POTENTIAL VALUE ADDED PRODUCTS FROM THE MINNESOTA ILMENITE DEPOSITS

COLERAINE MINERALS RESEARCH LABORATORY

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SUMMARY

As part of the University of Minnesota's ongoing support for the development of ilmenite deposits located within the Duluth complex, the University's Permanent Trust Fund sponsored a project by the Coleraine Minerals Research Laboratory to determine if valued added products could be produced from the ilmenite deposits and to determine if ilmenite recovery could be increased. A previous study sponsored by the Minerals Coordinating Committee indicated that using high pressure rolls in place of a rod mill to grind the ilmenite increases TiO_2 recovery by about 10 percent. The major loss of TiO_2 (about 25 %) was associated with the removal of magnetite by magnetic separation after spiral concentration. The objective of this program was to determine if the magnetic portion of the spiral concentrate could be upgraded to make a concentrate suitable for either blast furnace pellet feed or DRI feed. During upgrading of the magnetic portion, non-magnetic materials should contain the bulk of the ilmenite, and they would also be upgraded to determine the potential for additional ilmenite recovery.

Initial liberation grinds and Davis tube tests on the spiral magnetic concentrate indicated that grinding and magnetic separation alone could not upgrade the material sufficiently. Standard silica flotation on the ground and magnetically separated material did not provide significant upgrading. The best concentrate produced contained 58.84 percent iron, 6.66 percent TiO_2, and 5.74 percent silica. Perhaps this material could be used in the iron nugget process.

Amine flotation, fatty acid flotation and WHIMS were used to recover TiO_2 from the non-magnetic portion of the reground spiral magnetic concentrate. Only fatty acid flotation of the ilmenite showed any potential for recovering additional ilmenite at grade. Additional test work on the use of silicate depressants is needed. Elutriation tests on size fractions indicated that grinding to finer than 200 mesh is needed for liberation of the ilmenite from the silicate gangue.

While the previous test work showed increased TiO_2 recovery in the spiral non-magnetic fraction, no work was conducted on upgrading that material to determine if the increased recovery could be carried through to a final concentrate. Therefore, bench scale electrostatic separator tests were run on the spiral non-magnetic fraction produced in the previous project. The electrostatic tests indicated that both grade and recovery could be obtained.

INTRODUCTION

Within the Duluth Complex, several ilmenite deposits have been identified with combined potential ore reserves estimated at 50 million tons. The mineral ilmenite, $FeTiO_3$, can contain up to 52.6 percent TiO_2. Ilmenite is the most common feedstock used for the production of high purity TiO_2 for the manufacture of paint pigments and whitening agents for paper coatings. Deposits in Minnesota have the potential to supply high-grade titanium concentrate for this market if technical problems relating to concentration of the ilmenite and subsequent treatment to make high purity TiO_2 can be solved.

Initial test work[1] by the Coleraine Minerals Research Laboratory (CMRL) indicated that it was possible to produce an ilmenite concentrate containing about one percent silica (49 % TiO_2) by a combination of gravity, magnetic and high tension concentration. However, the TiO_2 recovery in the concentrate was only about 50 percent of the feed total. The highest TiO_2 losses were associated with ilmenite particles locked with magnetite (26 percent) in the magnetic concentrate and the slimes (14 percent) being removed prior to the spiral concentration.

A second test program[2] conducted by CMRL indicated that the use of High Pressure Rolls Grinding (HPR) in place of conventional rod milling could increase the TiO_2 recovery from about 50 percent to greater than 60 percent. This increased recovery came from the reduction of fines (minus 200 mesh) in the grinding step, thereby eliminating the need for desliming prior to the spirals. TiO_2 losses associated with the magnetic concentrate were the same in both test programs.

The purpose of this test program is to determine how much of the ilmenite associated with the magnetite can be recovered; whether the magnetic concentrate can be upgraded to produce a product suitable for pellet feed and if the concentrate can be upgraded to determine if a V_2O_5 rich slag can be produced during iron reduction; and to demonstrate that the increased ilmenite recovery in the concentrate will not affect the upgrading characteristics during electrostatic separation.

TEST PROCEDURES AND RESULTS

All of the test work was conducted at laboratory scale using materials that were produced from the pilot plant testing of the HPR ground material[2]. The pilot plant flowsheet is shown in Figure 1. HPR ground material was fed to two stages of spirals; the spiral concentrate was sent to a drum magnetic separator; the magnetic concentrate was collected, dried and stored in drums; and the magnetic tails (ilmenite concentrate) were dewatered in a screw classifier, dried and stored in drums.

<u>Magnetic Concentrate</u>:

The initial study[1] indicated that it might be possible to reduce the TiO_2 content in the magnetic concentrate to around 5 percent by grinding and magnetic separation as shown in Figure 2 and presented on Table I. Therefore, a series of grinds was run in a batch 12-inch by 12-inch ball mill using the magnetic concentrate from the HPR pilot plant. Reground material was upgraded in a laboratory drum magnetic separator. Weight splits and chemistry of the resultant magnetic concentrates and tailings are given in Table II with the TiO_2 and SiO_2 grade and recovery for the concentrate being plotted against grind, Figure 3. Even with a grind of 90.6 percent passing 270 mesh, the magnetic concentrate contained about 6 percent silica and 16 percent TiO_2. Based on a plot of the SiO_2 and TiO_2 recoveries versus weight recovery in the magnetic concentrate, Figure 4, it appears that TiO_2 and SiO_2 are being rejected at about the same rate.

Based on the magnetic separation tests on the reground magnetic concentrate, it appears that it is not possible to produce a high grade magnetite concentrate by grinding and magnetic separation alone. Therefore, preliminary flotation tests were conducted to determine if the silica could be floated from the magnetite. The initial test was run on spiral magnetic concentrate that had been ground to about 85 percent passing 270 mesh and had been upgraded in a laboratory magnetic separator. This size was chosen because it was typical of the size of taconite flotation feed. A 1000-gram portion of the reground, upgraded magnetic concentrate was floated to completion using 0.08 lb/lt of MG82 di-ether amine collector and 0.07 lb/lt of MIBC frother. The results, given in Table III, showed very little upgrading with the flotation of 7 percent of the weight and 11.7 percent of the silica. Next, a stage addition test was run on the same material as above. In the first stage, 0.08 lb/lt of MG82 and 0.07 lb/lt of MIBC were added to 1000 grams of sample and floated to completion. In each succeeding stage, 0.04 lb/lt MG82 and 0.03 lb/lt MIBC were added (note that reagent addition rates are based on new feed). Flotation was to completion in all stages. Results are also given in Table III and indicate very poor flotation response with some of the froths having a lower silica content than the final concentrate. A final stage addition flotation test was run on material that had been ground to 90.6 percent passing 270 mesh and upgraded in the laboratory magnetic separator. The test procedure was the same as above. As shown in Table III, the results were essentially the same as with the coarser grind, namely, poor upgrading with TiO_2 floating preferentially to the silica at the higher MG82 additions.

In hindsight, it is not too surprising that the standard silica flotation for taconite did not work for the magnetite associated with the ilmenite, since the gangue minerals are significantly different. All of the easily floated minerals, such as quartz and plagioclase, were removed in the spiral. The remaining olivine and pyroxene are complex iron-magnesium silicates, which should not be expected to float as well as quartz. It may be possible with additional research to find reagents and conditions that will favor flotation of olivine and pyroxene.

Non-magnetics:

Concurrent with the amine flotation of silica from the magnetic concentrates, amine flotation was run on the non-magnetic portions of the reground material. Stage addition tests were run on the magnetic tails from the grinds at 37.9, 51.8, 62.4, 84.9, and 90.6 percent passing 270 mesh. Tests were run as above with 0.04 lb/lt MG82 being added in the first stage and 0.02 lb/lt being added in each following stage. Based on the small amount of weight floated, Table IV, chemical analyses were run on only the 90.6 percent minus 270 mesh test, Table IV. As was the case with the magnetite portion, amine flotation on the non-magnetic material resulted in little upgrading.

Since it was not possible to float the silica from the ilmenite, flotation tests were run to float the ilmenite from the silica. Observation of the initial testing with non-magnetic material that had been reground to 38 percent passing 270 mesh indicated that desliming of the reground material prior to flotation would be necessary. The following procedure was established for floating the non-magnetic material that had been reground to various percents passing 270 mesh: The material was ground for the desired period of time, the mill discharge was filtered, the desired weight (1000-grams on a dry basis) of filter cake was placed in the flotation bowl, water was added to make a 35 percent solids slurry, the agitator was activated for 2 minutes after which it was turned off, the slurry was allowed to settle for 2 minutes, and then was decanted to the settled solids. After desliming, the pulp was adjusted to a pH of 3.5 and conditioned for 10 minutes with various amounts of a 1:1 mixture of Oleic acid and fuel oil. After conditioning, water was added to bring the slurry to volume and 0.05 lb/st of MIBC frother was added. The air was adjusted and the material was floated to completion.

The first test involving desliming was run on material that had been ground to 42 percent passing 270 mesh. Desliming removed about 8.9 percent of the weight and 7.6 percent of the TiO_2, as shown in Table V, which gives the results for all of the Oleic acid flotation tests. To conserve funds, only TiO_2 analyses were conducted on the flotation tests. An initial dose of 3.0 lb/t of the Oleic acid-fuel oil mixture produced a concentrate containing 38 percent of the weight and 43.79 percent of the TiO_2 at a TiO_2 grade of 42.12 percent, Table V. An additional 2 lb/t of collector was added, which floated another 27 percent of the weight and 28 percent of the TiO_2 with a grade of 38.99 percent TiO_2. The two concentrates were combined and refloated with the addition of 0.5 lb/t frother. Over 97 percent of the material refloated and, therefore, the upgrading was minimal.

