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LOW-SILICA HEMATITE CONCENTRATES

by

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SYNOPSIS

Using three samples of specular hematite concentrates from the Labrador-Quebec area, high-grade hematite concentrates with silica contents of less than 0.5 per cent have been produced by fine grinding followed by high-intensity wet magnetic separation and by flotation of the silica. The product has many potential uses in pigment manufacture and in direct reduction, amply justifying the moderate cost of the process.

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CONCENTRÉS D'HÉMATITE À FAIBLE TENEUR EN SILICE

par

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RÉSUMÉ

A partir de trois échantillons de concentrés d'hématite spéculaire en provenance de la région du Labrador-Nouveau-Québec, on a élaboré des concentrés d'hématite de haute qualité d'une teneur en silice inférieure à 0.5 p. 100, en recourant au broyage très fin suivi de la séparation magnétique du fer à haute intensité par voie humide et de la flottation de la silice. Le produit obtenu peut servir à de nombreux usages dans les fabriques de pigments et dans les usines de réduction directe, ce qui justifie amplement le faible coût du procédé.

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INTRODUCTION

With the completion in 1962 of the Quebec Cartier Mining Company's iron ore concentrator at Gagnon in northern Quebec, and of the Carol Lake concentrator of the Iron Ore Company of Canada near Labrador City, Newfoundland, large quantities of specular hematite concentrates are now being produced by gravity concentration that contain 67-69% iron and 3-5% silica (mainly as quartz). The particle size ranges from 10 to 325 mesh with about 75% plus 150 mesh. Most of the production will be used in blast furnaces for pig iron production.

However, there are indications of a demand for concentrates that contain less than 1% silica and from which iron or iron oxide products can therefore be made directly; the high-grade coarse specularite concentrate is an attractive starting point for super-concentration.

EARLIER TEST WORK

In 1959, tests were made on a coarse specular hematite gravity concentrate with the object of producing a low-silica hematite concentrate for direct reduction in a kiln to iron powder (1). Since a coarse product was desired, the minus 20 plus 200 mesh fraction of the sample was treated. The best specularite product obtained by high-intensity dry magnetic separation contained 68.80% iron and 2.25% silica. However, after magnetizing roasting, concentration by a low-intensity dry separator yielded products containing as high as 71.2% iron and as low as 1.24% silica. Visual examination of the products showed that much finer grinding would be necessary for complete liberation of the silica.

With the introduction of the Jones high-intensity wet magnetic separator, the feasibility of magnetic treatment of finely ground material renewed the interest in super-concentration of hematite concentrates after fine grinding. Initial tests were made in 1959 (2). In one test at minus 100 mesh, a concentrate containing 67.67% iron and 1.69% silica was produced. Other tests indicated that a much lower silica content can be obtained by finer grinding and lower magnetic intensity, if high recovery is sacrificed.

OUTLINE OF INVESTIGATION

In 1960 several inquiries were received by the Mines Branch for sources of high-grade iron oxide concentrates for use in direct iron production, powder metallurgy, and pigment manufacture. The specifications ranged from 0.1 to 1.0% silica, but, in general, it was evident that a hematite concentrate with a silica content of less than 0.5% would have attractive possibilities for a number of uses where a high-grade iron oxide concentrate is being produced either by hydrometallurgy or by pyrometallurgy.

Several sources of iron oxide were considered, including magnetite concentrates, mill scale, and direct reduction products from high-iron concentrates. In all cases either the source of material was unreliable or silica removal was difficult and expensive. Consideration of the results of the tests outlined above on specular hematite concentrates using the Jones separator directed the investigations to the Quebec-Labrador specularite concentrates as raw material for further concentration.

Two methods of silica removal were tried, and the results are described in this bulletin. One method uses high-intensity wet magnetic separation, and the other uses cationic silica flotation. To lower the silica content below 0.5%, fine grinding (dry or wet) to minus 100 mesh is required.

The tests described were on three different samples of Quebec-Labrador specular hematite concentrates: Samples A and B were obtained from interested industrial firms, and Sample C from a Mines Branch stockpile. All the concentrates were obtained by Humphreys spirals and are typical of concentrates now being produced at the Quebec Cartier and the Carol Lake concentrators.

RESULTS

Preliminary Tests

The object of the first series of tests was to discover whether concentrates containing less than 0.5% silica can readily be produced. Two methods of separation were tried separately: high-intensity wet magnetic separation, and cationic silica flotation.

High-Intensity Wet Magnetic Separation

Samples were pulverized to minus 100 mesh and treated at different intensities by a Jones high-intensity wet magnetic separator. In the first test a 2000-gram portion of sample A was treated. Magnetics were first removed at 0 amperes, and the middling and tailing products were combined and were repassed at 10 amperes. The results of this test are shown in Table 1.

