MINES BRANCH
DEPARTMENT OF MINES, OTTAWA, CANADA

Memorandum Series | April 1924 | No. 15

THE SELECTIVE FLOTATION OF THE LOWER GRADE NICKELIFEROUS PYRRHOTITE ORES OF ONTARIO.

By:
W. B. Timm,
Chief, Division of Ore Dressing and Metallurgy

INTRODUCTORY

The present practice of smelting the copper-nickel ores of the Sudbury District direct in the blast furnace, or by mixing the green ore with a certain portion of roasted product, or by smelting the roasted fines in a reverberatory furnace, has given very favourable results in the past. This practice has been especially adaptable to the higher grade ores when consideration is given to the favourable market conditions that have prevailed to within the last few years.

In the treatment of the lower grade ores of the district, of which there are enormous reserves, it is a question whether it would not be more economical to apply certain methods of concentration to produce a product with a fairly high copper-nickel content prior to smelting operations. One of the operating companies has for several years been treating a portion of the lower grade material from their mines by concentration on tables and by flotation, to eliminate the gangue. By sintering this concentrated product with flue dust and mine fines, they obtain a roasted product very desirable in many ways for mixing with green ore for the blast furnace charge.

Experimental tests were conducted in the Mines Branch laboratories at Ottawa to determine whether a large portion of the barren pyrrhotite, as well as the siliceous gangue, could be eliminated, with the production of a copper-nickel concentrate, the copper-nickel content of which would be similar to the content of the blast furnace matte being produced. Further, as the success of any such process would depend to a large extent on the concentration of the precious metal values in the ores, as well as the copper-nickel values, the experimental work included a study of the concentration products, to determine whether the precious metal values were reporting in the concentrate with the copper and nickel minerals.

THE SELECTIVE FLOTATION OF THE LOWER GRADE COPPER-NICKEL ORES OF THE SUDBURY DISTRICT, ONTARIO

Experimental tests: The first series of tests was made on the lower grade ores from two of the mines, to determine whether the copper-nickel values could be concentrated by selective flotation, with the production of a high grade copper-nickel product with high recoveries of the copper and nickel values, by the elimination of the siliceous gangue minerals and a large portion of the barren pyrrhotite. No attention was paid to where the precious metal values were reporting in this series of tests.

Table I gives the results of tests Nos. 1, 2, 4, and 5, on an ore of the following analysis:

Copper	1.25%
Nickel	1.35%
Iron	23.70%
Sulphur	10.70%
Silica	37.85%

Recoveries indicated include the actual recovery made in the concentrate plus 50% of the copper-nickel values in the middling, which would be recovered by returning this product to the head of the circuit. This percentage was proven to be a conservative estimate.

Table II gives the results of tests Nos. 6 and 8 on the same ore, when the middling was re-run without further grinding. With re-grinding of the middling product, higher recoveries could be expected.

Table III gives the results of tests Nos. 1, 2, 3, 4, 5, 6, and 8, on a still lower grade ore, of the following analysis:

Copper	0.47%
Nickel	1.17%
Iron	20.90%
Sulphur	11.19%
Silica	42.15%

TABLE I

Test No.	Concentration Products	Weight grams	Analysis Cu. per cent	Analysis Ni. per cent	Analysis Cu.+Ni. per cent	Percentage of values Cu.	Percentage of values Ni.	Total Recoveries Cu. per cent	Total Recoveries Ni. per cent	Total Recoveries Cu.+Ni. per cent
1	Concentrate...	106	12.50	9.60	22.10	93.2	76.2	95.3	82.4	89.1
	Middling.....	147	0.40	1.13	...	4.1	12.4			
	Tailing.....	758	0.05	0.20	...	2.7	11.3			
2	Concentrate...	75	16.50	10.20	26.70	88.3	58.7	91.9	68.8	80.8
	Middling.....	155	0.65	1.70	...	7.2	20.2			
	Tailing.....	785	0.08	0.35	...	4.5	21.1			
4	Concentrate...	95	13.66	9.75	23.41	93.6	69.8	95.4	78.3	87.1
	Middling.....	146	0.35	1.55	...	3.7	17.0			
	Tailing.....	758	0.05	0.23	...	2.7	13.1			
5	Concentrate...	170	7.40	6.20	13.60	92.0	80.0	93.9	84.5	89.2
	Middling.....	94	0.55	1.27	...	3.8	9.0			
	Tailing.....	730	0.08	0.20	...	4.2	11.0			