In the second test, the material was ground to 61 percent passing 270 mesh before desliming. Desliming was excessive with 30.9 percent of the weight and 26.8 percent of the TiO_2 being removed with the slimes. A single addition of 3 lb/t of collector produced a rougher concentrate containing 66.4 percent of the weight and 71.27 percent of the TiO_2 with a TiO_2 grade of 42.28 percent. The rougher concentrate was refloated without additional collector to produce a 43.32 percent TiO_2 cleaner concentrate, which contained 57.9 percent of the initial weight and 63.62 percent of the TiO_2. While test two was an improvement over test one, the lack of upgrading in the cleaning stage indicated a potential middlings problem. Therefore, in test three the material was ground to 84.9 percent passing 270 prior to desliming. Care was taken to prevent excess slime removal, and only 10.5 percent of the weight and 7.83 percent of the TiO_2 was removed. However, the test was run without adjusting the pH to about 3.5, which accounts for the poor flotation response as shown in Table V. Test 4 was a repeat of test 3 except with pH adjustment. With the finer grind and pH adjustment it was possible to produce a 45.01 percent TiO_2 rougher concentrate containing 57.3 percent of the weight and 70.9 percent of the TiO_2. Cleaning of the rougher concentrate produced a 46.35 percent TiO_2 cleaner concentrate containing 48.5 percent of the weight and 62.35 percent of the TiO_2. While grinding to 84.9 percent passing 270 mesh did produce a higher grade concentrate, the grade was still below the target grade of 47 to 48 percent TiO_2.

To determine the degree of liberation of the ilmenite from the gangue in the non-magnetic fraction, the non-magnetic material was screened and the individual screen fractions were elutriated at various up flow velocities with the overflows from each velocity being analyzed along with the final underflow. The elutriation should make a separation based on the particle's specific gravity and therefore, give an indication of liberation. The screen fractions tested were: plus 150, 150 by 200, 200 by 270, 270 by 325, 325 by 400 and 400 by 500 mesh. Test results are given in Table VI. Results include the iron, SiO_2, and TiO_2 analyses; weight, iron, SiO_2, and TiO_2 distributions; and a calculated underflow grade for each overflow. From the results there appears to be little difference in head grade between the various size fractions and that the material must be ground to less than 200 mesh before any significant upgrading is obtained. This latter point is illustrated in Figure 5, which plots the calculated TiO_2 recovery versus grade for each size fraction. Even the finest fractions show some middling particles.

The next attempt at recovering TiO_2 from the non-magnetic material involves wet high intensity magnetic separation (WHIMS). To provide feed to the WHIMS, a new sample of pilot plant spiral magnetic concentrate was ground to various percents passing 270 mesh. These ranged from 87.5 to 98.4 percent passing 270 mesh. The ground material was double passed through the laboratory magnetic separator. The non-magnetic portion from each grind was filtered, dried and saved for WHIMS feed. Results of the magnetic separator tests for each grind are given in Table VII. As with the previous magnetic separator tests on reground magnetic concentrate, there was only a slight grade improvement with grind.

The tests were run in the pilot plant WHIMS unit at settings of 10, 20 and 30 amps, which correspond to increasing field strength with amperage. Tests were run on material that had been ground to 94.5, 96.9, and 98.4 percent passing 270 mesh at settings of 20 and 30 amps, tests 975-980. The results, given in Table VIII, indicate an increase in grade with increasing amps, but with a large loss in recovery. The lowest amperage was tested on the material ground to 96.9 percent passing 270 mesh, test 981 on Table VIII. The 20 amp test (977) with the 96.9 percent passing 270 mesh material was repeated, test 982. Results from the second test were different from the first in that more weight and TiO_2 were recovered in the concentrate. Concentrates from tests 975 and 976 were combined and run through the WHIMS to try to upgrade the concentrate, test 983. There was very little upgrading with the second pass, Table VIII.

During the tests, it was noted that the "scour" water that is used to wash the non-magnetic material from the magnetic material appeared to vary. Therefore, a flowmeter was added to the scour water and a series of tests (984-989) was run to determine if the scour water rate had any effect on performance. The scour water appeared to have little effect on the WHIMS performance. The distribution of MgO was also tracked during the scour water tests. MgO is associated with the ilmenite and the gangue. It is the MgO contained in the ilmenite that is one of the problems associated with the deposit. Unpublished work by USS Research indicated that the ilmenite contains about 3.4 percent MgO that cannot be removed by beneficiation. The WHIMS results indicate that the MgO follows the silica more closely than the TiO_2, Figure 6.

Attempts were made to upgrade the non-magnetic material by removing the gangue by flotation, by floating the ilmenite and by WHIMS. While none of the methods produced the desired product, the flotation of ilmenite appears to have the most potential. Elutriation tests indicated that a grind finer than 200 mesh will be needed for liberation.

Electrostatic Upgrading of the Spiral Non-magnetic Material:

After pilot plant magnetic separation of the spiral concentrates, the non-magnetic product was fed to a spiral classifier for dewatering, Figure 1. The classifier sands were saved for subsequent ilmenite concentration. The main objective of the pilot plant tests was to increase the TiO_2 recovery reporting to the classifier sands. However, increased recovery is not beneficial unless the material can be upgraded to a 47 to 48 percent TiO_2 concentrate without a significant loss in recovery. Therefore, a series of bench scale electrostatic separations was run. Figure 7 shows the flowsheet for the bench scale testing.

A Carpo high-tension rotor-type machine was used for the batch concentration of ilmenite in the classifier sands. A 12-inch diameter rotor was used for all test work with the feeder position at top-dead-center (TDC). Table IX shows the machine settings for tests 3 through 21. Tests 1 and 2 were run to provide initial machine setting for the series of tests that followed. The products were visually examined with no chemical analyses being run.

Tests 3, 5, 7, 9, and 11 were each run on approximately 2000-gram samples of classifier sand at different splitter positions to vary the weight percentages of rougher concentrates, middlings and tailings. Cleaner separations, tests 4, 6, 8, 10, and 12, were run on the respective rougher concentrates using the rougher splitter settings. Cleaner concentrate grades ranged from 45.29 to 47.23 percent TiO_2 with TiO_2 recoveries from 67.24 to 91.94 percent. Test 12 produced the highest concentrate grade with a very good TiO_2 recovery. Results for the rougher-cleaner tests are given in Table X.

A composite of the rougher middlings from the previous tests was concentrated in tests 13 (scavenger) and 14 (scavenger cleaner) to produce a concentrate of 46.48 percent TiO_2 with a TiO_2 recovery of 78.75 percent. Cleaner middlings from tests 4, 6, 8, 10, and 12 were combined to provide the feed for test 15 (cleaner scavenger). This separation produced a 46.86 percent TiO_2 concentrate with 83.51 percent TiO_2 recovery. The results from tests 13-15 are given in Table XI.

To investigate differences in response that might be due to particle size, products from test 15 were recombined after representative samples were split out for chemical analysis. The composited sample was then screened on 48 mesh with the oversize and undersize separated in tests 16 and 17 respectively, Table XII. Concentrate TiO_2 percent for test 17 was slightly higher than test 15, while the concentrate for test 16 was slightly lower grade. The combined concentrate from tests 16 and 17 was the same TiO_2 grade as test 15, but the overall TiO_2 recovery was lower. A sample of classifier sands (non-magnetic material) was screened on 48 mesh and the minus 48 mesh fraction was separated in a rougher stage, test 18, to produce a 48.28 percent TiO_2 concentrate, which was a higher grade than produced from the unscreened material; however, the TiO_2 recovery was significantly lower at 74.17 percent compared to 91.53 percent. The rougher middlings from test 18 were scavenged in test 19 to produce a 47.96 percent TiO_2 concentrate, Table XII.

By combining results from tests 12-15, a final concentrate grade and recovery can be calculated as shown in Table XIII. Combining the cleaner concentrate, cleaner scavenger concentrate and the scavenger cleaner concentrate produces a 47.21 percent TiO_2 concentrate containing 83.33 percent of the original weight of 95.47 percent of the original TiO_2. In a commercial operation, a number of the middling and tailings samples would be recirculated so the only losses would be associated with the rougher tails.

CONCLUSIONS AND RECOMMMENDATIONS

This test program has shown that the production of value added products from Minnesota ilmenite deposits is going to be difficult. The magnetite and ilmenite particles are intimately interlocked and even grinding to greater than 90 percent passing 270 mesh will not liberate the magnetite sufficiently to allow upgrading by magnetic separation. Conventional amine flotation as practiced by the taconite companies is not effective due to the presence of iron-magnesium silicate, such as olivine. It is possible that a different suite of reagents could be used to float the silicates. The new "iron nugget" process may be applicable to magnetic concentrates produced from the ilmenite and should be tested.

Recovering additional ilmenite from the spiral magnetic concentrate will require grinding to finer than 200 mesh for liberation from the silicates. As with the magnetite, amine flotation was not successful in significantly upgrading the material. Using WHIMS for upgrading the ilmenite was also not successful. The concentration method that appears to hold the most promise is fatty acid flotation of the ilmenite. Use of depressants for the silicates and optimization of pH and temperature along with regrinding and refloating may allow the recovery of an additional 10 to 15 percent of the ilmenite.

Bench scale electrostatic testwork indicated that the improved recovery obtained in the spiral pilot plant can be carried forward to the final product and that the higher recovery material can be upgraded.

REFERENCES

1. Benner, B.R. and Niles, H.B., "Pilot Plant Benefication Tests of a Bulk Sample of Ilmenite Ore Provided by American Shield Company," Coleraine Minerals Research Lab Report CMRL/TR-94-15, December 1994.

2. Benner, B. R., "Minnesota Ilmenite Processing Using High Pressure Rolls," Coleraine Minerals Research Lab Report CMRL/TR-01-13, Project #5601201, August 9, 2001.

