CONTACT INFORMATION
Mining Records Curator
Arizona Geological Survey
416 W. Congress St., Suite 100
Tucson, Arizona 85701
602-771-1601
http://www.azgs.az.gov
inquiries@azgs.az.gov

The following file is part of the A. F. Budge Mining Ltd. Mining Collection

ACCESS STATEMENT

These digitized collections are accessible for purposes of education and research. We have indicated what we know about copyright and rights of privacy, publicity, or trademark. Due to the nature of archival collections, we are not always able to identify this information. We are eager to hear from any rights owners, so that we may obtain accurate information. Upon request, we will remove material from public view while we address a rights issue.

CONSTRAINTS STATEMENT

The Arizona Geological Survey does not claim to control all rights for all materials in its collection. These rights include, but are not limited to: copyright, privacy rights, and cultural protection rights. The User hereby assumes all responsibility for obtaining any rights to use the material in excess of "fair use."

The Survey makes no intellectual property claims to the products created by individual authors in the manuscript collections, except when the author deeded those rights to the Survey or when those authors were employed by the State of Arizona and created intellectual products as a function of their official duties. The Survey does maintain property rights to the physical and digital representations of the works.

QUALITY STATEMENT

The Arizona Geological Survey is not responsible for the accuracy of the records, information, or opinions that may be contained in the files. The Survey collects, catalogs, and archives data on mineral properties regardless of its views of the veracity or accuracy of those data.

Column Leaching
Of
Korn Kob Ore

For

A. F. Budge (Mining) Limited
4301 N. 75th Street
Suit 101
Scottsdale, Arizona 85251

By

Mountain States R & D International, Inc. (MSRDI)
13801 E. Benson Highway
P. O. Box 310
Vail, Arizona 85641

Project No: 5274

Date: May 21, 1990

Prepared by: John McDonald
Vice President and
Project Manager

Approved by: Dr. Roshan B. Bhappu
President
Arizona P.E. License 04144

TABLE OF CONTENTS

SECTION	PAGE NO.
LETTER OF TRANSMITTAL	
INTRODUCTION	1
SUMMARY AND CONCLUSIONS	3
RECOMMENDATIONS	5
DISCUSSION	6

13801 E. BENSON HIGHWAY
P.O. BOX 310
VAIL, ARIZONA 85641

TEL. (602) 762-5364
TUCSON ONLY 624-7990
TELEX 9102502482 MSRD
TELEFAX 602-762-5717

Mountain States R & D International, Inc.

A World Leader in Mineral Technology

728 SPICE ISLANDS DRIVE
SPARKS, NEVADA 89431

TEL. (702) 356-7572
TELEFAX 702-356-7791

May 21, 1990

Mr. Dale Allen
A. F. Budge (Mining) Limited
4301 North 75th Street
Suite 101
Scottsdale, Arizona 85251

Subject: Column Leaching of Korn Kob Ore

Reference: MSRDI Project No. 5274

Dear Mr. Allen:

Mountain States R & D International, Inc. (MSRDI) has completed two, 4 inch diameter column leach tests on agglomerated Korn Kob Ore. The columns designated BM-1 and BM-2 were agglomerated with Nalco Binder 88-DZ-075 and a sulfuric acid solution, respectively. Agglomeration was required because the ore received was taken from highly oxidized surface road-cut material which may not be representative of the ore body. Without agglomeration, leach solutions would not percolate through the columns and pooled on the surface of the ore charge.

Originally, the proposal consisted of a leaching campaign of 30 days. This time period was extended to 45 days for column BM-1 and 41 days for column BM-2. The leaching program was extended to evaluate the effect of increasing the acid concentration of the barren leach solution advancing to BM-1 and to evaluate the effect of a rest cycle upon copper leaching BM-2.

One of the primary objectives of the test work was to achieve maximum copper recovery with minimum acid consumption. The ore body is known to contain lenses of carbonate minerals which are high acid consumers. To inhibit leaching of these carbonate minerals, the initial leach solutions were maintained at low acid

May 21, 1990

levels in an attempt to form a gypsum coating on the gangue that would stabilize this material. The effect of this leaching technique cannot be measured without conducting a mineralogical examination of the leach residue.

MSRDI personnel take this opportunity to thank you for allowing us to conduct this project. We look forward to your comments.

Sincerely,

John McDonald

John McDonald
Vice President and Manager of Projects

JMcD/rrj

INTRODUCTION

In February 1990, Mountain States R & D International, Inc. (MSRDI) received eight, 55 gallon drums of Korn Kob Ore from A. F. Budge (Mining) Limited. This material was a sample taken along the wall of a road cut on the property. The ore was a very fine, highly oxidized material. In preparation for leaching, the drums were composited, coned and quartered three times and a sample split out for crushing to minus one inch.

Four head assays were run on the ore to established the average head grade of 0.538 percent total copper and 0.376 percent acid soluble copper.

An acid consumption test was run on a pulverized sample of Korn Kob Ore. The results of this test were used to establish the maximum quantity of acid the ore would consume.

After crushing, copper assay screen analyses were conducted at 1 inch, 1/2 inch, 1/4 inch, and minus 1/4 inch. The results of these screen analyses demonstrate that the ore used was badly decrepitated.

After establishment of the particle size distribution and acid consumption for the ore, two, 4 inch diameter columns were charged with 15 kilograms of ore. One of the columns was to be cured with 50 percent of the acid required by the acid consumption test. This column was to stand for 7 days prior to leaching. The second 4 inch diameter, 5 foot high, column was to be leached in a

conventional, manner by the application of a 4.5 gpl H_2SO_4 leach solution containing approximately 3.0 gpl ferric iron and 0.09 gpl copper.

When cure solution was applied to the Column BM-1, it pooled and would not percolate through the column. Because pooling occurred during the application of the cure solution, a leach solution flow rate of 0.0045 gal/min/ft_2 could not be maintained and both columns had to be recharged with agglomerated fresh ore. After agglomeration, leaching was conducted for approximately 45 days without percolation problems.

SUMMARY AND CONCLUSIONS

Leaching of Korn Kob ore at Mountain States R & D International, Inc. (MSRDI) has been completed for A. F. Budge (Mining) Limited. Two columns were leached after the ore had been cured with acid. In one of the columns (BM-1) a Nalco reagent was added to assist in the agglomeration of the ore. In an initial test in which the ore was not agglomerated prior to loading into the column, the column was impermeable to the leach solution. Both columns were leached with a solution, made up to approximate the rafinate from a copper solvent extraction plant, for a period of 50 and 46 days for columns BM-1 and BM-2 respectively. The objective of the leach tests were to establish the kinetics of leaching, to develop acid consumption data and to evaluate the use of an agglomeration aid. The results of the test work are summarized below:

- Cumulative copper recovery was 73.33 percent after 50 days in Test BM-1 where an agglomeration aid was used and 73.97 percent after 46 days in Test BM-2. Acid consumption was 16.04 and 15.89 pounds of acid per pound of copper respectively in Tests BM-1 and BM-2. The head assay of the Korn Kob Ore was 0.538 percent copper and the calculated heads were 0.519 and 0.502 percent copper respectively in Tests BM-1 and BM-2.

- The pregnant solution in both tests averaged over 10 grams per liter copper during the initial 40 percent of copper recovery. This high solution grade is due to the acid cure phase before leaching was

started. Solution grades quickly dropped to below 0.5 gpl and averaged 0.7 gpl for the entire test.

- The incremental acid consumption at 70 percent copper recovery was about 50 pounds of acid per pound of copper in both tests.

- The leaching behavior of the Korn Kob Ore is typical of diffusion controlled kinetics where the rate is initially limited by the amount of acid available. If this is the case, both the rate of copper recovery and the copper concentration in the pregnant solution can be enhanced by increasing the acid strength of the leach solution. This, however, will have the disadvantage of increasing the acid consumed per pound of copper recovered.

- Although the acid consumption was higher than would be liked, the high pregnant solution grades and the relatively fast kinetics on minus one inch ore make this ore a candidate for heap or vat leaching.

RECOMMENDATIONS

Because of the high acid consumption of the Korn Kob Ore, it is recommended that a cost estimate be made for heap leaching this ore before any further metallurgical testing is conducted. If it appears that it is economical to leach this ore, then additional leach tests on ore crushed to different top sizes should be conducted to establish the variation of the leaching kinetics with size. At the same time the effect of acid strength on the kinetics should be established.

The data collected in the two column leach tests will allow the estimation of the pregnant solution grades and the rate of copper leaching for various operating conditions such as solution flow rate, heap heights, and acid concentration. Completion of this work would require about 80 additional man-hours.

DISCUSSION

In February 1990, approximately eight, 55 gallon drums of Korn Kob Ore were received by Mountain States R&D International, Inc. (MSRDI) from A. F. Budge (Mining) Limited. The ore was crushed to minus one inch, coned and quartered and two, 15 kilogram samples split out for charging two, 5 foot high, 4 inch diameter, leach columns. One sample was crushed to minus 10 mesh from which 4 samples were split out for the head assay. An additional sample was split out for assay/screen analyses.

