I & B

RI 7852

Bureau of Mines Report of Investigations/ 1974

Superconcentration of Commercial Magnetic Taconite Concentrates by Cationic Flotation

UNITED STATES DEPARTMENT OF THE INTERIOR

Report of Investigations 7852

Superconcentration of Commercial Magnetic Taconite Concentrates by Cationic Flotation

By David L. Veith
Twin Cities Metallurgy Research Center, Twin Cities, Minn.

MARCH 3, 1849

UNITED STATES DEPARTMENT OF THE INTERIOR
Rogers C. B. Morton, Secretary

BUREAU OF MINES
Thomas V. Falkie, Director

This publication has been cataloged as follows:

Veith, David L

Superconcentration of commercial magnetic taconite concentrates by cationic flotation. [Washington] U.S. Bureau of Mines [1974]

12 p. illus., tables. (U.S. Bureau of Mines. Report of investigations 7852)

1. Iron oxides. 2. Magnetite. 3. Taconite. I. U.S. Bureau of Mines. II. Title. III. Title: Cationic flotation. (Series)

TN23.U7 no. 7852 622.06173

U.S. Dept. of the Int. Library

CONTENTS

ILLUSTRATIONS

TABLES

SUPERCONCENTRATION OF COMMERCIAL MAGNETIC TACONITE CONCENTRATES BY CATIONIC FLOTATION

by

David L. Veith [1]

ABSTRACT

Caustic scrubbing followed by silica flotation with cationic ether primary amine proved effective in upgrading commercial magnetic concentrates to supergrade products containing 2 percent SiO_2 or less. Samples representing 41 million long tons per year of commercial magnetic concentrates from the Lake Superior region were tested by the Bureau of Mines. Bench-scale and pilot plant research indicated an estimated potential of 32 million long tons per year of superconcentrates to be available.

Two pilot plant investigations yielded superconcentrates containing 1.1 and 1.9 percent SiO_2 that were derived from commercial concentrates containing 7.0 and 4.2 percent SiO_2, respectively. Corresponding iron recoveries were 90 and 93 percent at reagent costs of just over 33 cents per long ton of superconcentrates produced.

Additional sources evaluated on a bench scale resulted in iron recoveries of 72 to 95 percent in products containing 1.7 to 2.0 percent SiO_2. Although reagent cost ranged up to 60 cents per long ton of superconcentrate, it is probable that these costs would be reduced in plant applications where benefits are derived from material and reagent recycle.

INTRODUCTION

In the context of this report, the term 'superconcentrate' refers to a premium-grade iron ore concentrate, high in iron and low in gangue content. For lack of industry specifications, superconcentrate is arbitrarily defined as a concentrate containing 2 percent SiO_2 or less, with an accompanying iron content of near 70 percent.

Such premium concentrates are not normal items of commerce in the United States. Indeed, the average grade of pellets produced in the U. S. Great Lakes and Canadian areas in 1971 was 63.3 percent Fe and 5.8 percent SiO_2.[2]

---

[1] Metallurgist.

[2] American Iron Ore Association. Grade Names and Analyses. Sec. VI, in Iron Ore. 1971, pp. 60-78.

This grade approaches the optimum or ideal for the blast furnace, whereas the use of superconcentrates would require additions of gravel or other siliceous material to insure an adequate slag volume. Therefore, superconcentrates alone in the blast furnace would not represent the best use of this premium, high-cost material.

Recently, the route of prereduction of high-grade concentrates and electric furnace steelmaking has been proposed as an alternate to the conventional blast furnace--basic oxygen furnace practice, to help provide the additional steel capacity needed for the 1980's and beyond. This proposal is based on the likelihood of impending shortages of metallurgical coke, expected increases in coke costs, and probable improvements in electrical furnace technology, contrasted to a fully developed blast furnace technology.[3] If these trends develop, much informed opinion holds that economics favor the prereduction-electric furnace route over blast furnaces for plants up to a capacity of 1 million net tons per year.

The first commercial prereduction-electric furnace steelmaking facility in the United States began operation in 1969 using high-grade imported concentrates. Terming the period 1969-71 as "years of prereduction breakthrough," one authority[4] predicted an increase in the use of metallized concentrates from less than 1 million to over 10 million net tons per year during the 1970 decade.

Production of superconcentrates would be the initial step in this evolving technology to bypass the blast furnace and go directly to electric steelmaking. Prereduced pellets made from these superconcentrates should be at least competitive with scrap, and actually preferred since they introduce no undesirable impurities, such as copper and nickel, which are often found in scrap materials.

