

## Processing Roper Bar Iron Ore Stage 3

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### Important Notice

This report applies only to the subject of the project.

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## INTRODUCTION

As a result of discussions between Keith Quast of the Ian Wark Research Institute from the University of South Australia and Bob Howard of western desert resources Ltd. on July 12 a program involving a series of tabling and selective flocculation tests was agreed. A sample designated Sample 3 was received as half core material on July 13 and it is the results obtained from processing this material that is the subject of this report.

## MATERIAL EXAMINED

The samples received were half core samples designated RBDDO 12 comprising Area E East WDR5 and WDR6. WDR5 was core between 45.00 and 50.00m and weighed 26.4 kg. WDR6 was core between 50.00 and 54.75m and weighed 24.3 kg. As instructed by the client, these were combined and treated as one sample.

## SAMPLE PREPARATION

The material was crushed using laboratory jaw, gyratory and spring rolls crushers to all passing 2.36 mm, mixed and riffled into 1 kg charges for testing.

Grinding calibrations were conducted on 1 kg charges ground in a laboratory rod mill with 15 stainless steel rods and 800 ml of tap water. This produced a ground product with 95% passing 150  $\mu\text{m}$  which was used in subsequent test work.

The ground material was passed through the 50 mm Mozley hydrocyclone, with the initial underflow fraction repassed to give a "doubly deslimed" underflow product. This was wet screened at 38  $\mu\text{m}$  to generate samples for passing across the Wilfley Table for comparison with the results for tabling other Roper Bar samples.

The sizing data for Sample 3 are given in Table 1.

Table 1: Sizing data for Sample 3.

Size ( $\mu\text{m}$ )	Weight (g)	Weight (%)
+150	29.5	3.6
+106	84.5	10.3
+75	131.4	16.0
+38	160.7	19.5
-38	238.0	28.9
Overflow	178.2	21.7
Total	822.3	

The +150 and +106  $\mu\text{m}$  fractions were combined as a single +106  $\mu\text{m}$  fraction for the tabling test.

## EXPERIMENTAL PROCEDURE

The size fractions were processed individually on the same Wilfley Table as the other samples of Roper Bar iron ore. Some photographs are given in Figures 1 and 2 below.



Figure 1: Tabling -150 + 106 um (left) and -106 + 75  $\mu\text{m}$  (right) fractions



Figure 2: Tabling -75 + 38 um (left) and -38  $\mu\text{m}$  (right) fractions

The tabling results are given in Table 2. The calculated underflow and head samples are given in Tables 3 and 4 respectively.

Table 2: Results for tabling Sample 3

Product	Wt. (g)	Wt. (%)	Assay (% Fe)	Dist. (% Fe)	Assay (% SiO <sub>2</sub> )	Dist. (% SiO <sub>2</sub> )	Assay (% LOI)	Dist. (% LOI)
<b>-150 + 106 µm</b>								
1 Con	15.0	15.7	58.1	21.3	6.96	4.1	8.32	17.4
2 Con	16.1	16.8	51.1	20.1	11.9	7.6	11.19	25.1
Tail	64.5	67.5	37.1	58.6	34.48	88.3	6.41	57.5
Total	95.6	100.0	42.75	100.0	26.4	100.0	7.51	100.0
<b>-106 + 75 µm</b>								
1 Con	18.5	16.4	59.4	22.6	5.71	3.6	6.83	14.1
2 Con	20.1	17.8	51.7	21.4	9.11	6.2	14.03	31.5
Tail	74.4	65.8	36.5	56.0	36.04	90.2	6.55	54.4
Total	113.0	100.0	43.0	100.0	26.28	100.0	7.93	100.0
<b>-75 + 38 µm</b>								
1 Con	19.3	16.4	63.35	23.1	4.39	3.0	5.72	10.6
2 Con	10.8	9.2	54.2	11.1	5.68	2.2	13.83	14.3
Tail	87.6	74.4	39.75	65.8	30.18	94.8	8.95	75.1
Total	117.7	100.0	44.95	100.0	23.7	100.0	8.87	100.0
<b>- 38 µm</b>								
1 Con	8.3	8.3	58.3	10.5	5.28	2.0	8.9	9.0
Tail	92.0	91.7	44.8	89.5	23.09	98.0	8.08	91.0
Total	100.3	100.0	45.9	100.0	21.6	100.0	8.15	100.0

Table 3: Calculated underflow for Sample 3

Size (µm)	Wt. (g)	Wt. (%)	Assay (% Fe)	Dist. (% Fe)	Assay (% SiO <sub>2</sub> )	Dist. (% SiO <sub>2</sub> )	Assay (% LOI)	Dist. (% LOI)
+ 150	29.5	4.6	42.75	4.4	26.4	5.1	7.51	4.2
-150 + 106	84.5	13.1	42.75	12.6	26.4	14.5	7.51	12.1
-106 + 75	131.4	20.4	42.95	19.7	26.3	22.4	7.93	19.8
-75 + 38	160.7	25.0	44.95	25.2	23.7	24.7	8.87	27.1
-38	238.0	37.0	45.89	38.1	21.6	33.4	8.15	36.9
Total	644.1	100.1	44.50	100.0	23.9	100.1	8.17	100.1

Table 4: Calculated head for Sample 3.

