CANADA

DEPARTMENT OF ENERGY, MINES AND RESOURCES

OTTAWA

MINES BRANCH INVESTIGATION REPORT

IR 72-25 June, 1972

AN INVESTIGATION OF AN ALL-FLOTATION APPROACH TO THE TREATMENT OF SIDERITIC IRON ORE FROM THE ALGOMA STEEL CORPORATION, SAULT STE. MARIE, ONTARIO

by

I.B. Klymowsky

Mineral Processing Division

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SUMMARY OF RESULTS

A pilot-plant investigation showed that Algoma siderite was amenable to treatment by flotation for removal of the sulphur and silica. The ore sample provided for this investigation contained some soft chloritic material, which slimed readily, and removal of the slimes was necessary prior to silica flotation. Slime flotation was found to be the most effective way of removing these slimes. The ore assayed 37.0% iron, 7.5% sulphur, and 7.35% silica; the siderite concentrates contained between 36.9 and 38.5% iron, as low as 0.28% sulphur, and 1.65% silica. The iron recoveries were between 60.9 and 75.2%, and the siderite recoveries were between 74.9 and 88.7%. Ratios of concentration were about 1.5:1.

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INTRODUCTION

The Algoma Steel Corporation is engaged in the mining and sintering of sideritic iron ore at Wawa, Ontario. Present facilities for treatment prior to sintering are limited to heavy-media concentration for removal of the quartz gangue. The ore, however, also contains pyrite and, in some cases, pyrrhotite. These sulphides are concentrated with the siderite so that, upon sintering, large quantities of sulphur dioxide gas are expelled into the atmosphere.

Aware of governmental concern about environmental pollution, Algoma has been investigating means of supplementing or replacing heavy-media concentration by a process which would exclude sulphides from the final concentrate, hence flotation has been given much consideration. In its laboratory research on the removal of both sulphur and silica by flotation, Algoma used a xanthate reagent for the flotation of the sulphides and an amine reagent in combination with a dextrin modifier for the flotation of the silica-bearing gangue.

Purpose of Investigation

The Mines Branch was asked to verify the results of the tests done by Algoma and to test the proposed flowsheet on a pilot-plant scale.

Ore Shipments

To facilitate verification of the results, the Mines Branch was provided with details of the experimental procedure and with a sample of ore similar to the sample used in developing the flowsheet. The sample was received on May 4, 1971, from Dr. H.O. Lien, Manager, Raw Materials Research, Algoma Steel Corporation. The sample weighed approximately 100 lb and was a composite of several samples of drill core.

A box containing 18 separate samples of drill core, representing ore to be mined in the future, was later received on May 20, 1971.

At the request of the Mines Branch, a sample of mine water from Wawa was also provided.

For testing the proposed flowsheet in the pilot plant, the Mines Branch was provided with 38 tons of ore crushed to minus 1 inch. This sample was received on September 16, 1971.

Sampling and Analysis

The composite sample was crushed to minus 10 mesh and divided into 2000-gram samples by riffling. Similarly, each of the samples of drill core was crushed to minus 10 mesh, and divided into 2000-gram samples for laboratory testing. All chemical analyses in connection with the laboratory testwork were done by the Analytical Chemistry Subdivision, Mineral Sciences Division.

Sampling of the ore provided for pilot-plant testing was done during each test run. A routine procedure was used in sampling the various products once the desired conditions for a test were established. Each product was sampled at regular intervals for a period of over an hour. All chemical analyses in connection with the pilot-plant investigation were done by Bondar-Clegg and Company. The average analysis of the ore treated in the pilot plant was 37.0% iron, 7.5% sulphur, and 7.35% silica.

OUTLINE OF INVESTIGATION

The results of the testing done by Algoma were verified by testing the composite sample, and several different samples of drill core were tested to check their amenability to the proposed flowsheet. In addition, the effect of mine water on flotation was also investigated.

The flowsheet was then tested in the pilot plant. When problems arose in the flotation of silica, samples of the feed to silica flotation were taken to the laboratory for closer investigation. The problems were found to be caused by slimes. The flowsheet was modified to deal with these slimes; then various combinations of reagents, flotation conditions, and grinds were investigated.

The pilot-plant tests are tabulated below:

Test 1, Standard test without desliming.

Test 2, Slime flotation, with stage additions of dextrin, and 0.4 lb/ton amine in silica flotation.

Test 3, Reagents reduced, dextrin to 1 lb/ton and amine in silica flotation to 0.25 lb/ton.

Test 4, Dextrin in conditioning prior to slime flotation increased to 2 lb/ton.

Test 5, Sodium hydroxide added to conditioning prior to slime flotation.

Test 6, Establishment of a coarser grind.

Test 7, The use of recycled water, in part of the circuit, for slime flotation and silica flotation.

Test 8, Dextrin in conditioning prior to slime flotation decreased to 1.0 lb/ton as in Test 3, but amine in silica flotation increased to 0.4 lb/ton.

Test 9, Mechanical desliming in the place of slime flotation.

DETAILS OF INVESTIGATION

In the laboratory tests done at the Mines Branch, to obtain maximum reproducibility in silica flotation, sulphide flotation was carried out on a large sample of ground material, and the sulphide flotation rejects were split to provide uniform feed for silica flotation. Details of the procedure are given in Table 1. Some typical results obtained with the composite sample are given in Table 2. These results compare favorably with the results given in Table 3, for a similar composite sample tested by Algoma.

