1	94.48	3.56	4.96
Silica conc 2 (Cells 7-12)	19.8	97.21	3.48	4.68
Tails	49.1	98.62	3.46	4.15
	100.0	97.20	3.49	4.52

TABLE 21

Silica Flotation: Recirculation of Middlings

Reagents: Armac T - 5 x 0.1 = 0.5 lb/t - Head of cells, No. 2, No. 4, No. 7 and No. 9 cells
Aerofroth 73 - 0.40 lb/t - Head of cells

Cell No.	A			B		
	Weight %	Acid Sol %	Sol Fe_2O_3 %	Weight %	Acid Sol %	Sol Fe_2O_3 %
1	2.8	69.98	4.12	2.6	67.08	3.48
2	18.3	61.98	4.65	11.5	61.32	3.65
3	9.5	66.73	5.03	7.4	66.52	3.88
4	4.2	73.92	5.11	3.9	72.27	3.95
5	5.5	83.71	3.97	4.1	80.89	3.88
6	2.7	89.42	4.05	2.5	85.77	4.47
7	9.3	96.00	3.97	4.7	88.34	4.37
8	3.0	97.05	3.81	3.2	93.26	3.92
9	18.5	99.31	3.33	14.0	98.86	3.62
10	1.5	99.09	3.39	2.0	98.42	3.62
11	1.5	98.96	3.43	2.3	98.11	3.64
12	2.4	99.12	3.30	2.3	99.20	3.61
Tails	20.8	99.32	2.88	39.5	99.45	3.07
	100.0	-	-	100.0	-	-

Fraction	Weight %	Acid Sol %	Fe as Fe_2O_3	
			Soluble	Total
Silica conc 1 (Cells 1-6)	38.6	73.49	3.85	8.18
Silica conc 2 (Cells 7-12)	28.0	98.41	3.54	4.27
Tails	33.4	99.49	3.05	3.07
	100.0	89.20	3.50	5.39

DISCUSSION

Results would have been more consistent if the metallurgy of the circuit had been worked out before trying to obtain a sample for test purposes. The flowsheet, however, followed closely the one used in bench scale tests and results were comparable.

The original concept of removing talc with pine oil, preceded or followed by fine grinding, floating silica and silicates plus most of the hematite with a cationic reagent and a higher alcohol frother, remains valid. The magnesite concentrate can be upgraded by removing more of the iron in the Jones Wet Magnetic Mineral Separator.

Talc, although softer than the other constituents of the ore, did not appear to concentrate appreciably in the finer sizes when the original feed was reduced with a cone crusher or a jaw crusher (Table 1).

In flotation work the preparation of the product by grinding is important, as it results in the liberation of the particles to be removed or left behind. The best grinding circuit tried was that shown in Table 15, where 78-81% of the material was ground to minus 200 mesh.

Removal of talc at this grind does not appear to present any difficulty. Whether to use excess pine oil and try to float the coarser talc, or a minimum amount and allow the remaining talc to come up with the first additions of Armac T is a matter of economics and recoveries. It can better be determined in the operation of a larger mill (Tables 16 and 17).

The lengths of run were such that difficulty was experienced in clearing the cells of material from previous work. This is evident where circuit samples show higher values than samples taken during the whole run.

Cell circuit samples are affected by surges in overflow and the fact that they are taken for a short period of time. Their analyses are indicative of conditions but recovery figures are misleading.

In the first part of the program when a large sample was sought, upgrading the final product to 0.50% SiO_2 or less was difficult. It required repeated flotation to clean the material and resulted in a low recovery. If the metallurgy of the circuit had been better known, this could probably have been accomplished with one long, sustained run, discarding the product first produced until the cells had settled down to constant conditions and had emptied themselves of contaminants from previous runs.

In Table 13, where the sample to be shipped out was screened, recoveries were low. If time had permitted, the plus 200 mesh material would have been re-screened. Theoretical recovery, if all minus 200 mesh, were removed would have been - Mags: 14.5%, +200 mesh: 16.4%; -200 mesh: 69.1%. Actual recovery was - Mags: 14.5%; +200 mesh:26.8%;-200 mesh: 58.7%.

To remove the maximum amount of silica, etc., required a longer float time, extra reagents and more cells than bench work indicated e.g., Tables 18 and 19 (24 cells) followed by additional flotation (12 cells) as shown in Tables 20 and 21. This long flotation time could obviously be reduced in continuous operation as indicated by the circuit sampling. In Table 5, a good grade of rougher tails was obtained with cell conditions similar to bench scale results.

