

WASTEWATER TECHNOLOGY CENTRE

REPORT NUMBER W109101

WELLAND RIVER SEDIMENTS

**APPLICATION OF FROTH FLOTATION AND
WET HIGH INTENSITY MAGNETIC SEPARATION
TO SEDIMENT CLEAN-UP**

STEFFEN ROBERTSON & KIRSTEN



Consulting Engineers

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Report Number W109101

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WET HIGH INTENSITY MAGNETIC SEPARATION
TO SEDIMENT CLEAN-UP**

Prepared for:

**Contaminated Sediment Treatment Technology Program
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1.0 INTRODUCTION

The Contaminated Sediment Treatment Technology Program (COSTTEP) was initiated by Environment Canada in 1991. Its mandate is to foster the development and demonstration of technologies to remediate contaminated sediment and to communicate the results to people involved with Great Lakes sediment remediation projects. COSTTEP is administered by the Wastewater Technology Centre (WTC). Funding for this project was provided by the Great Lakes Clean-up Fund.

Steffen, Robertson and Kirsten (Canada) Inc. (SRK) was contracted by WTC to carry out a preliminary investigation of two treatment processes, froth flotation and wet high intensity magnetic separation, that may be applicable in sediment remediation. The objective of the investigation was restricted to obtaining a preliminary indication of feasibility; no attempt was to be made to optimize the processes.

The results of the investigation are reported herein. Chapter 2 briefly presents background information on the two processes. Chapter 3 discusses the materials and methods used in the laboratory tests. Chapter 4 presents and discusses results of the laboratory tests. Chapter 5 presents our conclusions and recommendations.

2.0 TECHNOLOGY DESCRIPTION

As mentioned, the objective of this investigation was to test the ability of technology common in the mineral processing industry to separate contaminated phases from the Welland River sediment. The two methods tested were froth flotation and magnetic separation. The following sections briefly describe their use in mineral processing.

2.1 Froth Flotation

Froth flotation is one of the most common processes used for separating selected mineral phases from ore. In simple terms, froth flotation requires three steps:

- Grinding and wetting the ore to produce a slurry;
- Addition of reagents to render the target mineral phase hydrophobic and remove it to a floating "froth";
- Separation of the froth from the slurry by skimming of the slurry surface.

The complete theory of froth flotation is well reviewed by several texts (Klassen & Modrousove, 1963; Glembotskii *et al.*, 1972). Briefly, the process relies on differences in the hydrophobic characteristics of mineral surfaces. The differences are enhanced or suppressed by the addition of surfactant reagents, which also serve to collect and trap air bubbles. The trapped air bubbles allow the surfactant-bound mineral to float, forming a "froth" on the surface of the slurry. The froth is then separated from the slurry to yield a concentrated mineral phase.

The theory is seldom adequate to quantitatively design a flotation process. Instead, flotation reagent types and quantities, as well as reactor size and residence times, must be chosen through bench and pilot tests.

The available reagents can be categorised into three broad groups: collectors, frothers, and regulators. Collectors are surfactants that adhere to specific mineral surfaces, rendering them hydrophobic and leading to the formation of a froth. Frothers increase the stability of the froth phase, in order to prevent return of the floating mineral to the slurry. Regulators either activate or suppress adhesion of surfactants (collectors) to mineral phases, and are used to control the flotation process.

A combination of reagents is generally required to selectively remove a target mineral phases from the slurry. For example, reagent combinations suitable for removing sulphide phases are often used in ore processing. In some cases, a preliminary treatment to convert oxide phase surfaces to sulphidic form is required. Alternatively, the reagent combination can be selected to float silicate phases, leaving the metal-rich oxide and sulphide phases behind.

Most full-scale flotation processes are implemented in commercial Denver sub-aeration or the air induced Wemco Fagergren flotation cell. These are agitated vessels that disperse the air stream as fine bubbles in the slurry. Rotating paddles continuously remove the froth phase from the surface of the slurry. More recently, column flotation devices are being used to provide greater selectivity in the separation process. As is common for most engineered processes, the reactors are sized on the basis of pilot scale tests.

2.2 Wet High Intensity Magnetic Separation

Magnetic separators are used in many applications, including solid waste treatment and waste stream reduction. The magnetic separators in most common use are "low intensity", employing magnetic field strengths of less than 1 kGauss.

In the mineral processing industry, Wet High Intensity Magnetic Separation (WHIMS) is commonly used to upgrade low-grade iron ores. The process consists of four steps:

- Grinding and wetting the ore to produce a slurry;
- Passing the slurry through a matrix of small iron spheres, held within a high intensity magnetic field;
- Washing the iron sphere matrix to remove any non-magnetic material; and
- Removing the iron sphere matrix from the magnetic field to release the high grade iron ore.

In comparison to other magnetic separation methods, WHIMS has several advantages. First, the use of iron spheres within the slurry shortens the path that particles must take to reach the magnetic surfaces. Second, the use of wet separation avoids the problems typically associated with dry processes, such as agglomeration of magnetic and non-magnetic particles resulting in dilution of the magnetic fraction. Third, the use of high intensity magnetic fields makes the process suitable for very small particulate matter, to less than 5 μ m in size.

In typical operations, the WHIMS requires a high intensity electromagnet that is used to induce a magnetic field around a matrix of small iron spheres. The matrix is transported into and out of the magnetic field on a conveyer belt. The slurry is contacted with the matrix for part of its passage through the magnetic field. Before the matrix leaves the magnetic field, it is washed with low pressure water to remove any captured non-magnetic particles from the matrix. These particles are typically collected as a middling concentrate which is then re-treated. The matrix then carries the magnetic fraction out of the magnetic field where it is washed with high pressure water to collect the magnetic concentrate.

3.0 MATERIALS AND METHODS

As mentioned in the Introduction, this investigation was intended to be a preliminary study of the application of froth flotation and WHIMS to contaminated sediment. A sample of contaminated sediment

(approximately 35 kg) was supplied by WTC and the tests were carried out under conditions selected *a priori* by SRK. No attempt was made to optimize either the choice of the test material or the test conditions.

3.1 Materials

The tests were carried out on a sample of "Welland River Sediment" supplied by WTC. Two types of Welland River Sediment had been characterized in a previous study (Acres International Ltd., 1992). The sediment used in this study was the so-called "reef" sediment. It was obtained from the Welland River near the discharge of the of the Atlas-Mansfield outfalls. The sampled area is immediately offshore from a mill operated by Atlas Specialty Steel, which has assumed responsibility for cleanup.

The sediment was shipped to SRK in a 25-litre pail. Inspection of the sediment indicated that it was very heterogeneous in composition; metallic particles were clearly evident. The sample had a hydrocarbon odour and films of oil and grease were visible on some particles.

Oil and grease act as surfactants and modifying surface characteristics of solids particles and, consequently, may have a deleterious effect on flotation performance. It was therefore decided to remove as much as possible of the oil and grease prior to flotation testing. Since oil and grease is naturally hydrophobic it can be removed using flotation. The froth flotation of the oil and grease, and affected particles, was aided by the addition of a frothing agent to allow the formation of a stable froth.

To characterize the sediment, a size/assay analysis (fractional analysis) was performed following flotation of the oil and grease. The sample was screened at 20 mesh (841 μm), 48 mesh (297 μm), 100 mesh (149 μm) and 200 mesh (74 μm). The products were dried, weighed and analyzed.

3.2 Methods

Three tests were performed on samples taken from the 25L pail:

1. Test F1 - Metal sulphide flotation;
2. Test F2 - Silicate flotation; and,
3. Test T2 - Magnetic separation.

The tests were carried out at Process Research Associates Ltd. Metal analyses were by Rossbacher Analytical Laboratories Ltd. using inductively coupled plasma (ICP) analysis. For this method the samples were digested with aqua regia for a period of 2 hours at a temperature of 95°C. Oil and grease analyses were performed by ASL Laboratories Ltd. All results are reported on a dry weight basis.

Test F1 - Metal sulphide flotation

Test F1 was performed to determine if flotation could be used to concentrate the metals and thereby remove them from the soil. Typically in the mineral processing industry, metal sulphide minerals are floated using xanthate collectors to render the particle hydrophobic. Xanthate collectors are general, non-specific sulphide mineral collectors that are used as a standard reagent to test the response of a sample to sulphide flotation. If metal oxides are present, a sulphidizing agent can be added so that the oxide particles behave like sulphide minerals.

Prior to performing the flotation test, the coarse particles (+20 mesh), which are too coarse to float, were screened from the sample.