Table I – Results of Liberation Grind-Davis Tube Tests on Reground Spiral Magnetic Concentrate

Grind, % -270 Mesh	Sample	Weight Percent	Percent TiO_2	TiO_2 Distribution, %
30.0	DT Concentrate	58.2	21.72	48.8
	DT Tail	41.8	31.75	51.2
	Calc Head		25.91	
39.8	DT Concentrate	48.3	18.29	33.7
	DT Tail	51.7	33.57	66.3
	Calc Head		26.19	
42.9	DT Concentrate	41.4	16.39	25.5
	DT Tail	58.6	33.87	74.5
	Calc Head		26.63	
60.4	DT Concentrate	35.2	10.86	14.7
	DT Tail	64.8	34.13	85.3
	Calc Head		25.94	

Table II – Results of Laboratory Magnetic Separation Tests on Reground Spiral Magnetic Concentrate

Grind, % -270 Mesh	Sample	% Fe	% SiO_2	% TiO_2	Wt. Rec, %	Fe Rec, %	SiO2 Rec, %	TiO_2 Rec, %
37.9	Concentrate	44.78	8.59	20.01	60.3	70.4	50.4	47.9
	Tails	28.64	12.85	33.04	39.7	29.6	49.6	52.1
51.8	Concentrate	45.76	8.27	18.50	51.5	63.4	43.7	36.7
	Tails	28.17	11.31	33.86	48.5	36.6	56.3	63.3
62.4	Concentrate	46.34	7.39	18.30	50.3	61.8	35.2	35.7
	Tails	28.98	13.77	33.29	49.7	38.2	64.8	64.3
84.9	Concentrate	48.38	6.61	17.26	46.7	61.0	28.6	31.7
	Tails	27.08	14.49	32.59	53.3	39.0	71.4	68.3
90.6	Concentrate	50.40	6.02	15.91	39.1	53.7	22.5	23.7
	Tails	27.90	13.32	32.87	60.9	46.3	77.5	76.3

Table III – Results of Flotation Tests on Reground Magnetic Concentrate using MG82 Collector

Test	Sample	Wt %	% TiO_2	% Fe	% SiO_2	TiO_2 Dist, %	Fe Dist, %	SiO_2 Dist, %
84.9 % -270 mesh grind	Froth	7.02	2.74	39.33	10.92	11.56	5.66	11.68
	Conc	92.98	13.70	49.45	6.23	88.44	94.34	88.32
	Calc Head		14.40	48.74	6.56			
84.9 % -270 mesh grind 0.08 lb/lt in Stage 1, 0.04 lb/lt in all other stages	Stage 1	2.64	22.60	42.20	11.47	4.36	2.08	5.12
	Stage 2	5.33	29.60	41.91	6.81	11.54	4.15	6.14
	Stage 3	8.24	28.33	43.90	5.67	17.07	6.71	7.90
	Stage 4	12.72	23.28	47.83	5.66	21.66	11.30	12.18
	Stage 5	17.46	15.07	53.07	5.63	19.25	17.20	16.62
	Un'flow	53.62	6.66	58.84	5.74	26.12	58.57	52.05
	Calc Head		13.67	53.87	5.91			
90.6 % -270 mesh grind. Stage addition same as above	Stage 1	3.60	17.35	41.99	11.88	3.93	3.05	7.26
	Stage 2	9.65	19.95	45.72	7.29	12.13	8.90	11.95
	Stage 3	12.81	20.24	46.64	5.66	16.34	12.05	12.31
	Stage 4	12.62	18.70	49.87	4.74	14.87	12.69	10.16
	Un'flow	61.33	13.64	51.19	5.60	52.72	63.31	58.33
	Calc Head		15.91	50.37	6.02			

Table IV – Results of Stage Addition Tests on Non-magnetic Material at Various Grinds. Stage 1 used 0.08 lb/lt of MG82 collector and all other stages used 0.04 lb/lt MG82

Test	Sample	Weight %	% TiO_2	% Fe	% SiO_2
37.9 % minus 270 mesh grind	Stage 1	1.7			
	Stage 2	1.4			
	Stage 3	2.3			
	Un'flow	94.6			
51.8 % minus 270 mesh grind	Stage 1	2.3			
	Stage 2	2.5			
	Stage 3	3.8			
	Un'flow	91.5			
62.4 % minus 270 mesh grind	Stage 1	2.3			
	Stage 2	3.0			
	Stage 3	4.0			
	Un'flow	90.8			
84.9 % minus 270 mesh grind	Stage 1	3.8			
	Stage 2	3.4			
	Stage 3	5.0			
	Un'flow	87.8			
90.6 % minus 270 mesh grind	Stage 1	6.9	25.87	25.53	18.37
	Stage 2	4.5	26.36	25.73	17.97
	Stage 3	4.2	27.14	26.12	17.36
	Stage 4	4.9	27.97	26.50	16.67
	Un'flow	79.6	34.24	28.28	11.72
	Calc Head		32.71	27.80	12.94

Table V – Results from the Batch Flotation of Ilmenite
Using a 1:1 Mixture of Oleic Acid and Fuel Oil at a pH of 3.5

Test	Sample	Lb/t collector	Weight %	% TiO_2	TiO_2 Dist, %
Test 1 Non-mag from 42 % -270 mesh grind	Slimes		8.9	31.24	7.61
	Conc. 1	3.0	38.0	42.12	43.79
	Conc. 2	2.0	27.0	38.99	28.81
	Tails		26.2	27.63	19.79
	Calc Head				
	Reclnr Conc		63.1	41.75	70.73
	Reclnr Tail		1.9	36.85	1.87
Test 2 Non-mag from 61 % -270 mesh grind	Slimes		30.9	34.14	26.80
	Rghr Tail		2.7	28.04	1.93
	Rghr Conc	3.0	66.4	42.28	71.27
	Clnr Conc		57.9	43.32	63.62
	Clnr Tail		8.5	35.43	7.65
	Calc Head			39.40	
Test 3 Non-mag from 84.9 % -270 mesh grind	Slimes		10.5	26.99	7.83
	Rghr Tail		7.9	25.54	5.58
	Rghr Conc	3.0	81.7	38.45	86.59
	Clnr Conc		73.9	39.17	80.24
	Clnr Tail		7.8	29.39	6.35
	Calc Head			36.06	
Test 4 Non-mag from 84.9 % -270 mesh grind	Slimes		14.0	26.98	10.50
	Rghr Tail		28.6	23.30	18.47
	Rghr Conc	3.0	57.3	45.01	70.90
	Clnr Conc		48.5	46.35	62.35
	Clnr Tail		8.8	35.20	8.55
	Calc Head			36.01	

Table VI - Elutriation of Magnetic Tails by Screen Fraction from 84.9 Percent Passing 270 Mesh Grind

						Fe	SiO2	TiO2	Calc underflow		TiO2
Fraction	Flow, fpm	Wt%	% Fe	% SiO2	% TiO2	Dist, %	Dist, %	Dist, %	% SiO2	% TiO2	Dist, %
+150 m	0.196	10.30	20.69	27.14	15.27	7.07	25.59	4.41	9.07	37.98	95.59
	0.235	18.11	27.19	16.89	28.40	16.34	27.99	14.43	7.09	40.40	81.15
	0.275	15.99	29.96	10.85	35.97	15.90	15.87	16.13	6.00	41.68	65.02
	0.314	9.48	31.50	8.45	38.52	9.92	7.33	10.25	5.50	42.33	54.77
	Underflow	46.12	33.17	5.50	42.33	50.77	23.21	54.77			
	Calc Head		30.13	10.93	35.64						
150/200	0.235	11.34	21.82	24.66	19.28	8.46	24.96	6.24	9.48	37.03	93.76
	0.275	10.53	26.92	14.72	30.56	9.69	13.84	9.19	8.77	37.90	84.57
	0.314	6.90	27.80	12.94	32.63	6.56	7.97	6.43	8.37	38.41	78.14
	0.353	5.89	27.92	12.41	33.27	5.62	6.53	5.60	8.01	38.87	72.55
	0.393	8.35	26.70	14.39	30.27	7.62	10.73	7.22	7.07	40.13	
	Underflow	57.00	31.83	7.07	40.13	62.04	35.98	65.33			
	Calc Head		29.24	11.20	35.01						
200/270	0.314	13.24	13.79	34.86	5.19	6.15	44.60	1.89	6.61	41.02	98.11
	0.353	7.45	19.98	29.97	13.76	5.01	21.56	2.82	4.42	43.58	95.28
	0.393	8.98	27.97	16.25	28.97	8.46	14.09	7.17	2.91	45.45	88.11
	0.432	11.88	31.57	8.09	39.96	12.63	9.28	13.08	1.85	46.56	75.03
	0.476	12.24	33.28	3.27	44.31	13.72	3.87	14.95	1.48	47.16	
	Underflow	46.22	34.69	1.48	47.16	54.02	6.61	60.08			
	Calc Head		29.68	10.35	36.28						
270/325	0.235	10.39	14.18	36.73	5.79	5.05	33.65	1.68	8.31	38.86	98.32
	0.275	13.69	16.63	34.73	8.80	7.87	42.32	3.40	3.55	44.28	94.92
	0.314	12.39	28.34	13.30	30.38	12.15	14.67	10.61	1.65	46.98	84.31
	0.353	17.43	33.78	2.88	45.25	20.37	4.47	22.25	1.19	47.63	62.06
	Underflow	46.20	34.13	1.19	47.63	54.56	4.90	62.06			
	Calc Head		28.90	11.23	35.46						

Table VI (cont'd) - Elutriation of Magnetic Tails by Screen Fraction from 84.9 Percent Passing 270 Mesh Grind

