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Bench Scale Jig-Column Test on Network 1 Copper Ore

A Report to:

555 West Hasting Street
Suite 700
Vancouver B.C.
V6B 4N5

Attention: Mr. Felix Reyes

Submitted by: Robert de Laat
Technologist, Separation Processes
Recycling Technologies

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ORTECH

ORTECH Corporation, 2395 Speakman Dr., Mississauga, Ontario, Canada L5K 1B3 Phone: (905) 822-4111 Fax: (905) 823-1446

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1. INTRODUCTION

A copper ore sample was obtained from Network 1 Copper of Vancouver, British Columbia for copper extraction in the Mackie Vat Leach bench scale jig-column test apparatus. Two boxes of 4" ore weighing 20 kg and 25 kg respectively were crushed to 100% passing 0.263 inches using the laboratory scale jaws and rolls crusher. Subsequently, 2 lab extraction tests and 2 full jig-column tests were undertaken at ORTECH during the period from July 30 - September 20, 1997. A total recovered crushed ore weight of 65.65 kg was riffled down to 10.0 kg, 10.15 kg, 12.60 kg and 32.20 kg batches. The smaller 12.60 kg riffled batch was further riffled down to ~250 kg for size characterization and copper head analysis.

2. OBJECTIVES

The principal objective of testwork undertaken on the Network 1 copper ore was to determine copper leach rate and total copper extraction attainable in the Mackie Vat Leaching Jig (MVLJ) by simulation leaching in the jig-column apparatus.

3. DESCRIPTION OF THE TEST APPARATUS

A sketch of the jig-column test apparatus is shown in Figure 1. Measuring $6\frac{3}{8}$" inside diameter by 6 feed high, the column is constructed of pliable clear acrylic. During test operation, solution from the 1.5L head tank pulses downward to the bottom of the column through a $\frac{3}{4}$" diameter PVC pipe. As the supernatant solution percolates up through the ore bed, the ore bed fully fluidizes. Feed solution to the head tank is pumped from the clearer supernatant residing above the ore bed.

Solution pulsed upwards through the ore bed is controlled by a float-operated switch in the head tank. When the head tank nears full, the switch opens a solenoid valve, releasing leachant downward to the column bottom. Conversely, an empty head tank is allowed to fill with leach solution since the float switch closed the solenoid valve.

Leachant circulated from the supernatant above the ore bed is pumped with a $\frac{1}{2}$" Masterflex pump, which operates continually feeding the head tank. The Mackie Vat Leaching Jig (MVLJ) operates set-up in this co-current solution flow configuration.

4. SAMPLE PREPARATION

Two boxes of approximately 66 kg of 4" rock was received and logged into the ORTECH sample inventory (Sample ID #97-T13-A0039). Single stage jaw crushing followed by 5 stage rolls crushing reduced the entire sample to 100% minus 0.263". Four large homogenous splits of 65.65 kg of ore was achieved through riffling. Column acid-leaching would be undertaken on 10.0 kg or 10.15 kg splits with 12.60 kg and 32.20 kg held in reserve. Additionally, a riffed head sample was split out for copper and iron assaying. A second riffled head sample was size characterized on 3, 4, 6, 8, 10, 16, 20, 28, 35, 48, 65, 100, 150 and 200 Tyler mesh screens.

Following column acid-leaching, the recovered tailing material was displaced washed in the Buchner funnel with 10 gpL H_2SO_4 followed by a displacement distilled water wash. The sample was then oven dried. A representative tailing sample was obtained through riffling and submitted for iron and copper assaying.

5. OBSERVATIONS AND RESULTS

5.1 Bench Scale Test #1

Prior to acid leaching a minus 0.263" feed sample, a screen analysis was performed on a riffle split of 238.2 g. Table 1 shows the size characterization of the crushed Network 1 ore.

A representative split of the crushed ore weighing 211.80g was added to a 1L leach kettle with 550 ml of distilled water. Low speed agitation was undertaken with the addition of concentrated H_2SO_4 to control the pH of the leachant at 1.5-2.0. Sampling twice daily for in-situ copper continued for 9 days. Refer to Table 2 for data collected during Test #1. After 215.5 hours leaching of the minus 0.263" sample, the residue was acid washed and water washed and oven dried. The combined primary, acid and water filtrate was assayed for copper to determined an accurate copper extraction value. Test #1 was resumed with the addition of fresh pH = 1.5-2.0 leachant and resumed for an additional 164.5 hours. Copper analysis was continued at regular intervals.

Solution-based copper extraction results are shown in Table 3.