The results of the head assay analyses are as follows:

Sample	Cu (%)	A.S. Cu (%)
A	0.544	0.369
B	0.539	0.378
C	0.534	0.391
D	0.535	0.364
Average	0.538	0.376

The analyses performed show that 69.9 percent of the copper is acid soluble. The non-acid soluble copper is thought to be primarily chalcopyrite.

The results of the assay/screen tests are as follows:

Size Fraction Inches	Weight %	Cu %	Cu Distribution %
+0.75	3.22	0.322	1.98
-0.75 +0.5	9.67	0.334	6.35
-0.50 +0.25	17.80	0.302	10.71
-0.25	69.31	0.588	80.96
Calculated Head	100.00	0.504	100.00
Assay Head		0.538	

The results show a slight tendency for the copper to concentrate in the fines which is characteristic of an ore which breaks along the mineral veins. This is an advantage when leaching the ore in heaps or dumps.

Initial column leach tests were not successful because of the column's low permeability. Leach solution would not flow through the column at the required flow rate (0.0045 gal per min. per sq. ft.). As a result, two separate batches (each of 15 kilograms of ore) were agglomerated to enhance the permeability before loading into the columns . In Test BM-1 the ore was agglomerated with 200 ml of a one percent Nalco Binder solution 88-D2-075, plus 69.45 pounds per ton sulfuric acid and sufficient water to bring the moisture in the ore to 10 percent. An acid consumption test indicated that the ore will consume 138.9 pounds of acid, per ton. In Test BM-2 the ore was agglomerated with 69.45 pounds per ton sulfuric acid, plus sufficient water to bring the moisture in the

ore to 10 percent. The ore was then loaded into the columns and after 7 days leach solution was added to the column at the rate of 0.0045 gpm/ft². The leach solution was made up to simulate raffinate from a copper solvent extraction plant and contained 4.48 gpl sulfuric acid, 0.09 gpl copper and 3 gpl ferric iron. After 30 days of leaching the columns were allowed to drain for one day, washed with a weak acid solution for one day, then washed with water for one day. At the request of Budge Mining, the columns were restarted to see if additional copper could be leached by increasing the acid concentration of the leach solution extending the leach time or resting the ore. In this second leach, the leach solution acid concentration was increased to 6.04 gpl. Leaching continued for 15 days and 11 days for tests BM-1 and BM-2 respectively after which the columns were allowed to drain for one day, washed with a weak acid solution for one day and washed with water for one day.

The results of the column leach tests are shown in Tables I and II. Significant data from these tables are presented in Table III and in which a comparison is made between the two column tests. The results indicate that the Nalco reagent probably produced a stronger agglomerate; however, this resulted in a slightly slower leach rate and a correspondingly higher acid consumption. This is consistent with a shrinking core model of leaching in which the diffusion of acid through the leached shell is rate controlling. The 3 tables and 4 figures show:

1. Copper recoveries in excess of 70 percent are attainable in about 30 to 40 days of leaching. The initial rate of leaching is limited by available acid. As leaching progresses, the rate appears to be

controlled by diffusion of acid through the leached shell around each particle. Figures 1 and 2 show the recovery/time relationship for these tests.

Table I - Korn Kob Ore, 1 Inch, 4 Inch Column Leach
Agglomerated with 200 mls. of 1 percent Soln. Nalco and 69.45 Lb./T H2SO4 at 10 percent moisture.

Job No.: 5274
Test No.: BM-1

Date	Preg. No.	Preg. Soln. Vol(ml)	pH	EMF	H2SO4 Feed g/l	H2SO4 Preg. g/l	H2SO4 Consumed Grams	Cum. H2SO4 Consumed Grams	Cu g/l	Fe++ g/l	Fe+++ g/l	Cu Recov. Grams	Cum Cu Recov. Grams	% Cu Recov.	Cum % Cu Recov.	Acid Consumed #/#Cu	Cum H2SO4 Consumed #/#Cu
27-Feb	1	1500	12.3	1650	14.48	0.00	509.97	509.97	17.20	0.13	6.72	25.67	25.67	32.68	32.68	19.87	19.87
28-Feb	2	1810	12.4	1610	14.48	0.15	7.84	517.81	4.74	0.03	1.28	8.42	34.08	10.72	43.39	0.93	15.19
01-Mar	3	2210	12.4	1650	14.48	0.05	9.79	527.60	1.92	0.03	1.04	4.04	38.13	5.15	48.54	2.42	13.84
02-Mar	4	2130	12.4	1640	14.48	0.07	9.39	536.99	1.22	0.03	1.40	2.41	40.53	3.06	51.61	3.90	13.25
03-Mar	5	1930	12.3	1660	14.48	0.05	8.55	545.54	0.81	0.08	1.86	1.39	41.92	1.77	53.38	6.15	13.01
04-Mar	6	2610	12.3	1640	14.48	0.00	11.69	557.23	0.58	0.05	2.76	1.28	43.20	1.63	55.01	9.14	12.90
05-Mar	7	370	12.4	1630	14.48	0.00	1.66	558.89	0.57	0.03	2.89	0.18	43.38	0.23	55.23	9.33	12.88
06-Mar	8	2030	12.4	1650	14.48	0.00	9.09	567.99	0.51	0.05	2.39	0.85	44.23	1.09	56.32	10.67	12.84
07-Mar	9	2160	12.3	1655	14.48	0.00	9.68	577.66	0.47	0.03	3.01	0.82	45.05	1.05	57.36	11.79	12.82
08-Mar	10	2200	12.2	1655	14.48	0.20	9.42	587.08	0.40	0.03	3.16	0.68	45.73	0.87	58.23	13.81	12.84
09-Mar	11	2261	12.3	1610	14.48	0.00	10.13	597.21	0.35	0.03	3.29	0.59	46.32	0.75	58.98	17.23	12.89
10-Mar	12	2170	12.2	1665	14.48	0.10	9.50	606.71	0.35	0.03	3.77	0.56	46.89	0.72	59.70	16.85	12.94
11-Mar	13	2110	12.2	1670	14.48	0.15	9.14	615.85	0.32	0.03	3.85	0.49	47.37	0.62	60.32	18.83	13.00
12-Mar	14	2170	12.2	1670	14.48	0.24	9.20	625.05	0.30	0.03	3.78	0.46	47.83	0.58	60.90	20.19	13.07
13-Mar	15	2100	12.3	1680	14.48	0.17	9.05	634.10	0.28	0.03	3.59	0.40	48.23	0.51	61.40	22.68	13.15
14-Mar	16	2120	12.2	1670	14.48	0.25	8.97	643.07	0.28	0.05	3.72	0.40	48.63	0.51	61.92	22.26	13.22
15-Mar	17	2170	12.2	1670	14.48	0.17	9.35	652.42	0.28	0.03	3.59	0.41	49.04	0.52	62.44	22.68	13.30
16-Mar	18	2310	12.2	1670	14.48	0.34	9.56	661.98	0.26	0.03	3.29	0.39	49.43	0.50	62.94	24.35	13.39
17-Mar	19	1950	12.2	1670	14.48	0.53	7.70	669.69	0.25	0.03	3.08	0.31	49.75	0.40	63.34	24.69	13.46
18-Mar	20	2350	12.2	1670	14.48	0.34	9.73	679.42	0.23	0.03	2.95	0.33	50.08	0.42	63.76	29.57	13.57
19-Mar	21	1800	12.2	1680	14.48	0.43	7.29	686.71	0.22	0.03	3.18	0.23	50.31	0.30	64.06	31.15	13.65
20-Mar	22	2310	12.2	1675	14.48	0.53	9.12	695.83	0.24	0.03	2.48	0.35	50.66	0.44	64.50	26.33	13.74
21-Mar	23	2170	12.1	1675	14.48	0.88	7.81	703.64	0.23	0.03	3.19	0.30	50.96	0.39	64.88	25.71	13.81
22-Mar	24	2210	12.1	1670	14.48	0.48	8.84	712.48	0.21	0.03	3.19	0.27	51.22	0.34	65.22	33.33	13.91
23-Mar	25	2520	12.1	1660	14.48	0.24	10.68	723.17	0.22	0.03	3.19	0.33	51.55	0.42	65.64	32.62	14.03
24-Mar	26	2820	12.1	1650	14.48	0.53	11.14	734.31	0.20	0.03	3.21	0.31	51.86	0.39	66.03	35.91	14.16
25-Mar	27	2465	12.1	1660	14.48	0.44	9.96	744.26	0.21	0.03	3.31	0.30	52.16	0.38	66.41	33.67	14.27
26-Mar	28	1520	12.1	1660	14.48	0.44	6.14	750.41	0.20	0.03	3.38	0.17	52.33	0.21	66.62	36.73	14.34
27-Mar	29	2360	12.1	1670	14.48	0.59	9.18	759.59	0.20	0.01	3.21	0.26	52.58	0.33	66.95	35.36	14.44
28-Mar	30	2300	12.1	1660	14.48	0.41	9.36	768.95	0.20	0.03	3.25	0.25	52.84	0.32	67.28	37.00	14.55
29-Mar	Drain #1	380	12.0	1650	10.00	0.37	-0.14	768.81	0.21	0.03	3.38	0.08	52.92	0.10	67.38	-1.76	14.53
30-Mar	Wash #1	1750	12.1	1615	10.00	0.37	-0.65	768.16	0.22	0.08	2.86	0.39	53.30	0.49	67.87	-1.68	14.41
02-Apr	Drain #2	740	12.1	1585	10.00	0.49	-0.36	767.80	0.19	0.05	2.37	0.14	53.44	0.18	68.05	-2.58	14.37
03-Apr	31	1860	10.7	1610	16.04	0.17	10.92	778.71	0.15	0.04	0.91	0.11	53.55	0.14	68.19	97.83	14.54
04-Apr	32	2330	12.1	1640	16.04	0.29	13.40	792.11	0.18	0.03	2.35	0.21	53.76	0.27	68.46	63.89	14.73
05-Apr	33	2200	11.9	1650	16.04	0.46	12.28	804.39	0.20	0.03	4.09	0.24	54.01	0.31	68.76	50.73	14.89
06-Apr	34	1940	11.9	1675	16.04	0.71	10.34	814.73	0.21	0.03	4.65	0.23	54.24	0.30	69.06	44.42	15.02
07-Apr	35	2450	11.9	1625	16.04	0.73	13.01	827.74	0.20	0.03	4.58	0.27	54.51	0.34	69.40	48.27	15.19
08-Apr	36	1450	11.9	1630	16.04	0.66	7.80	835.54	0.22	0.03	4.25	0.19	54.70	0.24	69.64	41.38	15.28
09-Apr	37	2310	11.9	1645	16.04	0.88	11.92	847.46	0.20	0.03	4.59	0.25	54.95	0.32	69.97	46.91	15.42
10-Apr	38	2950	11.7	1640	16.04	1.29	14.01	861.47	0.19	0.03	4.65	0.30	55.25	0.38	70.34	47.50	15.59
11-Apr	39	2600	11.6	1640	16.04	1.12	12.79	874.26	0.19	0.03	4.34	0.26	55.51	0.33	70.67	49.20	15.75
12-Apr	40	2590	11.7	1630	16.04	1.34	12.17	886.44	0.18	0.01	4.10	0.23	55.74	0.30	70.97	52.22	15.90
13-Apr	41	2800	11.8	1645	16.04	1.78	11.93	898.36	0.18	0.01	4.44	0.25	55.99	0.32	71.29	47.33	16.04
14-Apr	42	2350	11.8	1645	16.04	1.43	10.83	909.20	0.18	0.01	4.46	0.21	56.20	0.27	71.56	51.22	16.18
15-Apr	43	3000	11.8	1650	16.04	1.43	13.83	923.03	0.18	0.01	4.48	0.27	56.47	0.34	71.90	51.22	16.34
16-Apr	44	2130	11.7	1650	16.04	1.51	9.65	932.68	0.18	0.01	4.50	0.19	56.66	0.24	72.15	50.33	16.46
18-Apr	45	3000	11.7	1630	10.61	1.56	-2.85	929.83	0.16	0.01	4.31	0.27	56.93	0.34	72.49	-10.56	16.33
19-Apr	Wash #1	2620			10.00	1.51	-3.96	925.87	0.17	0.13	3.31	0.45	57.38	0.57	73.06	-8.88	16.14
20-Apr	Wash #2	2315			10.00	0.95	-2.20	923.67	0.09	0.03	1.18	0.21	57.59	0.27	73.33	-10.56	16.04

