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MINES BRANCH INVESTIGATION REPORT

IR 72-48 October 1972

DEVELOPMENT OF A FLOWSHEET TO PRODUCE IRON AND COPPER CONCENTRATES FROM ORE OF PAULPIC GOLD MINES LIMITED, NEAR ATIKOKAN, ONTARIO

by

I. B. Klymowsky

Mineral Processing Division

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SUMMARY OF RESULTS

The two types of ore, high-sulphide (47.7% Fe, 0.54% Cu, 17.9% S) and low-sulphide (38.4% Fe, 0.17% Cu, 2.8% S) were similar mineralogically, but differed widely in magnetite:sulphide ratio.

Marketable iron concentrates were produced by conventional treatment (magnetic separation and flotation) of each ore separately and of a 45:55 composite of the two ores, as shown by the following results:

Ore Feed	Concentrate Analysis % Fe	% Cu	% S	Conc'n Ratio
High-Sulphide	71.2	0.01	0.31	8:1
Low-Sulphide	66.9	0.01	0.33	2.7:1
45:55 Composite	69.3	0.01	0.17	4.5:1

Satisfactory copper flotation concentrates (18.9% Cu) were produced from the high-sulphide ore and from the composite ore with recoveries above 70%.

* Engineer, Ferrous Ores Section, Mineral Processing Division, Mines Branch, Department of Energy, Mines and Resources, Ottawa, Canada.

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INTRODUCTION

Paulpic Gold Mines Limited holds 3,300 acres of mining land near the town of Atikokan, Ontario, about 140 miles northwest of Thunder Bay. Iron ore was mined on the property prior to 1912 by the Atikokan Iron Company, but the operation was short-lived because the ore had a high sulphur content and could not be treated profitably at that time. Paulpic optioned this property for exploration in 1970 and did some geophysical surveying and diamond drilling which indicated a large tonnage of low-grade iron and base metal ore on the property. Further drilling on the property was deferred until some metallurgical testing could be done on the ore.

Purpose of Investigation

The Mines Branch was asked to develop procedures for treating the Paulpic ore to produce a high-grade iron concentrate (with less than 1% sulphur) suitable for pelletizing; a marketable copper concentrate and, if practical, to recover the nickel and cobalt minerals.

Ore Shipment

On November 5, 1970, two samples of drill core were received at the Mines Branch from Mr. E. W. Bazinet, consultant at that time for Paulpic Gold Mines Limited. One sample, weighing about 225 lb,was sulphide-rich; the other, approximately 275 lb, was low in sulphides.

Sampling and Analysis

The high-sulphide ore sample was crushed to minus 10 mesh and riffled into smaller (2,000-gram) portions, one of which, selected at random, was ground to minus 100 mesh and sampled for analysis.

The low-sulphide drill core was crushed to minus 1/2 inch for cobbing. The products from this operation were crushed to minus 10 mesh and riffled into smaller (2,000-gram) portions which were ground to minus 100 mesh and sampled for analysis.

Results of chemical analysis are given below.

TABLE 1

Results of Chemical Analysis of Ore Samples

	Wt %	Total Fe %	Mag Fe %	Sol Fe %	Cu %	Ni %	Co %	S %	P %
Low-Sulphide Ore*	55.0	41.5	26.5	38.4	0.17	0.02	0.02	2.8	0.21
High-Sulphide Ore	45.0	50.2	36.0	47.7	0.54	0.08	0.08	17.9	-
Composite Ore **	100.0	45.4	30.8	42.6	0.33	0.05	0.05	9.6	-

* calculated from results of cobbing test.
** calculated.

MINERALOGICAL EXAMINATION+

Sixteen representative pieces of drill core (eight from the high-sulphide ore, eight from the low-sulphide ore) were sent to the Mineralogical Section of the Mineral Sciences Division for examination. Both high- and low-sulphide ores were found to have similar mineralogical characteristics except for variation in the magnetite:sulphide ratio.

Magnetite, the principal iron mineral, occurred as large clusters of grains in pyrrhotite and as remnants intimately associated with pyrrhotite. Pyrrhotite, also magnetic, occurred throughout the ore and was the host mineral for inclusions of copper, nickel, and cobalt.

Chalcopyrite, the only copper mineral detected, occurred over a wide range of sizes from large grains to fine inclusions in gangue, magnetite, pyrite, and pyrrhotite.

+ From Mineral Sciences Division Report IR 71-44, by R. G. Pinard.

Nickel and cobalt occurred in too small quantities for economic recovery.

Gangue minerals were chiefly talc, chlorite, quartz, and dolomite.

OUTLINE OF INVESTIGATION

Because of the marked difference in sulphur content between the high-sulphide ore (17.9% S) and the low-sulphide ore (2.8% S), laboratory tests were done separately on the two samples in the initial stage of the investigation.

For the high-sulphide ore, ground to minus 100 mesh , two general procedures were followed.

(1) Flotation of a copper rougher concentrate followed by successive cleaning; flotation of pyrrhotite from the copper flotation tailing; and magnetic separation of an iron concentrate from the final flotation tailing.

(2) Magnetic separation of a magnetite-pyrrhotite concentrate; flotation of pyrrhotite from the magnetic concentrate to leave an iron concentrate; and flotation of a copper rougher concentrate from the non-magnetic portion followed by successive cleaning of the copper concentrate.

The second procedure was selected as the basis for subsequent detailed investigation of the high-sulphide ore.

Magnetic cobbing was done on the low-sulphide ore at minus 1/2 inch, and procedures similar to those used on the high-sulphide ore were applied to the products of the cobbing operation.

At the beginning of the investigation, the idea of separate treatment of the high-sulphide and low-sulphide ores appeared promising, especially with regard to cobbing of low-sulphide ore; however, the practicability of mining the two types of ores separately was uncertain and this approach was not followed through. For the remainder of the investigation, composite ore was used to assess the best procedures indicated in previous tests and to integrate them into a practical flowsheet.

DETAILS OF INVESTIGATION

Full details of the procedures, reagents used, analytical results and metallurgical balances are provided by the Mines Branch Flotation Test Reports in the Appendix (Tests 1-18).