Economically, electric furnace steelmaking requires consideration of superconcentrates over normal commercial concentrates because of the relative gangue contents. Besides reducing the electric furnace capacity, each 100-pound increase in the slag weight of continuously charged heats in a 25-ton furnace increases the energy requirement by 40 kW-hr per net ton of steel.[5] Thus the need is obvious to restrict consideration for electric furnace feed materials to those of superconcentrate quality.

In anticipation of an increased demand for superconcentrates in the not-too-distant future, the Bureau of Mines undertook an evaluation of domestic

---

[3] Cartwright, F. Challenge to the Blast Furnace. New Scientist (London), May 4, 1972, pp. 252-255.

[4] Miller, J. R. Scrap, Prereduced Iron Ore, and Electric Furnace Steelmaking in the 1970 Decade. Blast Furnace and Steel Plant, June 1970, pp. 408-412; July 1970, pp. 471-475.

[5] Sibakin, J. G., P. H. Hookings, and G. A. Roeder. Electric Arc Steelmaking With Continuously Charged Reduced Pellets. Proc. Internat. Cong. on Production and Utilization of Prereduced Iron Ores, May 29-31, 1967, Evian, France, 1968, pp. 335-350.

taconite production to determine if substantial tonnages of current output could be converted to superconcentrates by application of intensive cationic flotation. Most of the samples were evaluated by batch, bench-scale tests; however, laboratory procedures were verified on two 50-long ton samples[6] using continuous processing in the Bureau's 900-pound-per-hour flotation pilot plant.

BENCH-SCALE INVESTIGATIONS OF MAGNETIC TACONITES

Bench-scale investigations were made on samples of magnetic taconite concentrates listed in table 1, which were obtained from six plants in Minnesota, one plant in Michigan, and one plant in Wisconsin. Initial bench work by Tippin[7] was performed on the sample designated as "Minnesota sample A" and the developed procedure formed the basis for evaluating the other samples. This procedure involved high-intensity scrubbing of the commercial "as is" concentrate for 5 to 10 minutes in pulps containing 50 percent solids and a varying amount of NaOH. Following caustic scrubbing, the sample was deslimed and/or washed to remove a small fraction of fine material and to lower the pH. Afterwards, the sample was subjected to intensive flotation using cationic promoters to collect the silica in the froth. This basic procedure was followed throughout, although in some instances, screening to remove the plus 325-mesh (Tyler) fraction as waste was employed advantageously. In addition, it was beneficial in some cases to regrind this plus 325-mesh fraction and return it to the circuit. The effectiveness of the caustic scrubbing-desliming method on flotation with 0.3 lb/long ton[8] of a 12-carbon-chain aliphatic amine is exemplified by figure 1, from which it can be seen that optimum scrubbing conditions (with sample A) occur within the range of 2 to 4 lb/long ton of NaOH, and with 5 to 10 minutes of scrubbing.

TABLE 1. - Partial chemical analysis of commercial magnetic taconite concentrates

Concentrate origin	Analysis, percent	
	Fe	SiO_2
Minnesota:		
A	67.9	4.7
B	67.7	4.8
C	67.0	5.1
D	67.0	5.3
E	63.6	10.0
F	65.7	6.1
Michigan	63.0	10.0
Wisconsin	66.9	7.0

---

[6] Long ton as used in this report signifies a ton of 2,240 pounds as is conventional in the iron ore industry.

[7] Tippin, R. B. Production of Magnetic Superconcentrates by Cationic Flotation. Trans. AIME, v. 252, March 1972, pp. 53-61.

[8] Reagent additions are in pounds per long ton of commercial concentrate feed, unless otherwise stated.