With regards to the products from silica flotation, a close correlation was found between insol analyses and the silica analyses. For example, a product with 3.93% silica had an insol analysis of 4.04%. Because the insol analyses were only slightly higher than the silica analyses, they were used to indicate the silica content of various products from silica flotation.

The procedure outlined in Table 1 was used to investigate the effect of mine water on flotation and to test several samples of drill core. In each case, sulphide flotation was done to completion, therefore analysis was limited to assaying the products from silica flotation for insol only. The results from using mine water in testing the composite sample are given in Table 4 and a comparison with the results given in Table 2 indicated that mine water had no significant effect on flotation. Siderite concentrates, produced from samples of drill core that were tested, assayed between 3.09 and 4.38% insol. The silica contents of these concentrates were slightly lower. Concentrates assaying about 4% silica were considered satisfactory by Algoma.

TABLE 1

Mines Branch Laboratory Flotation Procedure

Operation	Time	% Solids	pH	Unit Used	Reagents, Lb/Ton of Original Feed*				
					Xanthate Z-11	Sulphuric Acid	Dow Froth 250	Dextrin 4356	Amine 3037
Grinding	37	57.1		Denver Rod Mill	0.14				
Conditioning	2	33.0			0.07				
"	8		6.9	1000-Gram Denver		0.9			
Sulphide Flotation	5			Flotation Cell			0.08		
Splitting (Sulphide Flotation Rejects)				Wet Riffle					
Conditioning (Using ½ of Rejects)	5		7.4	500-Gram Wemco				0.9	
"	1			Flotation Cell					0.3
Silica Flotation	5	25.0							
Cleaning (Silica Float Product)	3			250-Gram Denver Flotation Cell					

*Original charge, 2000 grams.

TABLE 2

Results Obtained at Mines Branch with the Composite Sample

Product	Wt %	Analysis, %				Distribution, %		
		Fe	S	SiO_2	Insol	Fe	S	SiO_2
Siderite Conc	57.0	35.35	0.13	3.93	4.04	55.2	0.6	23.4
Middling	6.2	28.90	0.73	20.96	21.72	4.9	0.4	13.6
Silica	9.4	16.93	6.10	60.67	67.40	4.3	4.4	59.6
Sulphides	27.4	47.63	44.03	1.20	-	35.6	94.6	3.4
Original Feed*	100.0	36.68	12.75	9.57	-	100.0	100.0	100.0

TABLE 3

Results Obtained by Algoma

Product	Wt %	Analysis, %				Distribution, %		
		Fe	S	SiO_2	Insol	Fe	S	SiO_2
Siderite Conc	61.3	37.0	1.2	4.3		60.6	6.9	28.0
Silica	8.8	11.0	1.1	70.2		2.6	0.8	65.6
Sulphides	29.9	46.0	38.6	2.0		36.8	92.3	6.4
Original Feed*	100.0	37.4	12.5	9.4		100.0	100.0	100.0

TABLE 4

Results Obtained Using Mine Water from Wawa

Product	Wt %	Analysis, %				Distribution, %			
		Fe	S	SiO_2	Insol	Fe	S	SiO_2	Insol
Siderite Conc	58.5				4.22				
Middling	5.1				23.16				
Silica	9.3				63.78				
Sulphides	27.1				-				
Original Feed*	100.0								

*Calculated.

Testing in the pilot plant was begun using the flowsheet shown in Figure 1. Grinding was done in a 30 x 48-inch ball mill in closed circuit with a 100-mesh vibrating screen. The feed rate to the ball mill was 750 pounds per hour of 3/8-inch material. Sulphide flotation was done in a circuit consisting of two rougher stages. The concentrate from the first rougher stage was a finished product, while the product from the second rougher stage went to cleaning. Xanthate was added to the ball mill and to the 5th cell in the sulphide flotation circuit, and the total sulphide flotation time for the two rougher stages was 20 minutes. Silica flotation was done initially in a circuit consisting of a rougher stage and one cleaner stage. When difficulties in making a low-silica siderite concentrate were encountered, the cleaner stage was eliminated but this did not improve the grade of the concentrate. The results of Test 1, given in the Appendix, are typical of results obtained after the silica cleaner stage was eliminated.

Samples of the feed to silica flotation were taken to the laboratory for closer investigation. A number of tests were done, and it was found that slime was interfering with the flotation. The following measures were proposed to overcome the slime interference:

1) increasing the amine concentration in silica flotation to 0.45 lb/ton of ore;
2) using mechanical desliming prior to silica flotation; and
3) using slime flotation prior to silica flotation.

In the pilot plant, the first approach was abandoned when the high amine concentration caused uncontrollable froth in the silica flotation circuit. The second approach, mechanical desliming, necessitated flow interruption in an all-flotation circuit; therefore the third approach, slime flotation, was selected as a more suitable alternative.

Slime flotation was incorporated in the pilot-plant circuit as shown in Figure 2, and in Test 2, slime flotation successfully overcame the slime interference. Dextrin was added in stages to conditioning prior to slime flotation and to the first cell in silica flotation. The total amount of dextrin used was 2.33 lb/ton of ore. The amount of amine used in silica flotation was 0.4 lb/ton of ore. The siderite concentrate produced assayed 1.65% silica, and the recovery of iron as siderite was 84.7%. Recoveries calculated in terms of the iron as siderite were more useful in evaluating the results of pilot-plant tests than the overall iron recoveries. A sample calculation is given in Table 5.