TABLE II

Test No.	Concentration Products	Weight grams	Analysis			Percentage of values		
			Cu. per cent	Ni. per cent	Cu.-Ni. per cent	Cu.	Ni.	Cu.-Ni.
6	Concentrate...	376	7.60	5.70	13.30	91.4	86.5	89.2
	Tailing.....	1,594	0.17	0.21	0.38	8.6	13.5	10.8
8	Concentrate...	292	9.10	7.50	16.60	96.7	83.4	90.2
	Tailing.....	1,675	0.055	0.26	0.31	3.3	16.6	9.8

TABLE III

Test No.	Concentration Products	Weight grams	Analysis			Percentage of values			Total recoveries		
			Cu. %	Ni. %	Cu.+Ni. %	Cu.	Ni.	Cu.+Ni.	Cu. %	Ni. %	Cu.+Ni. %
1	Concentrate..	155	2.6	6.2	8.8	87.4	82.6)	84.0	90.0	86.8	87.8
	Middling.....	159	0.15	0.62	...	5.2	8.4)				
	Tailing.....	694	0.05	0.15	...	7.4	8.9				
2	Concentrate..	175	2.30	5.75	8.05	89.3	84.7)	86.0	90.7	87.0	88.0
	Middling.....	118	0.10	0.45	...	2.7	4.5)				
	Tailing.....	715	0.05	0.18	...	8.0	10.8				
3	Concentrate..	194	2.15	5.26	7.41	89.7	87.1)	82.4	90.9	81.6	84.1
	Middling.....	82	0.15	0.57	...	2.6	3.6)				
	Tailing.....	730	0.05	0.29	...	7.7	10.6				
4	Concentrate..	220	1.90	4.80	6.70	91.5	88.5)	89.3	92.3	90.3	90.8
	Middling.....	144	0.05	0.30	...	1.5	3.6)				
	Tailing.....	630	0.05	0.15	...	7.0	7.9				
5	Concentrate..	64	3.05	7.12	10.17	83.7	76.6)	78.6	86.3	80.0	81.8
	Middling.....	69	0.17	0.56	...	5.1	6.5)				
	Tailing.....	369	0.07	0.27	...	11.2	16.8				
6	Concentrate..	66	6.65	13.36	20.01	82.1	73.0)	75.7	84.9	79.6	81.2
	Middling.....	122	0.25	1.33	...	5.6	13.4)				
	Tailing.....	825	0.08	0.20	...	12.3	13.6				
8	Concentrate..	168	2.70	5.83	8.53	93.2	80.4)	84.0	94.6	85.5	88.1
	Middling.....	205	0.07	0.61	...	2.9	10.3)				
	Tailing,.....	632	0.03	0.18	...	3.9	9.3				

The procedure followed in conducting the tests was:

The ore was crushed to 20 mesh; 1000 grams were ground wet in a small ball mill with the reagents for about 40 minutes; a rougher concentrate and tailing were first made; the rougher concentrate was recleaned, making a concentrate and a middling. In tests nos. 6 & 8 of Table II, two 1000 gram lots were used, following the above procedure, in order to obtain sufficient middling for refloating. The concentrate from refloating the middling was added to the final concentrate, and the tailing to the rougher tailing, so as to have only two products, concentrate and tailing.

No test work was done to determine the degree of fineness to which the ores should be ground to obtain the best results. For the tests, approximately 90% would pass a 200 mesh screen. For test no. 8 of Table III, it was ground to pass a 100 mesh screen, 67% through 200 mesh.