Product	Wt. (g)	Wt. (%)	Assay (% Fe)	Dist. (% Fe)	Assay (% SiO <sub>2</sub> )	Dist. (% SiO <sub>2</sub> )	Assay (% LOI)	Dist. (% LOI)
U/flow	644.1	78.3	44.5	75.6	23.9	84.1	8.17	86.1
O/flow	178.2	21.7	51.9	24.4	16.4	16.0	4.76	13.9
Total	822.3	100.0	46.1	100.0	22.3	100.1	7.43	100.0

For the purpose of the calculations, the +150 µm and -150 + 106 µm were treated as one fraction since the + 150 µm fraction was mixed with the -150 + 106 µm fraction for the tabling test.

From Table 2, combining Con 1 + 2 to give an overall table product gives the results shown in Table 5.

Table 5: Overall table grades and recoveries for Fe.

Size fraction (µm)	Total con. grade (% Fe)	Total recovery (% Fe)
-150 + 106	54.5	41.5
-106 + 75	55.4	44.0
-75 + 38	60.1	34.1
-38	58.3	10.5

These results are similar to those obtained for tabling the other two Roper Bar samples. From Table 4, the cyclone overflow contains a higher concentration of iron than the underflow, in keeping with the results obtained by other samples of Roper Bar ore. This can act as a means of upgrading the ore, with the overflow slimes going to dewatering using flocculation and settling, or some form of selective flocculation (see Literature Survey at the end of this report). This is common practice in India (Das et al, 1992) in conjunction with spiral separation (Srivastava et al, 2001).

## LITERATURE REVIEW ON SELECTIVE FLOCCULATION OF IRON ORES

Early research by Cooke et al (1952) demonstrated that while most starches flocculated hematite suspensions they did not flocculate quartz particles.

The US Bureau of Mines had investigated the processing of low grade hematite-goethite jasper ores for many years (Frommer, 1964). To process these fine-grained ores, a process involving dispersion, selective flocculation and selective desliming ahead of flotation was deemed essential. This was accomplished by grinding the ore in the presence of sodium hydroxide to give a pH between 10 and 10.5, and the addition of sodium silicate, also in the grind. Selective flocculation was accomplished using calcium chloride and tapioca starch, followed by settling. The supernatant slimes were removed by siphoning, followed by the repetition of the desliming step. The purpose of the tapioca starch was to depress the flotation of the hematite. The silica remaining in the settled flocs could then be floated with either anionic (fatty acid) or cationic (amine) reagents. Bench and pilot scale testing on ores from the Marquette Range, Michigan proved that this technique had the promise of processing these ores which were not amenable to the available conventional processing flow sheets. The successful operation of the thickener was critical to the success of the project.

One of the well-documented examples of selective flocculation applied to processing iron ores was the Tilden Plant near Ishpeming, Michigan in the United States (Villar and Dawe, 1975, Rosenbaum (1976), Colombo and Frommer, 1976, Nummela, 1979, Colombo, 1979, 1980, 1986, Houot, 1983). This involved the development of a selective flocculation-deslime-flotation process to treat an oxidised taconite ore and produce iron ore pellets. The success of the process relied on the selective flocculation and desliming steps ahead of flotation. Dispersion of the feed pulps used sodium hydroxide, sodium silicate and sodium tripolyphosphate were added to the grind to raise the pH to 11. Causticised tapioca flour was used to selectively agglomerate the iron oxides and the thickener overflow containing much of the fine silica was sent to waste. The thickener underflow was fed to the flotation cells to produce a tailing product containing 64% Fe at 75% Fe recovery. Flotation of the silicates was achieved using a cationic collector (MG 98A) with causticised dextrin also used as a hematite depressant. Grind size was typically 80-85% passing 25

Pugh (1974) investigated the selective coagulation of mixtures of optically pure quartz and polycrystalline Swedish hematite in settling cylinders as a function of pH. The isoelectric points of the quartz and hematite were 2 and 6 respectively. The pulp density was 2.2 weight % (1.1 weight % of each mineral). The mean radius of the minerals was 0.1  $\mu\text{m}$ . These tests showed a selective coagulation zone around pH 7 where the quartz particles were stable and the hematite particles settled. At pH 9, in the presence of NaCl, quartz remained stable and hematite settled at concentrations between 0.015 and 0.1M NaCl. When suspensions of 90% silica/10 % hematite was used, more silica remained in the sediment (76%) compared to values of less than 10% for the 50:50 case.

Termes and Wilfong (1984, 1985) used crosslinked starches to flocculate hematite-quartz mixtures. Crosslinked starches were derived using carboxylate, carboxymethyl, diethanolamine, iminodiacetate and xanthate functional groups. Flocculation tests were conducted on 70% hematite/30% quartz mixtures in the presence of absence of sodium metasilicate and sodium metaphosphate dispersants. Optimum results were obtained at the natural pH using sodium metasilicate. Hematite grades were often in excess of 90% for the residue after the elutriation of the dispersed quartz. Pulp densities were 3g/250 ml and settling times were 5 minutes prior to elutriation. Some of the starches carried positive zeta potentials and some had negative zeta potentials. The isoelectric point of the hematite was approximately 5.