The reagent consumption in Test 2 was thought to be rather high, in particular the amount of dextrin used in silica flotation. Therefore a general reduction was made in the amounts of reagents used in Test 3. The floatability of silica was greatly reduced with the reduction of dextrin and amine, and the silica content of the siderite concentrate rose to 4.67%. The amount of silica removed with the silica product in Test 3 was almost as low as the amount of silica removed in Test 1.

To determine whether dextrin had any effect on the floatability of silica, the dextrin concentration in Test 4 was increased from 1.0 lb/ton to 2.0 lb/ton. The increase in the dextrin concentration improved the floatability of silica by fifty per cent. The concentrate produced assayed 2.04% silica, and the recovery of iron as siderite was 84.1%. In Test 5, sodium hydroxide was added to conditioning prior to silica flotation. This resulted in a marked increase in selectivity in silica flotation and improved siderite recovery. The recovery of iron as siderite was 88.7%.

In the pilot-plant tests to this point, the grind was approximately 77% minus 325 mesh, somewhat finer than desired. The circulating load was negligible, so it was suspected that overgrinding had caused the material to slime. Control of grinding was limited to changing the ball charge in the mill. Balls were removed until a more desirable coarser grind of 57% minus 325 mesh was established but the slimes persisted. In the light of previous work done by Algoma in which slimes were encountered, it was concluded that the source of the slimes wassoft chloritic material in the ore sample.

In the pilot-plant tests that followed, the coarser grind was maintained. In Test 6, to determine the effect of the change in the grind, the reagent levels were kept the same as in Test 4. Comparison of the results of Test 6 with those of Test 4 indicated that the change in the grind had no significant effect on the final result.

TABLE 5

Sample Calculation of the Recovery of Iron as Siderite

Product	Wt, %	Analysis, %					Units	Distribution, %
		(1) Total Fe	(2) Total S	(3) Sulphides	(4) (3) - (2) Fe as Sulphides	(5) (1) - (4) Fe as Siderite	Fe as Siderite	Fe as Siderite
Siderite	68.6	38.05	0.51	1.28*	0.77	37.28	2557	84.7
Original Feed	100.0	37.02	7.20	14.07**	6.83	30.19	3019	100.0

*Pyrrhotite was the principal source of sulphur in the siderite concentrate. The amount of pyrrhotite in the siderite concentrate could be calculated directly from its sulphur content, determined by electron-probe microanalysis at 40% S.

Wt of pyrrhotite in the siderite concentrate, $0.51 \times \frac{100}{40.0} = 1.28\%$

**Both pyrite and pyrrhotite were sources of sulphur in the feed.
Pyrrhotite was magnetic and, as such, could be concentrated in a Davis Tube.
Feed Sample (Davis Tube Concentrate)- 5.0% wt, 18.63% S.

% S as pyrrhotite, $0.05 \times 18.63 = 0.93\%$

% S as pyrite, $7.20 - 0.93 = 6.27\%$

Wt of pyrrhotite in feed, $0.93 \times \frac{100}{40.0} = 2.33\%$

Wt of pyrite in feed, $6.27 \times \frac{100}{53.4} = 11.74\%$

Total Sulphides in feed, $2.33 + 11.74 = 14.07\%$

Note: Siderite was assumed to include all iron-bearing minerals, other than sulphides.

In Test 7, water from the end of the silica flotation circuit was recycled to the head of the slime flotation circuit, as shown in Figure 2, while all other conditions were kept constant.

Recovery was slightly lower than in the previous test mainly because more material was removed in slime flotation.

In Test 8, the amount of dextrin added to conditioning prior to slime flotation was decreased to 1.0 lb/ton and the amount of amine used in silica flotation was increased to 0.4 lb/ton to determine the effect of a reduction in dextrin at a higher amine concentration. This produced a froth that was difficult to handle, and there was a sharp decrease in the recovery of siderite. The siderite concentrate produced assayed 2.09% silica, but the recovery of iron as siderite dropped to 76.4%. This decrease in the recovery was largely due to poor selectivity in silica flotation. Comparison with Test 2 indicated that an additional 1.0 lb/ton of ore of dextrin was necessary to maintain selectivity in silica flotation in the presence of an amine concentration of 0.4 lb/ton of ore.

In Test 9, the effectiveness of mechanical desliming was investigated. The pilot plant circuit was modified as shown in Figure 3. Dextrin was added to conditioning prior to silica flotation at a rate of 1.5 lb/ton of ore, and amine was added to the first cell in silica flotation at 0.35 lb/ton of ore. Additional frother was required because it was difficult to maintain an adequate froth in silica flotation.

The siderite concentrate produced assayed 2.75% silica, and the recovery of iron as siderite was 74.9%. It was found necessary to remove 12% of the weight in mechanical desliming to overcome the interference of slimes in silica flotation. This was a much higher weight loss than that incurred in desliming by flotation.

Size analyses of the feed to flotation and of the siderite concentrates are given in Table 6. A summary of the results obtained in each test is given in Table 7.

Sulphur can easily be floated from the siderite ore. The samples provided for the laboratory testwork were amenable to treatment as outlined in the proposed flowsheet; however, the ore provided for the pilot-plant testwork had to be deslimed before silica flotation.

Of the two methods investigated for slime removal (mechanical desliming and slime flotation) the latter was simpler to control, was more selective, and resulted in higher recoveries of siderite.

