University of
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Processing Roper Bar Iron Ore Stage 5 (Final report)

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This report consists on one cover page and 13 pages of text and figures (total 14 pages)

INTRODUCTION

Previous work conducted at the Ian Wark Research institute and Optimet Laboratories (see report 2010/365) had shown that it was possible to produce a high grade (60% Fe) concentrate from a composite sample of Roper Bar ore by tabling closely sized fractions. However, the Fe recovery obtained using this method was unacceptably low.

Attempts to increase recovery by further treating the table tailings by using wet high intensity separation (WHIMS) and the table middlings by flotation were unable to produce final products at the required Fe or SiO_2 grades.

As a result, it was decided to conduct a series of tests using flotation and WHIMS in an attempt to produce a final product of the required grade at an acceptable recovery.

MATERIALS

The test program was conducted using the same feed material as had been used for the previous series of tests. This comprised a composite of two previously tested samples. These were individually crushed to rod mill feed (-2.36 mm) and combined to form a composite which was made up of 6 kg of Sample 3 (8% LOI) 2 kg of sample 2 (4% LOI). These were well mixed and then split into 1 kg lots for grinding and further testing.

EXPERIMENTAL

Each 1 kg sample was ground in a laboratory rod mill with 15 stainless steel rods and 800 ml of Adelaide tap water for 10 minutes. This produced a ground product with 95% less than 150 µm. The ground products from each test were washed into buckets prior to desliming.

In order to assess the effect of slimes on the flotation process, three separate desliming treatments were used:

1. Deslimed at Optimet Laboratories to give an overflow of with an 80% passing size of approximately 6 µm.
2. Deslimed at the Wark laboratories to give an overflow with an 80 % passing size of approximately 9 µm.
3. Undeslimed.

In each case the cyclone underflow was filtered and dried and split into four equal masses for flotation testing.

The flotation tests were conducted in a 1.25 litre Magotteaux cell with an agitation rate of 800 rpm and an air flow rate of 3 l/min. Tests were normally conducted at pH 9.5. Two samples of starch (corn and regular maize) were used as an iron depressant. Four collectors (Flotigam EDA from Clariant, and Lilaflot 819M1, Lilaflot 811M and Lilaflot 817M from Akzo Nobel) were used. Where necessary, Huntsman W22 was used as a frother. In all cases Calgon (sodium hexametaphosphate) was added as a dispersant prior to any other reagent addition.

The general flotation scheme used in the initial tests is given in Table 1. It should be noted that in a number of cases not all stages were used due to the large mass of concentrate produced in the early stages.

Product	pH	Reagent	Amount	Time	Collector	Amount	Time	Float time
Conditioning	natural	1% Calgon	10 ml	5 min				
Conc 1	10	1% starch	10 ml	5 min	1% soln	10 ml	5 min	2 min
Conc 2	10				1% soln	10 ml	5 min	2 min
Conc 3	10	1% starch	2 ml	5 min	1% soln	10 ml	5 min	2 min
Conc 4	10			5 min	1% soln	10 ml	5 min	2 min
Conc 5	10				1% soln	10 ml	5 min	2 min

Table 1. Flotation scheme for initial tests.

The actual tests conducted in this initial phase are summarised in Table 2.

Test No.	Desliming	Depressant	Collector	No of stages
1	UniSA	Corn starch	Flotigam EDA	5
2	UniSA	Corn starch	Lilaflot 819M1	3
3	UniSA	Corn starch	Lilaflot 811M	4
4	UniSA	Corn starch	Lilaflot 817M	4
5	UniSA	Regular Maize	Flotigam EDA	5
6	UniSA	Regular Maize	Lilaflot 819M1	3
7	UniSA	Regular Maize	Lilaflot 811M	4
8	UniSA	Regular Maize	Lilaflot 817M	4
9	Undeslimed	Regular Maize	Flotigam EDA	5
10	Undeslimed	Regular Maize	Lilaflot 819M1	3
11	Undeslimed	Regular Maize	Lilaflot 811M	4
12	Undeslimed	Regular Maize	Lilaflot 817M	4
13	Optimet	Regular Maize	Flotigam EDA	5
14	Optimet	Regular Maize	Lilaflot 819M1	3
15	Optimet	Regular Maize	Lilaflot 811M	4
16	Optimet	Regular Maize	Lilaflot 817M	4

Table 2. Summary of initial set of flotation tests.

Because the results achieved in the initial tests were somewhat disappointing another series of tests was conducted. In these tests the pulp density was reduced by reducing the mass of solids to 100 g. Lilaflot 811M (which had given the highest grades but very low recovery values) was used as the collector, but at reduced rates. Regular maize starch was used as the iron depressant, with the addition rates being increased. These measures were introduced in an effort to reduce iron losses to the flotation concentrates. Other

variables investigated were flotation pH, the amount of dispersant added, and the amount of collector added to the first flotation stage. The details are summarised in Table 3.