The screened sample contained a significant amount of oil and grease (4.87 g per kg of dry solids) which could deleteriously effect flotation and other mineral processes. Since oil and grease is naturally hydrophobic it can be removed using flotation. Therefore, the first step for each of the four tests was to float the oil and grease. The flotation concentrate yield ranged from 0.7% to 1.7% by weight and graded 36.7 g per kg of dry solid which accounts for approximately 10% of the oil and grease in the sample.

Following the flotation of the oil and grease, potassium amyl xanthate (PAX) was added to attempt to float the metal sulphides. It was immediately apparent that no sulphides were floating and therefore no concentrate was obtained. In order to activate the metal oxide particles present, the pulp was conditioned with sodium sulphide and more PAX was added. The froth had a dark colour and appeared to contain metal particles.

A sample of the flotation tailings was then panned to determine if the metals could be recovered using gravity concentration processes.

Details of the procedures that were used for the test, along with the material balance, are shown in Table 3.3. Photos 1 and 2 show the sieving and oil and grease flotation processes. A diagrammatic representation of the flotation apparatus is provided in Figure 3.1, which illustrates the main components of the cell. Bench scale testing is usually performed in 2.0 litres cells and batch procedures are followed.

Test F2 - Silicate flotation

From test F1, it was observed that the sample contained a high metal content. Instead of floating all of the metals, the opposite approach of floating the silicate particles was tested. Details of the procedure and the material balance are shown in Table 3.4.

Coarse particles and oil and grease were removed as in Test F1. Silicate flotation can also be adversely affected by the presence of slime particles. The slime particles were therefore removed using a decantation procedure. The collector Armac T was added to float the silicate minerals. Armac T is the trade name for tallow alkylamine acetate, which selectively coats silicate particles to render them hydrophobic.

Test T2 - Magnetic separation

Tests were performed to evaluate magnetic separation to treat the sediment. Following the removal of the +20 mesh fraction and the flotation of the oil and grease, the remaining material was subjected to magnetic separation. The solids were first fed to a Sala wet low intensity magnetic separator. This separator has a permanent magnet with a field strength of approximately 700 gauss which will recover the ferromagnetic particles. A conventional magnetic drum separator is shown in section in Figure 3.2. Typically, the slurry is brought in close contact with the rotating drum. The magnetic fraction of the solids contained in the slurry then adhere to the drum and is moved from the bulk of the slurry. Once separated from the slurry, the drum transports the particles out of the immediate range of the magnetic field, and the particles are released and collected in the concentrate receptor.

The non-magnetic product was then fed to a Carpcow wet high intensity magnetic separator. This separator has an electromagnet which can be controlled to vary the magnetic field strength. The low intensity non-magnetic product was passed through the separator using a field strength of approximately 2.5 Kgauss to produce a paramagnetic product, which is referred to as Para-mag 2. The non-magnetic fraction from the 2.5 Kgauss was then re-fed to the separator with the field strength set at approximately 15 Kgauss.

Photos 3 and 4 show the low intensity magnetic separation. Photos 5 and 6 show the high intensity magnetic separation.

TABLE 3.1
Procedure for Test F1 - Metal Sulphide Flotation

STAGE	TIME (Minutes)	ADDITIONS	
		g/tonne	REAGENT
Screen at 20 mesh	-	-	-
+20 magnetic separation (hand magnet)	-	-	-
Flotation (-20 mesh solids)	-	-	-
Oil and grease float	12	46	DF 250 (frother - long chain alcohol)
Sulphide float	0	50	PAX (collector - potassium amyl xanthate) (Nothing floated)
Non-sulphide float (Sulphidization of metal oxides)	3	600 50	Na ₂ S (sulphidizer) PAX (collector)
Panning (Solids from float tails)			

TABLE 3.2
Procedure for Test F2 - Silicate Flotation

Stage	Time (Minutes)	Additions	
		g/tonne	Reagent
Screen at 20 mesh			
Flotation (-20 mesh solids)			
Oil and grease float	10	46	DF 250 (frother - long chain alcohol)
De-slime	10		Settle sands and decant slimes
Silicate float	9	200	Armac T (collector - tallow alkylamine acetate)
		46	DF 250 (frother)
	4	100	Armac T (collector - tallow alkylamine acetate)
		37	DF 250 (frother)

4.0 RESULTS AND DISCUSSION

The results of the test program were reported as a series of masses and metal concentrations for all fractions separated in each test. Raw data, comprising the mass and analytical results for each test product, are shown in Appendix A. Section 4.1 presents the results in graphical form. The significance of the results is discussed in Section 4.2.

4.1 Sediment Characterization

The material balance in Table 4.1 shows some variation in the metal assays with particle size. For example, the Fe content of the +20 mesh fraction is 36.8% compared to 52.7% in the -100 + 200 mesh fraction. However, all size fractions contained significant levels of metals.

Table 4.2 compares the overall heavy metal composition of the sample, calculated from the results of the size/assay analysis, to the results reported in Acres Limited (1992) and to the Ontario provincial sediment guidelines. It is clear that the sample is very contaminated with heavy metals. The chromium concentration, for example, exceeds "Lowest Effects Levels" (Persaud *et al.*, 1993) by more than two orders of magnitude.

TABLE 4.1
Results of Size/Assay Analysis

Products	Weight		Assays						
	(g)	(%)	Cu (%)	Pb (%)	Zn (%)	Ni (%)	Mn (%)	Fe (%)	Cr (%)
Oil and Grease	21.0	1.6	1.39	0.64	0.79	7.77	6.09	38.3	4.19
+20 mesh (841 um)	529.8	40.3	0.87	0.19	0.33	7.45	5.76	36.8	3.47
-20 +48 mesh (297 um)	279.5	21.2	1.04	0.12	0.30	9.53	6.31	42.8	3.47
-48 +100 mesh (149 um)	247.3	18.8	1.05	0.13	0.31	8.19	7.72	51.4	5.46
-100 +200 mesh (75 um)	142.6	10.8	0.96	0.13	0.26	7.13	8.21	52.7	6.71
-200 mesh (75 um)	95.6	7.3	1.26	0.38	0.90	8.33	7.22	41.9	5.40

Note: 1% = 10,000 µg/g

TABLE 4.2
Metal Concentrations in Sediment Samples

Metal	Concentrations from Earlier Study (Acres Limited, 1992)	Concentrations as Calculated from Results of Present Study	Lowest Effect Level*	Severe Effect Level*
Chromium (ug/g)	30,000	40,000-50,000	26	110
Copper (ug/g)	7,000	10,000	16	110
Lead (ug/g)	700	2,000	31	250
Zinc (ug/g)	600	4,000	120	820
Nickel (ug/g)	40,000	70,000-80,000	16	75
Manganese (ug/g)	60,000	70,000	460	1,100
Iron (%)	51	43	2	4

* Ontario Provincial sediment quality guidelines

4.2 Results

Figures 4.1 to 4.3 show the results of the three tests as 3-D plots of the mass of each metal associated with each fraction. Figure 4.1, for example, shows the mass of iron, nickel, manganese, chromium, copper, zinc, and lead in each of the eight fractions obtained from the sulphide flotation test. The leftmost row shows the "calculated head", *i.e.* the sum of all fractions. Figures 4.2 and 4.3 show similar results for the silicate flotation and WHIMS tests, respectively.

In evaluating the effectiveness of a treatment process, it is often important to know whether particular contaminants have been concentrated in any one fraction. Figure 4.4 to 4.6 show the test results as 3-D plots of concentration of each metal in each fraction. The layout of the plots is the same as that used in Figure 4.1 to 4.3.

4.3 Discussion

Test F1 - Metal Sulphide Flotation

As is clear from Figure 4.1, only a small mass of material was removed by the metal sulphide flotation. The results are confusing at first glance, because the sample contained a high proportion of metals which should have been effectively sulphidized and floated.

The reason for the poor results may be that the preliminary treatment did not effectively remove oil and grease from the metal surfaces. The concentrate of the oil and grease flotation comprised about 37 g per kg of dry solid. According to analyses reported by Acres International Ltd. (1992), that represents only about 10% of the total oil and grease in the reef sediment. The residual oil and grease would have been sufficient to foul the metal surfaces and inhibit the sulphidization and flotation reagents.

The results shown in Figure 4.4 indicate that the small mass of flotation concentrate was very similar in metal content to the overall sample. In other words, the removal was not selective. The oil and grease fouling may be responsible for the poor selectivity. Another explanation is presented below, in the discussion of the WHIMS results.

Test F2 - Silicate Flotation

Figure 4.2 shows that the silicate flotation separated more mass than the sulphide flotation. However, Figure 4.5 shows that the metal composition of the silicate fraction was not significantly different from that of the other material.