TABLE 6

Screen Tests

Feed to Flotation (Wt % Passing a Given Tyler Mesh)

Tyler Mesh	Test 1	Test 2	Test 3	Test 4	Test 5	Test 6	Test 7	Test 8	Test 9
100	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
200	90.5	88.7	87.8	87.8	87.8	71.5	73.7	72.6	74.1
325	79.5	77.5	77.0	77.0	77.0	57.3	60.3	60.0	57.2
500	57.0	53.6	51.4	51.4	51.4	41.6	41.6	41.4	41.2

Siderite Concentrates (Wt % Passing a Given Tyler Mesh)

Tyler Mesh	Test 1	Test 2	Test 3	Test 4	Test 5	Test 6	Test 7	Test 8	Test 9
100	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
200	93.4	88.0	90.3	90.3	90.3	72.5	73.7	71.9	74.0
325	81.2	77.5	78.6	78.6	78.6	59.5	60.7	58.8	58.8
500	59.6	56.6	51.6	51.6	51.6	41.0	41.6	36.8	39.7

TABLE 7

Summary of Pilot-Plant Test Results

Test No. and Remarks	Siderite Concentrate						
	Wt, %	Analysis, %				Recovery, %	
		Total Fe	Fe as Siderite	Total S	SiO_2	Total Fe	Fe as Siderite
1. Standard test without desliming.	75.6	36.31	35.14	0.78	6.95	73.1	90.1
2. Slime flotation; stage additions of dextrin, 2.33 lb/ton amine in silica flotation, 0.4 lb/ton.	68.6	38.05	37.28	0.51	1.65	70.5	84.7
3. Dextrin reduced to 1.0 lb/ton; amine in silica flotation reduced to 0.25 lb/ton.	71.1	36.92	36.00	0.62	4.67	71.3	84.7
4. Dextrin, 2.0 lb/ton; amine in silica flotation, 0.25 lb/ton.	69.7	37.78	36.78	0.67	2.04	71.1	84.3
5. Sodium hydroxide in conditioning prior to slime flotation, 0.5 lb/ton.	73.8	37.36	36.32	0.69	2.86	75.2	88.7
6. A coarser grind, and its effect on flotation in general.	67.1	38.15	37.71	0.29	2.09	68.8	84.1
7. The use of recycled water for slime flotation and silica flotation.	65.4	37.62	37.15	0.35	1.73	67.0	81.6
8. Dextrin, 1.0 lb/ton; amine in silica flotation increased to 0.4 lb/ton.	60.9	38.49	38.05	0.29	2.09	62.6	76.4
9. Mechanical desliming in the place of slime flotation.	59.8	37.23	36.76	0.35	2.75	60.9	74.9

CONCLUSIONS

Removal of slimes facilitated investigation of several factors affecting silica flotation. The following conclusions were drawn from the investigation.

(1) Dextrin has a dual role in silica flotation; first to maintain selectivity by depressing siderite, and then to increase the floatability of silica.

(2) Increasing the dextrin concentration is more efficient for lowering the silica in the final siderite concentrate than is increasing the amine concentration.

(3) Small amounts of sodium hydroxide (0.5 lb/ton of ore) in silica flotation greatly increase selectivity and improve the recovery of siderite.

(4) Small changes in the grind have no significant effect on the final results.

(5) Recycled water has no significant effect on the results of silica flotation.

ACKNOWLEDGEMENTS

The author wishes to record his appreciation to J. Laxton, Raw Materials Research Laboratory of the Algoma Steel Corporation, and to A. Boisonnault, supervisor of the Mines Branch pilot plant, for their assistance during the pilot plant test runs.

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APPENDIX

Data and Results of

Pilot-Plant Tests 1 to 9

Data and Results of Test 1

Operation	% Solids	pH	Reagents, lb per ton of ore					Grind % -325
			Xanthate 350	H_2SO_4	Dow Froth 250	Dextrin 4356	Amine 3037	
Grinding	66.0		0.167					79.0
Conditioning	33.0	6.9		0.9	0.2			
Sulphide Flotation	33.0		0.083					
Conditioning	33.0					1.33		
Silica Flotation	20.0	7.4					0.20	

Product	Wt %	Analysis, %				Distribution, %			
		Total Fe	Fe as Siderite	Total S	SiO_2	Total Fe	Fe as Siderite	Total S	SiO_2
Siderite Conc	75.6	36.31	35.14	0.78	6.95	73.1	90.1	7.0	74.8
Silica	5.8	27.37	-	3.34	27.97	4.2	-	2.2	23.1
Silica Float Feed*	81.4	34.45	-	0.96	8.44	77.3	-	9.2	97.9
Sulphides	18.6	45.81	-	41.29	0.81	22.7	-	90.8	2.1
Original Feed*	100.0	37.56	29.49	8.46	7.02	100.0	100.0	100.0	100.0

*Calculated

Data and Results of Test 2

Operation	% Solids	pH	Reagents, lb per ton of ore					Grind % -325
			Xanthate 350	H_2SO_4	Dow Froth 250	Dextrin 4356	Amine 3037	
Grinding	66.0		0.167					77.5
Conditioning	33.0	6.8		0.9	0.2			
Sulphide Flotation	33.0		0.083					
Conditioning	33.0					1.33		
Slime Flotation	20.0						0.25	
Silica Flotation	20.0	7.4				1.0	0.40	

Product	Wt %	Analysis, %				Distribution, %			
		Total Fe	Fe as Siderite	Total S	SiO_2	Total Fe	Fe as Siderite	Total S	SiO_2
Siderite Conc	68.6	38.05	37.28	0.51	1.65	70.5	84.7	4.9	15.4
Silica	7.9	22.03	-	3.39	47.72	4.7	-	3.7	51.4
Silica Float Feed*	76.5	36.39	-	0.81	6.41	75.2	-	8.6	66.8
Slimes	6.0	22.65	-	1.65	35.73	3.7	-	1.4	29.1
Sulphide Underflow*	82.5	35.39	-	0.87	8.53	78.9	-	10.0	95.9
Sulphides	17.5	44.69	-	37.03	1.71	21.1	-	90.0	4.1
Original Feed*	100.0	37.02	30.19	7.20	7.43	100.0	100.0	100.0	100.0