TABLE 1

Treatment of Sample A by Jones Separator

Product	Weight %	Analysis %	Distn %
		SiO_2	SiO_2
0 amp conc	5.4	3.70	3.8
10 amp conc	71.0	0.20	2.6
" " midd	12.5	15.88	37.3
" " tail	11.1	27.00	56.3
Feed*	100.0	5.42	100.0

*Calculated.

In another test, on Sample B, the same procedure was used. The results are shown in Table 2.

TABLE 2

Treatment of Sample B by Jones Separator

Product	Weight %	Analysis %		Distn %
		Sol Fe**	SiO_2	Sol Fe
0 amp conc	10.0	67.5		10.0
10 amp conc	70.2	70.0	0.47	72.5
" " midd	12.1	62.5		11.1
" " tail	7.7	56.8		6.4
Feed*	100.0	67.82		100.0

*Calculated.

**Iron oxide content cannot be calculated since some magnetite is present.

Further tests on Sample B showed that, with finer grinding, a concentrate containing 0.32% silica with a weight recovery of 61.2% of the original feed can be produced. However, the highest grade concentrate produced by high-intensity wet magnetic separation still contained 0.20% silica.

Screen tests were done on the magnetic concentrates of samples A and B, with the results shown in Table 3.

TABLE 3

Size Distribution of Magnetic Concentrates

Size	Sample A (0.20 % SiO_2)		Sample B (0.32 % SiO_2)	
	Weight %	Cum Weight %	Weight %	Cum Weight %
+100 m	0.6		-	
-100 +150	28.7	29.3	39.0	
-150 +200	23.6	52.9	25.6	64.6
-200 +325	23.5	76.4	19.0	83.6
-325 m	23.6		16.4	
Total	100.0		100.0	

Flotation Tests

Flotation tests were first done on Sample C. In previous work it had been discovered that, in the presence of iron minerals, cationic flotation of silica from iron oxides is most effective on particles ground finer than 150 mesh. Accordingly, in all the tests the flotation feed was ground to minus 150 mesh.

After several preliminary tests, it was found that good results are obtained using a combination of Rosin Amine D Acetate (RADA) and a frother mixture (POA) consisting of 50% pine oil, 2.5% Aerosol OT 100, and 47.5% water by volume The feed is first conditioned with Dextrine WW82.

To obtain the results shown in Table 4 a 2000-gram sample was ground wet to minus 150 mesh, and conditioned in the cell for 5 minutes with 2 lb of dextrine per ton. A total of 0.2 lb each of RADA and POA per ton was added, and, after 30 seconds conditioning, a froth was floated for 5 minutes.

TABLE 4

Silica Flotation of Sample C

Product	Weight %	Analysis %		Distn %	
		Sol Fe	SiO_2	Sol Fe	SiO_2
Froth	15.8	45.57	33.04	10.9	94.6
Concentrate	84.2	69.68	0.36	89.1	5.4
Feed*	100.0	65.87	5.52	100.0	100.0

*Calculated.

The froth was cleaned separately with no additional reagents, but the additional concentrate recovered contained 14.6% silica. The reagent cost in the test would be about $0.35 per ton of product.

In another test, using the same procedure but with 0.3 lb each of RADA and POA per ton, a concentrate was produced containing 0.28% silica with a weight recovery of 64.1% of the original feed.

A screen test was done on the concentrate shown in Table 4, with the results shown in Table 5.

TABLE 5

Size Distribution of Flotation Concentrate (Sample C)

Size	Weight %	Cum Weight %
+150 m	0.5	
-150 +200	16.6	17.1
-200 +325	38.0	55.1
-325	44.9	
Total	100.0	

Production of Super-Concentrates

Having successfully produced concentrates containing less than 0.5% silica, the investigation was extended to the production of super-concentrates with less than 0.10% silica. A further lot of sample A was received for these additional tests.

At first, a 2000-gram sample was ground to minus 150 mesh and then floated using the same procedure as before. The feed was conditioned with 1 lb of dextrine per ton, and a total of 0.4 lb RADA and 0.1 lb of POA per ton was added. The results of this test are shown in Table 6.

TABLE 6

Results of Silica Flotation (Sample A)

Product	Weight %	Analysis %		Distn %
		Sol Fe	SiO_2	Sol Fe
Froth No. 1	10.7	63.26		10.3
" " 2	12.6	44.11		8.5
" " 3	25.6	69.06	0.82	27.0
Concentrate	51.1	69.46	0.12	54.2
Feed*	100.0	65.5		100.0

*Calculated.