Test No.	Desliming	Calgon (mls)	pH	Collector to Stage 1 (mls)	Collector to Stage 2 + (mls)
17	Optimet	5	10	1	1
18	Optimet	5	10	2	1
19	Optimet	5	9	2	1
20	Undeslimed	5	10	2	1
21	Indeslimed	10	10	2	1

Table 3. Details for supplementary tests.

The use of wet high intensity magnetic separation was tested at RMG Services. The separator is shown in Figure 1 while the mesh collector is shown in Figure 2.

Figure 1. Wet High Intensity Magnetic Separator.

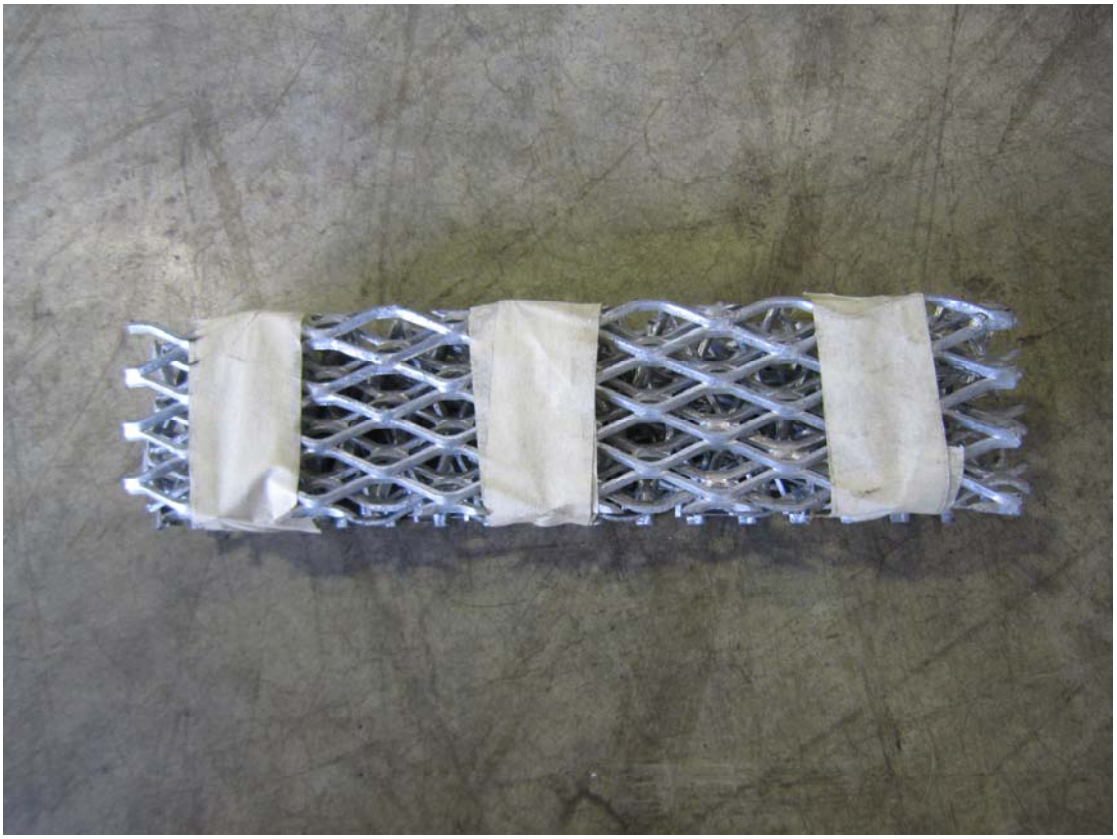

Figure 2. WHIMS mesh collector.

Two tests were conducted. In one test ground material that had been deslimed at UniSA was used as the WHIMS feed, with the concentrate then being used as feed to flotation using the same conditions as flotation test 17, while in the other test the flotation product obtained using the method used of test 17 above was used as the WHIMS feed.

For each WHIMS test two passes were made in which a dilute slurry of the feed material was pumped to the separator and allowed to pass through the magnetic field which was set at 15,000 Gauss. The concentrate and tailing were collected and the tail repassed at 20,000 Gauss. All products were collected, allowed to settle decanted, filtered and dried.

The test on the unfloated material was done in two separate batches of approximately 100 g and 50 g respectively in order to obtain sufficient material for subsequent flotation and to assess the variability of the process.

RESULTS

The calculated head grade for the composite feed was 44.5% Fe, 25.2% SiO_2 and 6.2% LOI. After desliming, the Fe grade decreased to 42% and the SiO_2 and LOI increased to 28.4% and 6.6% respectively. This would appear to be due to losses of soft oolitic hematite to the slimes, which previous work has shown to contain around 52% Fe, 17% SiO_2 and 4% LOI.