Residue weight = 14756
Feed weight = 15000

residue 0.142 %Cu 20.95
TOTAL Copper 78.54

Calculated head = 0.524 % Cu
Assayed head = 0.536 % Cu

Table II - Korn Kob Ore, 1 Inch, 4 Inch Column Leach
Agglomerated with 69.45 Lb./T H2SO4 at 10 percent moisture.

Job No.: 5274
Test No.: BM-2

Date	Preg. No.	Preg. Soln. Vol(ml)	pH	EMF	H2SO4 Feed g/l	H2SO4 Preg. g/l	H2SO4 Consumed Grams	Cum. H2SO4 Consumed Grams	Cu g/l	Fe++ g/l	Fe+++ g/l	Cu Recov. Grams	Cum Cu Recov. Grams	% Cu Recov.	Cum % Cu Recov.	Acid Consumed #/#Cu	Cum H2SO4 Consumed #/#Cu
27-Feb	1	1450	12.2	1630	14.48	10.10	509.97	509.97	116.00	0.05	6.37	123.07	23.07	30.40	30.40	22.11	22.11
28-Feb	2	2050	12.5	1640	14.48	10.05	9.08	519.05	4.64	0.03	1.82	9.33	32.40	12.29	42.69	0.97	16.02
01-Mar	3	2160	12.5	1670	14.48	10.07	9.53	528.58	1.99	0.03	1.41	4.10	36.50	5.41	48.10	2.32	14.48
02-Mar	4	1630	12.4	1660	14.48	10.07	7.19	535.77	1.44	0.03	1.61	2.20	38.70	2.90	51.00	3.27	13.84
03-Mar	5	2120	12.4	1675	14.48	10.03	9.43	545.20	1.08	0.08	1.94	2.10	40.80	2.77	53.77	4.49	13.36
04-Mar	6	2830	12.4	1640	14.48	10.00	12.68	557.88	0.69	0.05	2.68	1.70	42.50	2.24	56.00	7.47	13.13
05-Mar	7	1940	12.4	1670	14.48	10.00	8.69	566.57	0.59	0.03	2.74	0.97	43.47	1.28	57.28	8.96	13.03
06-Mar	8	2220	12.3	1670	14.48	10.00	9.95	576.51	0.51	0.05	2.83	0.93	44.40	1.23	58.51	10.67	12.98
07-Mar	9	2030	12.3	1680	14.48	10.03	9.03	585.55	0.46	0.03	2.84	0.75	45.15	0.99	59.50	12.03	12.97
08-Mar	10	2190	12.3	1660	14.48	10.00	8.06	593.61	0.40	0.03	2.84	0.68	45.83	0.89	60.40	11.87	12.95
09-Mar	11	2260	12.3	1660	14.48	10.00	10.12	603.73	0.36	0.03	3.29	0.61	46.44	0.80	61.20	16.59	13.00
10-Mar	12	2200	12.2	1675	14.48	10.19	9.44	613.17	0.32	0.03	3.98	0.51	46.95	0.67	61.87	18.65	13.06
11-Mar	13	2140	12.2	1685	14.48	10.10	9.37	622.54	0.31	0.03	3.75	0.47	47.42	0.62	62.49	19.91	13.13
12-Mar	14	2220	12.2	1680	14.48	10.39	9.08	631.62	0.29	0.03	3.63	0.44	47.86	0.59	63.07	20.45	13.20
13-Mar	15	2150	12.2	1690	14.48	10.34	8.90	640.52	0.26	0.03	3.28	0.37	48.23	0.48	63.55	24.35	13.28
14-Mar	16	2140	12.2	1690	14.48	10.39	8.75	649.28	0.26	0.03	3.51	0.36	48.59	0.48	64.03	24.06	13.36
15-Mar	17	2210	12.2	1685	14.48	10.25	9.35	658.63	0.26	0.03	3.39	0.38	48.97	0.50	64.53	24.88	13.45
16-Mar	18	2490	12.1	1680	14.48	10.36	10.26	668.88	0.24	0.03	3.00	0.37	49.34	0.49	65.02	27.47	13.56
17-Mar	19	2200	12.1	1685	14.48	10.48	8.80	677.68	0.24	0.03	3.31	0.33	49.67	0.43	65.46	26.67	13.64
18-Mar	20	2435	12.1	1690	14.48	10.43	9.86	687.55	0.23	0.03	2.89	0.34	50.01	0.45	65.91	28.93	13.75
19-Mar	21	1820	12.1	1700	14.48	10.53	7.19	694.73	0.22	0.03	3.01	0.24	50.25	0.31	66.22	30.38	13.83
20-Mar	22	2350	12.1	1690	14.48	10.34	9.73	704.46	0.23	0.03	2.49	0.33	50.58	0.43	66.65	29.57	13.93
21-Mar	23	2190	12.1	1680	14.48	10.48	8.76	713.22	0.22	0.03	3.20	0.28	50.86	0.38	67.03	30.77	14.02
22-Mar	24	2230	12.0	1660	14.48	10.48	8.92	722.14	0.22	0.03	3.31	0.29	51.15	0.38	67.41	30.77	14.12
23-Mar	25	2560	12.0	1650	14.48	10.39	10.47	732.61	0.21	0.03	3.28	0.31	51.46	0.40	67.81	34.08	14.24
24-Mar	26	2800	12.0	1660	14.48	10.56	10.98	743.59	0.20	0.03	3.20	0.31	51.77	0.41	68.22	35.64	14.36
25-Mar	27	2450	12.0	1650	14.48	10.63	9.43	753.02	0.19	0.03	3.19	0.25	52.01	0.32	68.54	38.50	14.48
26-Mar	28	1550	12.0	1670	14.48	10.73	5.81	758.83	0.19	0.03	3.19	0.16	52.17	0.20	68.75	37.50	14.55
27-Mar	29	2360	12.0	1680	14.48	10.78	8.73	767.57	0.18	0.01	3.30	0.21	52.38	0.28	69.03	41.11	14.65
28-Mar	30	2300	12.0	1675	14.48	10.71	8.67	776.24	0.19	0.03	3.29	0.23	52.61	0.30	69.33	37.70	14.75
29-Mar	Drain	360	12.0	1670	14.48	11.00	1.25	777.49	0.20	0.03	3.29	0.07	52.68	0.09	69.42	17.40	14.76
30-Mar	Wash	1675	12.1	1630	10.84	10.46	0.71	778.20	0.19	0.08	2.68	0.36	53.04	0.47	69.89	2.00	14.67
02-Apr	Drain	660	12.1	1610	10.00	10.90	-0.59	777.61	0.16	0.05	1.86	0.11	53.14	0.14	70.03	-5.63	14.63
07-Apr	31	2050	12.3	1630	16.04	10.24	11.89	789.50	0.15	0.03	0.68	0.12	53.27	0.16	70.19	96.67	14.82
08-Apr	32	1940	12.1	1640	16.04	10.24	11.25	800.75	0.20	0.03	2.48	0.21	53.48	0.28	70.48	52.73	14.97
09-Apr	33	1900	12.0	1650	16.04	10.44	10.64	811.39	0.20	0.03	4.17	0.21	53.69	0.28	70.75	50.91	15.11
10-Apr	34	2850	11.7	1635	16.04	10.85	14.79	826.18	0.19	0.03	4.37	0.29	53.97	0.38	71.13	51.90	15.31
11-Apr	35	2550	11.7	1645	16.04	10.95	12.98	839.16	0.18	0.03	4.46	0.23	54.20	0.30	71.43	56.56	15.48
12-Apr	36	2550	11.7	1630	16.04	11.34	11.99	851.15	0.17	0.01	4.43	0.20	54.41	0.27	71.70	58.75	15.64
13-Apr	37	2770	11.7	1650	16.04	11.56	12.41	863.56	0.18	0.01	4.39	0.25	54.66	0.33	72.03	49.78	15.80
14-Apr	38	2525	11.8	1650	16.04	11.43	11.64	875.20	0.17	0.01	4.11	0.20	54.86	0.27	72.29	57.62	15.95
15-Apr	39	2850	11.7	1655	16.04	11.58	12.71	887.91	0.17	0.01	4.36	0.23	55.09	0.30	72.59	55.75	16.12
16-Apr	40	2230	11.8	1660	16.04	11.44	10.26	898.17	0.18	0.01	4.63	0.20	55.29	0.26	72.86	51.11	16.25
17-Apr	41	2700	11.6	1630	10.68	11.49	-1.65	896.52	0.16	0.01	4.49	0.24	55.53	0.32	73.18	-6.78	16.14
18-Apr	Wash	2460			10.00	11.29	-3.17	893.35	0.16	0.13	2.99	0.39	55.92	0.52	73.70	-8.06	15.97
19-Apr	Wash	2100			10.00	10.77	-1.62	891.73	0.10	0.01	1.23	0.21	56.13	0.28	73.97	-7.70	15.89