The difficulties in treating the high-sulphide ore were:

(1) reducing sulphur to a satisfactory level (below 1%) in the iron concentrate, and

(2) overcoming the interference of slimes (talc and chlorite) in copper flotation.

The principal source of sulphur in the iron concentrate was pyrrhotite. To provide uniform feed for tests to determine the best conditions for flotation of pyrrhotite, a large sample of ore (ground to minus 100 mesh) was treated by magnetic separation, and the magnetic concentrate so produced was split into several portions. The effects of soda ash and sulphuric acid on pyrrhotite flotation (in the presence of copper sulphate) were compared. The effect of regrinding the magnetic iron concentrate before flotation was investigated and the effect of pyrrhotite cleaner flotation on iron recovery was also investigated.

Similarly, the large non-magnetic fraction of the sample was split into several portions for copper flotation tests. Some tests were done to determine whether the interference of the slimes could be overcome by incorporating a slime flotation stage prior to copper flotation. Other tests were done to see if the copper would float better in a sulphuric acid circuit, and to compare different collectors, Minerec 27 and Z-200.

The best procedures were then incorporated in a final test on a sample of high-sulphide ore to confirm a tentative flowsheet for production of a magnetic iron concentrate and a copper concentrate.

When the results of the Davis Tube tests on the products of the low-sulphide ore cobbing operation indicated good recovery of iron in the cobber concentrate, it was decided to treat the cobber concentrate and cobber tailing separately. High-grade iron concentrates were made from the cobber concentrate by magnetic separation, and the small amount of sulphur in the iron concentrate was removed by flotation. Several attempts were made at recovering the small amount of copper in the cobber tailing, but none were successful.

A composite of 45% high-sulphide ore and 55% low-sulphide ore, ground to minus 48 mesh, was treated along the lines of procedure (2), namely:

(a) wet magnetic separation;

(b) regrinding of the magnetic fraction to minus 100 mesh and flotation of pyrrhotite;

(c) regrinding of the non-magnetic fraction to minus 100 mesh and flotation of a copper concentrate.

To reduce the loss of copper in the magnetic fraction separated at minus 48 mesh, the composite ore was ground to minus 100 mesh and treated by the same procedure, but without regrinding of the rougher concentrates.

Finally, to check the encouraging results of the preliminary cobbing, a composite ore made up of 60% high-sulphide ore and 40% cobber concentrate was treated by procedure (2) as outlined above.

In the initial test on the high-sulphide ore using procedure (1), a copper concentrate was made assaying 23.16% Cu with a copper recovery of 56.0%, and an iron concentrate was made assaying 67.3% Fe, 5.1% S, and 0.03% Cu with an iron recovery of 24.1%.

In Test 2, by the alternative procedure, namely magnetic separation, pyrrhotite flotation from the magnetic fraction and copper flotation from the non-magnetic tailing, a copper concentrate was made assaying 21.75% Cu with a recovery of 59.6% and an iron concentrate assaying 67.0% Fe, 7.1% S, and 0.02% Cu with an iron recovery of 28.4%.

The minimal loss of copper in the magnetic fraction and slightly greater recovery of magnetite by the second procedure prompted its selection as the basis for subsequent investigation, particularly since the prior removal of the magnetic fraction (61.8% of the feed) sharply reduced the amount of material for copper flotation.

In Test 3, the flotation of pyrrhotite from the magnetic fraction at minus 100 mesh, using soda ash and an increased amount of copper sulphate (0.5 lb per ton of ore) at pH 8.5, produced a 66.3% iron concentrate with 5.8% S. The results of screen analysis of the iron concentrate (Table 2) suggest that regrinding to minus 400 mesh might result in a lower sulphur content. In Test 4, regrinding of the feed to flotation resulted in a higher grade of iron concentrate (69.4% Fe), but not in any significant reduction in the sulphur content (5.0% S). However, in Test 5, without regrinding, and using a combination of sulphuric acid and copper sulphate, flotation at pH 6.0 facilitated the separation of pyrrhotite and produced an iron concentrate containing only 0.6% S with 68.0% Fe. By hydro-separation, that iron concentrate was upgraded to 68.9% Fe (21.2% recovery).

In an attempt to increase the recovery of iron, the pyrrhotite was floated in three stages and the third stage cleaned to leave a magnetite-rich tailing (Test 6). Although the latter contributed an additional 3.5% recovery of iron for a total of 25.8%, the sulphur content of the iron concentrate increased sharply from 0.7% to 1.5%.

In Tests 1 and 2, copper flotation was done at a pH of 10.0 using Z-200 as collector and satisfactory copper concentrates were produced, but difficulties were encountered in obtaining a clean separation of the copper from the slimes inspite of the fact that a slime depressant (causticized starch) was used.

In Test 7, slime flotation was tried prior to copper flotation, using pine oil to float the slimes. A loss of 46% of the copper was incurred in the slimes. In Test 8, slime flotation was tried again, but this time using sodium cyanide to control copper losses in the slimes. The losses were reduced to 8.4% while 84.7% was recovered in the rougher concentrate, assaying 6.3% Cu.

In Test 9, flotation was done using Minerec 27 as collector and sulphuric acid to adjust the pH to 6.0. A high-grade rougher concentrate was made assaying 11.9% Cu with a recovery of 81.9% of the copper. Scavenger flotation, using Z-6 as collector, separated another 12.2% of the copper at only 0.8% copper grade due to inclusions of copper in pyrite. In a similar test (Test 10), using sulphuric acid to adjust the pH to 6.0 and Z-200 as collector, 87.1% of the copper was recovered in the rougher concentrate, but the grade was only 7.22%. The slimes appeared to float more readily with Z-200 and a grade of only 9.5% was obtained after one cleaning.