325/400	0.196	6.95	14.50	38.87	4.16	3.45	24.09	0.80	9.15	38.38	99.20
	0.235	17.05	17.29	32.30	11.79	10.10	49.11	5.58	3.95	44.34	93.62
	0.275	22.95	30.27	9.24	38.46	23.81	18.91	24.52	1.67	46.88	69.10
	0.314	24.32	34.57	1.96	46.81	28.82	4.25	31.63	1.42	46.94	37.47
	Underflow	28.73	34.34	1.42	46.94	33.81	3.64	37.46			
	Calc Head		29.18	11.21	36.00						
400/500	0.157	11.89	13.48	40.13	4.85	6.08	39.98	1.62	8.13	39.73	98.38
	0.196	19.49	22.77	22.57	23.72	16.83	36.86	12.99	4.03	44.28	85.39
	0.235	23.98	28.59	7.03	41.03	26.00	14.13	27.64	2.41	46.03	57.75
	0.275	25.39	27.90	2.45	46.30	26.87	5.21	33.03	2.37	45.68	24.72
	Underflow	19.25	33.17	2.37	45.68	24.22	3.82	24.71			
	Calc Head		26.37	11.93	35.59						

Table VII - Results from Grinding and Magnetic Separation of WHIMS Feed

							Distribution			
%-270	Sample	Wt %	% Fe	% SiO_2	% TiO_2	% MgO	% Fe	% SiO_2	% TiO_2	% MgO
87.5	Mag conc	44.70	49.10	6.12	16.00	6.47	59.54	28.58	28.35	29.31
	Mag tail	55.30	26.97	12.36	32.69	12.61	40.46	71.42	71.65	70.69
	Calc Head		36.86	9.57	25.23	9.87				
91.5	Mag conc	44.39	48.81	5.67	16.40	6.48	58.80	27.07	28.78	29.02
	Mag tail	55.61	27.29	12.19	32.39	12.65	41.20	72.93	71.22	70.98
	Calc Head		36.84	9.30	25.29	9.91				
94.5	Mag conc	42.68	51.43	5.35	14.85	6.68	56.72	24.54	25.85	28.91
	Mag tail	57.32	29.22	12.25	31.72	12.23	43.28	75.46	74.15	71.09
	Calc Head		38.70	9.31	24.52	9.86				
96.9	Mag conc	41.50	51.37	5.15	15.03	5.96	56.54	22.44	24.75	25.08
	Mag tail	58.50	28.01	12.63	32.42	12.63	43.46	77.56	75.25	74.92
	Calc Head		37.70	9.53	25.20	9.86				
98.4	Mag conc	43.76	50.47	5.19	16.05	6.16	58.68	24.15	27.87	27.18
	Mag tail	56.24	27.65	12.68	32.32	12.84	41.32	75.85	72.13	72.82
	Calc Head		37.64	9.40	25.20	9.92				

Table VIII - Results of WHIMS Tests on Non-magnetic Material

WHIMS	Sample	Fe	SiO2	TiO2	wt%	Fe Dist	Si Dist	TiO2 Dist
Test 975								
94.5-270	Conc	32.4	6.28	40.40	45.67	52.28	23.47	57.37
20 amp	Tail	24.6	17.59	24.73	49.25	42.86	70.89	37.86
	Mids	27.1	13.56	30.19	5.08	4.87	5.64	4.77
		28.3	12.22	32.16				
Test 976	Conc	32.3	4.93	42.65	28.84	32.64	11.73	37.44
94.5-270	Tail	26.9	15.19	28.69	68.15	64.36	85.43	59.51
30 amp	Mids	28.5	11.43	33.33	3.01	3.00	2.84	3.05
		28.5	12.12	32.86				
Test 977								
96.9-270	Conc	31.2	6.61	40.12	51.02	57.28	27.38	63.89
20amp	Tail	21.9	21.01	20.71	36.55	28.85	62.33	23.63
	Mids	31.0	10.20	32.18	12.43	13.87	10.29	12.48
		27.8	12.32	32.04				
Test 978	Conc	32.2	5.00	41.98	26.59	30.31	11.29	34.10
96.9-270	Tail	26.6	14.62	28.85	66.43	62.58	82.50	58.55
30 amp	Mids	28.7	10.46	34.46	6.98	7.11	6.20	7.35
		28.2	11.77	32.73				
Test 979								
98.4-270	Conc	33.5	5.97	37.99	56.74	64.43	27.05	71.35
20 amp	Tail	24.0	21.79	18.98	38.30	31.07	66.63	24.06
	Mids	26.7	15.93	27.93	4.97	4.50	6.32	4.59
		29.5	12.52	30.21				
	Sample	Fe	SiO2	TiO2	wt%	Fe Dist	Si Dist	TiO2 Dist
Test 980	Conc	31.3	7.26	39.19	58.74	66.44	34.19	71.27
98.4-270	Tail	20.7	22.72	19.33	31.69	23.69	57.72	18.96
30 amp	Mids	28.6	10.54	32.92	9.58	9.87	8.09	9.76
		27.7	12.47	32.30				

Table VIII (cont'd) - Results of WHIMS Tests on Non-magnetic Material

Test 981										
96.9-270	Conc	31.0	7.60	38.96		60.81	67.72	36.86	72.78	
10 amp	Tail	22.7	20.39	22.52		34.97	28.57	56.87	24.19	
	Mids	24.5	18.63	23.33		4.22	3.71	6.27	3.03	
		27.8	12.54	32.55						
Test 982										
96.9-270	Conc	30.6	8.21	38.14		63.18	69.38	39.11	74.28	
20 amp	Tail	21.6	24.63	19.93		27.35	21.19	50.79	16.80	
	Mids	27.8	14.15	30.56		9.47	9.44	10.10	8.92	
		27.9	13.26	32.44						
Test 983	Conc	32.4	5.14	42.25		83.60	84.67	73.11	85.79	
975+976	Tail	26.9	13.35	30.30		7.31	6.16	16.59	5.38	
conc	Mids	32.3	6.66	40.02		9.09	9.17	10.30	8.84	
20 amp		32.0	5.88	41.17						
	Sample	Fe	SiO2	TiO2	MgO	wt%	Fe Dist	Si Dist	TiO2 Dist	MgO Dist
Test 984										
87.5-270	Conc	28.4	9.79	36.22	10.13	80.19	85.74	61.40	89.02	68.06
30 amp	Tail	18.4	25.81	17.11	19.73	17.24	11.94	34.81	9.04	28.51
3gpm	Mids	24.0	18.84	24.52	15.94	2.57	2.32	3.79	1.93	3.43
		26.5	12.79	32.62	11.93					
Test 985										
87.5-270	Conc	28.6	9.98	35.93	10.18	82.55	87.80	65.47	91.04	70.79
30 amp	Tail	18.3	25.40	16.44	20.13	15.59	10.59	31.48	7.87	26.44
4 gpm	Mids	23.3	20.60	19.14	17.63	1.86	1.61	3.05	1.09	2.77
		26.9	12.58	32.58	11.87					
Test 986	Conc	29.2	9.45	36.03	9.77	81.48	87.10	63.37	89.88	68.14
87.5-270	Tail	17.9	25.42	16.17	20.96	15.66	10.24	32.77	7.75	28.10
30 amp	Mids	25.4	16.39	27	15.36	2.86	2.66	3.85	2.36	3.76
5 gpm		27.3	12.15	32.66	11.68					

Table VIII (cont'd) - Results of WHIMS Tests on Non-magnetic Material

	Sample	Fe	SiO2	TiO2	MgO	wt%	Fe Dist	Si Dist	TiO2 Dist	MgO Dist
Test 987										
87.5-270	Conc	29.0	10.25	36.00	10.58	72.54	76.31	56.52	80.50	61.59
20 amp	Tail	20.8	25.53	17.50	20.52	18.01	13.62	34.96	9.72	29.66
3gpm	Mids	29.4	11.88	33.59	11.55	9.44	10.07	8.53	9.78	8.75
		27.5	13.16	32.44	12.46					
Test 988										
87.5-270	Conc	28.9	9.83	36.97	10.37	69.99	75.13	52.12	79.11	57.86
20 amp	Tail	19.2	25.58	17.71	20.44	20.75	14.81	40.21	11.23	33.81
2 gpm	Mids	29.3	10.93	34.09	11.29	9.26	10.06	7.67	9.65	8.33
		27.0	13.20	32.71	12.54					
Test 989	Conc	29.2	9.45	36.03	9.77	74.76	80.97	55.47	84.41	60.20
87.5-270	Tail	17.9	25.42	16.17	20.96	17.00	11.27	33.94	8.62	29.37
30 amp	Mids	25.4	16.39	27	15.36	8.24	7.76	10.60	6.97	10.43
3 gpm		27.0	12.74	31.91	12.13					

TABLE IX

CARPCO High Tension-Electrostatic Separator Settings

Test No.	ilmenite-bearing Feed Material	Rotor Speed, R.P.M.	Electrode Potential, kV	Electrode Position (0=TDC)	Splitter Positions Left	Splitter Positions Right	Wire Position H.T.	Wire Position Es.	Feed Rate, lbs./hr.
1	Classifier Sands	100	26	35 degr.,Pin	40	41	X		
2	#1 Ro. Conc.	100	26	35 degr.,Pin	40	40	X		
3	Classifier Sands	100	26	35 degr.,Pin	50	41	X		111
4	#3 Ro. Conc.	100	26	35 degr.,Pin	50	41	X		130
5	Classifier Sands	100	26	35 degr.,Pin	40	40	X		121
6	#5 Ro. Conc.	100	26	35 degr.,Pin	40	40	X		109
7	Classifier Sands	150	26	35 degr.,Pin	65	43	X		88
8	#7 Ro. Conc.	150	26	35 degr.,Pin	65	43	X		82
9	Classifier Sands	150	26	35 degr.,Pin	70	42	X		115
10	#9 Ro. Conc.	150	26	35 degr.,Pin	70	42	X		109
11	Classifier Sands	80	26	35 degr.,Pin	35	39	X		132
12	#11 Ro. Conc.	80	26	35 degr.,Pin	35	39	X		107
13	Ro. Midds. Comp.	100	26	35 degr.,Pin	40	42	X		48
14	#13 Conc.+Midds.	70	30	35 degr.,Pin&Lif	40	42	X	X	49
15	Clnr. Midds. Comp.	70	30	35 degr.,Pin&Lif	40	40	X	X	
16	Clnr Midds Comp, +48m	70	30	35 degr.,Pin&Lif	40	42	X	X	
17	Clnr Midds Comp, -48m	100	26	35 degr.,Pin&Lif	40	42	X	X	
18	-48m Classifier Sands	100	26	35 degr.,Pin&Lif	40	43	X	X	
19	#18 Ro. Midds.	100	26	35 degr.,Pin&Lif	40	43	X	X	
20	-65m pinned, 10-19-94 Pl	100	26	45 degr.	50	41	X		
21	#20 Ro. Midds.	100	26	45 degr.	50	41	X		