The results for the initial series of tests are summarised in Tables 4 to 7 below. In each case the Fe, SiO_2 and LOI grades and recoveries of the final product (flotation tail) are reported. It should be noted that for SiO_2 and LOI the aim is to achieve low grade and recovery values in the final product, while achieving high Fe grade and recovery values. The complete mass balance by stage data are given in Appendix 1.

Collector	Fe		SiO_2		LOI	
	Grade %	Recovery %	Grade %	Recovery %	Grade %	Recovery %
EDA	48.03	63.69	20.08	39.96	7.01	58.55
819M1	49.84	46.62	17.97	24.99	6.11	36.21
811M	50.62	33.89	16.37	16.27	5.96	25.12
817M	48.39	62.70	19.58	38.69	6.76	55.42

Table 4. Final flotation results using corn starch for sample deslimed at UniSA .

Collector	Fe		SiO_2		LOI	
	Grade %	Recovery %	Grade %	Recovery %	Grade %	Recovery %
EDA	47.76	63.77	19.15	38.92	7.11	59.61
819M1	50.15	44.47	17.11	22.75	6,42	35.95
811M	50.02	36.62	17.17	18.73	5.89	30.41
817M	47.81	62.96	19.11	36.77	7.00	58.00

Table 5. Final flotation results using regular maize starch for sample deslimed at UniSA.

Collector	Fe		SiO_2		LOI	
	Grade %	Recovery %	Grade %	Recovery %	Grade %	Recovery %
EDA	44.79	72.17	24.02	68.48	6.91	80.25
819M1	45.72	52.87	22.06	44.96	7.57	63.95
811M	48.87	39.99	17.77	25.87	5.95	39.56
817M	44.62	80.77	25.30	81.06	6.66	87.84

Table 6. Final flotation results using regular maize starch for undeslimed sample.

Collector	Fe		SiO_2		LOI	
	Grade %	Recovery %	Grade %	Recovery %	Grade %	Recovery %
EDA	47.65	63.49	19.29	38.82	6.74	56.37
819M1	49.89	45.84	21.49	24.22	5.65	32.83
811M	50.08	36.57	16.89	18.13	5.94	27.15
817M	47.02	69.69	20.30	45.35	6.79	62.09

Table 7. Final flotation results using regular maize starch for sample deslimed at Optimet.

The results for the supplementary series of flotation tests are summarised in Table 8. The complete mass balances by stage for these tests are given in Appendix 2.

Test No.	Fe		SiO_2		LOI	
	Grade %	Recovery %	Grade %	Recovery %	Grade %	Recovery %
17	47.80	67.66	18.07	35.99	7.39	64.79
18	47.11	64.18	18.80	36.59	7.18	60.16
19	49.25	51.54	18.18	27.67	6.19	40.25
20	46.42	62.97	20.23	46.68	7.58	74.00
21	47.14	60.63	18.80	41.16	7.57	71.24

Table 8. Results for tests 17-21.

The results for the magnetic separation tests are summarised in Table 9. The complete mass balances are given in Appendix 3

Test No.	Fe		SiO_2		LOI	
	Grade %	Recovery %	Grade %	Recovery %	Grade %	Recovery %
1 (mags)	49.03	77.22	16.65	40.08	8.05	81.38
1 (float)	50.25	68.18	14.64	57.26	7.80	62.97
2 (float)	47.82	N/A	18.08	N/A	7.60	N/A
2 (mags)	49.08	85.05	15.86	72.67	8.00	87.13
3 (mags)	48.17	82.24	17.50	45.67	8.06	88.34
3 (float)	50.25	68.18	14.64	57.26	7.80	62.97

Table 9. Results for WHIMS testing.

DISCUSSION

In all cases the grade of the final product was much lower than desired for a saleable product. The highest grade achieved was slightly over 50%, but to do this the recovery was less than 50%. The reasons for this are not clear. The presence of a significant number of coarse silica particles in the final product is evident when this material is viewed under a microscope. These particles are obviously not floating, either due to poor collector coverage or detachment due to turbulence in the cell.

Another possibility is the presence of slime coatings. Silica that was coated by iron mineral slimes would not be expected to float, thus contributing to the low grade. Similarly, iron minerals coated by silica slimes may well float, thus contributing to the low recoveries obtained. This may be exacerbated by the fact that the samples were dried prior to testing.

The presence of composite particles would also result in the effects noted above.

The initial experimental program was established to investigate the effect of starch type, collector type, and desliming of Fe grade and recovery for flotation of the composite sample used in this work.