In the final test on the high-sulphide ore ground to minus 100 mesh (Test 11), a magnetic iron concentrate assaying 71.2% Fe and only 0.3% S, at a concentration ratio of 8:1, was obtained using sulphuric acid copper sulphate as modifiers in pyrrhotite flotation. Increasing the xanthate (Z-6) conditioning time to 5 minutes favored rapid flotation of the pyrrhotite. By flotation from the non-magnetic fraction, which contained 89.6% of the copper in the original ore, 71.7% recovery was achieved at 18.9% copper grade after two cleanings, using sulphuric acid and Minerec 27. Again, scavenging proved ineffective as a means of recovering more copper. The scavenger concentrate consisted mainly of pyrite, comprised 7.9% of the weight, contained 0.64% Cu, and represented 9.5% of the original copper. Another 10.2% of the copper was irrecoverably tied up in the pyrrhotite. The procedure used in Test 11, but without the final scavenger step, was adopted as the standard test procedure.

Because of the much higher magnetite:gangue ratio in the low-sulphide ore, dry magnetic cobbing at the 1/2-inch size was used to separate magnetic iron from copper minerals. Results of cobbing and Davis Tube tests (Tables 3 and 4) show that 93% of the magnetic iron was retained in the cobber concentrate. After crushing it to minus 10 mesh, separating magnetically, and grinding to minus 100 mesh for another stage of magnetic separation a 67.6% iron concentrate was produced, containing only 0.02% Cu, but with 1.6% sulphur (Test 12). However, in Test 13, magnetic separation at minus 100 mesh, followed by flotation of the pyrrhotite from the magnetic iron concentrate, reduced the sulphur content to 0.33% and the copper to 0.01% in a 66.9% iron concentrate.

Copper flotation from the cobber tailing was less successful. Using the best procedure developed for the high-sulphide ore, only 36.9% of the copper was recovered in Test 14, using Minerec 27 and Z-6 as collectors; while in Test 15, with Z-6 alone, copper recovery was 52.8%. Cleaner concentrate grades were only 7.9% Cu and 8.7% Cu respectively. Despite the ease with which a marketable iron concentrate could be produced from the low-sulphide ore by coarse cobbing and magnetic separation after regrinding, this approach was not followed through because of the uncertainty of mining the two types of ores separately.

In Test 16, on the composite ore (45% high-sulphide, 55% low-sulphide), the initial magnetic separation was done at minus 48 mesh. However, some 22.7% of the copper was retained in the magnetic fraction and was thus almost irrecoverably lost. As a result, after regrinding the non-magnetic tailing, flotation gave a copper recovery of only 57.9% in the cleaner concentrate. After regrinding the magnetic fraction, pyrrhotite was floated off without the addition of copper sulphate, and an iron concentrate assaying 64.8% Fe was produced containing only 0.3% S. Subsequent magnetic separation yielded a high-grade iron concentrate assaying 69.7% Fe and 0.33% S.

In Test 17, the "standard" treatment was applied to another portion of composite ore (45:55) ground initially to minus 100 mesh. Only 9% of the copper was lost in the magnetic fraction. From the non-magnetic tailing, a copper concentrate was produced assaying 18.9% Cu with a recovery of 74.0% of the copper in the original feed. By floating pyrrhotite from the magnetic fraction a 69.3% iron concentrate containing only 0.17% S was produced.

Finally, in Test 18, to check the encouraging results of preliminary cobbing, the successful "standard" procedure was applied to a composite ore made up of 60% high-sulphide ore and 40% cobber magnetic concentrate, i.e., after removal of about 25% of the original low-sulphide feed as a non-magnetic tailing containing little recoverable iron. Consequently, recovery of iron was about the same as in Test 17, although the grade of the concentrate dropped to 67.3% Fe and the sulphur content increased to 0.88% S. Grade of the copper concentrate was well maintained at 18.8% Cu, but overall recovery fell to 64.6% because of the copper discarded in the non-magnetic cobber tailing.

For comparison, the results of the final three tests are summarized below:

Test No.	Feed			Iron Concentrate					Copper Concentrate	
			Mesh	Analysis			Conc	% Distn	Analysis	Recovery
	Hi-S	Lo-S	Size	% Fe	% Cu	% S	Ratio	Fe	% Cu	%
16	45%	55%	- 48	69.7	0.01	0.33	4.3	38.3	19.9	57.9
17	45%	55%	-100	69.3	0.01	0.17	4.5	36.3	18.9	75.2
18	45%	30%*	-100	67.3	0.01	0.88	3.6 e	37.3	18.8	64.6 x

* cobber magnetic concentrate
e excluding cobber non-magnetic tailing
x original ore basis.

TABLE 2

Screen Analysis of Iron Concentrate, Test 2

Mesh Size	Wt %	Analysis, %	
		Fe	S
-100+200	5.4	50.99	17.19
-200+270	11.5	60.91	18.72
-270+325	17.1	65.08	12.78
-325+400	3.5	67.06	8.77
-400+500	25.7	69.84	2.66
-500	36.8	70.63	1.16
Total (Calcd)	100.0	67.2	6.7

TABLE 3

Metallurgical Results of Cobbing, Low-Sulphide Ore

Product	Wt %	Analysis, %			Distribution, %		
		Sol Fe	Mag Fe	Cu	Sol Fe	Mag Fe	Cu
Cobber conc	55.0	53.27	44.91	0.12	76.2	93.0	40.0
Cobber tail	45.0	20.28	4.12	0.22	23.8	7.0	60.0
Feed (calcd)	100.0	38.43	26.55	0.17	100.0	100.0	100.0

TABLE 4

Results of Davis Tube Tests on Cobber Concentrate and Tailing

Product	Wt %	Analysis	Dist'n
		% Sol Fe	% Sol Fe
Cobber Conc - D.T. Mags	67.6	66.43	85.2
D.T. Non-mags	32.4	24.16	14.8
Feed (calcd)	100.0	52.73	100.0
Cobber Tail - D.T. Mags	7.8	52.87	20.7
D.T. Non-mags	92.2	17.08	79.3
Feed (calcd)	100.0	19.87	100.0

CONCLUSIONS

A procedure for treating the Paulpic ore has been developed as follows:

(1) grinding to minus 100 mesh (70-75% minus 325 mesh);

(2) conventional low-intensity magnetic separation;

(3) flotation of pyrrhotite from the magnetic fraction without regrinding, using Z-6 as collector, Dow Froth 250 frother, and sulphuric acid to adjust the pH to 6.0;

(4) flotation of a copper concentrate from the non-magnetic portion, without regrinding, using Minerec 27 as collector, and sulphuric acid to adjust the pH to 6.0; successive cleaning of the rougher concentrate.