Table X - Results of Electrostatic Rougher Cleaner Tests on Non-magnetic Material

H.T. Concentration of Ilmenite in P.P. NonMag Classifier Sands

Test No.	Test Product	Weight, Grams	Weight, percent	Chemical Analyses, percent SiO2	Chemical Analyses, percent TiO2	Chemical Analyses, percent Calc Fe	Recovery, percent SiO2	Recovery, percent TiO2	Recovery, percent Calc Fe
3	Ro Tails	215.0	10.76	35.65	2.89	17.30	63.70	0.76	5.68
3	Ro Midds	143.3	7.17	7.49	38.33	32.94	8.92	6.72	7.21
3	Calc Ro Conc	1639.0	82.06	2.01	46.13	34.79	27.38	92.52	87.11
3	Calc Ro Feed	1997.3	100.00	6.02	40.91	32.77	100.00	100.00	100.00
4	Clnr Tails	9.2	0.46	31.45	7.57	20.67	2.40	0.09	0.29
4	Clnr Midds	104.5	5.23	3.95	43.35	34.95	3.43	5.54	5.58
4	Clnr Conc	1525.3	76.37	1.70	46.55	34.86	21.55	86.89	81.24

Test No.	Test Product	Weight, Grams	Weight, percent	Chemical Analyses, percent SiO2	Chemical Analyses, percent TiO2	Chemical Analyses, percent Calc Fe	Recovery, percent SiO2	Recovery, percent TiO2	Recovery, percent Calc Fe
5	Ro Tails	176.3	8.84	37.94	2.25	14.86	55.02	0.48	4.10
5	Ro Midds	94.6	4.74	12.20	32.57	29.31	9.49	3.76	4.34
5	Calc Ro Conc	1724.0	86.42	2.50	45.53	33.93	35.49	95.76	91.56
5	Calc Ro Feed	1994.9	100.00	6.09	41.09	32.03	100.00	100.00	100.00
6	Clnr Tails	19.4	0.97	33.53	4.48	18.28	5.35	0.11	0.56
6	Clnr Midds	74.6	3.74	5.64	40.80	32.80	3.46	3.71	3.83
6	Clnr Conc	1630.0	81.71	1.99	46.24	34.17	26.68	91.94	87.17

Table X (cont'd) - Results of Electrostatic Rougher Cleaner Tests on Non-magnetic Material

H.T. Concentration of Ilmenite in P.P. NonMag Classifier Sands

Test No.	Test Product	Weight, Grams	Weight, percent	Chemical Analyses, percent: SiO_2	Chemical Analyses, percent: TiO_2	Chemical Analyses, percent: Calc Fe	Recovery, percent: SiO_2	Recovery, percent: TiO_2	Recovery, percent: Calc Fe
7	Ro Tails	49.1	2.46	35.22	4.33	15.37	13.83	0.26	1.17
7	Ro Midds	434.0	21.77	12.79	32.50	28.56	44.38	17.31	19.14
7	Calc Ro Conc	1510.8	75.77	3.46	44.44	34.16	41.79	82.42	79.70
7	Calc Ro Feed	1993.9	100.00	6.27	40.86	32.48	100.00	100.00	100.00
8	Clnr Tails	7.1	0.36	20.25	22.80	24.45	1.15	0.20	0.27
8	Clnr Midds	301.7	15.13	6.53	40.47	32.89	15.75	14.99	15.32
8	Clnr Conc	1202.0	60.28	2.59	45.57	34.54	24.89	67.24	64.11

Test No.	Test Product	Weight, Grams	Weight, percent	Chemical Analyses, percent: SiO_2	Chemical Analyses, percent: TiO_2	Chemical Analyses, percent: Calc Fe	Recovery, percent: SiO_2	Recovery, percent: TiO_2	Recovery, percent: Calc Fe
9	Ro Tails	32.6	1.63	33.81	6.52	16.68	9.20	0.26	0.81
9	Ro Midds	274.0	13.73	16.16	28.35	26.71	36.94	9.40	10.85
9	Calc Ro Conc	1688.7	84.63	3.82	44.19	35.28	53.86	90.34	88.34
9	Calc Ro Feed	1995.3	100.00	6.01	41.40	33.80	100.00	100.00	100.00
10	Clnr Tails	8.5	0.43	17.70	25.99	26.14	1.26	0.27	0.33
10	Clnr Midds	205.5	10.30	9.44	37.02	30.58	16.19	9.21	9.32
10	Clnr Conc	1474.7	73.91	2.96	45.29	35.99	36.42	80.86	78.70

Table X (cont'd) - Results of Electrostatic Rougher Cleaner Tests on Non-magnetic Material

H.T. Concentration of Ilmenite in P.P. NonMag Classifier Sands

Test No.	Test Product	Weight, Grams	Weight, percent	Chemical Analyses, percent SiO2	Chemical Analyses, percent TiO2	Chemical Analyses, percent Calc Fe	Recovery, percent SiO2	Recovery, percent TiO2	Recovery, percent Calc Fe
11	Ro Tails	260.3	13.04	31.41	9.24	18.69	66.93	2.92	7.57
11	Ro Midds	68.0	3.41	13.16	31.58	28.83	7.33	2.61	3.05
11	Calc Ro Conc	1667.9	83.55	1.89	46.63	34.42	25.75	94.47	89.37
11	Calc Ro Feed	1996.2	100.00	6.12	41.24	32.18	100.00	100.00	100.00
12	Clnr Tails	28.8	1.44	21.53	19.56	24.47	5.08	0.68	1.10
12	Clnr Midds	43.7	2.19	4.86	42.45	32.92	1.74	2.25	2.24
12	Clnr Conc	1595.4	79.92	1.45	47.23	34.64	18.94	91.53	86.04

Table XI - Results of Electrostatic Scavenging Tests

H.T. Concentration of Ilmenite in P.P. NonMag Classifier Sands

Feed--Ro Midds Composite

Test No.	Test Product	Weight, Grams	Weight, percent	Chemical Analyses, percent SiO2	Chemical Analyses, percent TiO2	Chemical Analyses, percent Calc Fe	Recovery, percent SiO2	Recovery, percent TiO2	Recovery, percent Calc Fe
13	Clnr Tails	274.6	29.89	32.55	5.58	17.94	74.59	5.29	18.83
13	Calc Clnr Conc	644.0	70.11	4.73	42.57	32.97	25.41	94.71	81.17
13	Calc Clnr Feed	918.6	100.00	13.04	31.51	28.48	100.00	100.00	100.00
14	Scav Tails	93.4	10.17	18.66	23.70	26.44	14.55	7.65	9.44
14	Scav Midds	60.1	6.54	6.39	40.01	32.60	3.21	8.31	7.49
14	Scav Conc	490.5	53.40	1.87	46.48	34.26	7.65	78.75	64.24

Feed--Clnr Midds Composite

Test No.	Test Product	Weight, Grams	Weight, percent	Chemical Analyses, percent SiO2	Chemical Analyses, percent TiO2	Chemical Analyses, percent Calc Fe	Recovery, percent SiO2	Recovery, percent TiO2	Recovery, percent Calc Fe
15	Scav Tails	143.5	23.31	19.65	21.91	25.45	74.44	12.56	18.45
15	Scav Midds	26.0	4.22	8.07	37.84	31.35	5.54	3.93	4.12
15	Scav Conc	446.0	72.46	1.70	46.86	34.36	20.02	83.51	77.43
15	Calc Feed	615.5	100.00	6.15	40.66	32.16	100.00	100.00	100.00

Table XII - Results of Electrostatic Separator Tests on Sized Material

H.T. Concentration of Ilmenite in P.P. NonMag Classifier Sands

Feed--Clnr Midds Composite, + and - 48 mesh

Test No.	Test Product	Weight, Grams	Weight, percent	Chemical Analyses, percent SiO2	Chemical Analyses, percent TiO2	Chemical Analyses, percent Calc Fe	Recovery, percent SiO2	Recovery, percent TiO2	Recovery, percent Calc Fe
16	+48 Tails	25.8	11.04	35.20	4.73	17.89	65.10	1.27	6.02
16	+48 Midds	25.2	10.78	7.36	38.35	32.16	13.29	10.08	10.57
16	+48 Conc	182.7	78.18	1.65	46.51	34.99	21.61	88.65	83.40
16	+48 Calc Feed	233.7	100.00	5.97	41.02	32.80	100.00	100.00	100.00
17	-48 Tails	81.8	24.86	21.51	19.12	25.10	78.38	11.99	19.28
17	-48 Midds	43.0	13.07	4.21	43.03	34.27	8.06	14.19	13.84
17	-48 Conc	204.2	62.07	1.49	47.14	34.88	13.55	73.82	66.88
17	-48 Calc Feed	329.0	100.00	6.82	39.64	32.37	100.00	100.00	100.00
	+48 Calc Feed	233.7	41.53	5.97	41.02	32.80	38.34	42.37	41.85
	-48 Calc Feed	329.0	58.47	6.82	39.64	32.37	61.66	57.63	58.15
	Calc Comp	562.7	100.0	6.47	40.21	32.55	100.00	100.00	100.00
16&17	Total Concentrate	386.9	68.76	1.57	46.84	34.93	17.36	80.82	74.68