The effect of the type of starch used was investigated using the sample that had been deslimed at the University of South Australia. As shown in Figure 3, for a given collector the Fe grade of the final product (flotation tail) was essentially the same for the two starch types used. This indicates that as long as the starch is correctly causticised, the type of starch used as no real effect on the final product grade. A comparison of Tables 4 and 5 above shows that for a particular collector the recovery values are also similar.

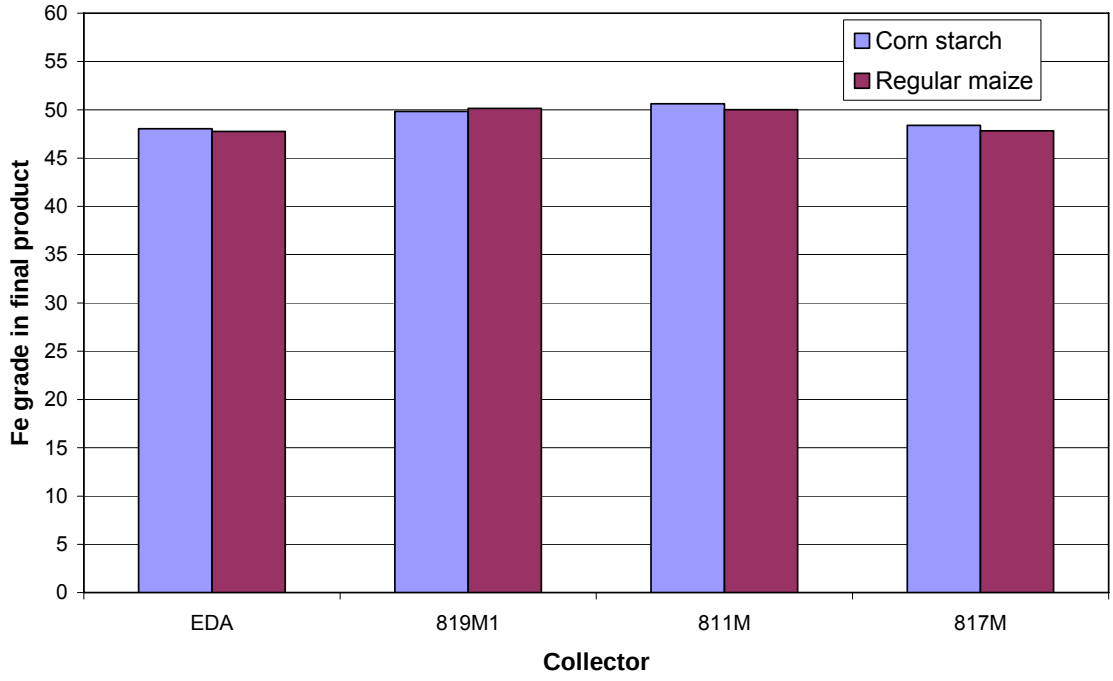

Figure 3. Effect of starch type on final Fe grade.

The effect of collector type on Fe grade and recovery for the same samples is shown in Figure 4 below. As can be seen, the collector has a considerable effect. In all cases the collector addition rate was held constant to allow direct comparison. The use of Lilaflot 819M1 and 811M resulted in a slight improvement in grade from around 48% to 50% Fe. However, this was at the expense of recovery, which decreased significantly from over 60% to around 40%. These two collectors are obviously more powerful than Flotigam EDA and Lilaflot 817M and were used to see if an improved grade could be achieved by increasing collector power. This would be expected to be accompanied by a loss of selectivity. While an improvement in grade was evident when the stronger collectors were

used, the Fe grade is still below the desired value and the recovery is much too low to be viable.