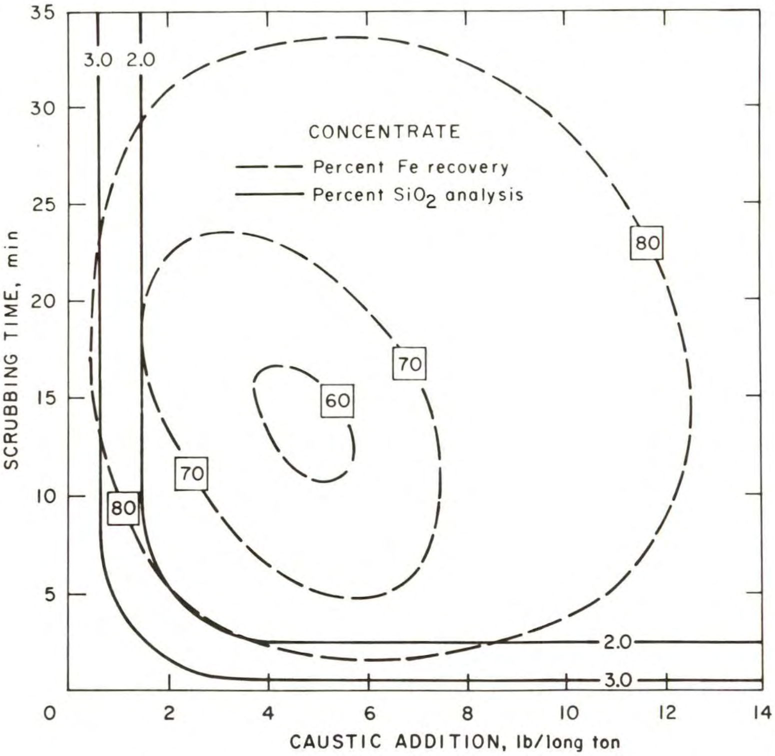


FIGURE 1. - Laboratory flotation results of Minnesota sample A after caustic scrubbing, illustrated as constant value recovery and analysis curves.

Several alternative schemes to the caustic scrubbing-desliming procedure were explored in bench-scale tests with the Michigan sample (table 2), but none proved as satisfactory. In addition to those alternatives shown, other less effective procedures included scrubbing with various dispersants (without caustic additions), and acid scrubbing-desliming.

Additional bench-scale investigations were made to determine the effect of collector structure on the flotation of silica from the Michigan sample. These data, given in table 3, show that the optimum combination of concentrate grade and iron recovery was obtained with an ether primary amine having the chemical structure: $R\text{-}O\text{-}(CH_2)_3NH_2$, where R = $C_8\text{-}C_{10}$ alkyl group mixture.

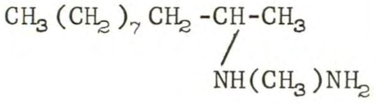
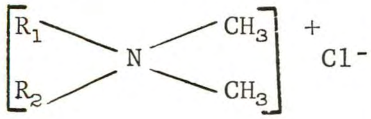
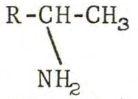
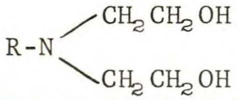
TABLE 2. - Effects of pretreatment on flotation of Michigan sample[1]

Pretreatment	Analysis of flotation concentrate, pct			Remarks
	Fe	SiO_2	Fe distribution	
None............	70.0	2.1	72.4	Caustic used for pH control only. No desliming.
Caustic addition and desliming.	69.9	2.0	76.1	1.1 lb/long ton caustic stirred into pulp, followed by static desliming.[2]
Caustic conditioning and desliming.	70.0	2.1	76.7	1.1 lb/long ton caustic conditioned into pulp, followed by static desliming.
Scrubbing only..	68.4	3.6	80.1	Scrubbing pulp at high solids for 10 minutes. Caustic used for pH control only. No desliming.
Caustic scrubbing.	70.3	1.9	79.8	Scrubbing pulp at high solids for 10 minutes with 4.4 lb/long ton caustic. No desliming.

[1] Collector: 0.5 lb/long ton ether primary amine.

[2] Static desliming involves stirring the caustic into the pulp, baffling to quiet the pulp, allowing the heavy solids to settle, and decanting the slime-laden effluent. These steps are done at specified time intervals held constant throughout the test series.

TABLE 3. - Superconcentrate production as a function of amine type, Michigan sample[1]

Amine description		Concentrate analysis, pct		
Type	Chemical structure	Fe	SiO_2	Fe distribution
Ether primary amine	$R\text{-}O\text{-}(CH_2)_3NH_2$ ($R = C_8\text{-}C_{10}$ mixture)	69.9	2.0	79.4
Beta diamine.......	 $CH_3(CH_2)_7CH_2\text{-}CH(NH(CH_3)NH_2)\text{-}CH_3$	70.3	1.9	68.2
Primary amine......	$R\text{-}NH_2$ (R = primarily C_{12})	70.0	2.0	60.8
Quaternary ammonium chloride.		69.0	3.4	84.7
Beta amine.........	 $R\text{-}CH(NH_2)\text{-}CH_3$ ($R = C_7$)	67.1	5.9	94.7
Polyethoxylated amine.		64.3	9.9	50.4

[1] Caustic scrubbing-desliming-flotation system employing 4.5 lb/long ton NaOH in the scrubbing step and 0.6 lb/long ton amine for flotation of the gangue.

In production of superconcentrates, the flotation process can benefit from elimination of sizes coarser than 325 mesh. The screen analysis of Minnesota sample B given in table 4 is illustrative of a common condition in which incomplete liberation is evidenced by decreasing iron content with increasing particle size. In production of commercial concentrates, maintenance of these relative coarse grinds is favored for economic reasons. However, these factors must be subordinated to the need for more complete liberation if these materials are to be utilized fully as sources of superconcentrate. Since rapped screens capable of making a nominal size separation at 325 mesh are a commercial reality,[9] there now exists the potential for improving the process by removing the plus 325-mesh fraction, regrinding it to minus 325 mesh, and reintroducing the ground product to the head of the circuit. This practice proved beneficial with a number of the concentrates studied.