*Calculated

Data and Results of Test 3

Operation	% Solids	pH	Reagents, lb per ton of ore					Grind % -325
			Xanthate 350	H_2SO_4	Dow Froth 250	Dextrin 4356	Amine 3037	
Grinding	66.0		0.084					77.0
Conditioning	33.0	6.8		0.9	0.2			
Sulphide Flotation	33.0		0.056					
Conditioning	33.0					1.0		
Slime Flotation	20.0						0.25	
Silica Flotation	20.0	7.4					0.25	

Product	Wt %	Analysis, %				Distribution, %			
		Total Fe	Fe as Siderite	Total S	SiO_2	Total Fe	Fe as Siderite	Total S	SiO_2
Siderite Conc	71.1	36.92	36.00	0.62	4.67	71.3	84.7	6.4	43.7
Silica	8.0	28.47	-	4.62	28.43	6.2	-	5.3	29.8
Silica Float Feed*	79.1	36.07	-	1.02	7.07	77.5	-	11.7	73.5
Slimes	5.9	25.80	-	2.65	30.29	4.1	-	2.3	23.5
Sulphide Underflow*	85.0	35.35	-	1.14	8.68	81.6	-	14.0	97.0
Sulphides	15.0	45.13	-	39.80	1.53	18.4	-	86.0	3.0
Original Feed*	100.0	36.82	30.20	6.94	7.61	100.0	100.0	100.0	100.0

*Calculated

Data and Results of Test 4

Operation	% Solids	pH	Reagents, lb per ton of ore					Grind % -325
			Xanthate 350	H_2SO_4	Dow Froth 250	Dextrin 4356	Amine 3037	
Grinding	66.0		0.084					77.0
Conditioning	33.0	6.8		0.9	0.2			
Sulphide Flotation	33.0		0.056					
Conditioning	33.0					2.0		
Slime Flotation	20.0						0.25	
Silica Flotation	20.0	7.4					0.25	

Product	Wt %	Analysis, %				Distribution, %			
		Total Fe	Fe as Siderite	Total S	SiO_2	Total Fe	Fe as Siderite	Total S	SiO_2
Siderite Conc	69.7	37.78	36.78	0.67	2.04	71.1	84.3	6.8	19.1
Silica	9.8	28.13	-	4.11	36.04	7.5	-	5.8	47.6
Silica Float Feed*	79.5	36.59	-	1.09	6.23	78.6	-	12.6	66.7
Slimes	5.5	20.85	-	1.79	40.75	3.1	-	1.4	30.2
Sulphide Underflow*	85.0	35.58	-	1.14	8.46	81.7	-	14.0	96.9
Sulphides	15.0	45.13	-	39.80	1.53	18.3	-	86.0	3.1
Original Feed*	100.0	37.01	30.39	6.94	7.42	100.0	100.0	100.0	100.0

*Calculated

Data and Results of Test 5

Operation	% Solids	pH	Reagents, lb per ton of ore						Grind % -325
			Xanthate 350	H_2SO_4	Dow Froth 250	Dextrin 4356	NaOH	Amine 3037	
Grinding	66.0		0.084						77.0
Conditioning	33.0	6.8		0.9	0.2				
Sulphide Flotation	33.0		0.056						
Conditioning	33.0					2.0	0.5		
Slime Flotation	20.0							0.25	
Silica Flotation	20.0	8.8						0.25	

Product	Wt %	Analysis, %				Distribution, %			
		Total Fe	Fe as Siderite	Total S	SiO_2	Total Fe	Fe as Siderite	Total S	SiO_2
Siderite Conc	73.8	37.36	36.32	0.69	2.86	75.2	88.7	7.5	28.7
Silica	6.9	19.79	-	2.88	49.69	3.7	-	3.0	46.7
Silica Float Feed*	80.7	35.86	-	0.88	6.86	78.9	-	10.5	75.4
Slimes	4.3	22.00	-	2.31	36.63	2.6	-	1.4	21.5
Sulphide Underflow*	85.0	35.16	-	0.95	8.38	81.5	-	11.9	96.9
Sulphides	15.0	45.13	-	39.80	1.53	18.5	-	88.1	3.1
Original Feed*	100.0	36.66	30.24	6.78	7.53	100.0	100.0	100.0	100.0

*Calculated

Data and Results of Test 6

Operation	% Solids	pH	Reagents, lb per ton of ore					Grind % -325
			Xanthate 350	H_2SO_4	Dow Froth 250	Dextrin 4356	Amine 3037	
Grinding	66.0		0.084					57.3
Conditioning	33.0	6.8		0.9	0.2			
Sulphide Flotation	33.0		0.056					
Conditioning	33.0					2.0		
Slime Flotation	20.0						0.25	
Silica Flotation	20.0	7.7					0.25	