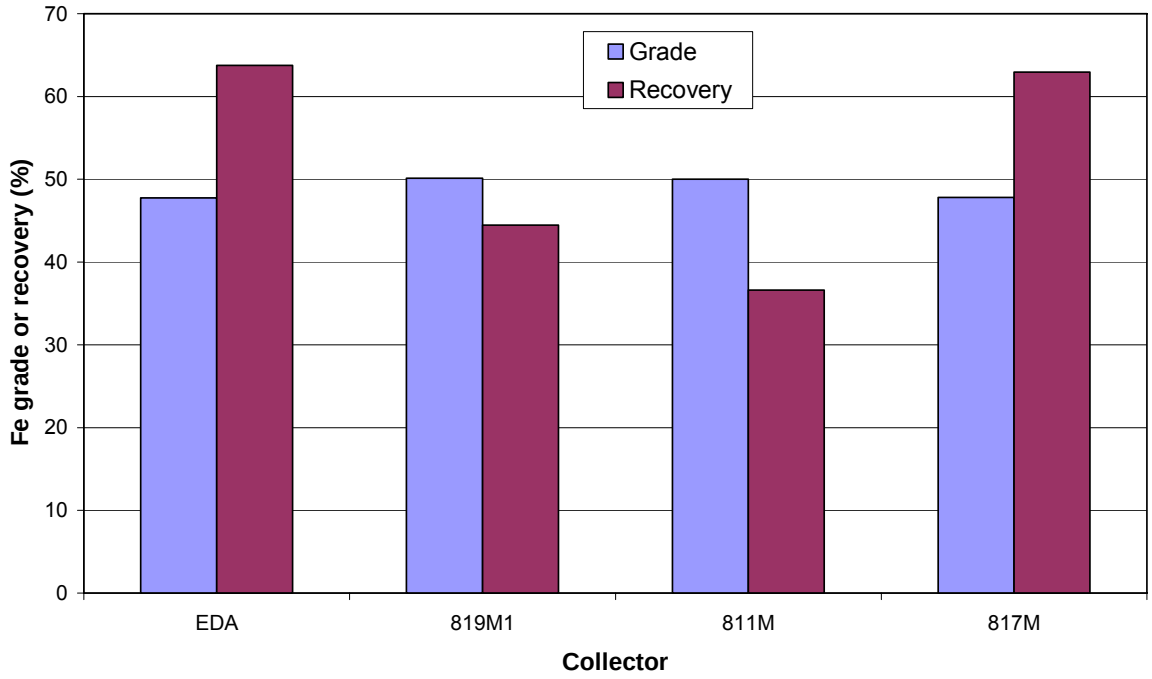

Figure 4. Effect of collector type on Fe grade and recovery.

The effect of desliming is shown in Figure 5 below.

These results show the importance of desliming. When the ground solids were treated without desliming the Fe grade of the final product was less than that obtained for the deslimed samples. For three of the collectors used the difference was 3% or greater, but for Lilaflot 811M the difference was around 1%. A comparison of the results reported in Tables 5 to 7 shows that the silica grade of the final product was also significantly higher for the undeslimed feed.

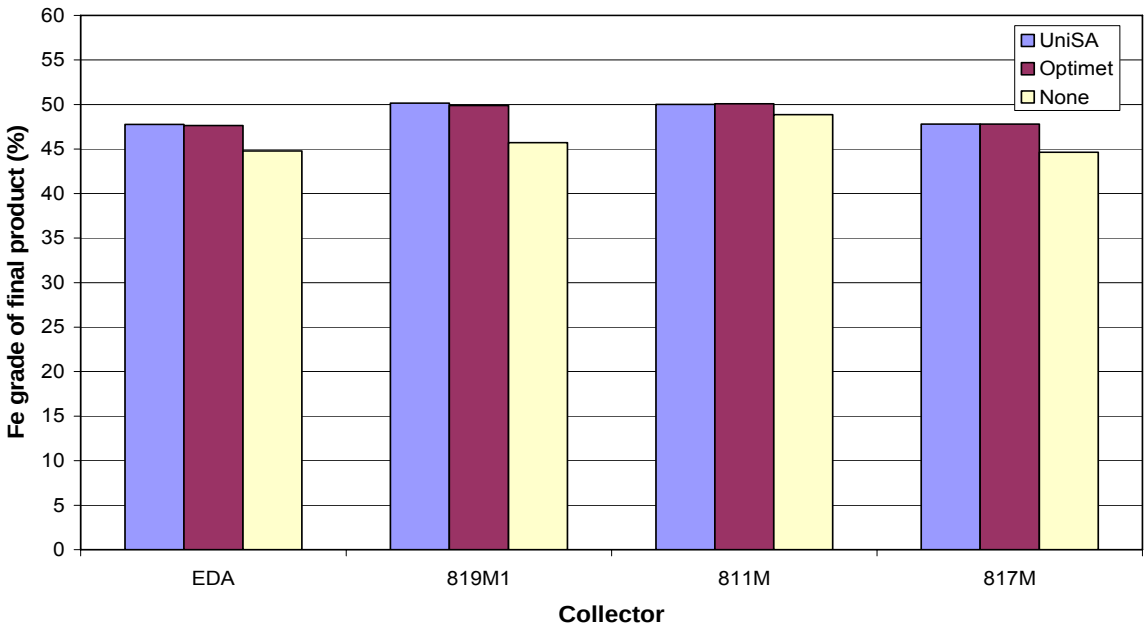

Figure 5. Effect of desliming on Fe grade of final product.

In all of the initial tests the Fe grades and recoveries were much lower than desired. Similarly, SiO_2 grades were much higher than required for a saleable product. Interestingly, the LOI grades of the final product also increased, indicating that the siderite did not float and reported to the final product.

In an attempt to improve both grade and recovery a series of supplementary tests was undertaken. In these tests the pulp density was decreased in an effort to improve dispersion and the collector addition rate was decreased in an attempt to improve selectivity. Both deslimed and undeslimed feeds were used.