Residue weight 14739 grams, residue 0.134 % Cu 19.75
TOTAL 75.88

Feed starting weight 15000 grams

Calculated head = 0.506 % Cu
Assayed head = 0.538 % Cu

Table III

Summary of Column Leach Test Results

Recovery %	Time, Days		Ave. Preg., gpl Cu		Incremental Preg Grade, gpl Cu		Ave. Acid Cons. Lb./Lb. Cu		Incremental Acid Cons. Lb./Lb. Cu	
	BM-1	BM-2	BM-1	BM-2	BM-1	BM-2	BM-1	BM-2	BM-1	BM-2
43	2	2	10.3	9.3	4.74	4.64	15	16	—	—
48	3	3	6.9	6.4	1.92	1.99	14	14	2.4	2.3
51	4	4	5.3	5.3	1.22	1.44	13	14	3.9	3.3
55	6	5	3.5	4.3	0.58	1.08	13	13	9.1	4.5
60	12	9	2.0	2.4	0.35	0.46	13	13	17	12
65	22	17	1.13	1.36	0.24	0.26	14	13	26	25
70	40	31	0.68	0.80	0.20	0.20	16	15	47	32

FIGURE 1

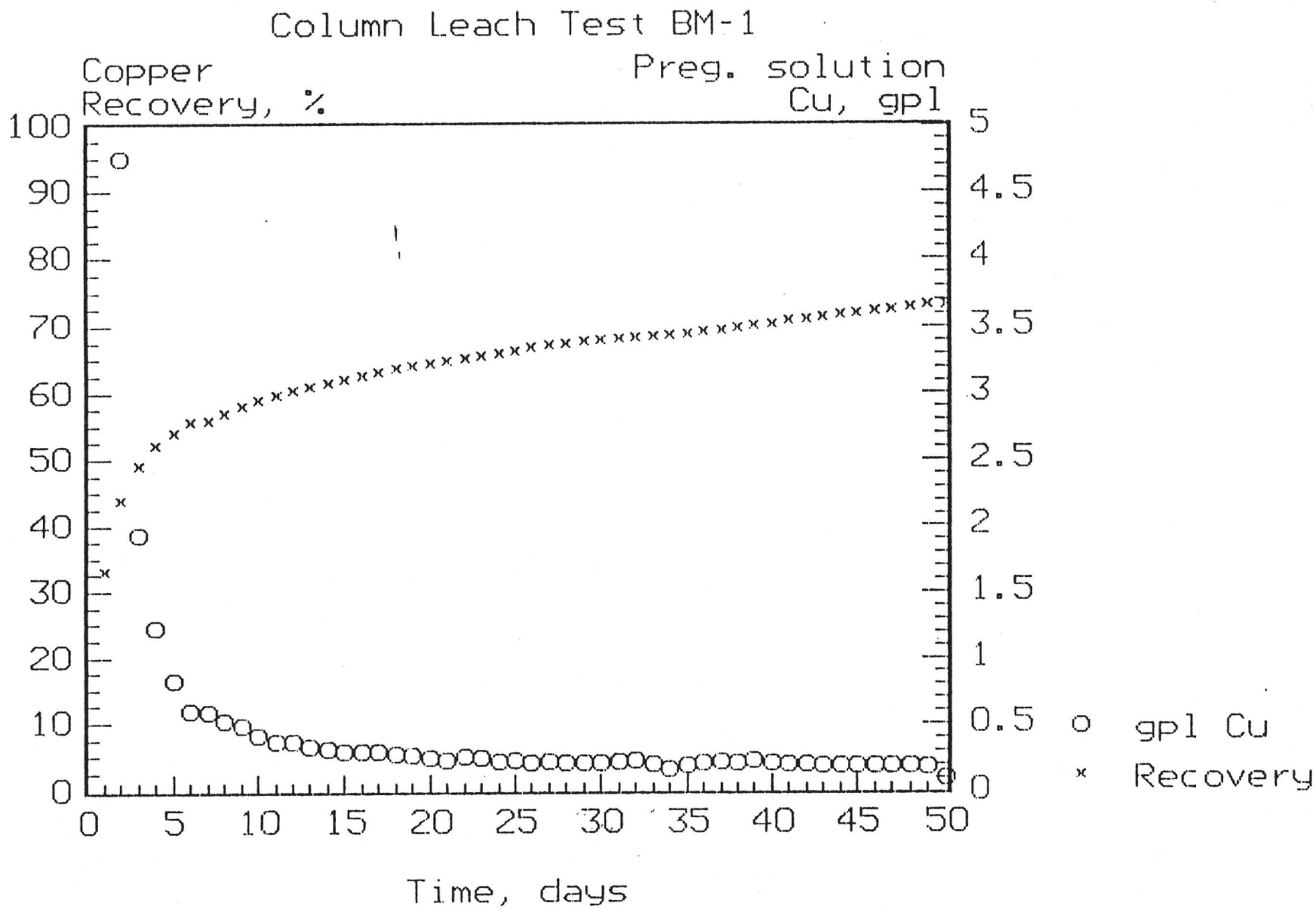
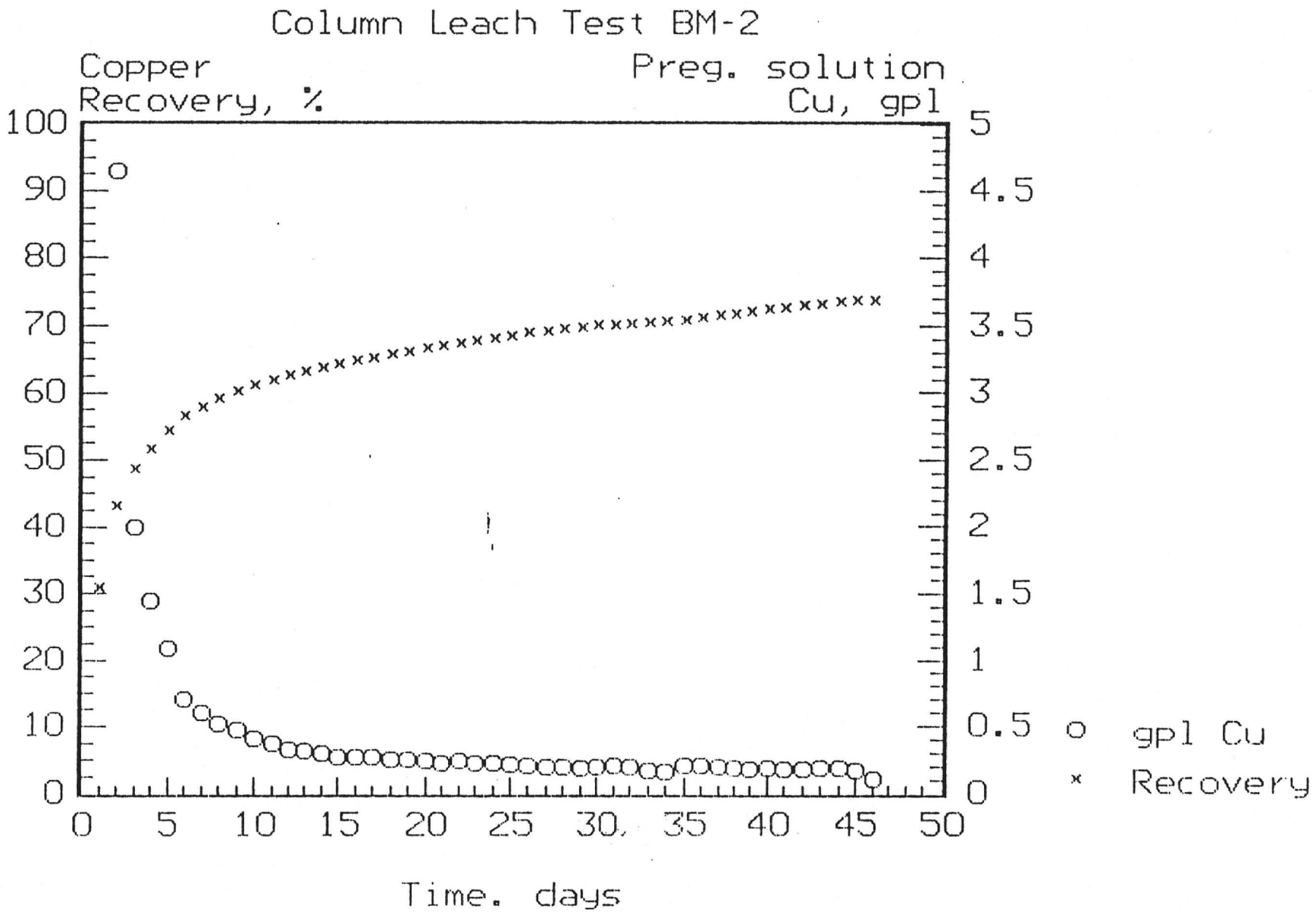