Conclusions from Experimental tests: There is no apparent difficulty in making a fairly high grade copper-nickel concentrate, with a good recovery of the copper-nickel values in the ores. A concentration product was made, in certain cases, with a higher copper-nickel content than that contained in the blast furnace mattes, certainly higher than the mattes that would be produced by present practice on the same grades of ores.

For the selective flotation of the ores, the alphabetical reagents were found to be the most suitable. In using these reagents, the essential point is to carry an alkaline pulp, obtained by the addition of lime, soda ash, or caustic soda. The chalcopyrite floats with remarkable ease, the nickel minerals are more difficult to float.

Examination for the amounts of pyrrhotite being eliminated in the tailing was made on the flotation products of the tests run for the determination of precious metal values as given in Tables IV and VI following, where the concentration was not nearly so good as in some of the tests given above in Tables I and III. This was found to be 30% and 41% respectively, of the amounts in the ore. This elimination of practically barren pyrrhotite, together with the gangue minerals, is very desirable, and means considerable savings in several directions. Taking the flotation products of tests nos.1, 2, and 4 of Table I and of test no. 6 of Table III, where high grade concentrates were made, the percentage of pyrrhotite eliminated in the tailings would be much higher than that given above.

THE PRECIOUS METAL VALUES IN THE FLOTATION PRODUCTS OF THE LOWER GRADE COPPER-NICKEL ORES OF THE SUDBURY DISTRICT

Experimental tests: To determine if the precious metal values in the ores were being concentrated with the copper-nickel values, flotation tests were conducted on 13 kilograms of each ore, in one kilogram lots. The products from the thirteen tests on each ore were combined in order to obtain sufficient quantities of the flotation products for accurate determination of the precious metal contents. In conducting these tests attention was not paid to obtaining the best flotation results, as this was demonstrated by former tests, the results of which are given in Tables I, II and III.

Tables IV and V give the results on the first ore, the flotation results on which are given in more detail in Tables I and II.

Tables VI and VII give the results on the second ore, which was of still lower grade, the flotation results on which are given in more detail in Table III.

TABLE IV

Product	Weight grams	Assays: Nickel per cent	Copper per cent	Gold oz/ton	Plat. oz/ton	Palladm. oz/ton	Rhod., Irid., etc. oz/ton	Precious metal values content.
Concentrate..	2,050	5.88	7.55	0.036	0.062	0.072	0.006*	$13.18
Middling	1,490	0.93	0.20	0,012	0,019	0,022	0,004	4.47
Tailing.	9,460	0.16	0.05	0.002	0.0027	0.0038	trace	0.62
Ore.....	13,000	1.15	1.25	0.008	0.014	0.017	0.0014	$3.04

* Results are no doubt low due to oxidation and volatilization in fusing and scorifying.

** Figures from December 1922 quotations on these metals.

TABLE V

Product	Percentages in Products						
	Weight	Nickel	Copper	Gold	Plat.	Palladm.	Precious metal values.
Concentrate...	15.8	80.6	95.5	66.8	70.3	68.5	68.4
Middling.	11.5	9.3	1.8	16.1	15.7	16.3	16.8
Tailing..	72.7	10.1	2.9	17.1	14.0	15.2	14.8

TABLE VI

Product	Assays							
	Weight grams	Copper per cent	Nickel per cent	Gold oz/ton	Plat. oz/ton	Palladm. oz/ton	Rhod., Irid., etc. oz/ton	Precious metal values content
Concentrate,..	1,635	2.90	6.40	0.027	0.032	0.043	0.005 *	$7.40 **
Middling.	1,418	0.27	1.65	0.013	0.016	0.015	0.003	3.54
Tailing..	9,947	0.05	0.21	0.0009	0.0011	0.0026	...	0.30
	13,000	0.43	1.14	0.0055	0.0067	0.0009	0.0009	$1.55

* Results are no doubt low due to oxidation and volatilization in fusing and scorifying.