Table XII (cont'd) - Results of Electrostatic Separator Tests on Sized Material

H.T. Concentration of Ilmenite in P.P. NonMag Classifier Sands

Ro Feed-- Minus 48 mesh from NonMag Classifier Sands

Test No.	Test Product	Weight, Grams	Weight, percent	Chemical Analyses, percent SiO2	Chemical Analyses, percent TiO2	Chemical Analyses, percent Calc Fe	Recovery, percent SiO2	Recovery, percent TiO2	Recovery, percent Calc Fe
18	Ro Tails	282.0	31.63	23.01	19.47	22.69	89.83	15.91	23.61
18	Ro Conc	530.2	59.47	0.98	48.28	33.81	7.19	74.17	66.13
18	Calc Ro Midds	79.4	8.91	2.71	43.12	35.04	2.97	9.92	10.26
18	Calc Ro Feed	891.6	100.00	8.10	38.71	30.40	100.00	100.00	100.00
19	Feed (Ro Midds)	79.4	100.00	2.71	43.12	35.04	100.00	100.00	100.00
19	Clnr Tails	8.2	10.33	13.98	30.39	27.30	53.36	7.28	8.05
19	Clnr Midds	10.0	12.59	2.37	23.91	49.19	11.03	6.98	17.68
19	Clnr Conc	61.2	77.08	1.25	47.96	33.76	35.61	85.74	74.27
	Total -48 Conc (Ro plus Clnr)	591.4	66.33	1.01	48.25	33.80	8.25	82.68	73.75

Table XIII – Summary of Electrostatic Separation Results

Sample	Weight Percent	Percent TiO_2	TiO_2 Dist, %
Feed	100.0	41.24	100.0
Rougher			
Tail	13.04	9.24	2.92
Middlings	3.41	31.58	2.61
Concentrate	83.55	46.63	94.47
Cleaner from Rougher			
Tails	1.44	19.56	0.68
Middlings	2.19	42.45	2.25
Concentrate	79.92	47.23	91.53
Cleaner Scavenger from Cleaner Middlings			
Tails	0.51	21.91	0.28
Middlings	0.90	37.84	0.09
Concentrate	1.59	46.86	1.88
Scavenger from Rougher Middlings			
Tails	1.02	5.58	0.14
Concentrate	2.39	42.57	2.47
Scavenger Cleaner			
Tails	0.35	23.70	0.20
Middlings	0.22	40.01	0.21
Concentrate	1.82	46.48	2.06
Final Concentrate	83.33	47.21	95.47

Figure 1 - Ilmenite pilot plant schematic

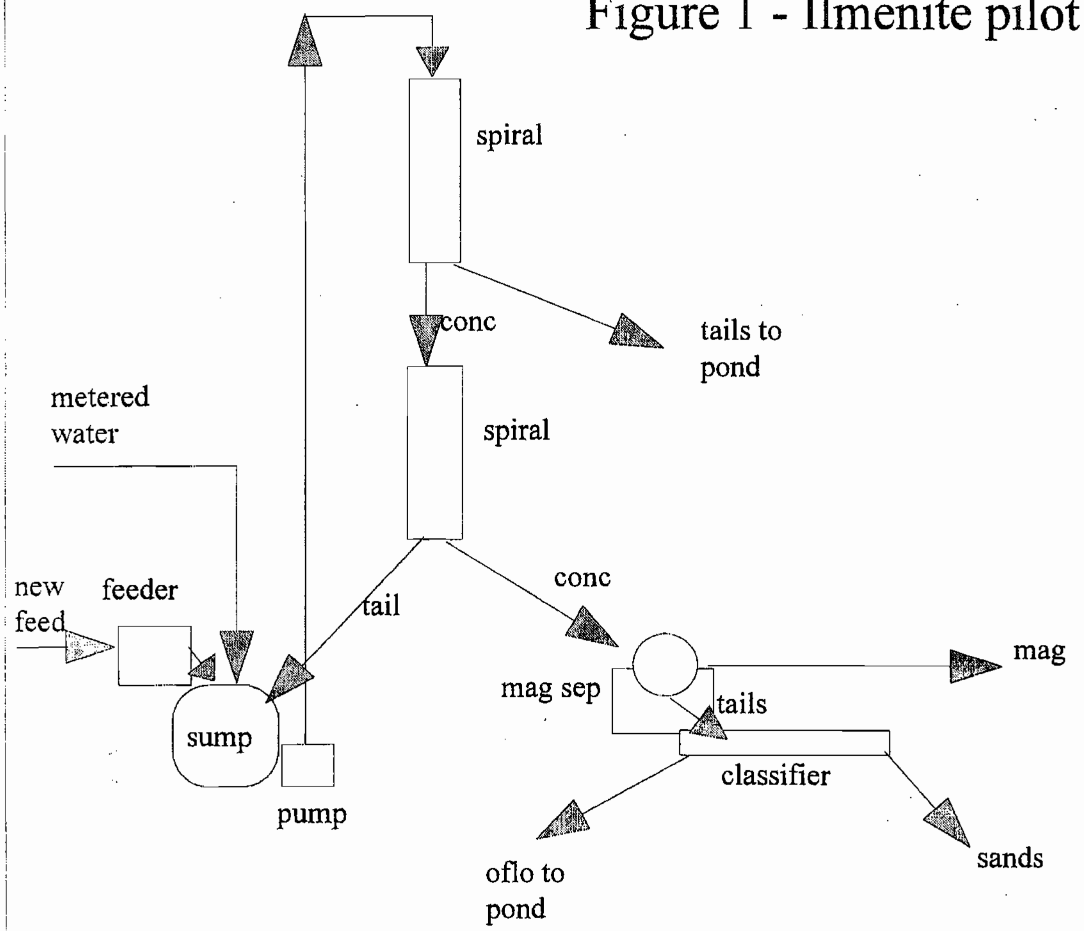


Figure 2 - Effect of Grind on TiO2 grade and Recovery in DT Conc

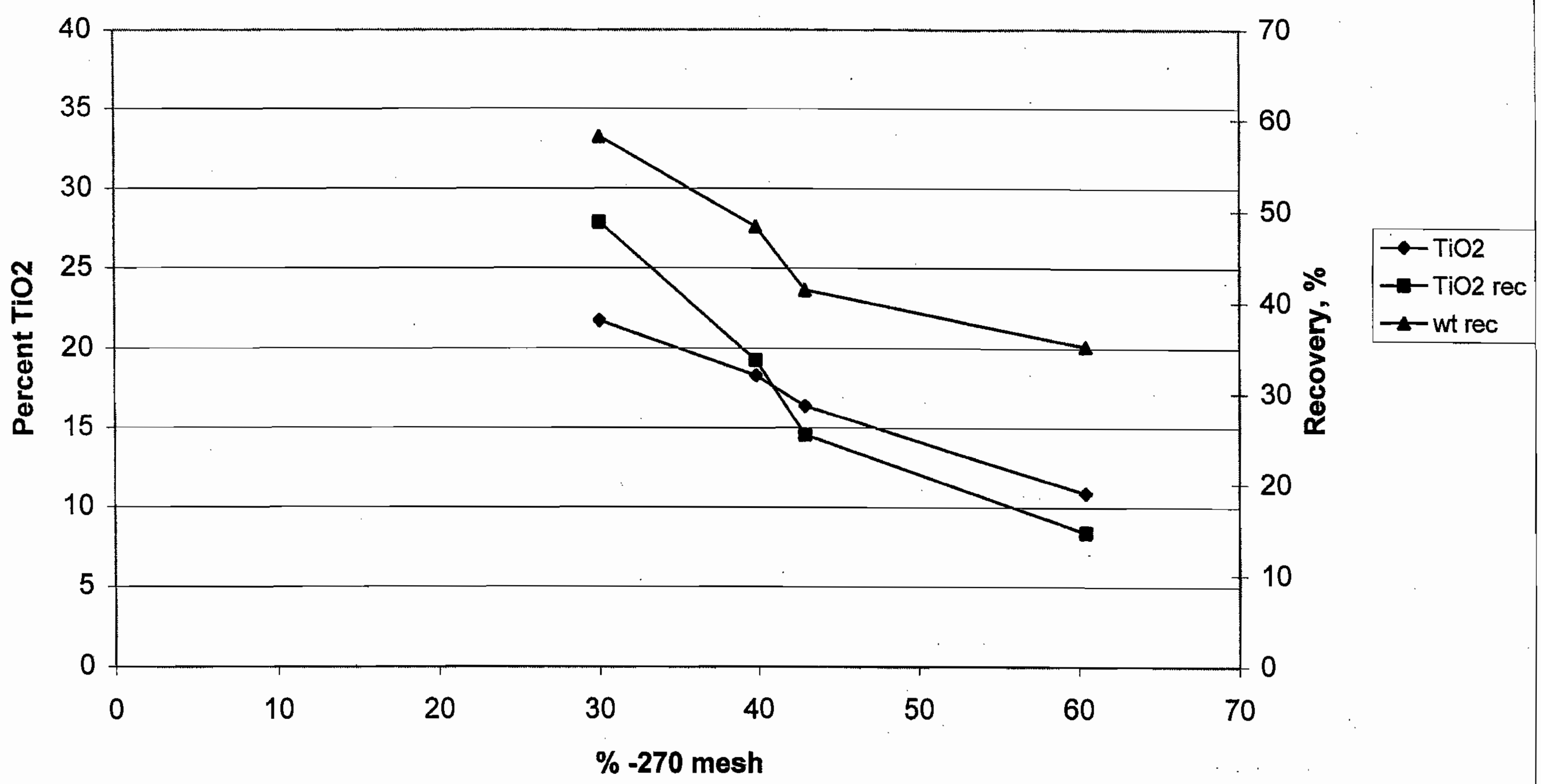


Figure 3 - Effect of Grind on SiO2 and TiO2 Grade and Recovery in Lab Mag Sep Conc