---

[9] Keller, L. D. Fine Screening--The Current State of the Art. Skillings' Min. Rev., v. 60, No. 19, May 8, 1971, pp. 8-11, 23.

TABLE 4. - Screen analysis of Minnesota sample B commercial magnetic taconite concentrate

Size fraction, mesh[1]	Fractional analysis, percent				
	Weight	Fe	SiO_2	Fe distribution	SiO_2 distribution
Plus 200..................	7.6	49.3	25.2	5.6	39.8
Minus 200 plus 325........	14.3	64.8	7.4	13.7	22.0
Minus 325 plus 400........	20.4	69.7	2.8	21.1	11.8
Minus 400.................	57.7	69.9	2.2	59.7	26.4
Total or average.......	100.0	67.6	4.8	100.0	100.0

[1] Tyler standard mesh size.

The best metallurgical response of the various concentrate samples to bench-scale treatment is given in table 5, which also shows reagent levels and other treatment employed. These data will be utilized in subsequent sections of this report as a basis for projecting tonnages of superconcentrates available.

TABLE 5. - Bench-scale superconcentration metallurgical results, commercial magnetic taconite concentrates

Sample	Superconcentrate analysis, percent				Reagent addition lb/long ton		Other treatment
	Weight	Fe	SiO_2	Fe distribution	NaOH	Amine	
Minnesota:							
A........	82.5	70.5	1.8	84.3	4.0	[1]0.3	None.
B........	64.8	69.5	[2]2.2	68.4	4.0	[1] .3	None.
C........	91.7	69.7	1.9	95.5	4.5	.4	Screened on 325 mesh. Grind oversize to 325 mesh before flotation.
D........	78.6	70.0	1.7	82.0	4.7	.6	Screened on 325 mesh. Grind oversize to 325 mesh before flotation.
E........	64.6	70.4	1.9	71.5	4.5	.6	Flotation concentrate screened to remove plus 325-mesh fraction.
F........	84.3	69.4	2.0	88.6	4.5	.6	Flotation concentrate screened to remove plus 325-mesh fraction.
Michigan...	80.5	70.0	1.8	89.5	4.5	.6	Screened on 325 mesh. Grind oversize to 325 mesh before flotation.
Wisconsin..	91.1	70.6	1.3	96.8	4.5	.6	None.

[1] A 12-carbon-chain aliphatic amine. In all other instances, the collector was of the ether primary amine type.

[2] Not superconcentrate quality.