In Tables 18A and 19A very little weight recovery with five additions of Armac T is shown. This may be caused by locked particles of talc, and coarse talc, not removed by pine oil. Talc is amine avid and probably uses up the reagent before it has time to become attached to silica. There is also the question of carry-over from previous runs as discussed earlier.

Comparing Tables 18 and 19, it appears that grinding plus 200 mesh material to minus 200 mesh improves recovery and grade. This is to be expected, as silica being harder tends to accumulate in the coarser sizes, and would thus be more difficult to float. Any non-floated silica would remain with the magnesite in the tails.

Results of recirculation of middlings are always hard to predict from small scale runs. This problem is usually only satisfactorily solved in practice. The data shown in Table 21, however, indicates that low-grade middlings will refloat easily without lowering grade, and should increase recovery.

CONCLUSIONS

1. Autogenous grinding appears to be suitable for primary grinding, e.g., -65 to -100 mesh, but not to give a very fine product.

2. All, or as much as possible, of the talc should be removed with pine oil, or other frothers, before adding the silica collector.

3. Fine grinding is necessary to free the magnesite from impurities, and permit maximum upgrading.

4. Removing 25-30% by weight of the material, in a talc float, the product is upgraded to 75-79% acid soluble from 57-59%.

5. This product can be beneficiated to 99.49% acid soluble by removing silica, hematite and silicates with a cationic float using Armac T as collector and Aerofroth 73 as frother.

6. By passing a high grade product through the Jones Wet Magnetic Mineral Separator, its iron content is lowered. However, the silica content of the "non-mags" fraction increases slightly.

7. Long runs in a larger mill should give a better product. Steady conditions are important in this type of flotation.

8. Middlings should not present a problem. Whether it is better to recirculate them, or treat them separately for a lower grade product, cannot accurately be concluded from this type of work.

9. A grind of 79-82% minus 200 mesh gives a product that will assay 99.3-99.49% acid soluble with total iron content around 3.0% Fe_2O_3.

APPENDIX A

Rock Pebble Grinding (Self Grinding)

Grinding trials were made in a 2 by 3 foot ceramic-lined mill charged with "pebbles" of the ore, to see if this method would be appropriate for producing flotation feed. The "pebble" charge consisted of 100 lb of 6 inch lumps and 100 lb of mixed 1 to 3 inch lumps. The feed was -3/4 inch ore having the following size distribution:

-3/4 + 1/2 inch	28.2%
-1/2 + 3/8 inch	16.1%
-3/8 + 4 mesh	20.7%
-4 + 8 mesh	10.5%
-8 + 10 mesh	3.8%
-10 mesh	20.7%
	100.0%

A number of preliminary tests were made of which the two most successful are recorded below:

Density (% solids)		Feed Rate (lb/min)		Product Size (mesh)			
Set	Actual	Set	Actual	+28	-28+100	-100+325	-325
15	15.4	3.0	3.0	1.2	28.3	39.4	31.1
25	22.5	3.0	2.8	0.9	23.1	39.4	36.6

The mill was dumped and an assessment made of the "pebble" consumption rate on the basis of remaining + 1 inch. It was found that the charge weighed 175 lb or a loss of 25 lb to grind 260 lb of -3/4 inch feed. This would be a little below 200 lb per ton of feed.

The mill was next operated for two hours during which time variations were made in pulp density and feed rate. The same -3/4 inch feed was used, and the charge was maintained by adding 6 inch lumps at regular intervals at the rate of 200 lb per ton of feed. Samples were taken at 25 and 30 minute intervals after each change of conditions. Results are as follow:

Sample Time (min from start)	Density (% solids)		Feed Rate (lb/min)		Product Size (mesh)			
	Set	Actual	Set	Actual	+28	-28+100	-100+325	-325
25	30	34	3.0	4.0	11.9	15.6	33.1	39.4
30	30	31	3.0	3.3	11.9	18.5	35.1	34.5
55	40	35	4.0	3.5	4.8	25.5	36.3	33.4
60	40	36	4.0	3.6	6.1	25.8	35.7	32.4
85	45	44	4.0	3.6	9.8	22.4	33.5	34.3
90	45	45	4.0	3.7	6.5	19.9	34.9	38.7
115	50	57	3.0	3.2	11.6	19.7	33.6	35.1
120	50	56	3.0	3.4	10.5	18.7	35.1	35.7

At this point the mill was again dumped and "pebble" consumption assessed. It was found that approximately 80 lb of "pebbles" had been consumed in grinding 800 lb of feed, again very close to 200 lb per ton of feed. Composition of the -3/4 inch dumped from the mill was also ascertained as a comparison with the feed size distribution. This is given below.