In an effort to reduce the silica content of the flotation concentrate further, it was decided to pass it through a Jones separator at 10 amperes. This test was done and a concentrate containing only 0.03% silica was produced. Weight recovery was 48.3% of the original feed. The froth No. 3 product shown in Table 6 was also treated by the same method, and the silica content was reduced to 0.19%. Combining these two concentrates would give a product containing 0.06% silica at a weight recovery of 70.7% of the original feed. The results of these tests are shown in Table 7.

TABLE 7

Treatment of Flotation Products by Jones Separator

Source	Product	Weight % of original feed	Analysis % SiO_2	Distn % of original feed SiO_2
Flot. conc	10 amp conc	48.3	0.03	0.3
" "	" " midd	2.1	0.75	0.4
" "	" " tail	0.7	2.67	0.4
No. 3 froth	10 amp conc	22.4	0.19	0.8
" "	" " midd	1.7	5.1	1.6
" "	" " tail	1.5	5.3	1.4

High-intensity wet magnetic separation, on Sample A ground to minus 150 mesh, was also tried and a magnetic concentrate containing 0.42% silica was produced. Microscopic examination of the crude sample showed that most of the silica grains were liberated. It was thought that a high-grade concentrate might be produced by pulverizing to minus 28 mesh, followed by wet tabling. This test was done and a concentrate containing 0.62% silica was produced. Weight recovery was 68.3% of the original feed.

A semi-quantitative spectrographic analysis was done on the super-concentrate containing 0.03% silica, with the results shown in Table 8.

TABLE 8

Results of Super-Concentrate Spectrographic Analysis

Elements %

Fe*	SiO_2*	Mn	Mg	Ca	Cu	Ti	Ni	V	Zr	Al	Cr
69.12	0.03	0.05	0.02	0.5	0.004	0.04	0.04	0.004	0.004	0.20	Tr

*Determined by chemical analysis.

Further Tests

Flotation tests using (1) another cationic collector, Armac C, and (2) an anionic collector, Acintol D, were done on sample A for comparison with the results obtained with RADA and POA. Samples were first ground to minus 150 mesh.

The results obtained with Armac C were similar to those obtained using RADA. A flotation concentrate containing 0.10% silica was produced. When this concentrate was treated by a Jones separator the silica content was reduced to 0.03%. For a comparable weight recovery, a slightly higher silica content was obtained. A flotation concentrate containing 0.17% silica was produced with a weight recovery of 74.6% of the original feed. After passing this concentrate through a Jones separator, the silica content was reduced to 0.08% with a weight recovery of 56.8% of the original feed. Reagent consumptions were 1 lb of dextrine per ton and 0.3 lb of Armac C per ton.

Silica floats readily using an anionic collector at a pH of from 11 to 11.5. A 2000-gram sample was conditioned with 1 lb of dextrine per ton and the pH then raised to just over 11 with about 1 lb of NaOH per ton. The pulp was next conditioned with 1 lb of calcium chloride per ton, followed by the addition of 1 lb of Acintol D per ton. A froth was floated for 10 minutes. A concentrate containing 0.70% silica, with a weight recovery of 81.5% of the original feed, was obtained. This concentrate was treated by a Jones separator, and the silica content was reduced to 0.21% with a weight recovery of 63.8% of the original feed. In another anionic flotation test followed by high-intensity wet magnetic separation, the final concentrate contained 0.11% silica with a weight recovery of 47.4% of the original feed.

CONCLUSIONS

The results show that three different samples of specular hematite gravity concentrates can be upgraded by simple means to products containing less than 0.5% silica, with good weight recoveries.

Further tests show that on Sample A, by silica flotation, the silica content can be reduced to 0.10%. By further treatment, using a Jones high-intensity wet magnetic separator, the silica content is reduced to 0.03%.

As the best grade of concentrate produced by high-intensity wet magnetic separation alone contains 0.20% silica, it appears that a combination of flotation and high-intensity wet magnetic separation is necessary to obtain super-concentrates of 0.03% (or less) silica content.

It appears that cationic flotation will produce a higher grade of super-concentrates than will anionic flotation. However, anionic reagent costs will be slightly lower.

The major costs involved in the process are in grinding and reagents, both of which are moderate when considered in relation to the metallurgical advantages obtained.

It is believed that high-grade iron oxide concentrates are attractive to steel companies desiring an alternative feed source for the direct reduction and powder pyrometallurgical industries. The ability to produce super-concentrates containing under 0.10% silica may lead to important industrial uses.

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REFERENCE

(1) Pickett, D.E., Internal Report MDT 59-16, Mineral Dressing and Process Metallurgy Division, Mines Branch, Department of Mines and Technical Surveys, Ottawa, Canada, Feb. 19, 1959.

(2) Wyman, R.A., Stone, W.J.D., and Hartman, F.H., Mines Branch Technical Bulletin TB 36, Department of Mines and Technical Surveys, Ottawa, Canada, June 1962, p. 59.

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