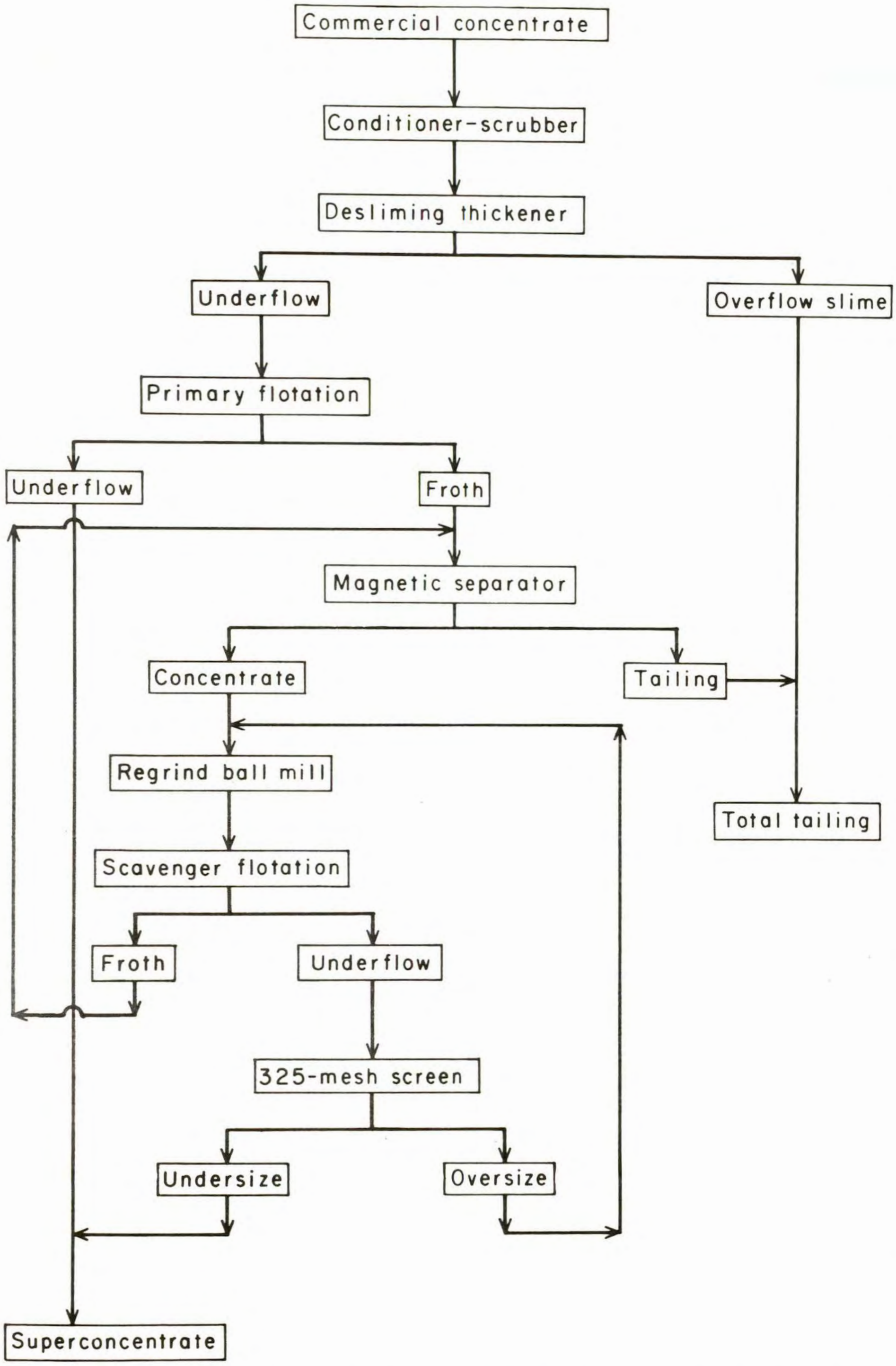


FIGURE 2. - Pilot plant superconcentration flowsheet, Minnesota sample B.

PILOT PLANT EVALUATION

Pilot plant confirmation of the bench-scale results in table 5 was undertaken on 50-long ton lots of Minnesota sample B and the Wisconsin sample. The pilot plant, with a feed rate of 900 pounds per hour, was set up to reproduce the caustic scrubbing-desliming-flotation conditions developed in the bench-scale investigations. In addition, being a continuous-flow type of operation, screen sizing, regrinding, and magnetic separation at selected points in the process streams could also be evaluated to determine their cumulative effect on grade and recovery. Superconcentrates produced from these bulk concentrates also were required in pellet and steelmaking investigations underway at the Twin Cities Metallurgy Research Center as concurrent activities.

Minnesota Sample B

Continuous pilot plant tests

on Minnesota sample B have been described in detail by Tippin[10] and will only be summarized here. A number of flowsheets were investigated, as well as a variety of other conditions, in which either (1) both standard grade and supergrade concentrates were sought, or (2) the emphasis was on optimizing the conversion of the feed product completely to superconcentrate. Alternative 2 is discussed in the following paragraphs.

Sample B averaged 68.0 percent Fe, 4.2 percent SiO_2, and had a surface area of 1,770 cm^2/g as determined by the Blaine air permeability method. This feed material was scrubbed for 15 minutes at 45 percent solids with 2.2 lb/long ton of NaOH, then routed to a thickener where fresh water was added as a wash. The resultant thickener overflow removed a small amount of slime, generally containing less than 0.5 percent of the iron, and the thickener underflow with a pH in the range of 10 to 11 was routed to the primary flotation cells (fig. 2). The only reagent used in flotation was 0.6 lb/long ton of ether primary amine added to the primary circuit. The resulting flotation underflow was a superconcentrate containing 73 percent of the iron in 70 percent of the feed weight, and analyzing 70.3 percent Fe and 1.8 percent SiO_2. This product required no additional treatment.

The froth from primary flotation, containing 27 percent of the iron in 29 percent of the weight, was given additional treatment to improve the overall recovery. As shown in figure 2, this froth product was passed through a magnetic drum separator, where a final tailing and a magnetic concentrate were made. This magnetic concentrate in turn passed through successive stages of regrinding and scavenger flotation. The scavenger underflow was screened on 325 mesh to make a product of 69.8 percent Fe and 2.4 percent SiO_2 in the undersize. This screen undersize and the primary flotation underflow were combined, yielding a superconcentrate containing 70.2 percent Fe and 1.9 percent SiO_2, while recovering 93 percent of the iron in 90 percent of the feed weight. The screen oversize and scavenger froth were returned to advanced stations in the circuit as shown in figure 2.