Testwork on a similar copper ore done for Network 1 Copper showed a maximum copper extraction of 38%. This work was conducted on minus 65 mesh material using conventional agitation leaching. In Test #1, minus ¼" copper ore is leachable in 217.5 hours. An additional 8% copper is extracted in 7 extra days.

5.2 Bench Scale Test #2

Due to poor copper dissolution rates in Test #1, a second bench scale test was undertaken on a sample crushed down from minus ¼" to 100% minus 10 mesh. From the original 12.60 kg minus ¼" split, the entire sample was further rolls crushed to 100% minus 10 mesh. Table 4 shows the size characterization of the Network 1 copper ore passing 10 mesh.

For Test #2, 232.1g of feed material was combined with 550 ml of distilled water and concentrated H_2SO_4 at pH = 1.5-2.0. Leaching continued for 167.5 hours with regular copper sampling. Refer to Table 5 for data collected during Test #2.

After the initial 167.5 hour leaching period, the minus 10 mesh residue was acid and water washed. The combined filtrate was assayed for copper and total copper extraction was calculated. The wet residue was continued leaching with fresh pH = 1.5-2.0 H_2SO_4 leachant. An additional 115 hours of copper dissolution continued with regular copper solution sampling.

Solution-based copper extraction results are shown in Table 6.

In comparison with Test #1 extraction data, minus 10 mesh feed material reaches the soluble copper dissolution limit in 100.5 hours versus 217.5 hours. An additional 10% copper extraction is achieved in another 182 hours.

5.3 Acid Column Leach Test #3

In direct comparison with conventional leaching results, all leachable copper (~38%) must be attained in approximately 48 hours. The Mackie Vat Jig-Column is tested on 9.50 kg of 100% minus 10 mesh material.

A representative split of the minus 10 mesh feed material was placed in the jig-column and 24 liters of tap water added through the head tank. The pump operation was initiated with 7 second head tank pulse times and 2.5 minute total cycle times. A period of 2 hours was allowed for ore/water conditioning prior to adding 50 kg/Tonne H_2SO_4 to commence the test. Concentrated sulphuric acid was added throughout the test to maintain a leachant pH = 1.5-2.0.

Leaching conditions for the 48 hours period were as follows:

- pH of lixiviant = 1.5-2.0 (with H_2SO_4)
- Temperature = ambient (21°C)
- Cycle Times = 3-5 minutes
- Pulse Times = 5-10 seconds
- Sampling Times = 1, 3, 19, 27, 43 and 48 hours

Refer to Table 7 for data collected during column acid leach Test #3.

Extraction data shown in Table 8 shows only 20% copper extraction in 48 hours.

5.4 Acid Column Leach Test #4

Because of disappointing copper extraction results in column Test #3, a 10 kg representative split of minus ¼" feed material was further size reduced through crushing and grinding to 100% minus 65 mesh. Refer to Table 9 for the size characterization of the minus 65 mesh feed material for Test #4.

Test #4 was conducted identically to Test #3 except for the following:

- 9.25 kg of feed material sized at 100% passing 65 mesh (3.28 wt. % copper)
- sampling times = 2.5, 5, 21, 29 and 50 hours

Refer to Table 10 for data collected during acid column leach Test #4.

Copper extraction calculations in Table 11 shown solution-based copper extraction of only 18% in 48 hours on minus 65 mesh feed material. A more accurate residue-based copper extraction is 24.97%. Of note, by further size reducing the Network 1 sample to minus 65 mesh, 8% more iron is extracted and 20 kg/Tonne more H_2SO_4 is required to maintain pH at 1.5-2.0.

6. CONCLUSIONS

- stir-tank test results indicate
  - minus ¼" material leaches copper to its extractable limit (~38%) in 217.5 hours
  - minus 10 mesh material leaches copper to the extractable limit (~38%) in 100.5 hours
- acid column leach tests indicate
  - 50% of extractable copper is leached in 48 hours on minus 10 mesh material
  - 65% of extractable copper is leached in 48 hours on minus 65 mesh material

7. RECOMMENDATIONS

- For the Network 1 copper ore provided, the acid digestable copper (CuO, Cu_2O) should be accurately determined. Additionally, x-ray diffraction should be used to establish copper sulphide concentrations in the ore.
- Based upon the size characterization of the minus ¼" crushed ore, very fine sample was limited (4% -100M). Extraction results were also poor for the minus 10 mesh jig-column leach (12% -100M feed size). In column Test #4, 45% -200M material leached faster but was limited to 25% copper extraction. Finer material has been successfully operated in the jig-column apparatus. Therefore, additional testwork should examine:
  - liberation of the copper ore to minus 200 mesh prior to 48 hour acid dissolution in the jig-column
  - operation of the jig-column at elevated temperatures, ie., 40°C to improve leaching kinetics and overall copper extraction

- Additionally, testwork could be conducted as follows:
  - multi-element chemical analysis of leach pregnant solution to determine additional elements acid soluble during leaching. This could be extended to x-ray diffraction testing of leach feed and tailings to determine minerals present before and after acid digestion.
  - varying acid addition during the leach to maximize copper dissolution and limit iron, gangue and other minerals from solubilization.
  - use of a surfactant to enhance both copper leach rates and overall copper extraction.