The effect of the total amount of collector added for the deslimed feed is shown in Figure 6. In comparing these results it should be remembered that the test using 2 kg/t of collector was carried out at a higher pulp density than the tests at lower additions.

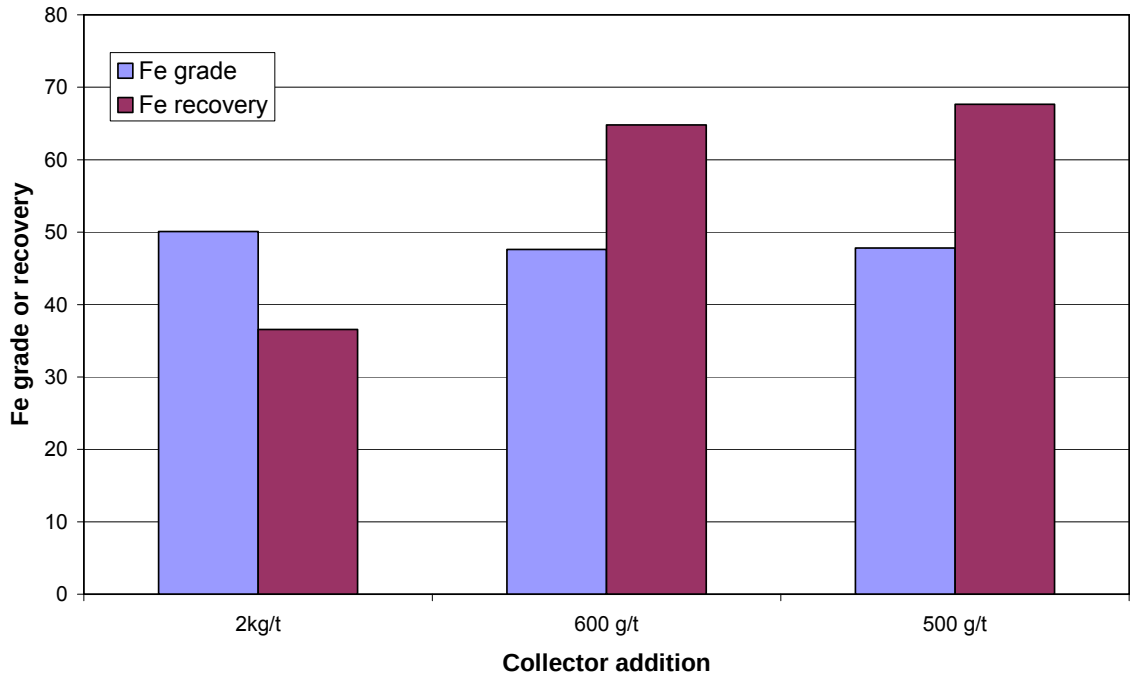

Figure 6. Effect of Lilaflot 811M addition.

Decreasing the total amount of Lilaflot 811M added as a collector resulted in a decrease of approximately 2% in the Fe grade of the final product. However, this was accompanied by a large increase in the total amount of Fe recovered in the final product.

The effect of changing the amount of collector added to the first flotation stage is shown in Figure 7 below. This shows a similar trend to that observed overall. An increase in collector addition to the first stage resulted in an increase in the Fe grade of the material remaining in the cell, but at the expense of Fe recovery. Interestingly, the change observed when the collector dose was increased from 100 g/t to 200 g/t was relatively small. It must be remembered that for these two tests the starch addition was also increased, which would have helped to reduce iron losses.

Similarly, an increase in the collector dose brought about an increase in silica removal. This was especially the case for the highest addition of 500 g/t.