Table 6 summarizes the results given above. The superconcentrates had a Blaine surface area of 1,450 cm^2/g, which was less than the plant concentrate surface area of 1,770 cm^2/g. Such coarsening benefits filtration, but in this case the surface area was found to be almost too low for good pellet formation.

Considering only the primary flotation underflow, the pilot plant results were slightly better than those obtained in batch tests for this ore (table 5). However, with the additional treatment afforded by magnetic separation, regrinding, scavenger flotation, and fine screening, the pilot plant recovery exceeded that of the bench-scale tests by more than 20 percent, and without sacrifice in grade of product.

---

[10] Work cited in footnote 7.

TABLE 6. - Typical pilot plant superconcentration results, Minnesota sample B

Product description	Analysis, percent			
	Weight	Fe	SiO_2	Fe distribution
Commercial concentrate	100.0	68.2	4.1	100.0
Slime	.6	33.6	31.9	.3
Flotation feed	99.4	68.2	3.9	99.7
Primary flotation underflow	70.4	70.3	1.8	72.8
Primary flotation froth	29.0	63.1	9.1	26.9
Magnetic separator feed	109.8	66.2	6.4	106.9
Magnetic concentrate	100.8	67.8	4.8	100.5
Magnetic tailing	9.0	48.2	24.0	6.4
Reground scavenger flotation feed	109.4	67.7	4.9	108.9
Scavenger flotation underflow	28.6	68.9	3.3	28.9
Scavenger flotation froth	80.8	67.3	5.4	80.0
Screen oversize	8.6	66.8	5.4	8.4
Screen undersize	20.0	69.8	2.4	20.5
Superconcentrate[1]	90.4	70.2	1.9	93.3
Total tailing[1]	9.6	47.3	24.5	6.7

[1] Calculated.

Wisconsin Sample

Approximately 55 long tons of a Wisconsin commercial magnetic concentrate was processed in the Bureau's flotation pilot plant to confirm the effectiveness of the caustic scrubbing-desliming-cationic flotation process on yet another concentrate. A secondary objective was to produce superconcentrate in sufficient quantity to support other research in the Center's pelletizing and steelmaking activities. The commercial concentrate averaged 66.8 percent Fe and 7.0 percent SiO_2, with a screen structure of 87 percent minus 400 mesh, and a Blaine surface area of 1,920 cm^2/g. Approximately 25 percent of the silica was in the minus 325-mesh fraction.

Before the pilot plant operation, bench-scale testwork established that superconcentrate could readily be made from the Wisconsin sample. Products were made containing as little as 0.1 percent SiO_2 with 77 percent iron recovery, and up to 99 percent iron recovery with a silica content of just under 2.0 percent. Minor variations in reagents and procedures were used to obtain this range of metallurgical results, but the basic system consisted of 50 percent solids conditioning with 4.0 lb/long ton NaOH in a 1,500-rpm conditioner, reducing the pH from 12.5 to 9.5 by desliming, and three stages of flotation with a total addition of 0.3 to 0.7 lb/long ton ether primary amine. The bench-scale investigation also demonstrated that fine screening was not needed to produce superconcentrate from the Wisconsin sample.

The flowsheet shown in figure 3 was evolved for the production run and employed a 2- by 4-ft rodmill containing only five rods in place of the high-solids conditioner. This mill served to break the numerous lumps in the concentrate and slurry the material at 50 percent solids. Sodium hydroxide (3.4 lb/long ton) was added to the rodmill to maintain a scrubbing pH of about 12. The pulp was diluted and deslimed in a 5- by 3-ft thickener, which reduced the pH from 12 to 11 with negligible overflow slime losses.