Marketable iron concentrates can be made from either the high-sulphide ore or the low-sulphide ore or a composite of the two ores.

A satisfactory copper concentrate (18% Cu) can be made from the high-sulphide ore with a recovery above 70%, and the high-sulphide ore can be blended with the relatively copper-poor (0.17% Cu) low-sulphide ore for treatment without significantly affecting the overall recovery and grade.

If the two types of ore can be mined separately, then coarse cobbing (at minus 1/2 inch) should be considered in the treatment of the low-sulphide ore, as 45% of the weight of this type of ore can be rejected with little loss of recoverable iron.

Separate treatment of the low-sulphide cobber tailing for copper does not appear to be practical because of the small quantity of copper involved and the intimate association of the copper with pyrite.

Recovery of cobalt and nickel does not appear to be practical because the cobalt and nickel minerals occur in too small quantities and are not concentrated in any of the products.

The pyrrhotite concentrate (60% Fe and 22% S) can be used as a source of iron or sulphur, or can be stockpiled for possible use in the future.

ACKNOWLEDGEMENTS

All chemical analyses in connection with this investigation were done by the Analytical Chemistry Sub-Division of the Mineral Sciences Division.

The author wishes to express his appreciation to Mr. R. P. Bailey of the Mineral Processing Division for his assistance in the preparation of this report.

APPENDIX

Mines Branch Flotation Test Reports

Abbreviations Used in Test Reports

CS	Caustic starch - aqueous solution of caustic soda and starch in the ratio 1:2
Z-200	Carbamate, made by Dow Chemical Co.
DF 250	Dow Froth 250
H_2SO_4	Sulphuric Acid
$CuSO_4$	Copper Sulphate Pentahydrate
Z-6	Potassium Amyl Xanthate, made by Dow Chemical Co.
CaO	Lime, 85% pure
Na_2CO_3	Soda Ash, Laboratory grade
PO	Pine Oil
Min 27	Minerec 27, made by Minerec Corporation.

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MINES BRANCH FLOTATION TEST REPORT

TEST NO. 1	SAMPLE: High-Sulphide Ore	DATE:
OBJECT OF TEST: To investigate the flotation of copper from the ore prior to magnetic separation		CHARGE: 2000 grams
		TESTED BY:

OPERATION	Time min	% Solids	pH	Unit used	Reagents, lb per ton of High-Sulphide Ore									
					CS	Z-200	DF250	H2SO4	CuSO4	Z-6	CaO			
Grinding to -100 mesh	30	57.1		Ball Mill										
Conditioning	5	33.3	10.0	1000-g cell	0.6									
Cu Rougher Flotation	5			"		0.04	0.008							
Conditioning	5		7.0	"				2.4	0.20					
Pyrrhotite Flotation	10			"			0.008			0.10				
Magnetic Separation				Sala										
Regrinding														
Cu Rougher Conc	15	57.1	11.0	Ball Mill							0.33			
Cu Cleaner No. 1				250-g cell										
" No. 2				"										
" No. 3				"										

PRODUCT	WT %	ANALYSIS %							DISTRIBUTION %				
		Fe	Cu	S					Fe	Cu	S		
Cu Cleaner Conc	1.3	33.85	23.16	32.31					0.9	56.0	2.3		
Cu Cleaner Tails	8.6	30.93	1.22	17.21					5.6	19.5	8.2		
Cu Rougher Conc*	9.9	31.31	4.10	19.19					6.5	75.5	10.5		
Pyrrhotite Conc	53.9	55.31	0.20	27.87					62.1	20.0	83.4		
Flotation Conc*	62.8	52.40	0.82	26.94					68.6	95.5	93.9		
Magnetic Iron Conc	17.2	67.32	0.03	5.11					24.1	1.0	4.9		
Magnetic Sep'n Tail	19.0	18.41	0.10	1.11					7.3	3.5	1.2		
Final Flot'n Tail*	36.2	41.66	0.07	3.01					31.4	4.5	6.1		
Feed*	100.0	47.99	0.54	18.01					100.0	100.0	100.0		

* Calculated

REMARKS:

MINES BRANCH FLOTATION TEST REPORT

TEST NO. 2	SAMPLE: High Sulphide Ore	DATE:
OBJECT OF TEST: To investigate the alternative procedure - magnetic separation followed by flot'n of pyrrhotite from the magnetic fraction of the ore, and flot'n of copper from the non-magnetic tailing		CHARGE: 4000 grams
		TESTED BY:

OPERATION	Time min	% Solids	pH	Unit used	Reagents, lb per ton of High Sulphide Ore									
					Na2CO3	CuSO4	Z-6	CS	Z-200	DF250	CaO			
Grinding to -100 mesh	30	57.1		Ball Mill										
Magnetic Separation				Sala										
Magnetics-Conditioning	5	33.3	8.5	1000-g cell	0.5									
"	5			"		0.20								
Pyrrhotite Flotation	15			"			0.10			0.02				
Non-Mags-Conditioning	5	25.0	10.0	"				0.6						
Cu Rougher Flotation	5			"					0.04	0.008				
Regrinding														
Cu Rougher Conc	15	57.1	11.0	Ball Mill							0.33			
Cu Cleaner Conc No. 1				250-g cell										
" No. 2				"										
" No. 3				"										

PRODUCT	WT %	ANALYSIS %							DISTRIBUTION %				
		Fe	Cu	S					Fe	Cu	S		
Iron Conc	20.4	66.96	0.02	7.06					28.4	0.8	8.0		
Pyrrhotite Float	41.4	59.92	0.12	29.30					51.6	9.7	67.3		
Total Magnetics *	61.8	62.25	0.09	21.96					80.0	10.5	75.3		
Cu Cleaner Conc	1.4	27.28	21.75	26.54					0.8	59.6	2.1		
Cu Cleaner Tails	5.2	24.81	1.31	11.15					2.7	13.3	3.2		
Cu Rougher Conc*	6.6	25.32	5.66	14.45					3.5	72.9	5.3		
Cu Rougher Tail	31.6	25.08	0.27	11.09					16.5	16.6	19.4		
Total Non-Magnetics*	38.2	25.12	1.20	11.67					20.0	89.5	24.7		
Feed*	100.0	48.07	0.51	18.03					100.0	100.0	100.0		