- To maximize copper sulphide mineral recovery, Network 1 copper ore should be ground to minus 200 mesh. Then, bench scale flotation testwork would be undertaken for sulphide mineral collection. Flotation tailings would then be acid leached in the Mackie Jig-column apparatus.

Robert de Laat
Technologist, Separation Processes
Recycling Technologies

Approved by:

Marc Rishea
Manager, Separation Processes
Recycling Technologies

RJD:or

Table 1

Size Characterization of Crushed Network 1 Ore - Passing 0.263"

Mesh Size	Screen Opening		Cumulative wt % Passing
	(inches)	(mm or µm)	
3	0.263	6.680	99.96
4	0.185	4.699	75.61
6	0.132	3.350	52.94
8	0.093	2.362	38.66
10	0.0661	1.700	27.92
16	0.0394	1.000	18.05
20	0.0331	850	15.74
28	0.0234	600	12.05
35	0.0164	417	9.45
48	0.0116	295	7.18
65	0.0082	208	6.97
100	0.0059	150	4.37
150	0.0041	106	3.36
200	0.0029	75	2.52
-200	-0.0029	-75	0.00

Table 2

Network 1 - 3.80 Copper Test #1
211.80 g Cu @ 3.28 wt % Cu → 6.94704 g Copper Total, 550 mL D. H_2O

Date	Test Time	Test Time (hours)	pH	g Conc. H_2SO_4 Added	Comments Hour Sample Taken
July 30/97	11:30 AM	0	9.00 to start/1.60	3.80	--
	11:35 AM	½	1.30	3.70	--
	11:45 AM	¼	1.20	--	--
	1:00 PM	1.5	1.70	--	--
	1:30 PM	2	2.00	1.40	2 hr.
	3:45 PM	4¼	2.30	2.20	--
	4:30 PM	5	1.40	4.20	5 hr.
July 31/97	8:00 AM	20.5	1.60	--	20.5 hr.
	11:30 AM	24	1.80	--	--
	1:00 PM	25.5	2.00/1.45	1.90	--
	4:00 PM	28.5	1.50	--	28.5 hr.
Aug. 1/97	8:30 AM	45	2.20	2.10	45 hr.
	9:00 PM	45.5	--	--	stop test for week-end restart test on Monday
Aug. 5/97	8:30 AM	45.5	2.00	2.80	**TEST RE-STARTED**
	9:30 AM	46.5	1.50	--	46.5 hr.
	11:45 AM	45¾	1.50	--	--
	4:30 PM	53.5	1.40	--	53.5 hr.
Aug. 6/97	8:30 AM	69.5	2.00	3.10	69.5 hr.
	4:00 PM	77	1.60	--	77 hr.
Aug. 7/97	8:30 AM	93.5	1.80	1.50	93.5 hr.
	4:00 PM	101	1.60	--	101 hr.
Aug. 8/97	8:00 AM	117	2.00	3.10	117 hr.
	8:00 PM	129	1.50	--	129 hr.
Aug. 9/97	4:30 PM	149.5	1.90	--	149.5 hr.
Aug. 10/97	12:30 PM	169.5	2.20	4.40	169.5 hr.
Aug. 11/97	10:00 AM	190.0	1.65	--	190 hr.
Aug. 12/97	11:45 AM	215.5	2.05	4.60	215.5 hr.

626 ml primary filtrate
500 ml 10 gpL H_2SO_4 wash
1126 ml Total A#3592

Table 2 (cont'd.)