It is likely that the silicate flotation was also inhibited by oil and grease fouling of particle surfaces. The fouling may explain the poor selectivity. It is also possible that the silicate fraction of the sample may actually be metal-contaminated. For example, some of the silicate material may be the residue of siliceous fluxes used in the nearby steel mill.

Test T2 - Wet High Intensity Magnetic Separation

Figure 4.3 shows that the low intensity magnetic separation removed a large fraction of the sample, and that the increasingly higher intensity tests removed relatively less. The non-magnetic portion comprised only 1.1% of the total mass. Figure 4.6 shows that the non-magnetic fraction, although low in total mass, was significantly less contaminated than the other fractions.

It is interesting to note that metals such as chromium and copper report to the magnetic fraction. The indication is that those metals are intimately associated with iron, probably as alloys. As a consequence, separation of individual metals would be extremely difficult, perhaps further explaining the poor selectivity of the flotation processes.

5.0 CONCLUSIONS

The specific conclusions of the preliminary investigation can be summarized as follows.

- The Welland River "reef sediment" is poorly suited to treatment by flotation processes. The sediment contains high levels of oil and grease which were not effectively removed by flotation. The residual oil and grease inhibits the action of sulphidization and flotation reagents. Furthermore, heavy metals in the sample appear to be present as alloys, making separation of individual contaminants extremely difficult.
- The reef sediment is highly magnetic. Only about 1% of the sample reported to the non-magnetic fraction in the wet low and high intensity magnetic separation tests. The non-magnetic fraction was significantly less contaminated. However, its small volume makes the application of magnetic separation to this sediment unlikely to be economically attractive.

The broader objective of the investigation was to indicate the feasibility of using flotation and WHIMS processes in sediment remediation. In that respect, the investigation revealed several useful points.

- There is no over-riding technical constraint on the application of flotation or magnetic separation to treating contaminated sediments. The bench scale tests conducted in this study used methods developed in the mineral industry, which were easily translated to the new application. Pilot scale testing and full scale applications would benefit in a similar fashion from experience in the mineral processing industry.
- Sediment samples selected for flotation testing should be low in oil and grease or should be aggressively pre-treated, for example by solvent stripping, to remove oil and grease.
- Both flotation and WHIMS processes would be most beneficial in treating less contaminated material, where significant volume reductions would be attained. Silicate flotation, for example, would be applicable to sediment further from the "reef", where a significant component of native silicate material is present.


As mentioned above, no attempt was made to optimize the sample selection or the processes. It is our considered opinion that further testing of froth flotation processes is justified. The sample selected for further tests should be lower in oil and grease and contain a significant fraction of uncontaminated material. Once a promising sample has been identified, a series of tests to select and optimize the flotation process should be carried out. A further assessment of process costs and remediation performance would then be possible.

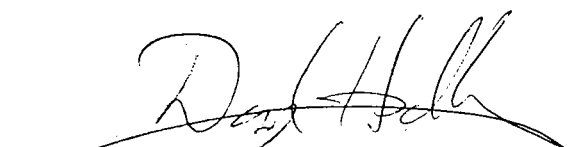
It is our opinion that wet high intensity magnetic separation is less likely to be widely applicable. We recommend that further testing be restricted to sediments or treatment residuals that contain significant iron but are not amenable to low intensity magnetic separation.

In conclusion, we appreciate the support of WTC in carrying out this project. We hope the objectives have been met to your satisfaction.

This report, Report Number W109101, has been prepared by:

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Daryl Hockley, P.Eng.
Project Manager

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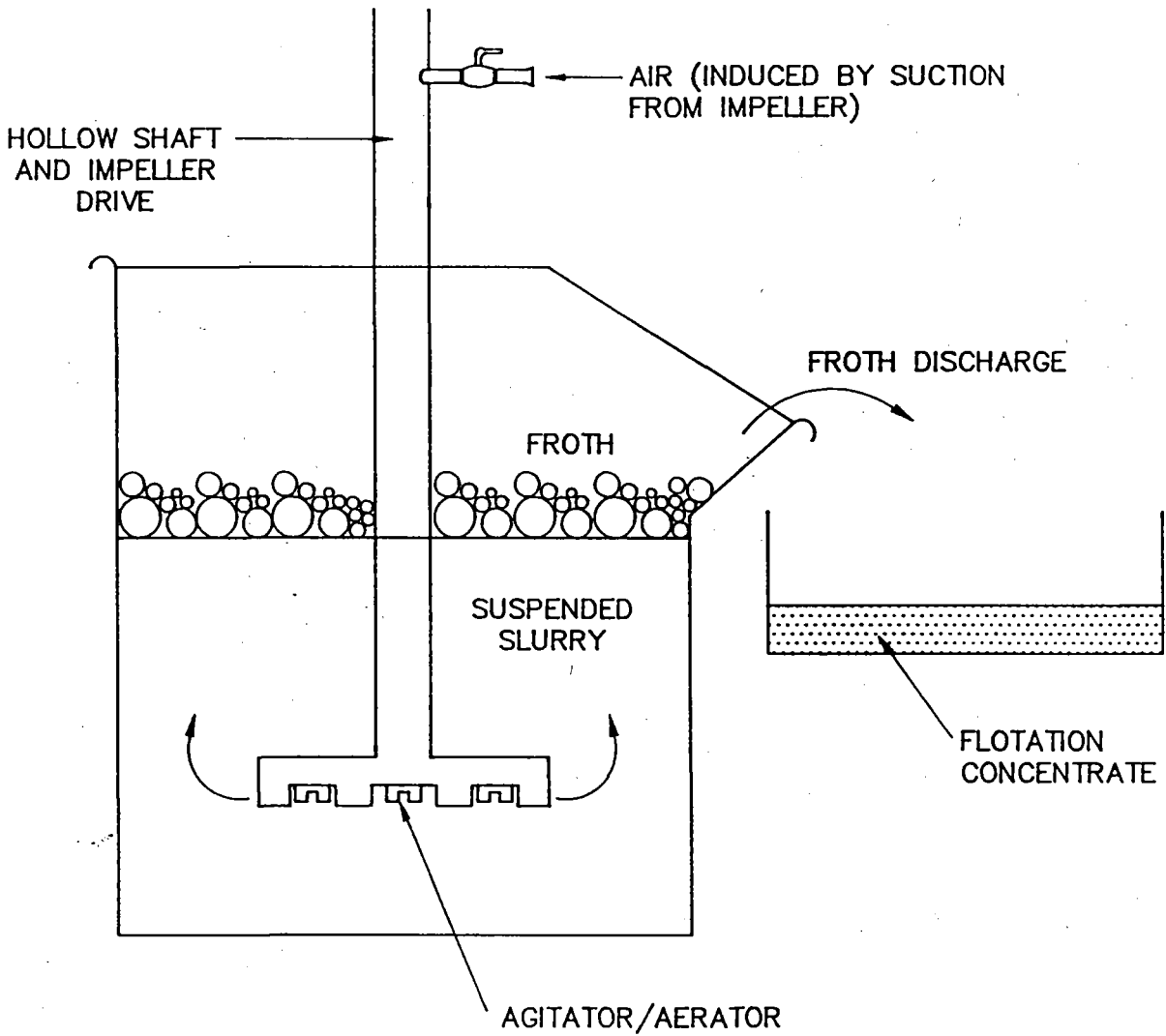
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FIGURES