* Calculated

REMARKS:

MINES BRANCH FLOTATION TEST REPORT

TEST NO. 3	SAMPLE: High-Sulphide Ore, Magnetic Iron Concentrate	DATE:
OBJECT OF TEST: To investigate the effect of soda ash and copper sulphate on pyrrhotite flotation		CHARGE: 1262 grams
		TESTED BY:

OPERATION	Time min	% Solids	pH	Unit used	Reagents, lb per ton of High-Sulphate Ore									
					Na_2CO_2	$CuSO_4$	Z-6	DF 250						
Conditioning	5	33.3	8.5	500-g cell	0.5									
"	10			"		0.5								
"	1			"			0.05							
Pyrrhotite Flotation	5			"				0.024						
"	3			"			0.05	0.016						

PRODUCT	WT %	ANALYSIS %							DISTRIBUTION %				
		Fe	S	SiO_2					Fe	S			
Final Iron Conc	26.6	66.27	5.80	3.11					28.4	6.9			
Total Pyrrhotite Float	73.4	60.69	28.10						71.6	93.1			
Feed*	100.0	62.18	22.17						100.0	100.0			

* Calculated

REMARKS:

MINES BRANCH FLOTATION TEST REPORT

TEST NO. 4	SAMPLE: High-Sulphide Ore, Magnetic Iron Concentrate	DATE:
OBJECT OF TEST:	To investigate the effect of regrinding the magnetic concentrate before flotation	CHARGE: 1262 grams
		TESTED BY:

OPERATION	Time min	% Solids	pH	Unit used	Reagents, lb per ton of High Sulphide Ore: Na2Co3	CuS04	Z-6	DF 250					
Regrinding	15	57.1		Ball Mill									
Conditioning	5	33.3	8.5	500-g cell	0.5								
"	10			"		0.5							
"	1			"			0.05						
Pyrrhotite Flotation	5			"				0.024					
"	7			"			0.05	0.016					
Hydroseperation				Wade									

PRODUCT	WT %	ANALYSIS %: Fe	S	Si02				DISTRIBUTION %: Fe	S			
Final Iron Conc	22.5	69.42	4.96	1.12				25.1	5.0			
Hydroseperator Overflow	1.3	35.97	3.00					0.8	0.2			
Total Pyrrhotite Float	76.2	60.50	27.60					74.1	94.8			
Feed*	100.0	62.19	22.19					100.0	100.0			

* Calculated

REMARKS:

Flotation was considerably slower.

MINES BRANCH FLOTATION TEST REPORT

TEST NO. 5	SAMPLE: High-Sulphide Ore, Magnetic Iron Concentrate	DATE:
OBJECT OF TEST:	To investigate the effect of sulphuric acid and copper sulphate on pyrrhotite flotation.	CHARGE: 1288 grams
		TESTED BY:

OPERATION	Time min	% Solids	pH	Unit used	Reagents, lb per ton of High-Sulphide Ore H2SO4	CuSO4	Z-6	DF 250						
Conditioning	10	33.3	6.0	500-g cell	1.8	0.5								
"	1						0.10							
Pyrrhotite Flotation	5			"				0.024						
"	3			"			0.05	0.016						
Hydroseperation				Wade										

PRODUCT	WT %	ANALYSIS % Fe	S					DISTRIBUTION % Fe	S			
Final Iron Conc	19.3	68.88	0.58					21.2	0.5			
Hydroseperator Overflow	0.5	34.93	-					0.3	-			
Total Pyrrhotite Float	80.2	61.50	27.90					78.5	99.5			
Feed *	100.0	62.78	22.49					100.0	100.0			

* Calculated

REMARKS:

MINES BRANCH FLOTATION TEST REPORT

TEST NO. 6	SAMPLE: High-Sülphide Ore, Magnetic Iron Concentrate	DATE:
OBJECT OF TEST:	To study the effect of pyrrhotite cleaner flotation on iron recovery	CHARGE: 1272 grams
		TESTED BY:

OPERATION	Time min	% Solids	pH	Unit used	Reagents, lb per ton of High-Sulphide Ore: H2SO4	CuSO4	Z-6	DF 250						
Conditioning	10	33.3	6.0	500-g cell	1.8	0.5								
"	1			"			0.05							
Pyrrhotite Flot'n:														
No. 1 stage	2			"				0.024						
No. 2 stage	3			"				0.016						
No. 3 stage	5			"			0.05	0.016						
Cleaning No. 3														
Pyrrhotite Float.	5			500-g cell										
Hydroseperation				Wade										

PRODUCT	WT %	ANALYSIS %: Fe	S						DISTRIBUTION %: Fe	S			
Final Iron Conc	20.3	68.57	0.73						22.3	0.7			
Hydroseperator Overflow	0.8	32.68	-						0.4	-			
No. 1 Stage Float	23.6	60.43	30.71						22.8	32.8			
No. 2 Stage Float	11.3	60.93	30.95						11.0	15.8			
No. 3 Stage Cleaner Float	40.6	61.38	27.05						40.0	49.7			
No. 3 Stage Cleaner Tail	3.4	65.11	6.17						3.5	1.0			
Feed *	100.0	62.46	22.09						100.0	100.0			
Final Iron Conc + No. 3 Stage Cleaner Tail*	23.7	68.06	1.52						25.8	1.7			

* Calculated

REMARKS:

MINES BRANCH FLOTATION TEST REPORT

TEST NO. 7	SAMPLE: High-Sulphide Ore,Non-Magnetic Fraction	DATE:
OBJECT OF TEST:	To determine the effect of slime flotation, without cyanide to control copper losses prior to copper flotation	CHARGE: 738 grams
		TESTED BY:

OPERATION	Time min	% Solids	pH	Unit used	Reagents, lb per ton of High-Sulphide Ore CaO	Pine Oil	Z-200							
Conditioning	10	25.0	10.0	500-g cell	0.5									
Slime Flotation	5			"		0.04								
Cu Rougher Flotation	2			"			0.02							
"	3			"			0.02							

PRODUCT	WT %	ANALYSIS % Cu						DISTRIBUTION % Cu				
Cu Rougher conc	11.3	5.18						46.8				
Rougher Tail	75.1	0.12						7.2				
Slimes	13.6	4.22						46.0				
Feed *	100.0	1.25						100.0				

* Calculated

REMARKS:

High copper losses were incurred in slime flotations in this test.