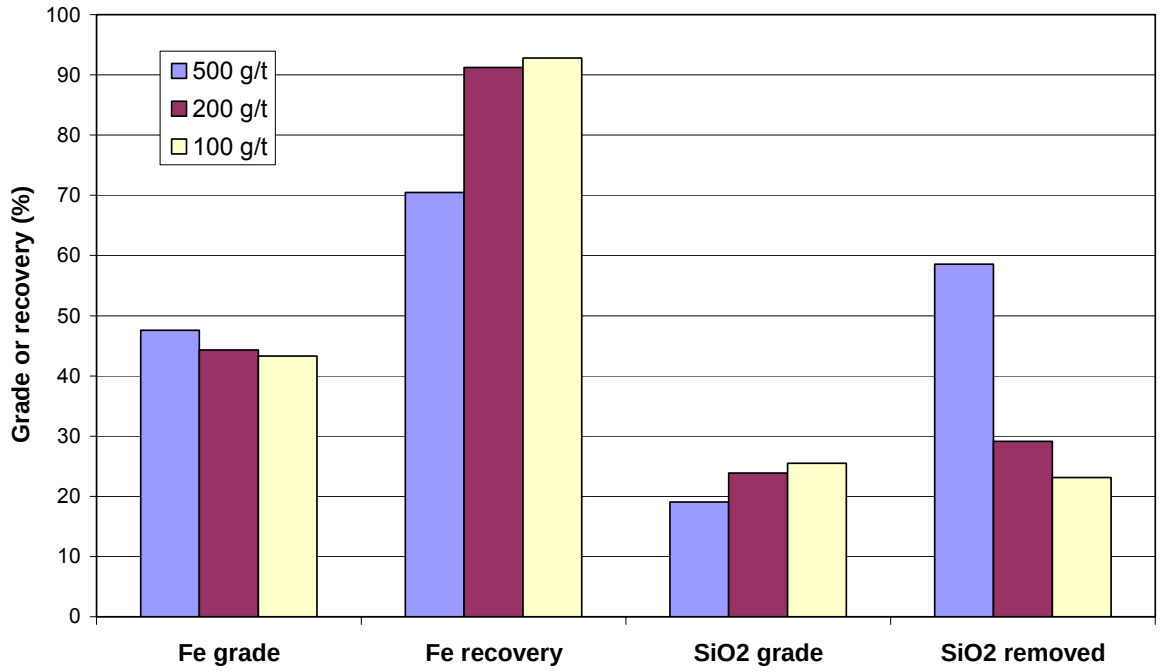

Figure 7. Effect of collector addition to first stage.

The effect of adding the collector in stages or as a single dose is shown in Figure 8 below. This shows that there was little difference in the Fe grade between the different methods of collector addition. However, adding the collector in stages was accompanied by a decrease in Fe recovery. At the same time the SiO_2 grade of the final product was slightly lower and the amount of SiO_2 removed was significantly higher. The most likely explanation for this behaviour is increased entrainment of fines due to the longer flotation times involved with stage additions.

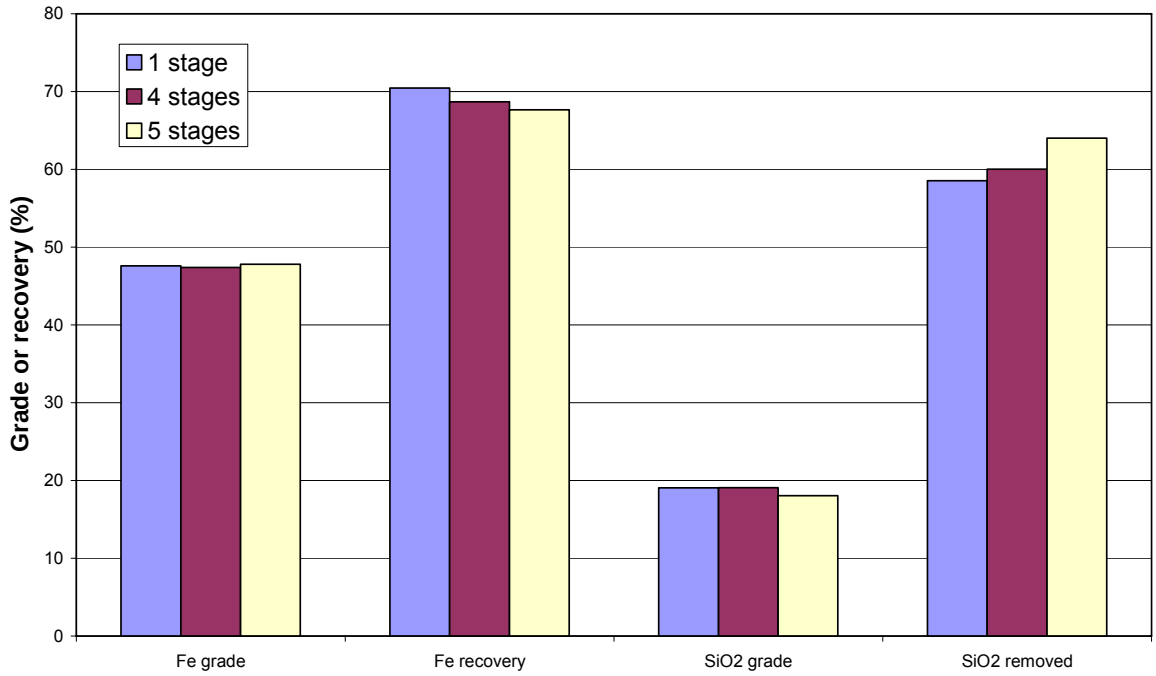

Figure 8. Effect of the number of collector additions.

The effect of desliming is shown in Figure 9.