Product	Wt %	Analysis, %				Distribution, %			
		Total Fe	Fe as Siderite	Total S	SiO_2	Total Fe	Fe as Siderite	Total S	SiO_2
Siderite Conc	67.1	38.15	37.71	0.29	2.09	68.8	84.1	2.6	19.2
Silica	8.8	22.75	-	1.65	41.19	5.4	-	2.0	49.7
Silica Float Feed*	75.9	36.36	-	0.45	6.61	74.2	-	4.6	68.9
Slimes	7.4	26.47	-	2.44	27.44	5.3	-	2.4	27.9
Sulphide Underflow*	83.3	35.49	-	0.62	8.46	79.5	-	7.0	96.8
Sulphides	16.7	45.81	-	41.56	1.38	20.5	-	93.0	3.2
Original Feed*	100.0	37.21	30.10	7.46	7.28	100.0	100.0	100.0	100.0

*Calculated

Data and Results of Test 7

Operation	% Solids	pH	Reagents, lb per ton of ore					Grind % -325
			Xanthate 350	H_2SO_4	Dow Froth 250	Dextrin 4356	Amine 3037	
Grinding	66.0		0.084					60.0
Conditioning	33.0	6.8		0.9	0.2			
Sulphide Flotation	33.0		0.056					
Conditioning	33.0					2.0		
Slime Flotation	20.0						0.25	
Silica Flotation	20.0	7.7					0.25	

Product	Wt %	Analysis, %				Distribution, %			
		Total Fe	Fe as Siderite	Total S	SiO_2	Total Fe	Fe as Siderite	Total S	SiO_2
Siderite Conc	65.4	37.62	37.15	0.35	1.73	67.0	81.6	3.1	15.3
Silica	8.1	23.82	-	2.11	39.45	5.3	-	2.3	43.2
Silica Float Feed*	73.5	36.10	-	0.54	5.89	72.3	-	5.4	58.5
Slimes	9.4	24.76	-	1.78	30.52	6.3	-	2.4	38.7
Sulphide Underflow*	82.9	34.81	-	0.69	8.69	78.6	-	7.8	97.2
Sulphides	17.1	45.98	-	39.53	1.23	21.4	-	92.2	2.8
Original Feed*	100.0	36.72	29.73	7.33	7.41	100.0	100.0	100.0	100.0

*Calculated

Data and Results of Test 8

Operation	% Solids	pH	Reagents, lb per ton of ore					Grind % -325
			Xanthate 350	H_2SO_4	Dow Froth 250	Dextrin 4356	Amine 3037	
Grinding	66.0		0.084					60.3
Conditioning	33.0			1.9	0.2			
Sulphide Flotation	33.0		0.056					
Conditioning	33.0					1.0		
Slime Flotation	20.0						0.25	
Silica Flotation	20.0	7.7					0.40	

Product	Wt %	Analysis, %				Distribution, %			
		Total Fe	Fe as Siderite	Total S	SiO_2	Total Fe	Fe as Siderite	Total S	SiO_2
Siderite Conc	60.9	38.49	38.05	0.29	2.09	62.6	76.4	2.4	17.6
Silica	12.0	27.51	-	1.49	30.31	8.8	-	2.4	50.6
Silica Float Feed*	72.9	36.68	-	0.49	6.74	71.4	-	4.8	68.2
Slimes	9.8	29.14	-	2.42	21.19	7.6	-	3.2	28.9
Sulphide Underflow*	82.7	35.79	-	0.73	8.45	79.0	-	8.0	97.1
Sulphides	17.3	45.49	-	39.71	1.21	21.0	-	92.0	2.9
Original Feed*	100.0	37.47	30.34	7.47	7.20	100.0	100.0	100.0	100.0

*Calculated

Data and Results of Test 9

Operation	% Solids	pH	Reagents, lb per ton of ore						Grind % -325
			Xanthate 350	H_2SO_4	Dow Froth 250	Dextrin 4356	Amine 3037	Pine Oil	
Grinding	66.0		0.167						57.2
Conditioning	33.0	6.8		0.9	0.2				
Sulphide Flotation	33.0		0.083						
Desliming									
Conditioning	40.0					1.5			
Silica Flotation	20.0	8.1					0.35	0.1	

Product	Wt %	Analysis, %				Distribution, %			
		Total Fe	Fe as Siderite	Total S	SiO_2	Total Fe	Fe as Siderite	Total S	SiO_2
Siderite Conc	59.8	37.23	36.76	0.35	2.75	60.9	74.9	2.7	21.9
Silica	8.5	16.70	-	0.80	52.55	3.9	-	0.9	59.8
Silica Float Feed*	68.3	34.69	-	0.41	8.95	64.8	-	3.6	81.7
Slimes	12.0	34.02	-	0.29	7.88	11.1	-	0.7	12.7
Sulphide Underflow*	80.3	34.58	-	0.41	8.79	75.9	-	4.3	94.4
Sulphides	19.7	44.72	-	37.11	2.13	24.1	-	95.7	5.6
Original Feed*	100.0	36.58	29.29	7.64	7.47	100.0	100.0	100.0	100.0