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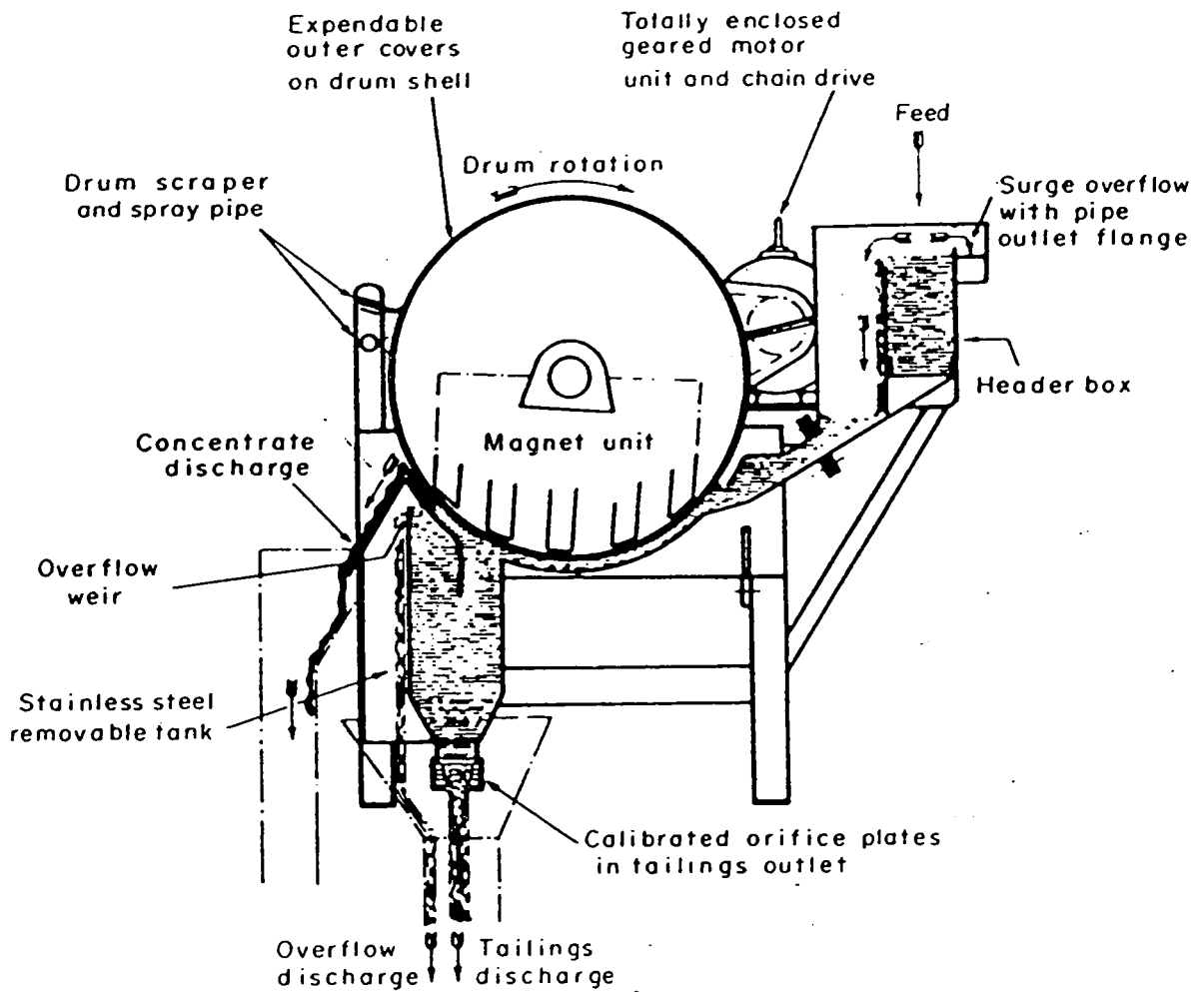
WELLAND RIVER SEDIMENT

DIAGRAM OF FLOTATION CELL

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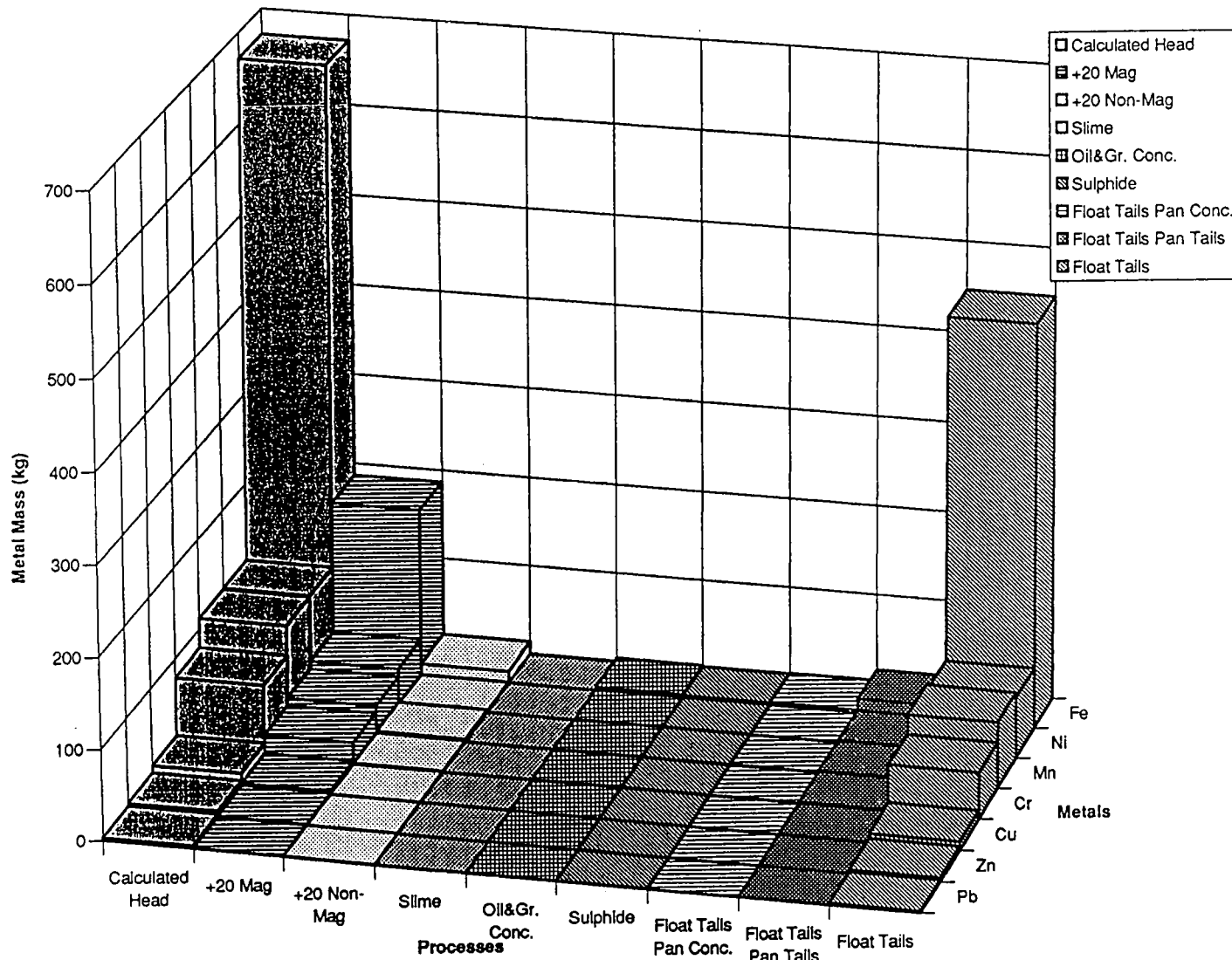
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MAGNETIC DRUM SEPARATOR

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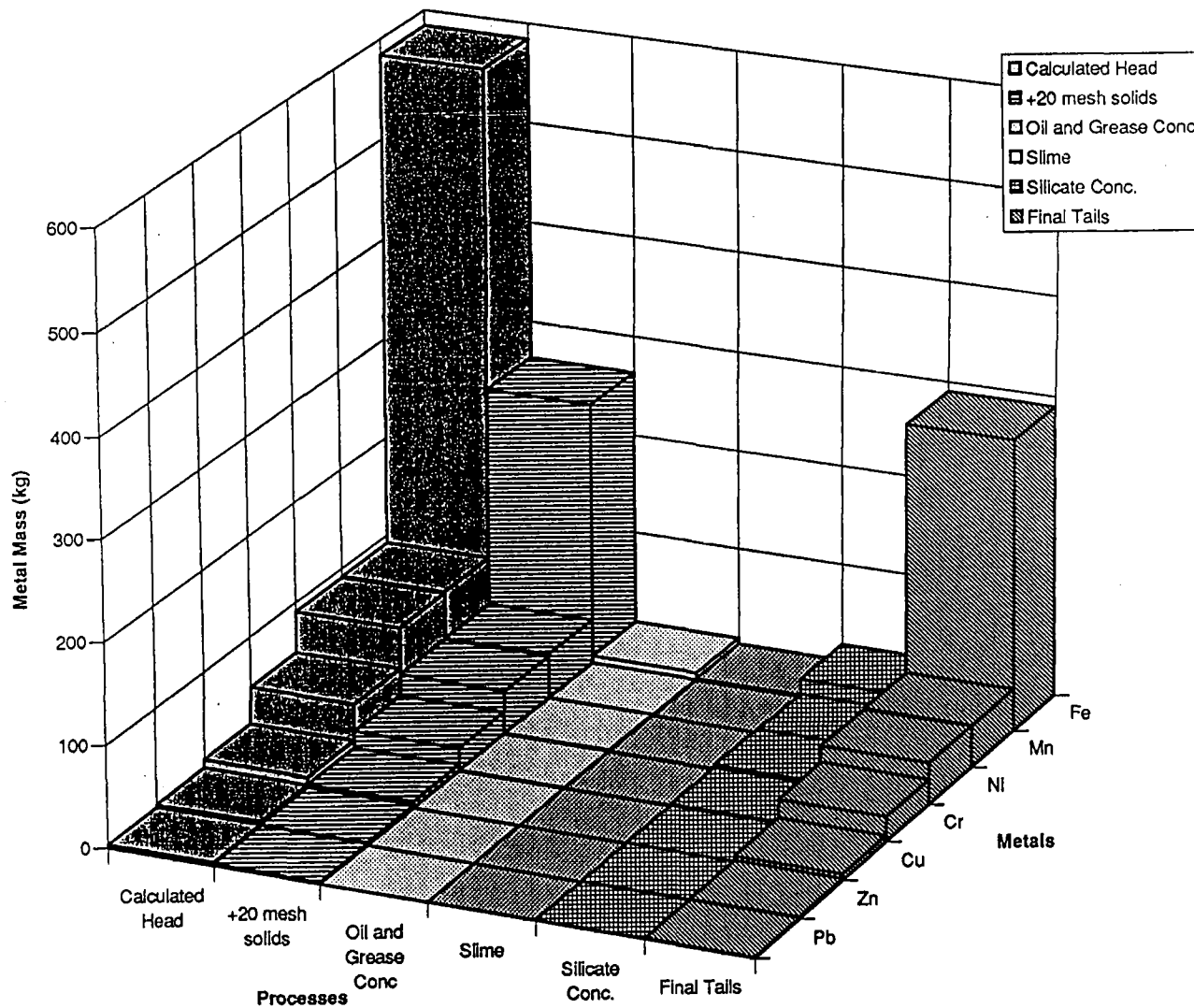
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F1 SULPHIDE FLOTATION
METAL MASSES