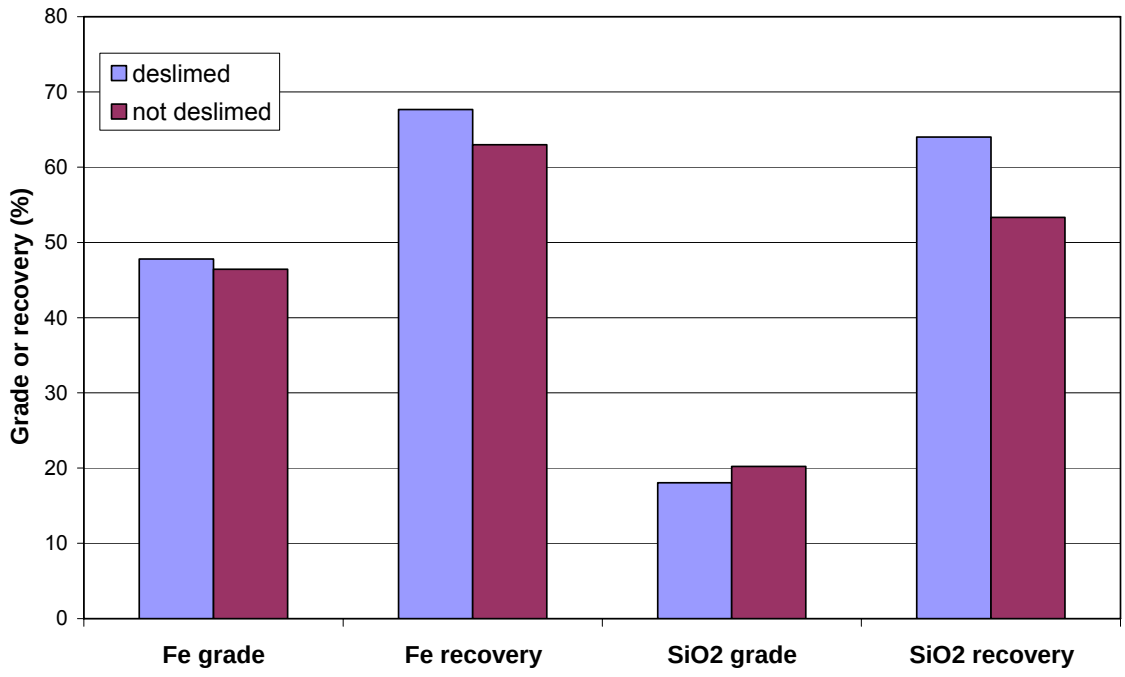

Figure 9. Effect of desliming.

This shows the benefits of desliming. The Fe grade of the final product achieved using deslimed feed was higher, while the recovery was also higher. However, it must be remembered that this value does not include the Fe that reported to the cyclone overflow. Previous work has shown that this material is in fact of higher grade than the flotation product and so cannot be discarded. As far as SiO_2 is concerned the differences were even greater, with the grade of the final product being significantly higher and the amount removed much less when the flotation feed had not been deslimed.

It had been hoped that treating the flotation product using wet high intensity magnetic separation (WHIMS) would result in a significant upgrade. However, the results did not show this. WHIMS treatment of the flotation product produced only a slight improvement in Fe grade from 47.8% to 49.1% at 85% recovery. The SiO_2 content was reduced from 18.1% to 15.9% while the LOI value was reduced slightly from 8.0% to 7.6%. The reason for this is not clear. It may be due to silica being held up in the magnetic fraction due to insufficient washing, or it may be due to the presence of composite particles. Another possibility is the presence of iron slimes coating silica particles.

WHIMS treatment of the deslimed feed resulted in an increase in Fe grade from 42.3% to 48.7% while the SiO_2 grade decreased from 27.7% to 16.9% and LOI increased from 6.6 to 8.0%. The Fe recovery was 80% The upgrade achieved here was similar to that which had previously been achieved using flotation, although the recovery was significantly higher.

Flotation of the WHIMS concentrate resulted in a slight increase in Fe grade to 50.2% while SiO_2 and LOI decreased to 14.5% and 7.8% respectively.

CONCLUSIONS

This work has emphasised the difficulty involved in obtaining a high grade product from the composite sample that was used in this work. Even when recovery was sacrificed, the highest Fe grade achieved by flotation alone was only 50%.Similar results were achieved using combinations of WHIMS and flotation. The reasons for the low product grades are not clear but may include coarse silica particles not floating, the effect of slime coatings and the presence of composite particles in the feed material.

Desliming resulted in improved grades and recoveries. However, the slimes fraction has a higher grade than the cyclone underflow and would need to be treated in some way to recover these values.

FUTURE WORK

It is recommended that the next stage of the work should concentrate of determining the reasons for the low grades and recoveries obtained to date. This would include increased grinding to try to reduce the top size of the silica and also increase liberation and surface analysis to determine the presence or otherwise of slime coatings on particles. A QuemScan analysis of the composite feed may also be beneficial.