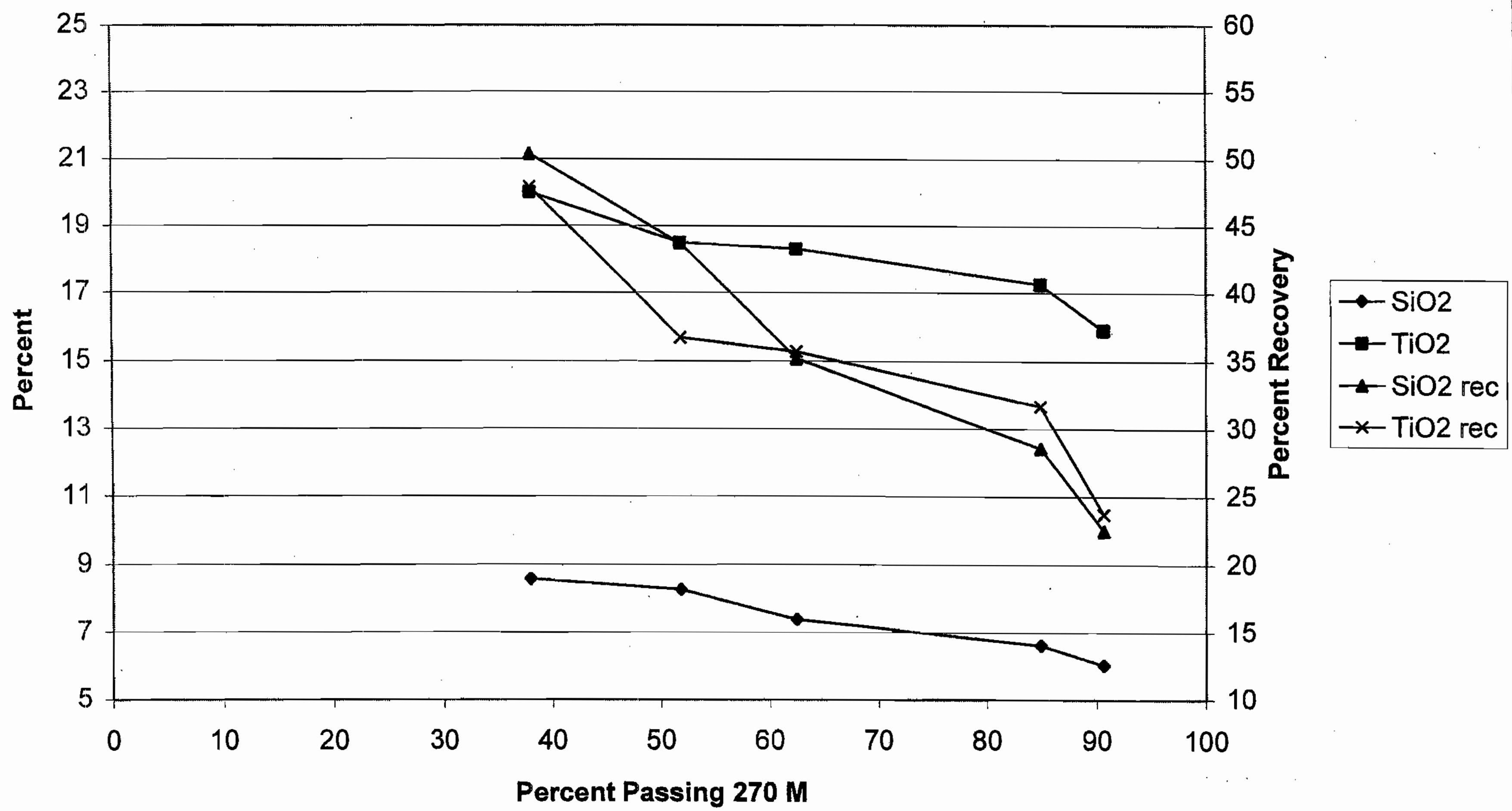


Figure 4 - SiO2 and TiO2 Recovery vs Weight Recovery in Mag Concentrate

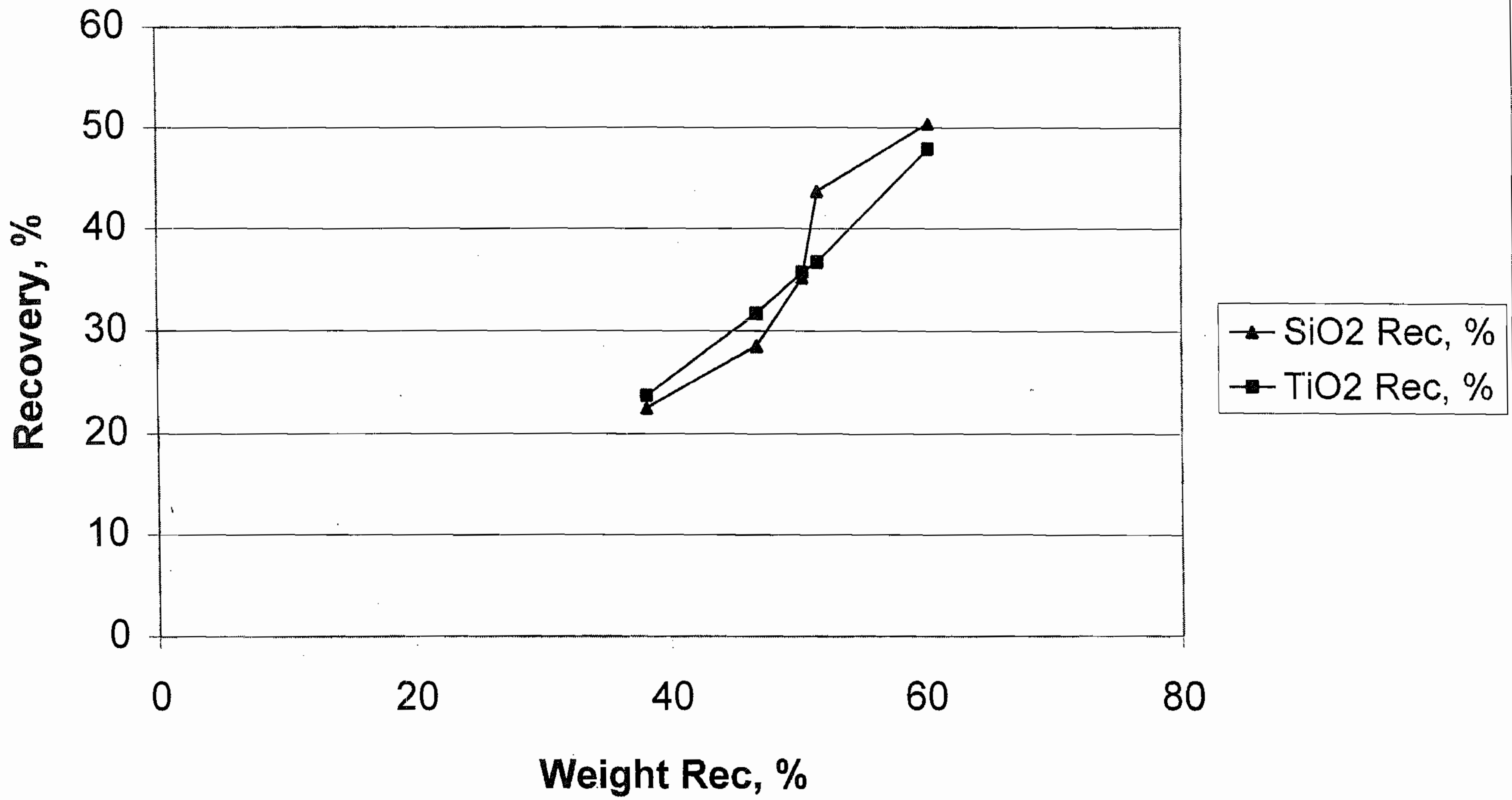


Figure 5 - TiO2 Grade vs Recovery for Elutriation Underflows