MINES BRANCH FLOTATION TEST REPORT

TEST NO. 8	SAMPLE: High-Sulphide Ore, Non-Magnetic Fraction	DATE:
OBJECT OF TEST:	To determine the effect of slime flotation, with cyanide to control copper losses, prior to copper flotation	CHARGE: 748 grams
		TESTED BY:

OPERATION	Time min	% Solids	pH	Unit used	Reagents, lb per ton of High-Sulphide Ore										
					CaO	NaCN	Pine Oil	Z-200							
Conditioning	10	25.0	10.0	500-g cell	0.5	0.25									
Slime Flotation	5			"			0.04								
Cu Rougher Flotation	2			"				0.02							
"	3			"				0.02							
Cu Cleaner No. 1				250-g cell											
" No. 2				"											

PRODUCT	WT %	ANALYSIS %						DISTRIBUTION %				
		Cu						Cu				
Cu Cleaner Conc	5.2	19.32						76.7				
Cu Cleaner Tails	12.4	0.85						8.0				
Slime Float	12.3	0.89						8.4				
Cu Rougher Tail	70.1	0.13						6.9				
Feed *	100.0	1.31						100.0				
Cu Rougher Conc	17.6	6.30						84.7				
* Calculated												

REMARKS:

MINES BRANCH FLOTATION TEST REPORT

TEST NO. 9	SAMPLE: High-Sulphide Ore, Non-Magnetic Fraction	DATE:
OBJECT OF TEST:	To determine the effect of sulphuric acid and Mineree 27 on copper flotation	CHARGE: 736 grams
		TESTED BY:

OPERATION	Time min	% Solids	pH	Unit used	Reagents, lb per ton of High-Sulphide Ore										
					H2804	Min27	Z-6	DF250							
Conditioning	5	25.0	6.0	500-g cell	1.8	0.04									
Cu Flotation	5			"				0.008							
Conditioning	5			"			0.05	0.05							
Scavenging	5			"				0.008							

PRODUCT	WT %	ANALYSIS %						DISTRIBUTION %				
		Cu						Cu				
Cu Conc	9.2	11.94						81.9				
Scavenger conc	20.8	0.79						12.2				
Final tail	70.0	0.11						5.9				
Feed *	100.0	1.34						100.0				

* Calculated

REMARKS:

MINES BRANCH FLOTATION TEST REPORT

TEST NO. 10	SAMPLE: High-Sulphide Ore, Non-Magnetic Fraction	DATE:
OBJECT OF TEST:	To determine the effect of sulphuric acid and Z-200 on copper flotation	CHARGE: 738 grams
		TESTED BY:

OPERATION	Time min	% Solids	pH	Unit used	Reagents, lb per ton of High-Sulphide Ore H2SO4	Z-200	DF250							
Conditioning	10	25.0	6.0	500-g cell	1.8									
Cu Rougher Flotation	2			"		0.02	0.008							
"	3			"		0.02								
Cu Cleaner No. 1				250-g cell										

PRODUCT	WT %	ANALYSIS % Cu							DISTRIBUTION % Cu				
Cu Cleaner Conc	11.3	9.55							84.0				
Cu Cleaner Tail	4.2	0.96							3.1				
Cu Rougher Tail	84.5	0.20							12.9				
Feed *	100.0	1.29							100.0				
Cu Rougher Conc*	15.5	7.22							87.1				

*Calculated

REMARKS:

MINES BRANCH FLOTATION TEST REPORT

TEST NO. 11	SAMPLE: High-Sulphide Ore	DATE:
OBJECT OF TEST: To incorporate the best procedures of the previous tests to confirm a tentative flowsheet for the production of a magnetic iron concentrate and a copper concentrate.		CHARGE: 4000 grams
		TESTED BY:

OPERATION	Time min	% Solids	pH	Unit used	Reagents, lb per ton of High-Sulphide Ore									
					H2SO4	CuSO4	Z-6	Min27	DF250					
Grinding to -100 mesh	30	57.1		Ball Mill										
Magnetic Separation				Sala										
Magnetics Conditioning	10	33.3	6.0	1000-g cell	1.8	0.5								
"	5			"			0.10							
Pyrrhotite Flotation	5			"					0.56					
Non-Mags-Conditioning	5	25.0	6.0	1000-g cell	1.8			0.04						
Cu Rougher Flotation	5			"										
Scavenging	5			"			0.05		0.008					
Cu cleaner No. 1				500-g cell										
" No. 2				250-g cell										

PRODUCT	WT %	ANALYSIS %							DISTRIBUTION %				
		Fe	Cu	S	Ni	Co			Fe	Cu	S		
Iron Conc	12.5	71.17	0.01	0.31					18.5	0.2	0.2		
Pyrrhotite Float	49.2	61.69	0.11	27.92	0.14	0.09			63.1	10.2	75.9		
Total Magnetics*	61.7	63.61	0.09	22.33					81.6	10.4	76.1		
Cu Cleaner Conc	2.0	24.27	18.87	22.28	0.06	0.07			1.0	71.7	2.5		
Cu Cleaner Tails	1.6	22.20	1.25	11.65					0.8	3.8	1.0		
Cu Rougher Conc*	3.6	23.61	11.02	17.78					1.8	75.5	3.5		
Scavenger Conc	7.9	39.24	0.64	37.97	0.12	00.15			6.4	9.5	16.6		
Scavenger Tail	26.8	18.28	0.09	2.54					10.2	4.6	3.8		
Cu Rougher Tail*	34.7	23.05	0.21	10.60					16.6	14.1	20.4		
Total Non-Magnetics*	38.3	23.10	1.23	11.28					18.4	89.6	23.9		
Feed*	100.0	48.10	0.53	18.10					100.0	100.0	100.0		

REMARKS:

The Scavenger Concentrate consisted mainly of pyrite. Recovery of Nickel and Cobalt was impractical.