Network 1 - 3.80 Copper Test #1
211.80 g Cu @100 wt % Passing ¼"
6.94704 g Copper Head Total, 550 mL D. $_H$2O to Start

Date	Test Time	Test Time (hours)	pH	g Conc. H_2SO_4 Added	Comments Hour Sample Taken
Aug. 19/97	10:00 AM	215.5	3.20/1.20	12.90	**TEST RE-STARTED**
	12:00 PM	2/217.5	1.60	--	217.5 hr.
Aug. 20/97	8:30 AM	22.5/238	1.20	--	238 hr.
	4:00 PM	30/245.5	1.20	--	245.5 hr.
Aug. 21/97	8:30 AM	46.5/262	1.20	--	262 hr.
	4:00 PM	54/269.5	1.50	--	269.5 hr.
Aug. 22/97	8:30 AM	70.5/286	1.60	--	286 hr.
Aug. 25/97	8:30 AM	142.5/358	2.30	3.80	358 hr.
Aug. 26/97	8:30 AM	164.5/380	1.60	--	380 hr. **TEST END**

Table 3

Solution-Based Copper Extraction
Test #1 Stir-Tank Testwork

Test Time (hours)	Solution (pH)	Solution Copper Assay (mg/L)	Solution Based (Cumulative) Copper Extraction (%)
2	2.00	1470	11.64
5	1.40	1690	13.38
20.5	1.60	2790	22.09
28.5	1.50	2790	22.09
45	2.20	3100	24.54
46.5	1.50	3140	24.86
53.5	1.40	3210	25.41
69.5	2.00	3300	26.13
77	1.60	3070	24.31
93.5	1.80	3160	25.02
101	1.60	3150	24.94
117	2.00	3300	26.13
129	1.50	3400	26.92
149.5	1.90	3700	29.29
169.5	2.20	3780	29.93
190	1.65	3760	29.77
215.5	2.05	3930	31.11
Recover copper from primary and wash filtrate Re-start test with fresh pH = 1.50 to 2.00 H_2SO_4 leachant (500 ml)			
217.5	1.60	170	40.45
238	1.20	370	41.89
245.5	1.20	430	42.32
262	1.20	490	42.75
269.5	1.50	550	43.18
286	1.60	600	43.54
358	2.30	890	45.63
380	1.60	1110	47.21

Table 4

Size Characterization of Crushed Network 1 Ore - Passing 10 Mesh

Mesh Size	Screen Opening		Cumulative wt % Passing
	(inches)	(mm or µm)	
10	0.0661	1.700	99.91
16	0.0394	1.000	64.25
20	0.0331	850	54.40
28	0.0234	600	38.16
35	0.0164	417	28.15
48	0.0116	295	20.28
65	0.0082	208	15.04
100	0.0059	150	12.12
150	0.0041	106	8.34
200	0.0029	75	6.19
-200	-0.0029	-75	0.00

Table 5

Network 1 380 Copper → Stir-Tank Test #2
232.1 g Cu Ore @ 3.28 wt % Copper → 7.61288 g Cu Total
580 ml Distilled Water → Sample 100% Minus 10 Mesh

Date	Test Time	Test Time Hours	pH	g Conc. H_2SO_4 Added	Comments Hour Sample Taken
Aug. 5/97	2:00 PM	0	9.20/1.20	13.60	**TEST START**
	3:00 PM	1	1.40	--	1 HR.
	4:30 PM	2.5	1.60	3.70	Add conc. H_2SO_4
Aug. 6/97	8:30 AM	18.5	2.50	5.40	18.5 hr
	4:00 PM	26	1.40	--	26 hr.
Aug. 7/97	8:30 AM	44.5	2.00	4.60	44.5 hr.
	4:00 PM	52	1.40	--	52 hr.
Aug. 8/97	8:00 AM	68	1.90	3.80	68 hr.
	8:00 PM	80	1.50	--	80 hr.
Aug. 9/97	4:30 PM	100.5	1.50	--	100.5 hr.
Aug. 10/97	12:30 PM	120.5	2.50	7.0	120.5 hr.
Aug. 11/97	10:00 AM	142	1.80	--	142 hr.
Aug. 12/97	11:30 PM	167.5	2.10	4.00	167.5 hr. **TEST END**

450 ml primary filtrate
904 ml 10 gpL H_2SO_4 wash
1354 ml Total A#3593

Date	Test Time	Test Time (hours)	pH	g Conc. H_2SO_4 Added	Comments Hour Sample Taken
Aug. 21/97	1:30 PM	167.5	4.70/1.10	5.60	New leachant **RE-START TEST**
	4:00 PM	2.5/170	1.10	--	170 hr.
Aug. 22/97	8:30 AM	19/186.5	1.50	--	186.5 hr.
Aug. 25/97	8:30 AM	91/258.5	2.80	6.40	258.5 hr.
Aug. 26/97	8:30 AM	115/282.5	1.50	--	282.5 hr. **TEST END**

Table 6

Solution-Based Copper Extraction
Test #2 Stir-Tank Testwork → 100% Minus 10 Mesh Feed Material