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F2 SILICATE FLOTATION
METAL MASSES

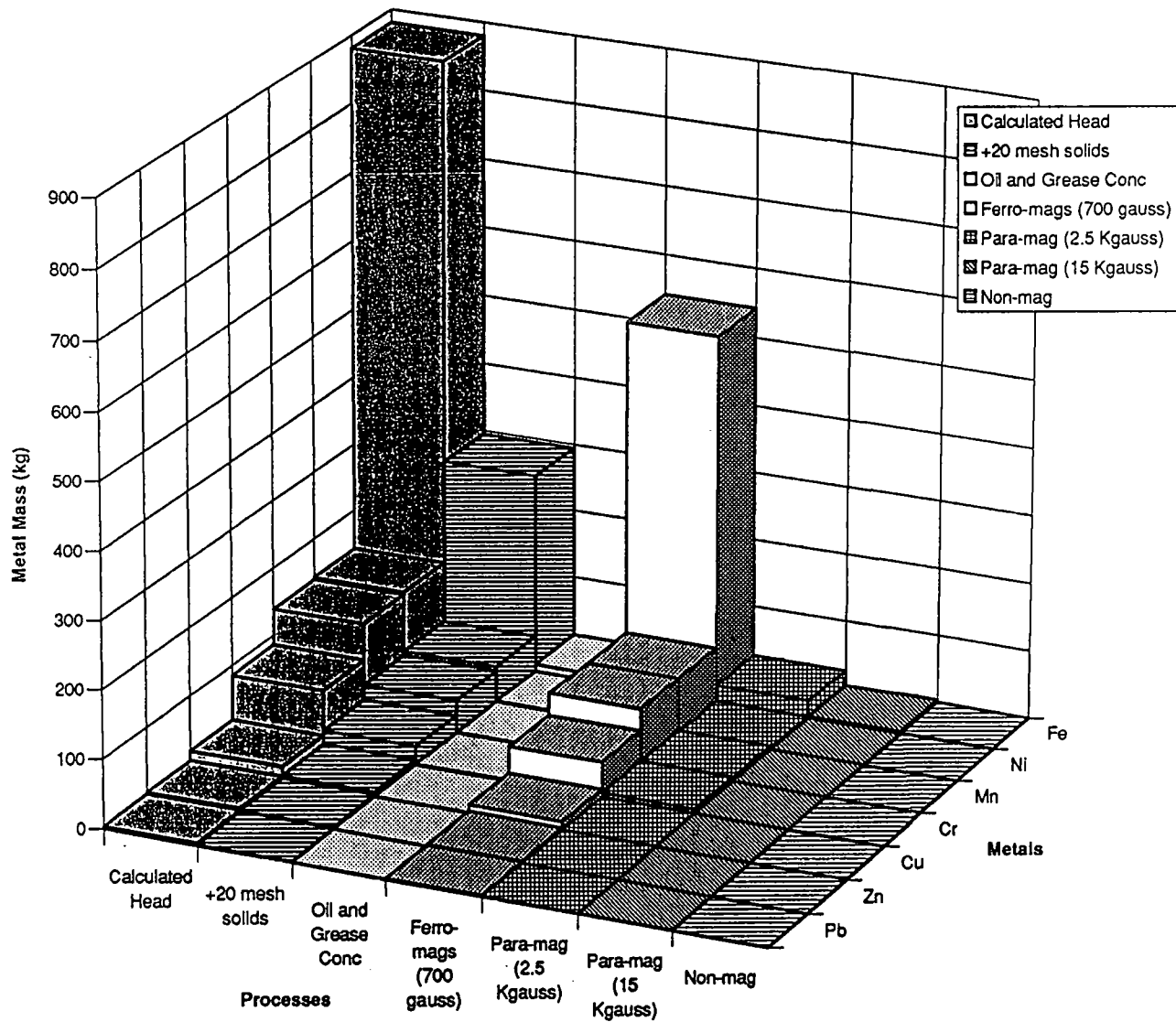
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FIGURE

4-2



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T2 WHIMS
METAL MASSES

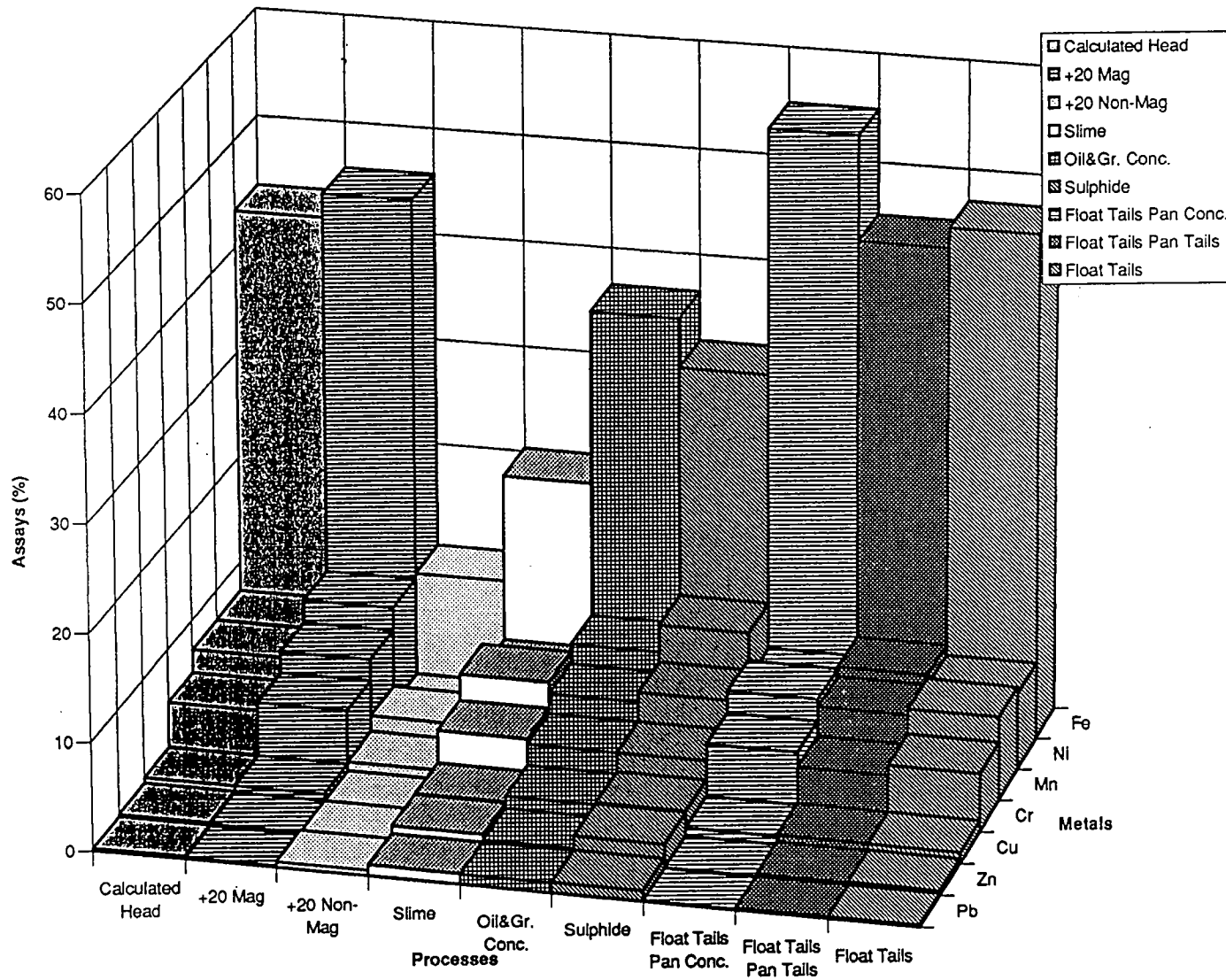
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FIGURE