MINES BRANCH FLOTATION TEST REPORT

TEST NO. 12	SAMPLE: Low-Sulphide Ore, Cobber Concentrate	DATE:
OBJECT OF TEST:	To investigate the recovery of iron from the magnetic cobber concentrate by magnetic separation	CHARGE: 2000 grams
		TESTED BY:

OPERATION	Time min	% Solids	pH	Unit used	Reagents, lb per ton									
Magnetic Separation				Sala										
Grinding of the Magnetic Fraction	30	57.1		Ball Mill										
Magnetic Separation				Sala										
Hydro Separation				Wade										

PRODUCT	WT %	ANALYSIS %							DISTRIBUTION %				
		Fe	Cu	S					Fe				
Magnetic Iron Conc.	72.2	67.56	0.02	1.59					90.1				
Hydroseparator overflow	0.8	43.05							0.7				
No. 2 Non-Magnetic tail	19.4	15.87							5.7				
No. 1 Non-Magnetic tail	7.6	25.20							3.5				
Original Feed*	100.0	54.12							100.0				

* Calculated

REMARKS:

Concentration ratio on original ore bases: $1/72.2 \times \frac{55}{100} = 2.5:1$

MINES BRANCH FLOTATION TEST REPORT

TEST NO. 13	SAMPLE: Low-Sulphide Ore, Cobber Conc	DATE:
OBJECT OF TEST:	To produce a low-sulphur iron concentrate by flotation of pyrrhotite from the magnetic concentrate.	CHARGE: 2000 grams
		TESTED BY:

OPERATION	Time min	% Solids	pH	Unit used	Reagents, lb per ton H2SO4	Z-6	DF250							
Grinding to -100 mesh	30	57.1		Ball Mill										
Magnetic Separation				Sala										
Conditioning	5		6.0	1000-g cell	1.8	0.1								
Pyrrhotite Flotation	5						0.04							

PRODUCT	WT %	ANALYSIS % Fe	Cu	S					DISTRIBUTION % Fe	Cu	S		
Final Iron Conc	67.5	66.91	0.01	0.33					80.8	4.1	9.6		
Pyrrhotite Float	5.0	59.06	0.27	17.61					5.5	9.6	40.6		
Magnetic Separation Tail	27.5	24.68	0.42	3.60					13.7	86.3	49.8		
Feed *	100.0	53.84	0.15	2.17					100.0	100.0	100.0		

* Calculated

REMARKS: Concentration Ratio on original ore basis: $1/67.5 \times \frac{55}{100} = 2.7:1$

MINES BRANCH FLOTATION TEST REPORT

TEST NO. 14	SAMPLE: Low-Sulphide Ore, Cobber Tailing	DATE:
OBJECT OF TEST: To investigate the recovery of copper using Minerec 27 and xonthate (Z-6)		CHARGE: 2000 grams
		TESTED BY:

OPERATION	Time min	% Solids	pH	Unit used	Reagents, lb per ton of Low-Sulphide Ore										
					H2SO4	Min 27	Z-6	DF 250							
Grinding to -100 mesh	30	57.1		Ball Mill											
Conditioning	5	33.3	6.0	1000-g cell	1.8	0.04	0.05								
Cu Rougher Flot'n	5			"				0.008							
Cu Cleaner No. 1				250-g cell											
" No. 2				"											

PRODUCT	WT %	ANALYSIS %							DISTRIBUTION %				
		Cu							Cu				
Cu Cleaner Conc	1.0	7.86							36.9				
Cleaner Tails	3.7	0.58							9.8				
Rougher Tail	95.3	0.12							53.3				
Feed*	100.0	0.21							100.0				

* Calculated

REMARKS:

MINES BRANCH FLOTATION TEST REPORT

TEST NO. 15	SAMPLE: Low-Sulphide Ore, Cobber Tailing	DATE:
OBJECT OF TEST:	To investigate the recovery of copper using xanthate (Z-6)	CHARGE: 2000 grams
		TESTED BY:

OPERATION	Time min	% Solids	pH	Unit used	Reagents, lb per ton of Low-Sulphide Ore		
					H2SO4	Z-6	DF250
Grinding	30	57.1		Ball Mill			
Conditioning	10	33.3	6.0	1000-g cell	1.8		
Cu Rougher Flot'n	1			"		.01	.032
"	1			"		.01	
"	1			"		.01	
"	2			"		.01	.008
Cu Cleaner No. 1				250-g cell			
" No. 2				"			
" No. 3				"			

PRODUCT	WT %	ANALYSIS % Cu	DISTRIBUTION % Cu
Cu Cleaner Conc	1.3	8.73	52.8
No. 3 Cleaner Tail	0.9	1.18	5.1
No. 2 Cleaner Tail	2.2	0.65	6.6
No. 1 Cleaner Tail	5.7	0.26	7.0
Cu Rougher Tail	89.9	0.07	28.5
Feed*	100.0	0.21	100.0

* Calculated

REMARKS:

MINES BRANCH FLOTATION TEST REPORT

TEST NO. 16	SAMPLE: Composite - 45% High-Sulphide: 55% Low-Sulphide	DATE:
OBJECT OF TEST:	To investigate the recovery of iron and copper after magnetic separation at minus 48 mesh	CHARGE: 4000 grams
		TESTED BY:

OPERATION	Time min	% Solids	pH	Unit used	Reagents, lb per ton of Composite Ore			
					H2SO4	Z-6	Min27	DF250
Grinding to -48 mesh	15	57.1		Ball Mill				
Magnetic Separation				Sala				
Regrinding								
Magnetic Fraction	20	57.1		Ball Mill				
Conditioning	10	33.3	6.0	1000-g cell	1.8	0.10		
Pyrrhotite Flotation	5			"				0.056
Magnetic Separation				Sala				
Regrinding								
Non-Magnetic Fraction	20	57.1		Ball Mill				
Conditioning	5	33.3	6.0	1000-g cell	1.8		0.04	
Cu Rougher Flotation	5			"				
Cu Cleaner No. 1,2,3				250-g cell				