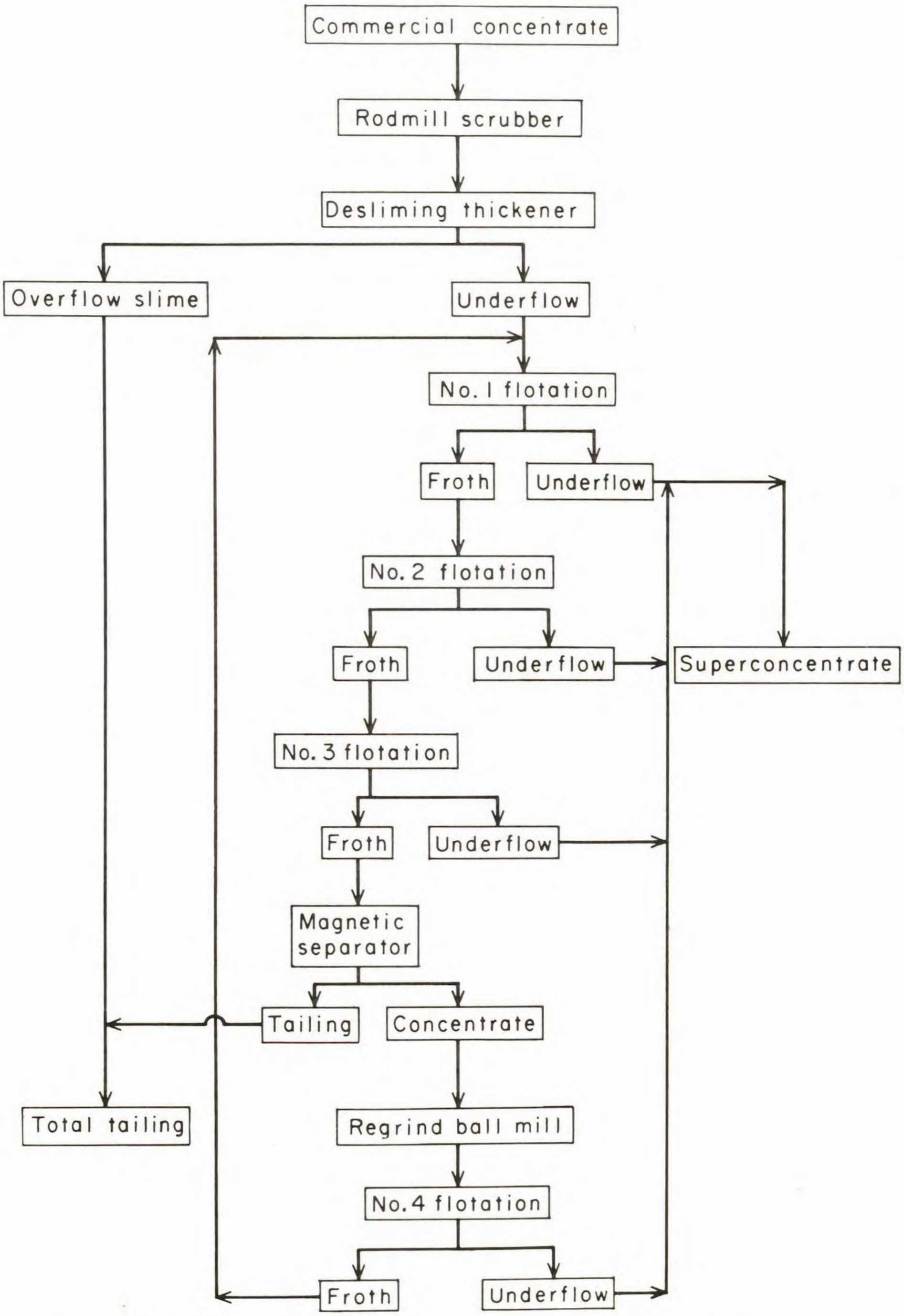


FIGURE 3. - Pilot plant superconcentration flowsheet, Wisconsin sample.

The deslimed thickener underflow was conditioned at 25 percent solids with 0.5 lb/long ton H_2SO_4 to further reduce the pH to 9.6 for flotation. In the first flotation stage, 0.35 lb/long ton ether primary amine was added; the first stage froth was cleaned in the second and third flotation stages. The third flotation froth was next scavenged in a magnetic separator to produce a final tailing and a middling (magnetic concentrate), which was reground in a 18- by 30-inch ball mill. The middling was refloated in a fourth stage with the aid of 0.05 lb/long ton ether primary amine and 0.006 lb/long ton frother. All flotation underflows were combined to comprise the total superconcentrate. Only the fourth stage flotation froth was recycled, being returned to the first stage of flotation.

A typical complete metallurgical balance is shown in table 7. The concentrate assayed 71.2 percent Fe and 1.1 percent SiO_2, and contained 90.4 percent of the iron in 84.9 percent of the feed weight. In this case, the superconcentrate Blaine surface area was 1,970 cm^2/g, compared with 1,920 cm^2/g for the commercial concentrate feed material.

TABLE 7. - Typical pilot plant superconcentration results, Wisconsin sample

Product description	Analysis, percent			
	Weight	Fe	SiO_2	Fe distribution
Commercial concentrate..........	100.0	66.9	7.0	100.0
Slime..........................	-	-	-	-
No. 1 flotation feed............	126.5	62.9	-	119.0
No. 1 flotation underflow.......	65.0	71.3	.9	69.4
No. 1 flotation froth...........	61.5	54.0	-	49.6
No. 2 flotation underflow.......	15.8	71.1	1.1	16.8
No. 2 flotation froth...........	45.7	48.1	-	32.8
No. 3 flotation underflow.......	0.4	69.9	2.1	.4
No. 3 flotation froth...........	45.3	47.9	-	32.4
Magnetic concentrate............	30.2	50.5	-	22.8
Magnetic tailing................	15.1	42.7	-	9.6
No. 4 flotation underflow.......	3.7	68.9	3.7	3.8
No. 4 flotation froth...........	26.5	47.9	-	19.0
Superconcentrate................	84.9	71.2	1.1	90.4
Total tailing...................	15.1	42.7	-	9.6

The magnetic separator as used in the figure 3 flowsheet rejected the only tailing; 23 percent of the original iron content reported in the magnetic concentrate and was returned to the circuit to improve the overall recovery.