4.3



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WELLAND RIVER SEDIMENT

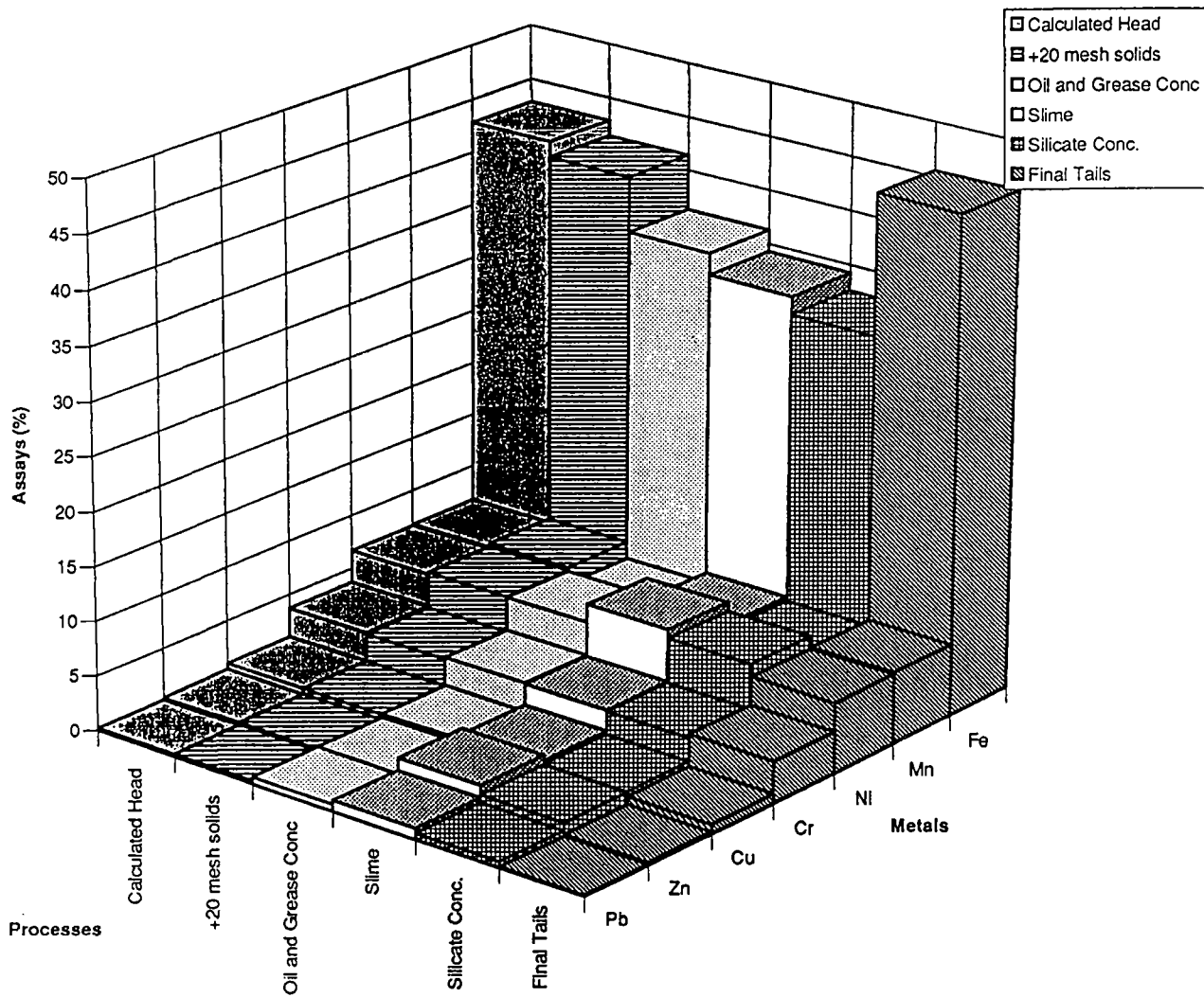
F1 SULPHIDE FLOTATION
METAL CONCENTRATIONS

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FIGURE
4.4



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F2 SILICATE FLOTATION
METAL CONCENTRATIONS

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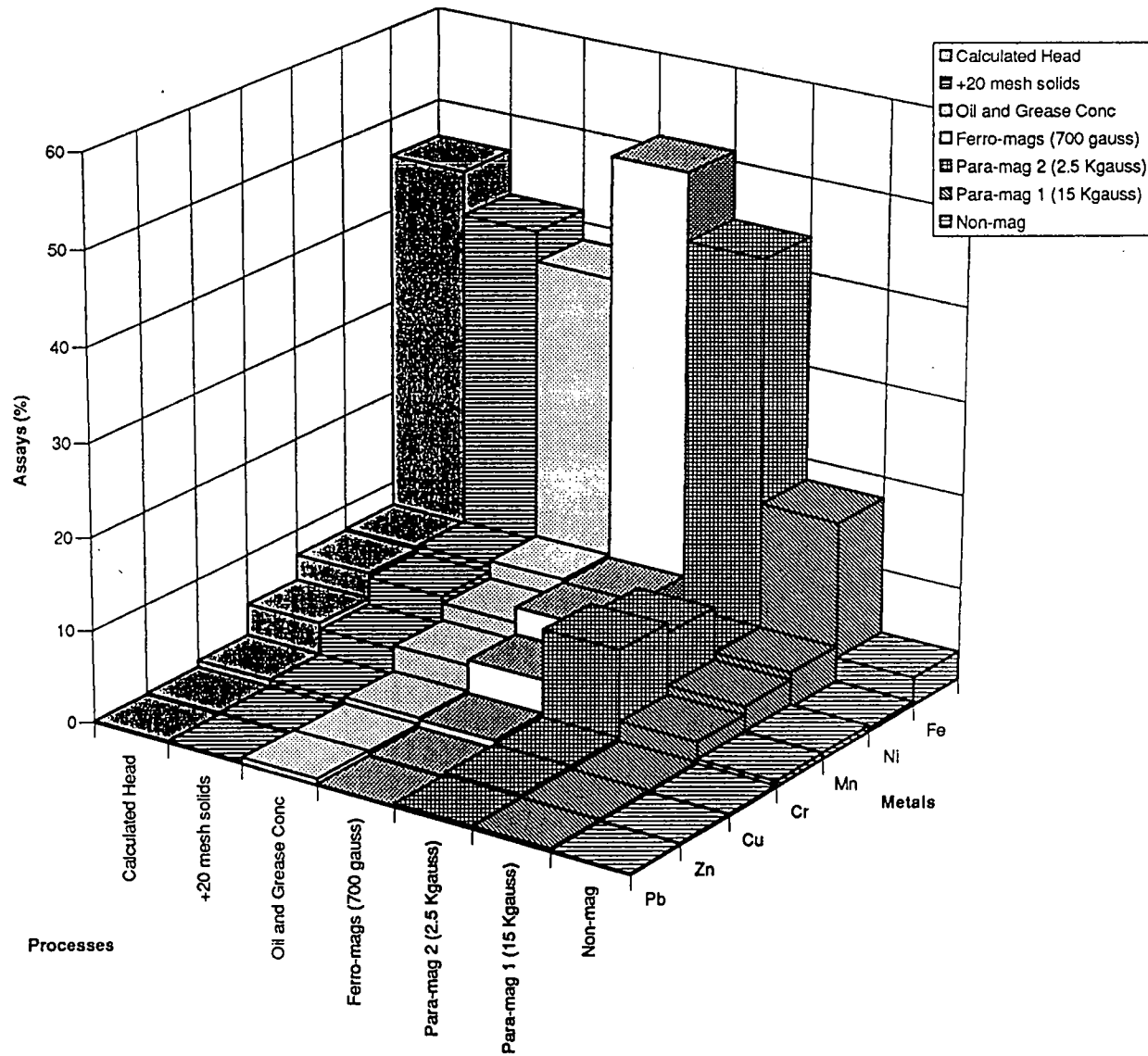
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FIGURE

4.5



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T2 WHIMS
METAL CONCENTRATIONS

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FIGURE

4.6

PHOTOS



Photo 1 Wet sieving to remove oversize fraction.