PRODUCT	WT %	ANALYSIS %			DISTRIBUTION %		
		Fe	Cu	S	Fe	Cu	S
Final Iron Conc	23.4	69.66	0.01	0.03	38.3	0.6	0.8
Magnetic Finisher Tail	2.6	20.48	0.04	0.20	1.3	0.3	-
Rougher Iron Conc*	26.0	64.78	0.01	0.30	39.6	0.9	0.8
Pyrrhotite Float	29.0	57.62	0.26	22.62	39.3	21.8	67.3
Total Magnetics*	55.0	60.98	0.14	12.07	78.9	22.7	68.1
Cu Cleaner Conc	1.0	24.50	19.89	23.20	0.6	57.9	2.4
Cu Cleaner Tails	2.3	20.00	0.75	9.56	1.1	4.9	2.2
Cu Rougher Conc*	3.3	21.50	6.54	13.63	1.7	62.8	4.6
Cu Rougher Tail	41.7	19.78	0.12	6.38	19.4	14.5	27.3
Total Non-Magnetics*	45.0	20.00	0.59	6.91	21.1	77.3	31.9
Feed*	100.0	42.50	0.34	9.75	100.0	100.0	100.0

REMARKS:

Regrinding was done to minus 100 mesh. Copper sulphate was not used in pyrrhotite flotation.

MINES BRANCH FLOTATION TEST REPORT

TEST NO. 17	SAMPLE: Composite - 45% High-Sulphide: 55% Low-Sulphide	DATE:
OBJECT OF TEST:	To investigate the recovery of iron and copper using the "standard" procedure.	CHARGE: 4000 grams
		TESTED BY:

OPERATION	Time min	% Solids	pH	Unit used	Reagents, lb per ton: H2SO4	Z-6	Min27	DF250
Grinding to -100 mesh	30	57.1		Ball Mill				
Magnetic Separation				Sala				
Magnetics-Conditioning	10	33.3	6.0	1000-g cell	1.8	0.10		
Pyrrhotite Flotation	5							0.056
Non-Mags-Conditioning	5	33.3	6.0	1000-g cell	1.8		0.04	
Cu Rougher Flotation	5			"				
Cu Cleaner No. 1				500-g cell				
" No. 2				250-g cell				
" No. 3				"				

PRODUCT	WT %	ANALYSIS % Fe	Cu	S	DISTRIBUTION % Fe	Cu	S
Iron Conc	22.4	69.29	0.01	0.17	36.3	0.6	0.4
Pyrrhotite Float	27.6	61.30	0.10	23.90	39.5	8.4	68.2
Total Magnetics *	50.0	64.88	0.06	13.28	75.8	9.0	68.6
Cu Cleaner Conc	1.3	25.38	18.92	23.08	0.8	74.0	3.1
Cu Cleaner Tails	3.9	20.25	0.42	7.69	1.8	4.9	3.1
Cu Rougher Conc*	5.2	21.50	5.05	11.54	2.6	78.9	6.2
Cu Rougher Tail	44.8	20.63	0.09	5.45	21.6	12.1	25.2
Total Non-Magnetics*	50.0	20.72	0.60	6.08	24.2	91.0	31.4
Feed*	100.0	42.80	0.33	9.68	100.0	100.0	100.0

* Calculated

REMARKS: Final Iron Conc: 96.4% minus 200 mesh
75.5% minus 325 mesh

MINES BRANCH FLOTATION TEST REPORT

TEST NO. 18	SAMPLE: Composite 60% High-Sulphide: 40% Magnetic Cobber Conc	DATE:
OBJECT OF TEST:	To investigate the recovery of iron and copper from a composite made without the Cobber Tailing using the "standard" procedure.	CHARGE: 6000 grams TESTED BY:

OPERATION	Time min	% Solids	pH	Unit used	Reagents, lb per ton of Composite Ore: H2SO4	Z-6	Min27	DF250						
Grinding to -100 mesh	30	57.1		Ball Mill										
Magnetic Separation				Sala										
Magnetics-Conditioning	10	33.3	6.0	2000-g cell	1.8	0.10								
Pyrrhotite Flotation	10			"				0.04						
Non-Mags-Conditioning	5	33.3	6.0	1000-g cell	1.8		0.04							
Cu Rougher Flotation	5			"										
Cu Cleaner No. 1				500-g cell										
" No. 2				250-g cell										
" No. 3				"										

PRODUCT	WT %	ANALYSIS % Fe	Cu	S				DISTRIBUTION % Fe	Cu	S		
Iron Conc	28.0	67.32	0.01	0.88				37.3	0.8	2.1		
Pyrrhotite Float	38.5	60.57	0.13	22.65				46.2	12.9	74.2		
Total Magnetics *	66.5	63.41	0.08	13.49				83.5	13.7	76.3		
Cu Cleaner Conc	1.5	27.33	18.83	24.00				0.8	72.9	3.1		
Cu Cleaner Tails	2.4	22.00	0.65	8.33				1.1	4.1	1.7		
Cu Rougher Conc*	3.9	24.10	7.64	14.36				1.9	77.0	4.8		
Cu Rougher Tail	29.6	24.86	0.12	7.50				14.6	9.3	18.9		
Total Non-Magnetics*	33.5	24.78	1.00	8.30				16.5	86.3	23.7		
Feed*	100.0	50.47	0.39	11.75				100.0	100.0	100.0		
* Calculated												

REMARKS: Final Iron Concentrate: 96.3% minus 200 mesh, 70.2% minus 325 mesh

Copper Recovery (on original ore basis):

$$72.9\% \text{ (Rec)} \times \frac{75\% \text{ Wt}}{100\% \text{ Wt}} \times \frac{0.39 \text{ Cu (in Test)}}{0.33 \text{ Cu (in Original Feed)}} = 64.6\%$$