Column Leach Test BM-1
Copper Recovery, %
Preg. solution Cu, gpl
100
90
80
70
60
50
40
30
20
10
0
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
0
5
10
15
20
25
30
35
40
45
50
Time, days
o gpl Cu
× Recovery

FIGURE 2


Column Leach Test BM-2
Copper Recovery, %
Preg. solution Cu, gpl
100
90
80
70
60
50
40
30
20
10
0
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
0 5 10 15 20 25 30 35 40 45 50
Time. days
o gpl Cu
x Recovery

2. Pregnant solution grades were above 10 gpl copper initially then drop to below 0.3 gpl as recovery exceeds 60 percent. The average pregnant solution grade is about 4 gpl until the recovery exceeds 45 percent. The incremental pregnant solution grade is shown in Figures 1 an 2.

3. Incremental acid consumption is initially about 14 pounds of acid per pound of copper but increases to above 30 pounds of acid per pound of copper as copper recovery exceeds 60 percent. The acid cure enhances the initial copper recovery and can be credited for the high average pregnant solution grades.

   Figures 3 and 4 show the relationship between the incremental acid consumption and copper recovery. Data for those days following column shut down were not included in the figures as they do not represent typical data. The curve drawn is an exponential curve and slightly exaggerates the trend.

4. Even in the later stages of leaching, acid in the leach solution was almost completely consumed as the leach solution passed though the column. Increasing the height of the column would allow a higher strength leach solution to be used and a higher grade pregnant solution to be obtained. This would have a tendency to increase the acid consumption but the trade off would be the higher grade pregnant solution at recoveries above 60 percent.

FIGURE 3

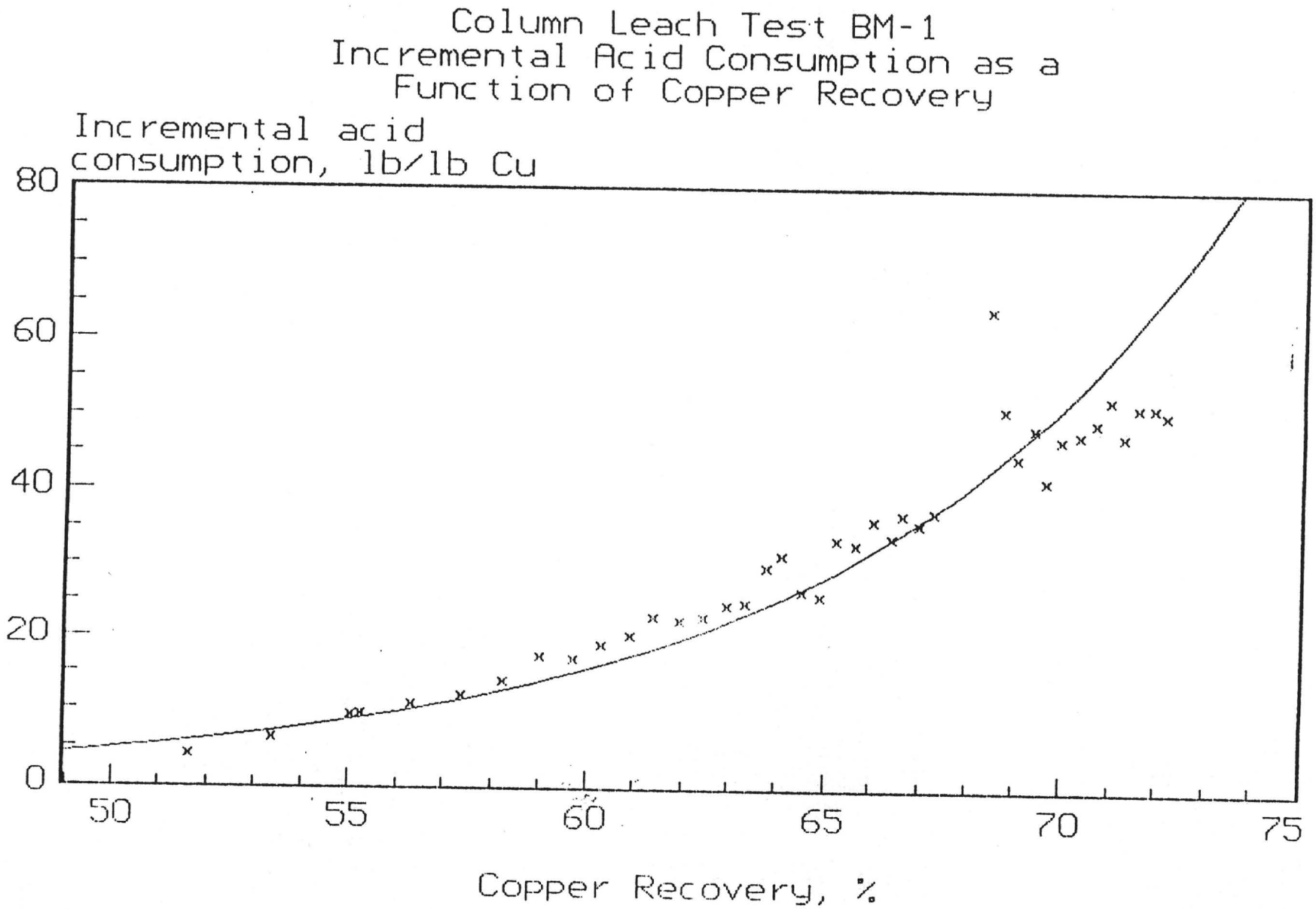
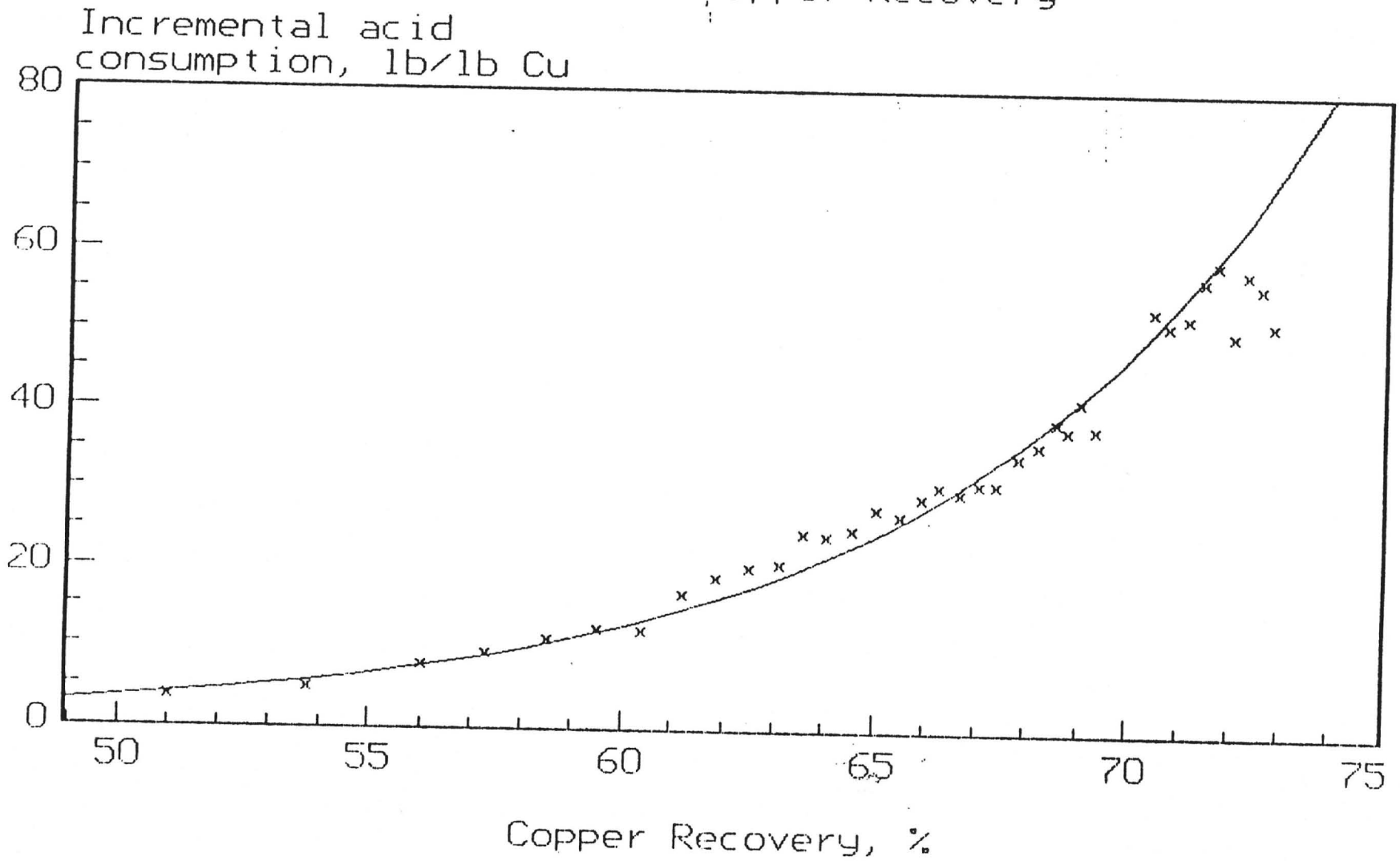