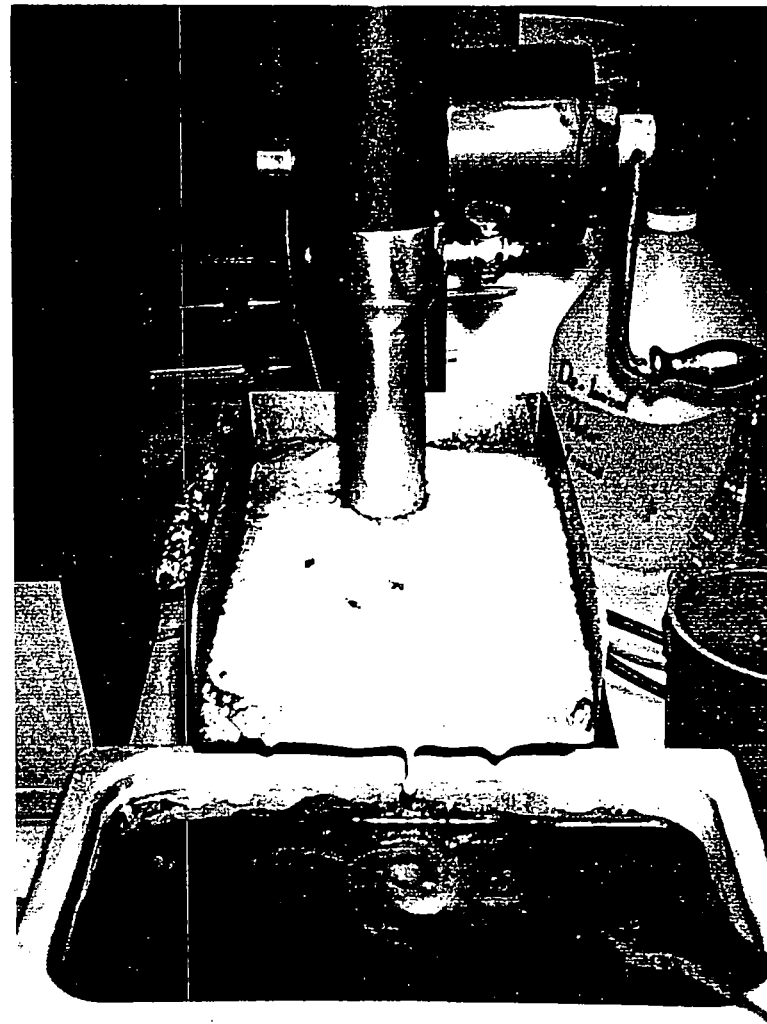


Photo 2 Oil and grease flotation.

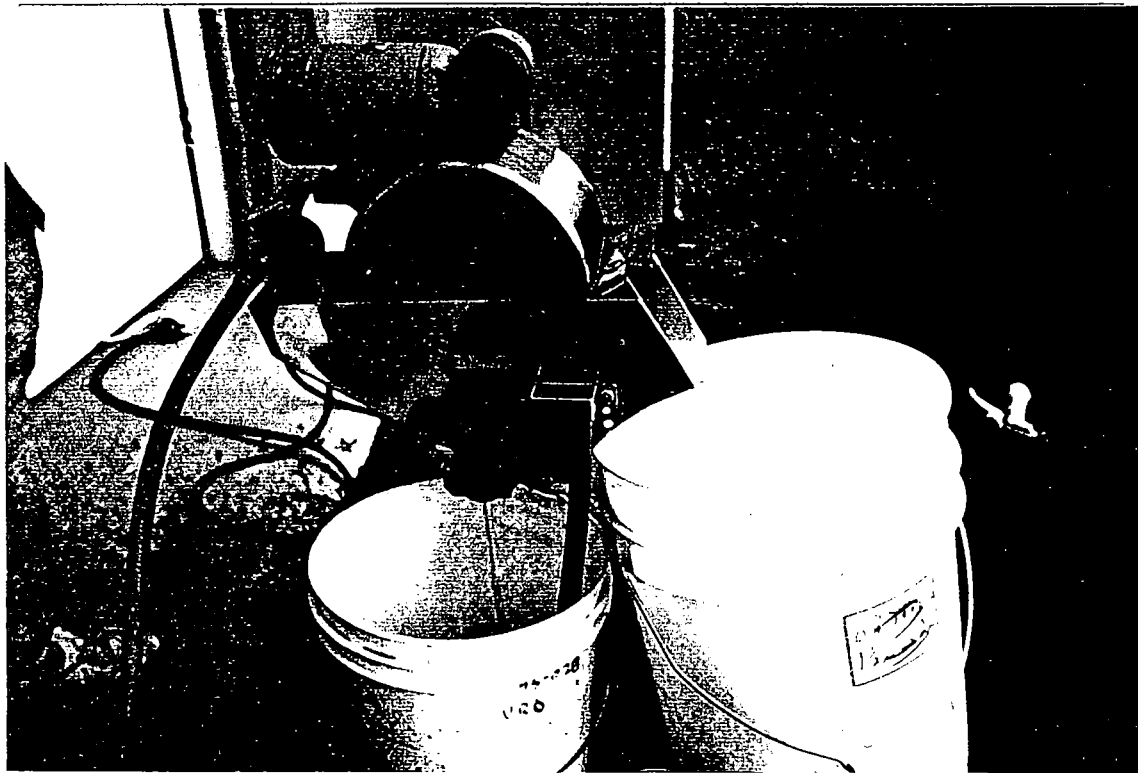


Photo 3 Low intensity magnetic separator.



Photo 4 Magnetic product.

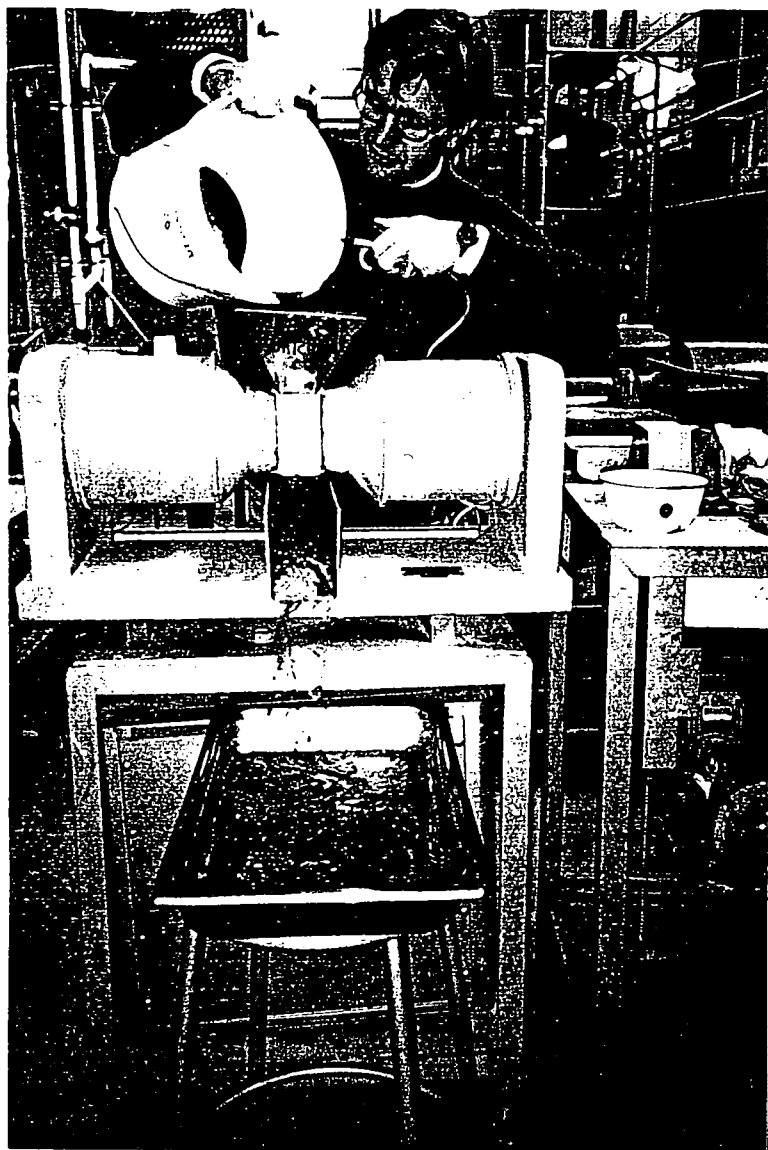


Photo 5 Wet high intensity magnetic separator in use.