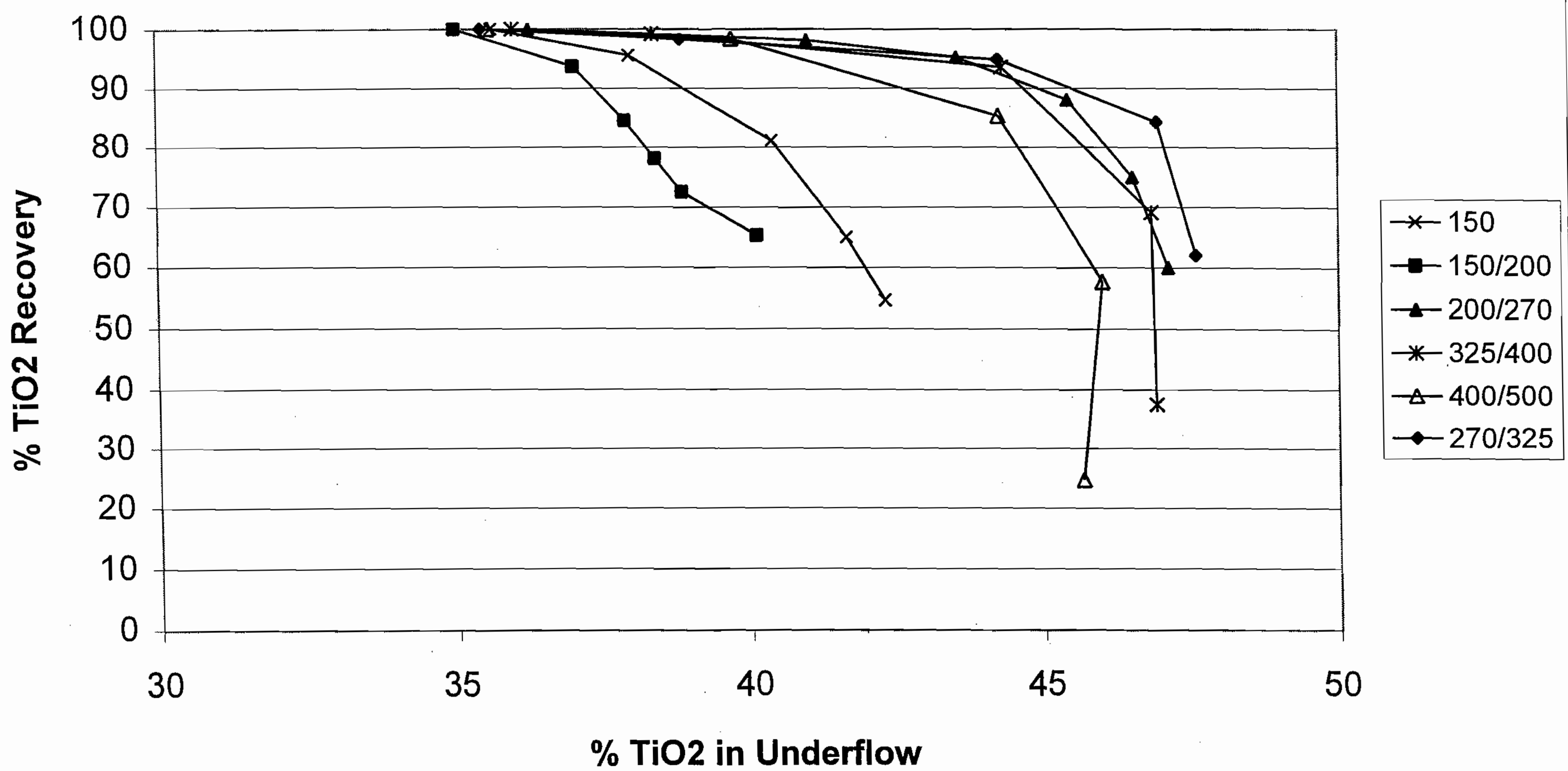
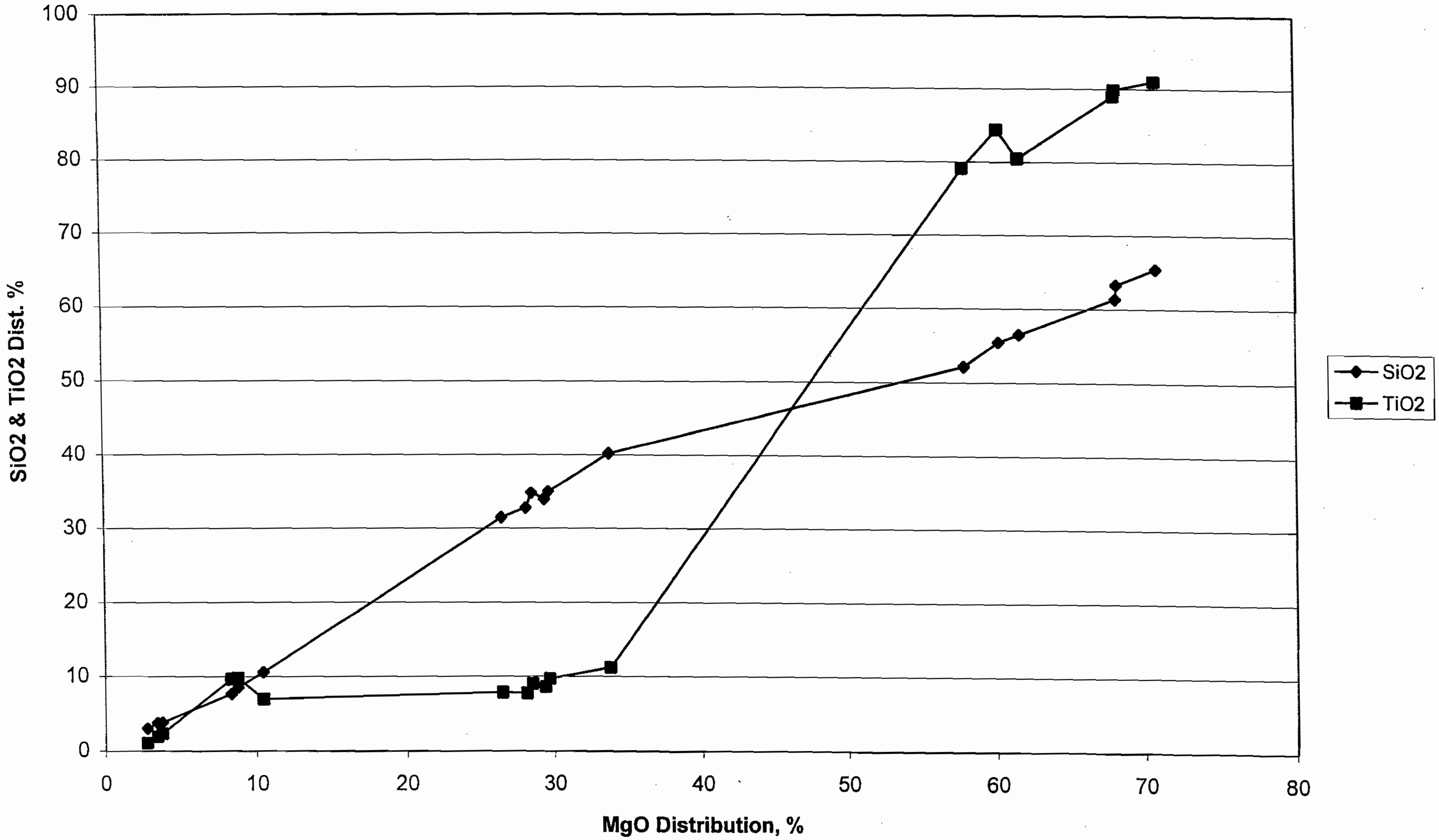


Figure 6 - MgO Distribution vs SiO2 and TiO2 Distributions



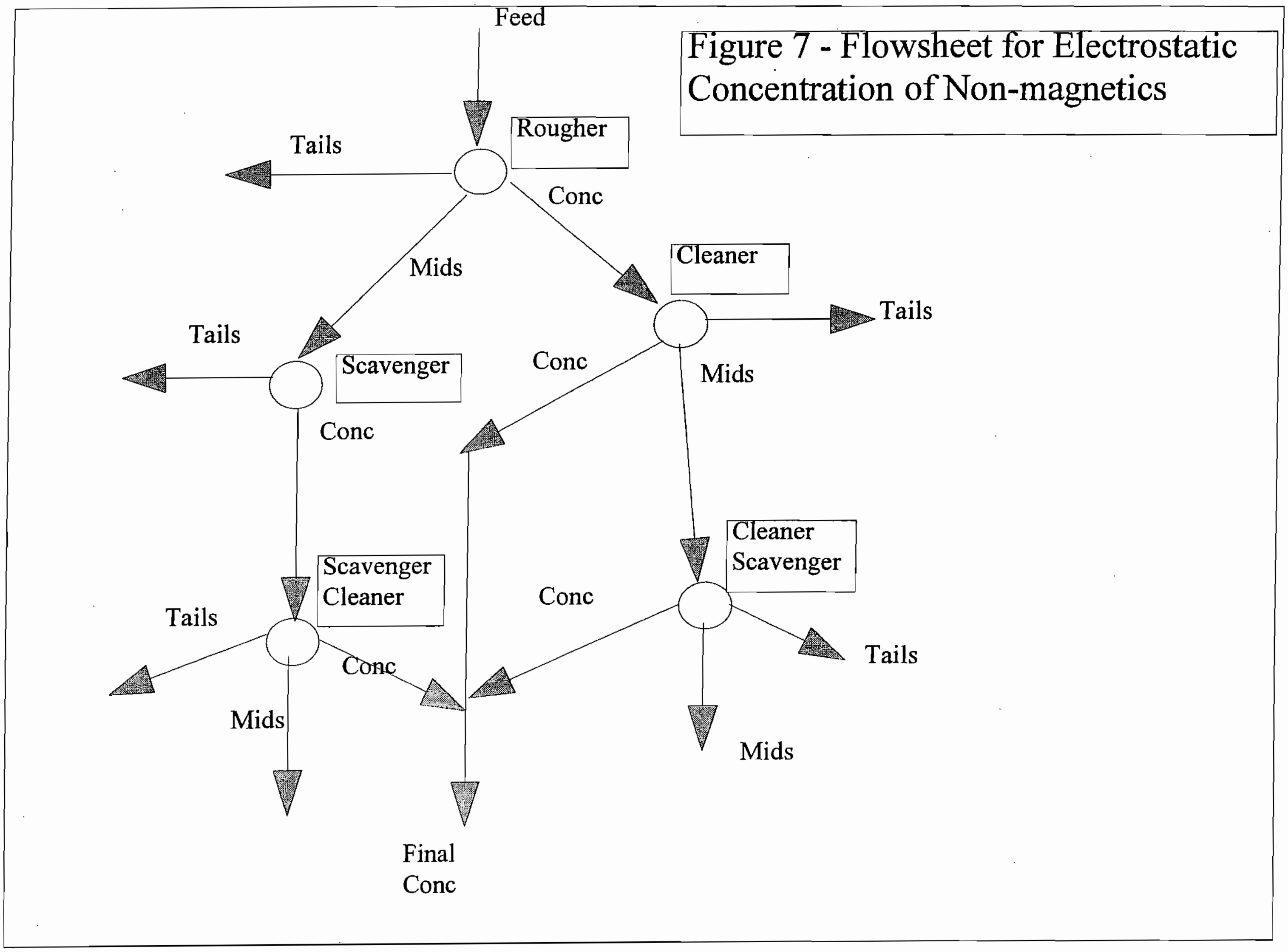


Figure 7 - Flowsheet for Electrostatic Concentration of Non-magnetics