Short tests were made without caustic scrubbing and desliming as a pretreatment to flotation. In one such test, four stages of flotation were employed with all flotation underflows combining as superconcentrate and the fourth stage froth comprising the only tailing. This test also eliminated the circulating load, the magnetic separator and the regrind ball mill. The only reagent addition was 0.35 lb/long ton ether primary amine to the first stage of flotation. The system was encouraging in that a marginal superconcentrate was produced, containing 2.0 percent SiO_2 and recovering 89.2 percent of the available iron.

ESTIMATED SUPERCONCENTRATE PRODUCTION AND REAGENT COSTS

Based on bench-scale and pilot plant investigations of commercial magnetic concentrates, superconcentrates can be produced at reagent costs of 33 to 60 cents per long ton of superconcentrate made. The samples investigated represent 41 million long tons per year of commercial concentrates; from this total, 32 million long tons per year of superconcentrates are potentially available. Table 8 lists the individual sample data. The lowest cost figures are pilot plant results, and the highest reflect estimates from laboratory investigations, which most probably would be reduced under operating conditions employing a continuous flow circuit.

TABLE 8. - Projected Lake Superior area superconcentrate production and reagent cost (based on 1972 production)

Sample	Commercial production			Reagent consumption, lb/long ton plant conc.		Projected superconcentrate production			
	Million long tons per year	Pct Fe	Pct SiO_2	NaOH	Amine	Million long tons per year	Pct Fe	Pct SiO_2	Reagent cost,[1] cents per long ton
Minnesota:									
A.........	2.3	67.9	4.7	4.0	[2]0.3	1.9	70.5	1.8	51.2
B.........	2.4	67.7	4.8	2.2	.6	2.2	70.2	1.9	[3]33.2
C.........	2.1	67.0	5.1	4.5	.4	1.9	69.7	1.9	34.4
D.........	9.6	67.0	5.3	4.7	.6	7.5	70.0	1.7	50.3
E.........	9.5	63.6	10.3	4.5	.6	6.1	70.4	1.9	59.9
F.........	10.6	65.7	6.1	4.5	.6	8.9	69.4	2.0	45.9
Michigan...	3.4	63.0	10.0	4.5	.6	2.7	70.0	1.8	48.1
Wisconsin..	.9	66.9	7.0	[4]3.4	.4	.8	71.2	1.1	[3]33.5
Total or average	40.8	65.6	7.0	-	-	32.0	70.0	1.8	-

[1] Reagent cost: NaOH, 3.8 cents per lb; amine, 36.0 cents per lb; H_2SO_4, 1.7 cents per lb; Frother, 30.0 cents per lb.

[2] A 12-carbon chain aliphatic amine at 90 cents per lb was used. In all other instances, the collector was of the ether primary amine type.

[3] Pilot plant results, all others are bench-scale values.

[4] Reagent suite includes 0.5 lb/long ton H_2SO_4 and 0.006 lb/long ton frother.

SUMMARY

Two 50-long ton samples of commercial magnetic iron ore concentrate were treated in the Bureau's flotation pilot plant to produce superconcentrate material containing less than 2 percent SiO_2. Both investigations were successful in producing 85 to 90 percent of the plant concentrate weight as superconcentrate analyzing 1.1 to 1.9 percent SiO_2 and containing 90 to 93 percent of the iron available. Total reagent cost was just over 33 cents per long ton superconcentrate in both cases, with the main cost items consisting of NaOH for caustic scrubbing and cationic ether primary amine as the collector.

Additional sources of commercial magnetic concentrate were selected and evaluated in bench-scale applications of the system. All concentrates responded favorably by yielding 65 to 92 percent of their weight as superconcentrate, ranging from 1.7 to 2.0 percent SiO_2, and containing 72 to 95 percent of the available iron. Reagent cost was notably higher in most cases, ranging up to 60 cents per long ton superconcentrate produced, but these costs are based on laboratory applications without benefit of recycle of intermediate products and reagents.

In total, samples representing 41 million long tons per year of commercial magnetic plant concentrates from the Lake Superior area were evaluated, and 32 million long tons per year of superconcentrates were shown to be potentially available.

INT.-BU.OF MINES,PGH.,PA. 19013