Test Time (hours)	Solution (pH)	Solution Copper Assay (mg/L)	Solution Based (Cumulative) Copper Extraction (%)
1	1.40	2540	19.35
18.5	2.50	3460	26.36
26	1.40	3400	25.90
44.5	2.00	3660	27.88
52	1.40	3660	27.88
68	1.90	4290	32.68
80	1.50	4300	32.76
100.5	1.50	5220	39.77
120.5	2.50	5450	41.52
142	1.80	5010	38.17
167.5	2.10	5750	43.18
Recover copper from primary and wash filtrate Re-start test with fresh pH = 1.50 to 2.00 H_2SO_4 leachant (500 ml)			
170	1.10	100	44.47
186.5	1.50	240	45.39
258.5	2.80	490	47.03
282.5	1.50	870	49.52

Table 7

Network 1 380 Copper → Column Acid - Leaching Test #3
950 kg of 100% Minus 10 Mesh Material
24L of Tap Water, Commence Test with 50 kg/Tonne H_2SO_4

Date	Time	Test Time (hours)	pH	g Conc. H_2SO_4 Added	Column Pulse/Cycle sec/min	Comments Hr. Sample Taken
Sept. 3/97	1:15 PM	0	7.20/1.20	492.2	--	Add 50 kg/Tonne H_2SO_4 to Start Test
	2:15 PM	1	1.40	--	7/2.5	1 hr.
	4:15 PM	3	1.55	--	7/2.5	3 hr.
Sept. 4/97	8:15 AM	19	2.20	38.90	3.5/2.75	19 hr.
	4:15 PM	27	2.05	38.90	4/2.50	27 hr.
Sept. 5/97	8:15 AM	43	2.25	38.90	7/2.50	43 hr.
	1:15 PM	48	1.95	--	7/2.50	48 hr. **TEST END**

Final Washed/Dry Tailing Weight = 8.75 kg

Table 8

Copper Extraction
Column Acid-Leaching Test #3

Test Time (hours)	Solution pH	Solution Assay (mg/L)		Tailing Assay (wt %)		Cumulative Solution-Based Copper Extraction (%) (%)	Residue-Based Copper Extraction (%) (%)
		Cu	Fe	Cu	Fe		
1	1.40	2090	--	--	--	16.10	--
3	1.55	2720	--	--	--	20.95	--
19	2.20	2810	--	--	--	21.64	--
27	2.05	2670	--	--	--	20.56	--
43	2.25	2550	--	--	--	19.64	--
48	1.95	2500	1720	2.86	7.58	19.26	19.69

Table 9

Size Characterization of Crushed/Ground Network 1 Ore - Passing 65 Mesh

Mesh Size	Screen Opening		Cumulative wt % Passing
	(inches)	(mm or µm)	
48	0.0116	295	99.60
65	0.0082	208	97.60
100	0.0059	150	82.40
150	0.0041	106	57.80
200	0.0029	75	45.50
-200	-0.0029	-75	0.00

Table 10

Network 1 380 Copper → Column Acid-Leaching Test #4
9.25 kg of 100% Minus 65 Mesh Material
18L of Tap Water, Commence Test with 50 kg/Tonne H_2SO_4

Date	Time	Test Time (hours)	pH	g Conc. H_2SO_4 Added	Column Pulse/Cycle sec/min	Comments Hr. Sample Taken
Sept. 18/97	11:30 AM	0	7.20/1.40	481.80	4/7.5	Add 50 kg/Tonne H_2SO_4 to Start Test
	2:00 PM	2.5	1.80	--	4/7.5	2.5 hr.
	4:30 PM	5	2.45	289.10	4/7.5	5 hr.
Sept. 19/97	8:30 AM	21	2.15	192.70	4/5.5	21 hr.
	4:30 PM	29	1.60	--	4/5.5	29 hr.
Sept. 20/97	1:30 PM	50	2.65	--	4/5.75	50 hr.
						TEST END

Final Washed/Dry Tailing Weight = 8.40 kg

Table 11

Copper Extraction
Column Acid-Leaching Test #4

Minus 65 mesh feed material head analysis
3.28 wt % Copper
7.95 wt % Iron

Test Time (hours)	Solution pH	Solution Assay (mg/L)		Tailing Assay (wt %)		Cumulative Solution-Based Copper Extraction (%) (%)	Residue-Based Copper Extraction (%) (%)
		Cu	Fe	Cu	Fe		
2.5	1.80	2710	2590	--	--	16.08	--
5	2.45	2670	2560	--	--	15.84	--
21	2.15	3050	4960	--	--	18.09	--
29	1.60	2950	5500	--	--	17.50	--
50	2.65	2410	5510	2.71	6.78	14.30	24.97