Bagster (1984) and Bagster and McIlvenny, (1985) used high molecular weight polymers to selectively flocculate hematite from beach sand using high molecular weight anionic polymers. Particle sizes were typically 80% passing 10  $\mu\text{m}$  and pulp densities were 1% solids by weight for effective selectivity. Polymer dosages were very low (typically 1 ppm). Other additions were 3 ppm Calgon and 200 ppm NaCl.

Nummela and Iwasaki (1986) reviewed the various processes involved in iron ore flotation. These authors emphasise the importance of selective desliming prior to the addition of the starch flocculant. The optimum conditions are extremely sensitive to the mineralogical characteristics of the ore and the type and amount of soluble salts in the pulp solutions. Calcium and magnesium ions can seriously affect the effectiveness of the selective flocculation stage of the process. These ions need to be de-activated prior to selective desliming. These authors gave an update of the Tilden operation. The reagent additions reported were 1 kg/t NaOH, 0.13 kg/t sodium silicate, 0.8 kg/t corn starch and 0.1 kg/y unneutralised primary amine. The ROM feed was upgraded from 34.7% to 44.1% Fe rejecting a slime tailing assaying 14.7% and accounting for 32.1% of the original mass.

Jin et al (1987) investigated the effect of the degree of hydrolysis of hydrolysed polyacrylamide on the selective flocculation of hematite from quartz. The selective flocculation of hematite from quartz was due to the fact that the polymer adsorbs on hematite through chemical bonding and weakly associated with quartz because of stronger electrostatic repulsion. Selective flocculation is sensitive to pH and the presence of calcium. Calcium ions associate with the polymer to destroy its appropriate chain stretching and adsorbs on the hematite blocking some surface active sites.

Uwadiale (1989, 1990) investigated the selective oil agglomeration of Nigerian iron ores using sodium silicate and oleic acid. Agglomeration was conducted on very fine material using a kitchen blender. The optimum iron recoveries of almost 90% were obtained at pH 8 and 9. Feed grade was 45.6% Fe and concentrate grades of 65% Fe were obtained by screening at 37  $\mu\text{m}$ . Grinding conditions were 50g ore, 50 ml water, 5 ml oleic acid, 0.07g of sodium silicate for 6 hours in a ball mill with 7 ml of kerosene added half way through the agitation period in the blender. The milled ore was 95% finer than 3  $\mu\text{m}$ . This author also reviewed the flotation of iron oxides and quartz in 1992.

Flocculation tests were also conducted on fine hematite and siderite particles using sodium oleate, sodium hexametaphosphate and octyl hydroxamic acid at various values of pH (Song and Lu, 1994). The isoelectric points of hematite and siderite were 5.4 and 7.6 respectively. The addition of sodium oleate changed the zeta potential of the minerals indicating strong adsorption which was reflected in the increased aggregation efficiency after surfactant addition. The contact angle was also increased as a result of the addition of the sodium oleate. Optimum aggregation efficiency occurred at the isoelectric points of the two minerals.

Pascoe and Doherty (1997) also used sodium oleate in the shear flocculation of hematite. Using fine (<10  $\mu\text{m}$ ) hematite particles and sodium oleate they found that the stages involved in the flocculation of hematite were:

- Oleate ion chemically adsorbs onto the hematite surface
- Oleic acid droplets form both on the mineral surface and in bulk solution
- Collision between oleate/oleic acid coated particles and further oleic acid droplets produces floc formation
- Floc growth and breakage occur until a dynamic equilibrium is reached.

The maximum floc size occurred in the weakly acidic region and increased as the concentration of insoluble oleic acid increased.

Shibata and Fuerstenau (2003) investigated the flocculation of reagent grade ferric oxide (surface area 7.9  $\text{m}^2/\text{g}$ ) with sodium oleate at 0.5 weight % solids. Flocculation occurred over a wide pH range (4-12) at high oleate additions, but the pH range at very low additions of oleate ( $10^{-9}$  M) was centred at pH 8.3, the isoelectric point for the hematite. Oleate adsorption was a combination of physical and chemical adsorption. Flotation recovery of the flocculated hematite was a maximum around pH 9. The conditions for good flocculation are a complex function of oleate concentration, pH and oleate solution chemistry.

## **SELECTIVE FLOCCULATION OF INDIAN IRON ORES**

There has been a considerable amount of work done on the selective flocculation of Indian iron ores and some of these articles will be briefly reviewed here. Gururaj et al (1981) used anionic and cationic polymers in conjunction with various dispersants to selectively flocculate a high alumina iron ore. The cationic polymer was used to flocculate the negatively charged clays and the anionic polymer was used to flocculate the iron-bearing minerals. Starch was also seen as a promising reagent for the iron-bearing minerals. Multiple stage flocculation had obvious merit. The method of preparation of starch has a major bearing on its effectiveness (Rao and Narasimhan, 1985).

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