*Calculated

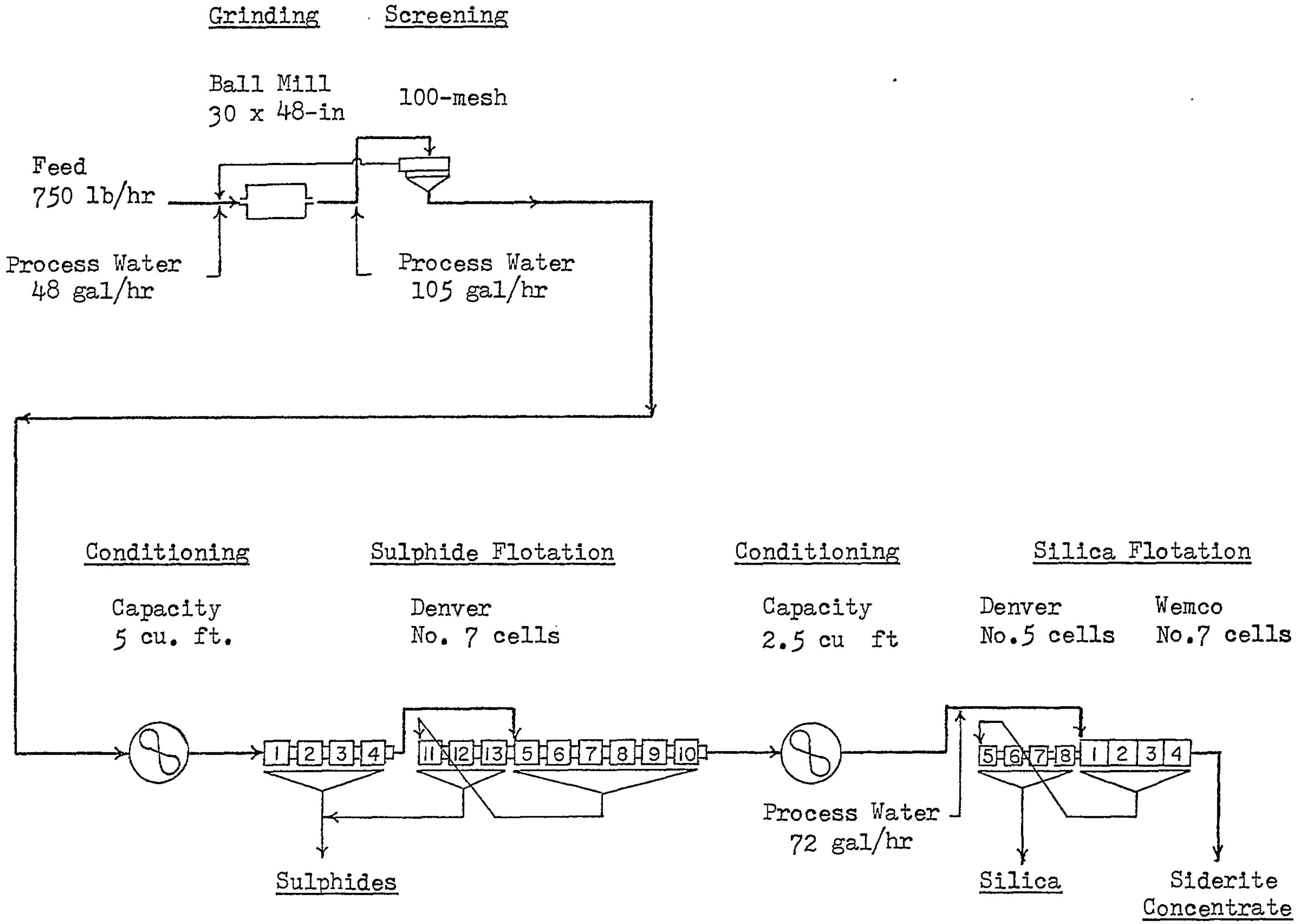

Fig. 1. Algoma Flowsheet.