Column Leach Test BM-1
Incremental Acid Consumption as a
Function of Copper Recovery
Incremental acid
consumption, lb/lb Cu
80
60
40
20
0
50
55
60
65
70
75
Copper Recovery, %

FIGURE 4

Column Leach Test BM-2
Incremental Acid Consumption as a
Function of Copper Recovery



If the shrinking core model holds for this ore, several predictions as to the behavior of the ore under various leaching conditions can be made:

1) Increasing the acid strength of the leach solution will enhance the leaching rate but at the expense of higher acid consumption.

2) Increased leach solution flow rate will probably increase the recovery rate. Pregnant solution strength and acid consumption will remain the same.

3) Finer crushing of representative ore will markedly increase the rate of leaching for recoveries above 50 percent and at the same time reduce the acid consumption. The initial rate of leaching would not be affected as this is directly dependent only on the acid content of the leach solution.

4) Agitation leaching of the ore will result in the lowest acid consumption, however, the recovery will be limited to the acid soluble copper whereas in heap leaching some of the non-acid soluble copper does leach.

At the conclusion of the leach test it was planned to do an assay/screen analyses on the leached residue to determine the recovery as a function of particle size. The agglomeration resulted in hard lumps of agglomerated ore which would make the results of this test meaningless. The particle

size/recovery relationship can be predicted if the shrinking core model is assumed. The time to attain a given recovery would be proportional to the square of the particle diameter.

mountain states research & development

Project No. 5274 | Date 2-23-90 | Sample ID Row Rob Ore | Test No.

METALLURGICAL RESULTS

Product	Weight (%)	% Cu	% Cu	Distribution % Cu
+ 3/4"	3.22	0.322	0.010	1.98
+ 1/2"	9.67	0.334	0.032	6.35
+ 1/4"	17.80	0.302	0.054	10.71
− 1/4"	69.31	0.588	0.408	80.76
Head (Calc.)			0.504	100.00
Head Assay*			0.538	

Remarks: *

Column Leaching
Of
Korn Kob Ore

For

A. F. Budge (Mining) Limited
4301 N. 75th Street
Suit 101
Scottsdale, Arizona 85251

By

Mountain States R & D International, Inc. (MSRDI)
13801 E. Benson Highway
P. O. Box 310
Vail, Arizona 85641

Project No: 5274

Date: May 21, 1990

Prepared by: John McDonald
John McDonald
Vice President and
Project Manager

Approved by: Roshan B. Bhappu
Dr. Roshan B. Bhappu
President
Arizona P.E. License 04144

TABLE OF CONTENTS

SECTION	PAGE NO.
LETTER OF TRANSMITTAL	
INTRODUCTION	1
SUMMARY AND CONCLUSIONS	3
RECOMMENDATIONS	5
DISCUSSION	6

13801 E. BENSON HIGHWAY
P.O. BOX 310
VAIL, ARIZONA 85641

TEL. (602) 762-5364
TUCSON ONLY 624-7990
TELEX 9102502482 MSRD
TELEFAX 602-762-5717

Mountain States R & D International, Inc.

A World Leader in Mineral Technology

728 SPICE ISLANDS DRIVE
SPARKS, NEVADA 89431

TEL. (702) 356-7572
TELEFAX 702-356-7791

May 21, 1990

Mr. Dale Allen
A. F. Budge (Mining) Limited
4301 North 75th Street
Suite 101
Scottsdale, Arizona 85251

Subject: Column Leaching of Korn Kob Ore

Reference: MSRDI Project No. 5274

Dear Mr. Allen:

Mountain States R & D International, Inc. (MSRDI) has completed two, 4 inch diameter column leach tests on agglomerated Korn Kob Ore. The columns designated BM-1 and BM-2 were agglomerated with Nalco Binder 88-DZ-075 and a sulfuric acid solution, respectively. Agglomeration was required because the ore received was taken from highly oxidized surface road-cut material which may not be representative of the ore body. Without agglomeration, leach solutions would not percolate through the columns and pooled on the surface of the ore charge.

Originally, the proposal consisted of a leaching campaign of 30 days. This time period was extended to 45 days for column BM-1 and 41 days for column BM-2. The leaching program was extended to evaluate the effect of increasing the acid concentration of the barren leach solution advancing to BM-1 and to evaluate the effect of a rest cycle upon copper leaching BM-2.

One of the primary objectives of the test work was to achieve maximum copper recovery with minimum acid consumption. The ore body is known to contain lenses of carbonate minerals which are high acid consumers. To inhibit leaching of these carbonate minerals, the initial leach solutions were maintained at low acid

May 21, 1990

levels in an attempt to form a gypsum coating on the gangue that would stabilize this material. The effect of this leaching technique cannot be measured without conducting a mineralogical examination of the leach residue.

MSRDI personnel take this opportunity to thank you for allowing us to conduct this project. We look forward to your comments.

Sincerely,

John McDonald

John McDonald
Vice President and Manager of Projects

JMcD/rrj

INTRODUCTION

In February 1990, Mountain States R & D International, Inc. (MSRDI) received eight, 55 gallon drums of Korn Kob Ore from A. F. Budge (Mining) Limited. This material was a sample taken along the wall of a road cut on the property. The ore was a very fine, highly oxidized material. In preparation for leaching, the drums were composited, coned and quartered three times and a sample split out for crushing to minus one inch.

Four head assays were run on the ore to established the average head grade of 0.538 percent total copper and 0.376 percent acid soluble copper.

An acid consumption test was run on a pulverized sample of Korn Kob Ore. The results of this test were used to establish the maximum quantity of acid the ore would consume.