	Feed	In Mill
-3/4 + 1/2 inch	28.2%	15.6%
-1/2 + 3/8 inch	16.1%	10.6%
-3/8 + 4 mesh	20.7%	8.8%
-4 + 8 mesh	10.5%	8.5%
-8 + 10 mesh	3.8%	1.8%
-10 mesh	20.7%	54.7%
	100.0%	100.0%

The "pebble" charge was returned to the mill together with enough -1 inch to make up the usual 200 lb. Operation was then continued for an additional hour, but this time -4 mesh feed was used. Sampling was again at 25 and 30 minute intervals following each change. Pulp density at two levels was tested. Results are as follow:

Sample Time (min from start)	Density (% solids)		Feed Rate (lb/min)		Product Size (mesh)			
	Set	Actual	Set	Actual	+28	-28+100	-100+325	-325
25	35	36.4	3.0	2.9	3.1	28.6	34.5	33.8
30	35	37.5	3.0	3.1	3.3	32.3	33.3	31.1
55	50	45	3.0	2.4	7.6	22.7	34.8	34.9
60	50	51	3.0	2.4	5.4	25.9	35.0	33.7

An unusual feature of this test work is the consistency of product regardless of pulp density or feed size. The -100 mesh produced is close to 70% in all cases except two, one 76 and one 64%, and the average is 70%. No recirculation of oversize at 65 or 100 mesh was tried, but the tests performed suggest that production of flotation feed by this means would be feasible. Trials reported in the earlier text in which rock "pebbles" were used proved unsatisfactory only because of inadequate classification facilities.

APPENDIX B

Vibrating Milling

Tests were made with the Sweco Vibro-Energy mill, a type of vibrating mill, to assess its usefulness for regrind purposes. The first test consisted of charging the mill with 197 lb of 1/2 inch burundum cylinders, 50 lb of -28 mesh feed and 6 1/2 litres of water. This gave a pulp level just clear of the grinding media and a density of 80% solids. The mill was run for an hour then allowed to drain while still vibrating. It took an additional hour to dump completely. The feed and product size distributions are given below:

Fraction	Feed	Product
+ 48 mesh	34.4%	9.2%
-48 + 65 mesh	13.7%	6.9%
-65 + 100 mesh	10.9%	9.4%
-100 + 150 mesh	10.2%	10.7%
-150 + 200 mesh	6.2%	7.6%
-200 mesh	24.6%	56.2%
	100.0%	100.0%

This test indicated a creation of 23.5% new -100 mesh or 31.6% new -200 mesh.

The second trial was made with the same grinding charge (197 lb burundum) but only 35 lb of -28 mesh feed. Water was again added to just cover the pellets. This gave a pulp density of approximately 70% solids. The mill was then run for 5 hours and then dumped. A comparison of the size distribution between feed and product is given below, together with the acid soluble determination of product fractions:

Fraction	Feed	Product	Acid Soluble
+ 48 mesh	34.4%	8.5%	27.40%
-48 + 65 mesh	13.7%	4.0%	48.31%
-65 + 100 mesh	10.9%	3.8%	59.91%
-100 + 150 mesh	10.2%	4.7%	65.49%
-150 + 200 mesh	6.2%	4.5%	68.47%
-200 mesh	24.6%	74.5%	65.23%
	100.0%	100.0%	61.28% (calcd)

In this test 42.7% new -100 mesh was created, or 49.9% new -200 mesh. The acid soluble determinations indicate the tendency for silica to remain in the coarser sizes.

A third test was run on a continuous, rather than the batch, basis. For this, the same grinding charge was used, 197 lb burundum. The -28 mesh feed was introduced at a rate of 1/2 lb per minute. Water was also introduced at this rate to give a pulp density of 50% solids. The lower density was used to reduce the viscosity of the pulp and facilitate movement through the mill. After an hour of operation, a 1 minute sample of the pulp product discharging was taken. This was found to weigh 240 grams, or 0.53 lb, thus checking the feed rate. A comparison of feed and product size distribution is given below:

Fraction	Feed	Product
+ 48 mesh	34.4%	20.1%
-48 + 65 mesh	13.7%	11.2%
-65 + 100 mesh	10.9%	9.1%
-100+ 150 mesh	10.2%	9.8%
-150+ 200 mesh	6.2%	5.5%
-200 mesh	24.6%	44.3%
	100.0%	100.0%

The continuous run produced less -100 mesh increase, 18.6%, and less -200 mesh increase, 19.7%, than either of the batch trials.

Although it must be observed that the feed used in these trials was coarser than would be expected in a regrinding operation on a flotation product, the trial with continuous operation suggests that this would not be an appropriate regrind device.

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FHH:RAW/DV