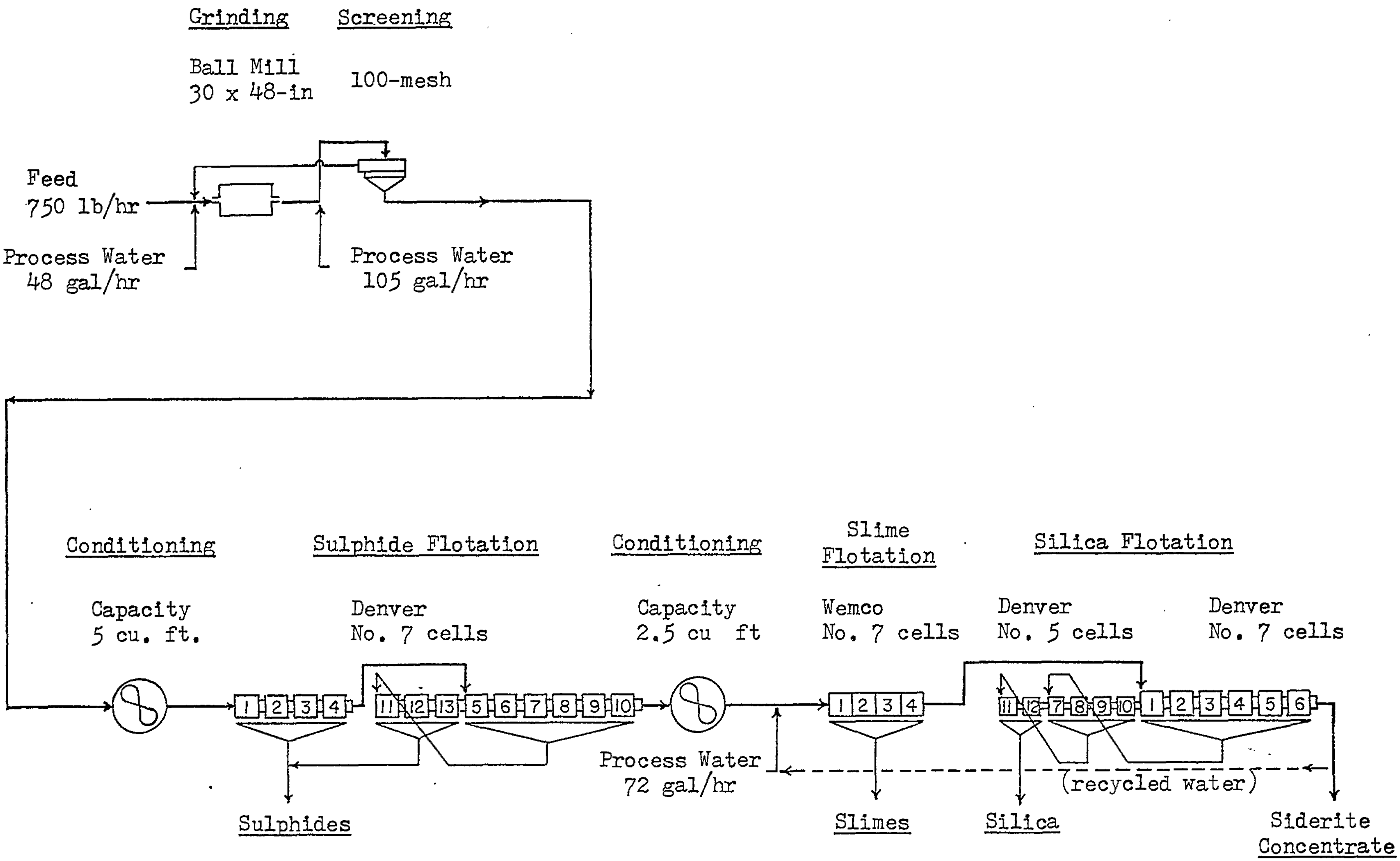

Fig. 2. Flowsheet Incorporating Slime Flotation.

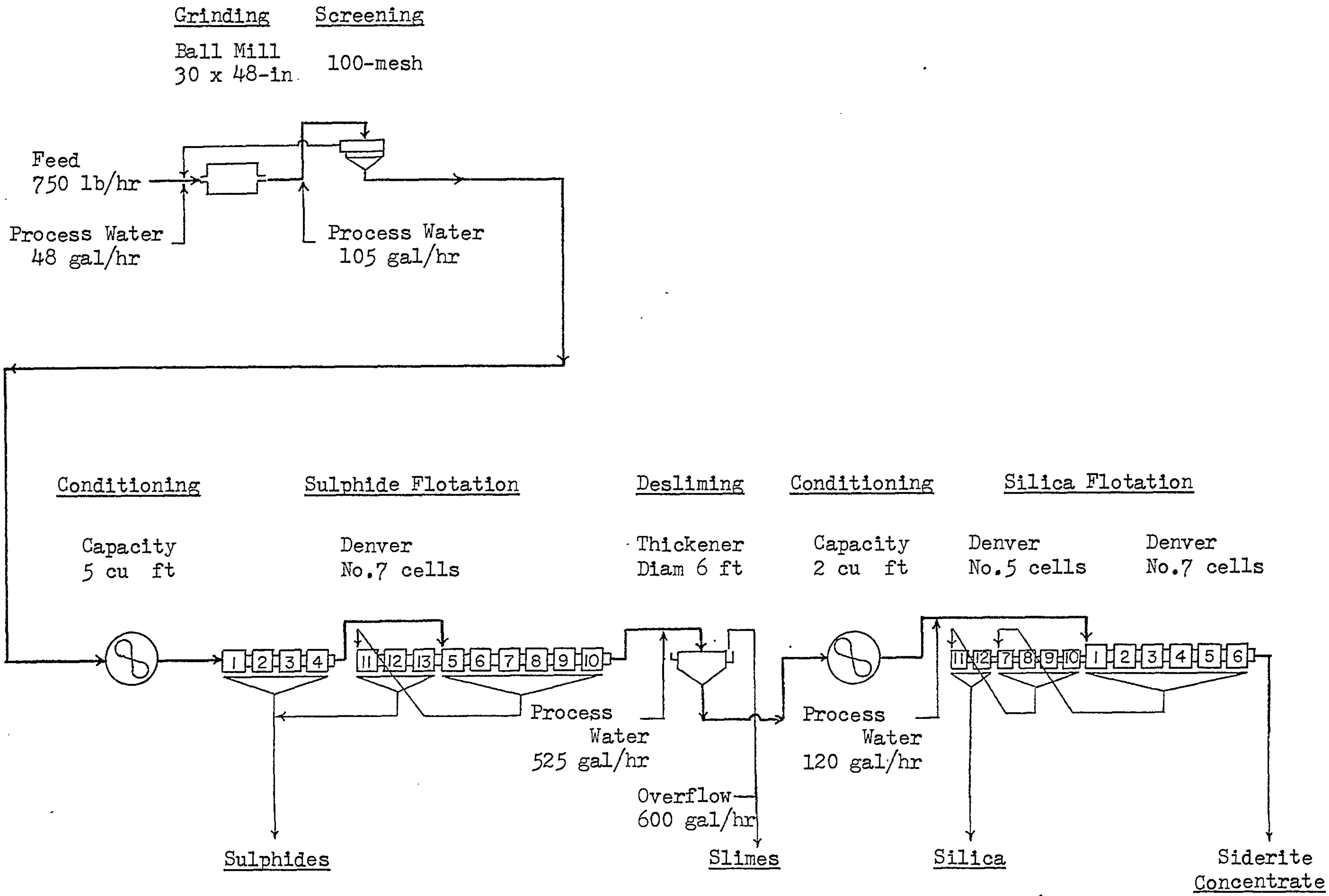

Fig. 3. Flowsheet Incorporating Mechanical Desliming.