After crushing, copper assay screen analyses were conducted at 1 inch, 1/2 inch, 1/4 inch, and minus 1/4 inch. The results of these screen analyses demonstrate that the ore used was badly decrepitated.

After establishment of the particle size distribution and acid consumption for the ore, two, 4 inch diameter columns were charged with 15 kilograms of ore. One of the columns was to be cured with 50 percent of the acid required by the acid consumption test. This column was to stand for 7 days prior to leaching. The second 4 inch diameter, 5 foot high, column was to be leached in a

conventional, manner by the application of a 4.5 gpl H_2SO_4 leach solution containing approximately 3.0 gpl ferric iron and 0.09 gpl copper.

When cure solution was applied to the Column BM-1, it pooled and would not percolate through the column. Because pooling occurred during the application of the cure solution, a leach solution flow rate of 0.0045 gal/min/ft_2 could not be maintained and both columns had to be recharged with agglomerated fresh ore. After agglomeration, leaching was conducted for approximately 45 days without percolation problems.

SUMMARY AND CONCLUSIONS

Leaching of Korn Kob ore at Mountain States R & D International, Inc. (MSRDI) has been completed for A. F. Budge (Mining) Limited. Two columns were leached after the ore had been cured with acid. In one of the columns (BM-1) a Nalco reagent was added to assist in the agglomeration of the ore. In an initial test in which the ore was not agglomerated prior to loading into the column, the column was impermeable to the leach solution. Both columns were leached with a solution, made up to approximate the rafinate from a copper solvent extraction plant, for a period of 50 and 46 days for columns BM-1 and BM-2 respectively. The objective of the leach tests were to establish the kinetics of leaching, to develop acid consumption data and to evaluate the use of an agglomeration aid. The results of the test work are summarized below:

- Cumulative copper recovery was 73.33 percent after 50 days in Test BM-1 where an agglomeration aid was used and 73.97 percent after 46 days in Test BM-2. Acid consumption was 16.04 and 15.89 pounds of acid per pound of copper respectively in Tests BM-1 and BM-2. The head assay of the Korn Kob Ore was 0.538 percent copper and the calculated heads were 0.519 and 0.502 percent copper respectively in Tests BM-1 and BM-2.

- The pregnant solution in both tests averaged over 10 grams per liter copper during the initial 40 percent of copper recovery. This high solution grade is due to the acid cure phase before leaching was

started. Solution grades quickly dropped to below 0.5 gpl and averaged 0.7 gpl for the entire test.

- The incremental acid consumption at 70 percent copper recovery was about 50 pounds of acid per pound of copper in both tests.

- The leaching behavior of the Korn Kob Ore is typical of diffusion controlled kinetics where the rate is initially limited by the amount of acid available. If this is the case, both the rate of copper recovery and the copper concentration in the pregnant solution can be enhanced by increasing the acid strength of the leach solution. This, however, will have the disadvantage of increasing the acid consumed per pound of copper recovered.

- Although the acid consumption was higher than would be liked, the high pregnant solution grades and the relatively fast kinetics on minus one inch ore make this ore a candidate for heap or vat leaching.

RECOMMENDATIONS

Because of the high acid consumption of the Korn Kob Ore, it is recommended that a cost estimate be made for heap leaching this ore before any further metallurgical testing is conducted. If it appears that it is economical to leach this ore, then additional leach tests on ore crushed to different top sizes should be conducted to establish the variation of the leaching kinetics with size. At the same time the effect of acid strength on the kinetics should be established.

The data collected in the two column leach tests will allow the estimation of the pregnant solution grades and the rate of copper leaching for various operating conditions such as solution flow rate, heap heights, and acid concentration. Completion of this work would require about 80 additional man-hours.

DISCUSSION

In February 1990, approximately eight, 55 gallon drums of Korn Kob Ore were received by Mountain States R&D International, Inc. (MSRDI) from A. F. Budge (Mining) Limited. The ore was crushed to minus one inch, coned and quartered and two, 15 kilogram samples split out for charging two, 5 foot high, 4 inch diameter, leach columns. One sample was crushed to minus 10 mesh from which 4 samples were split out for the head assay. An additional sample was split out for assay/screen analyses.

The results of the head assay analyses are as follows:

Sample	Cu (%)	A.S. Cu (%)
A	0.544	0.369
B	0.539	0.378
C	0.534	0.391
D	0.535	0.364
Average	0.538	0.376

The analyses performed show that 69.9 percent of the copper is acid soluble. The non-acid soluble copper is thought to be primarily chalcopyrite.

The results of the assay/screen tests are as follows:

Size Fraction Inches	Weight %	Cu %	Cu Distribution %
+0.75	3.22	0.322	1.98
-0.75 +0.5	9.67	0.334	6.35
-0.50 +0.25	17.80	0.302	10.71
-0.25	69.31	0.588	80.96
Calculated Head	100.00	0.504	100.00
Assay Head		0.538	

The results show a slight tendency for the copper to concentrate in the fines which is characteristic of an ore which breaks along the mineral veins. This is an advantage when leaching the ore in heaps or dumps.

Initial column leach tests were not successful because of the column's low permeability. Leach solution would not flow through the column at the required flow rate (0.0045 gal per min. per sq. ft.). As a result, two separate batches (each of 15 kilograms of ore) were agglomerated to enhance the permeability before loading into the columns . In Test BM-1 the ore was agglomerated with 200 ml of a one percent Nalco Binder solution 88-D2-075, plus 69.45 pounds per ton sulfuric acid and sufficient water to bring the moisture in the ore to 10 percent. An acid consumption test indicated that the ore will consume 138.9 pounds of acid, per ton. In Test BM-2 the ore was agglomerated with 69.45 pounds per ton sulfuric acid, plus sufficient water to bring the moisture in the

ore to 10 percent. The ore was then loaded into the columns and after 7 days leach solution was added to the column at the rate of 0.0045 gpm/ft². The leach solution was made up to simulate raffinate from a copper solvent extraction plant and contained 4.48 gpl sulfuric acid, 0.09 gpl copper and 3 gpl ferric iron. After 30 days of leaching the columns were allowed to drain for one day, washed with a weak acid solution for one day, then washed with water for one day. At the request of Budge Mining, the columns were restarted to see if additional copper could be leached by increasing the acid concentration of the leach solution extending the leach time or resting the ore. In this second leach, the leach solution acid concentration was increased to 6.04 gpl. Leaching continued for 15 days and 11 days for tests BM-1 and BM-2 respectively after which the columns were allowed to drain for one day, washed with a weak acid solution for one day and washed with water for one day.

The results of the column leach tests are shown in Tables I and II. Significant data from these tables are presented in Table III and in which a comparison is made between the two column tests. The results indicate that the Nalco reagent probably produced a stronger agglomerate; however, this resulted in a slightly slower leach rate and a correspondingly higher acid consumption. This is consistent with a shrinking core model of leaching in which the diffusion of acid through the leached shell is rate controlling. The 3 tables and 4 figures show:

1. Copper recoveries in excess of 70 percent are attainable in about 30 to 40 days of leaching. The initial rate of leaching is limited by available acid. As leaching progresses, the rate appears to be

controlled by diffusion of acid through the leached shell around each particle. Figures 1 and 2 show the recovery/time relationship for these tests.

Table I - Korn Kob Ore, 1 Inch, 4 Inch Column Leach
Agglomerated with 200 mls. of 1 percent Soln. Nalco and 69.45 Lb./T H2SO4 at 10 percent moisture.