** Figured from December 1922 quotations on these metals.

TABLE VII

Product	Percentages in Products						
	Weight	Copper	Nickel	Gold	Plat.	Palladm.	Precious metal values.
Concentrate...	12.6	84.8	70.3	61.8	60.9	60.0	60.3
Middling.	10.9	6.8	15.7	25.7	26.4	18.0	24.9
Tailing..	76.5	8.8	14.0	12.5	12.7	22.0	14.8

Conclusions from examination of flotation products: The results show, in the case of the first ore, 68% of the total precious metal values is contained in the concentrate, 17% in the middling product, and 15% in the tailing. By re-grinding and floating the middling, which represents 11.5% of the original feed, a total recovery of 80% of the precious metal values would be obtained in the copper-nickel concentrate by selective flotation.

The results show, in the case of the second ore of lower grade, 60% of the precious metal values is contained in the concentrate, 25% in the middling product, and 15% in the tailing. By re-grinding and floating the middling, which represents 10.9% of the original feed, a total recovery of 75% of the precious metal values would be obtained in the copper-nickel concentrate by selective flotation.

The results show that it has been demonstrated by the above tests that the gold and the platinum group metals are reporting to a large extent in the concentrate with the copper and nickel minerals.

In the determination of the precious metal contents, the total flotation products were used, and the assay results obtained figured to the 'per ton' basis. The assays so obtained should be reliable and accurate.

No definite conclusions are arrived at with regard to the particular mineral or minerals with which the platinum group metals are associated. In studying the ratios between these metals and the copper, nickel, iron and sulphur content in the flotation products, there is no definite uniformity of values or proportions between these metals and the chalcopyrite, pentlandite, pyrrhotite, content in the ores and flotation products. Whether this should be accepted in support of the opinion that the lower grade ores carry relatively higher values in the platinum group metals, is questionable.

THE SELECTIVE FLOTATION OF THE COPPER-NICKEL ORES OF SHEBANDOWAN LAKE DISTRICT, ONTARIO

Experimental tests: Tests were conducted on a shipment of ore from this district to determine whether a high grade copper-nickel concentrate could be obtained with a satisfactory recovery of the copper-nickel and precious metal values. The tests were made on an ore of the following analysis:

Nickel	2.97%	Lime	2.50%	
Copper	1.65%	Magnesia	7.64%	
Cobalt	0.15%	Sulphur	15.84%	
Iron	24.30%	Gold	0.01	oz/ton
Alumina	10.15%	Platinum	0.03	"
Silica	26.55%	Palladium	0.048	"

Table VIII gives the results of the tests. In test no. I a concentrate and tailing were made. In test no. 2 a concentrate, middling, and tailing were made.

TABLE VIII

Test No.	Product	Weight	Analysis			Percentage of values.			Total Recoveries		
			Cu.	Ni + Co	Cu + Ni + Co	Cu.	Ni + Co	Cu + Ni + Co	Cu.	Ni + Co	Cu + Ni + Co
		%	%	%	%				%	%	%
1	Concentrate.	25.7	6.35	9.88	16.23	83.0	92.1	88.3	83.0	92.1	88.3
	Tailing.....	74.3	0.45	0.24	...	17.0	7.9				
2	Concentrate.	30.7	5.00	8.56	13.56	88.3	95.5	92.7	91.1	96.4	94.4
	Middling....	17.0	0.58	0.30	...	5.7	1.9				
	Tailing.....	52.3	0.20	0.14	...	6.0	2.6				

Conclusions from experimental tests: A high recovery of the copper, nickel, and cobalt values was made in a good grade of concentrate. The recovery of the copper is not as good as on the Sudbury ores, probably due to oxidation. Continuous grinding and flotation tests will be made, and the precious metal values in the flotation products determined, to prove whether these values are reporting in the concentrate. Taking the results obtained in test no. 2 of Table VIII, determinations made show that 36% of the pyrrhotite in the ore is eliminated in the tailing and this elimination of pyrrhotite, if practically barren as is the case in the tests on the Sudbury ores, together with the gangue silicates, is very desirable for subsequent smelting operations.

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