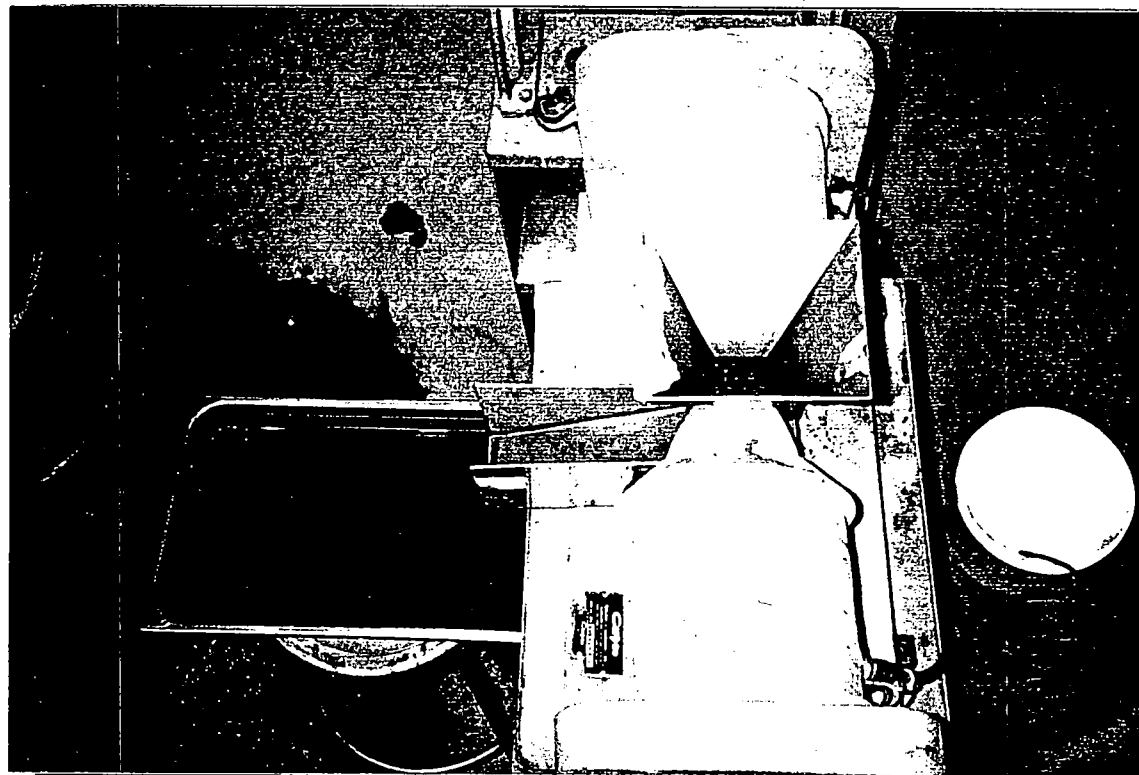


Photo 6 Interior of wet high intensity magnetic separator, showing iron sphere matrix.

APPENDIX A

TEST RESULTS

Table A1: Material Balance for F1 - Sulphide Flotation

Project No : 94-009

Test No : F1

Sample Description : Soil Sediment

Date : February 19, 1994

Products	Weight		Assays							% Distribution						
	(g)	(%)	Cu (%)	Pb (%)	Zn (%)	Ni (%)	Mn (%)	Fe (%)	Cr (%)	Cu	Pb	Zn	Ni	Mn	Fe	Cr
+20 Mag	408.0	26.4	0.91	0.12	0.31	9.87	7.77	45.70	5.85	25.4	14.5	19.0	35.5	28.2	27.7	30.2
+20 Non-Mag	126.6	8.2	0.21	0.50	0.28	0.87	2.49	10.40	1.05	1.8	18.8	5.3	1.0	2.8	2.0	1.7
Slime	0.9	0.1	1.72	0.98	1.65	4.84	7.19	20.30	4.73	0.1	0.3	0.2	0.0	0.1	0.0	0.1
Oil&Gr. Conc.	10.4	0.7	2.26	0.94	1.15	7.89	6.09	36.50	4.24	1.6	2.9	1.8	0.7	0.6	0.6	0.6
Sulphide	8.1	0.5	2.45	1.00	2.33	10.48	7.00	31.90	4.24	1.4	2.4	2.8	0.7	0.5	0.4	0.4
Float Tails Pan Conc.	6.3	0.4	0.92	0.10	0.19	6.25	7.85	54.90	5.79	0.4	0.2	0.2	0.3	0.4	0.5	0.5
Float Tails Pan Tails	35.1	2.3	1.06	0.18	0.40	8.05	7.15	45.10	4.44	2.5	1.9	2.1	2.5	2.2	2.4	2.0
Float Tails	950.0	61.5	1.03	0.21	0.48	7.06	7.70	47.00	5.39	66.8	59.1	68.5	59.2	65.2	66.4	64.7
Calculated Head	1545.4	100	0.95	0.22	0.43	7.34	7.26	43.5	5.12	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Table A2: Material Balance for F2 - Silicate Flotation

Project No : 94-009

Test No : F2

Sample Description : Soil Sediment

Date : February 19, 1994

Products	Weight		Assays							% Distribution						
	(g)	(%)	Cu (%)	Pb (%)	Zn (%)	Ni (%)	Mn (%)	Fe (%)	Cr (%)	Cu	Pb	Zn	Ni	Mn	Fe	Cr
+20 mesh solids	637.7	46.8	0.98	0.29	0.49	6.83	7.08	41.40	3.51	43.7	52.6	47.4	45.2	46.7	43.2	42.6
Oil and Grease Conc	23.2	1.7	1.06	0.66	0.70	6.78	5.54	36.30	3.66	1.7	4.4	2.5	1.6	1.3	1.4	1.6
Slime	7.4	0.5	1.65	1.00	2.11	8.41	6.42	34.30	3.56	0.9	2.1	2.4	0.6	0.5	0.4	0.5
Silicate Conc.	56.6	4.2	1.34	0.57	1.29	7.56	6.01	32.70	3.47	5.3	9.2	11.1	4.4	3.5	3.0	3.7
Final Tails	637.7	46.8	0.93	0.10	0.24	6.36	6.53	45.60	3.81	41.4	18.2	23.2	42.1	43.1	47.6	46.2
Calculated Head	1362.6	100.0	0.98	0.26	0.48	7.08	7.09	44.9	3.86	93.0	86.5	86.5	93.9	95.2	95.6	94.65

Table A3: Material Balance for T2 - Wet Low and High Intensity Magnetic Separation

Project No : 94-009

Test No : T2

Date : February 19, 1994

Sample Description : Soil Sediment

Products	Weight		Assays							% Distribution						
	(g)	(%)	Cu (%)	Pb (%)	Zn (%)	Ni (%)	Mn (%)	Fe (%)	Cr (%)	Cu	Pb	Zn	Ni	Mn	Fe	Cr
+20 mesh solids	714.3	37.3	1.02	0.21	0.37	7.62	6.82	41.30	3.82	36.7	43.9	44.2	38.1	35.0	33.5	31.8
Oil and Grease Conc	33.0	1.7	1.34	0.67	0.63	8.06	6.05	38.10	4.16	2.2	6.5	3.5	1.9	1.4	1.4	1.6
Ferro-mags (700 gauss)	1062.0	55.5	1.09	0.13	0.25	7.74	7.74	51.10	4.74	58.3	40.4	44.4	57.5	59.0	61.6	58.6
Para-mag (2.5 Kgauss)	60.2	3.1	0.70	0.37	0.61	4.27	9.17	43.80	10.23	2.1	6.5	6.1	1.8	4.0	3.0	7.2
Para-mag (15 Kgauss)	21.6	1.1	0.35	0.29	0.36	4.23	3.45	17.70	2.49	0.4	1.8	1.3	0.6	0.5	0.4	0.6
Non-mag	21.8	1.1	0.18	0.12	0.14	0.37	0.70	3.00	0.65	0.2	0.8	0.5	0.1	0.1	0.1	0.2
Calculated Head	1912.9	100.0	1.04	0.18	0.31	7.47	7.28	46.06	4.49	100.0	100.0	100.0	100.0	100.0	100.0	100.0