Job No.: 5274
Test No.: BM-1

Date	Preg. No.	Preg. Soln. Vol(ml)	pH	EMF	H2SO4 Feed g/l	H2SO4 Preg. g/l	H2SO4 Consumed Grams	Cum. H2SO4 Consumed Grams	Cu g/l	Fe++ g/l	Fe+++ g/l	Cu Recov. Grams	Cum Cu Recov. Grams	% Cu Recov.	Cum % Cu Recov.	Acid Consumed #/#Cu	Cum H2SO4 Consumed #/#Cu
27-Feb	1	1500	12.3	1650	14.48	0.00	509.97	509.97	17.20	0.13	6.72	25.67	25.67	32.68	32.68	19.87	19.87
28-Feb	2	1810	12.4	1610	14.48	0.15	7.84	517.81	4.74	0.03	1.28	8.42	34.08	10.72	43.39	0.93	15.19
01-Mar	3	2210	12.4	1650	14.48	0.05	9.79	527.60	1.92	0.03	1.04	4.04	38.13	5.15	48.54	2.42	13.84
02-Mar	4	2130	12.4	1640	14.48	0.07	9.39	536.99	1.22	0.03	1.40	2.41	40.53	3.06	51.61	3.90	13.25
03-Mar	5	1930	12.3	1660	14.48	0.05	8.55	545.54	0.81	0.08	1.86	1.39	41.92	1.77	53.38	6.15	13.01
04-Mar	6	2610	12.3	1640	14.48	0.00	11.69	557.23	0.58	0.05	2.76	1.28	43.20	1.63	55.01	9.14	12.90
05-Mar	7	370	12.4	1630	14.48	0.00	1.66	558.89	0.57	0.03	2.89	0.18	43.38	0.23	55.23	9.33	12.88
06-Mar	8	2030	12.4	1650	14.48	0.00	9.09	567.99	0.51	0.05	2.39	0.85	44.23	1.09	56.32	10.67	12.84
07-Mar	9	2160	12.3	1655	14.48	0.00	9.68	577.66	0.47	0.03	3.01	0.82	45.05	1.05	57.36	11.79	12.82
08-Mar	10	2200	12.2	1655	14.48	0.20	9.42	587.08	0.40	0.03	3.16	0.68	45.73	0.87	58.23	13.81	12.84
09-Mar	11	2261	12.3	1610	14.48	0.00	10.13	597.21	0.35	0.03	3.29	0.59	46.32	0.75	58.98	17.23	12.89
10-Mar	12	2170	12.2	1665	14.48	0.10	9.50	606.71	0.35	0.03	3.77	0.56	46.89	0.72	59.70	16.85	12.94
11-Mar	13	2110	12.2	1670	14.48	0.15	9.14	615.85	0.32	0.03	3.85	0.49	47.37	0.62	60.32	18.83	13.00
12-Mar	14	2170	12.2	1670	14.48	0.24	9.20	625.05	0.30	0.03	3.78	0.46	47.83	0.58	60.90	20.19	13.07
13-Mar	15	2100	12.3	1680	14.48	0.17	9.05	634.10	0.28	0.03	3.59	0.40	48.23	0.51	61.40	22.68	13.15
14-Mar	16	2120	12.2	1670	14.48	0.25	8.97	643.07	0.28	0.05	3.72	0.40	48.63	0.51	61.92	22.26	13.22
15-Mar	17	2170	12.2	1670	14.48	0.17	9.35	652.42	0.28	0.03	3.59	0.41	49.04	0.52	62.44	22.68	13.30
16-Mar	18	2310	12.2	1670	14.48	0.34	9.56	661.98	0.26	0.03	3.29	0.39	49.43	0.50	62.94	24.35	13.39
17-Mar	19	1950	12.2	1670	14.48	0.53	7.70	669.69	0.25	0.03	3.08	0.31	49.75	0.40	63.34	24.69	13.46
18-Mar	20	2350	12.2	1670	14.48	0.34	9.73	679.42	0.23	0.03	2.95	0.33	50.08	0.42	63.76	29.57	13.57
19-Mar	21	1800	12.2	1680	14.48	0.43	7.29	686.71	0.22	0.03	3.18	0.23	50.31	0.30	64.06	31.15	13.65
20-Mar	22	2310	12.2	1675	14.48	0.53	9.12	695.83	0.24	0.03	2.48	0.35	50.66	0.44	64.50	26.33	13.74
21-Mar	23	2170	12.1	1675	14.48	0.88	7.81	703.64	0.23	0.03	3.19	0.30	50.96	0.39	64.88	25.71	13.81
22-Mar	24	2210	12.1	1670	14.48	0.48	8.84	712.48	0.21	0.03	3.19	0.27	51.22	0.34	65.22	33.33	13.91
23-Mar	25	2520	12.1	1660	14.48	0.24	10.68	723.17	0.22	0.03	3.19	0.33	51.55	0.42	65.64	32.62	14.03
24-Mar	26	2820	12.1	1650	14.48	0.53	11.14	734.31	0.20	0.03	3.21	0.31	51.86	0.39	66.03	35.91	14.16
25-Mar	27	2465	12.1	1660	14.48	0.44	9.96	744.26	0.21	0.03	3.31	0.30	52.16	0.38	66.41	33.67	14.27
26-Mar	28	1520	12.1	1660	14.48	0.44	6.14	750.41	0.20	0.03	3.38	0.17	52.33	0.21	66.62	36.73	14.34
27-Mar	29	2360	12.1	1670	14.48	0.59	9.18	759.59	0.20	0.01	3.21	0.26	52.58	0.33	66.95	35.36	14.44
28-Mar	30	2300	12.1	1660	14.48	0.41	9.36	768.95	0.20	0.03	3.25	0.25	52.84	0.32	67.28	37.00	14.55
29-Mar	Drain #1	380	12.0	1650	10.00	0.37	-0.14	768.81	0.21	0.03	3.38	0.08	52.92	0.10	67.38	-1.76	14.53
30-Mar	Wash #1	1750	12.1	1615	10.00	0.37	-0.65	768.16	0.22	0.08	2.86	0.39	53.30	0.49	67.87	-1.68	14.41
02-Apr	Drain #2	740	12.1	1585	10.00	0.49	-0.36	767.80	0.19	0.05	2.37	0.14	53.44	0.18	68.05	-2.58	14.37
03-Apr	31	1860	10.7	1610	16.04	0.17	10.92	778.71	0.15	0.04	0.91	0.11	53.55	0.14	68.19	97.83	14.54
04-Apr	32	2330	12.1	1640	16.04	0.29	13.40	792.11	0.18	0.03	2.35	0.21	53.76	0.27	68.46	63.89	14.73
05-Apr	33	2200	11.9	1650	16.04	0.46	12.28	804.39	0.20	0.03	4.09	0.24	54.01	0.31	68.76	50.73	14.89
06-Apr	34	1940	11.9	1675	16.04	0.71	10.34	814.73	0.21	0.03	4.65	0.23	54.24	0.30	69.06	44.42	15.02
07-Apr	35	2450	11.9	1625	16.04	0.73	13.01	827.74	0.20	0.03	4.58	0.27	54.51	0.34	69.40	48.27	15.19
08-Apr	36	1450	11.9	1630	16.04	0.66	7.80	835.54	0.22	0.03	4.25	0.19	54.70	0.24	69.64	41.38	15.28
09-Apr	37	2310	11.9	1645	16.04	0.88	11.92	847.46	0.20	0.03	4.59	0.25	54.95	0.32	69.97	46.91	15.42
10-Apr	38	2950	11.7	1640	16.04	1.29	14.01	861.47	0.19	0.03	4.65	0.30	55.25	0.38	70.34	47.50	15.59
11-Apr	39	2600	11.6	1640	16.04	1.12	12.79	874.26	0.19	0.03	4.34	0.26	55.51	0.33	70.67	49.20	15.75
12-Apr	40	2590	11.7	1630	16.04	1.34	12.17	886.44	0.18	0.01	4.10	0.23	55.74	0.30	70.97	52.22	15.90
13-Apr	41	2800	11.8	1645	16.04	1.78	11.93	898.36	0.18	0.01	4.44	0.25	55.99	0.32	71.29	47.33	16.04
14-Apr	42	2350	11.8	1645	16.04	1.43	10.83	909.20	0.18	0.01	4.46	0.21	56.20	0.27	71.56	51.22	16.18
15-Apr	43	3000	11.8	1650	16.04	1.43	13.83	923.03	0.18	0.01	4.48	0.27	56.47	0.34	71.90	51.22	16.34
16-Apr	44	2130	11.7	1650	16.04	1.51	9.65	932.68	0.18	0.01	4.50	0.19	56.66	0.24	72.15	50.33	16.46
18-Apr	45	3000	11.7	1630	10.61	1.56	-2.85	929.83	0.18	0.01	4.31	0.27	56.93	0.34	72.49	-10.56	16.33
19-Apr	Wash #1	2620			10.00	1.51	-3.96	925.87	0.17	0.13	3.31	0.45	57.38	0.57	73.06	-8.88	16.14
20-Apr	Wash #2	2315			10.00	0.95	-2.20	923.67	0.09	0.03	1.18	0.21	57.59	0.27	73.33	-10.56	16.04

Residue weight = 14756
Feed weight = 15000

residue 0.142 %Cu 20.95
TOTAL Copper 76.54

Calculated head = 0.524 % Cu
Assayed head = 0.538 % Cu

Table II - Korn Kob Ore, 1 Inch, 4 Inch Column Leach
Agglomerated with 69.45 Lb./T H2SO4 at 10 percent moisture.

Job No.: 5274
Test No.: BM-2

Date	Preg. No.	Preg. Soln. Vol(ml)	pH	EMF	H2SO4 Feed g/l	H2SO4 Preg. g/l	H2SO4 Consumed Grams	Cum. H2SO4 Consumed Grams	Cu g/l	Fe++ g/l	Fe+++ g/l	Cu Recov. Grams	Cum Cu Recov. Grams	% Cu Recov.	Cum % Cu Recov.	Acid Consumed #/#Cu	Cum H2SO4 Consumed #/#Cu
27-Feb	1	1450	2.2	630	4.48	0.10	509.97	509.97	16.00	0.05	6.37	23.07	23.07	30.40	30.40	22.11	22.11
28-Feb	2	2050	2.5	640	4.48	0.05	9.08	519.05	4.64	0.03	1.82	9.33	32.40	12.29	42.69	0.97	16.02
01-Mar	3	2160	2.5	670	4.48	0.07	9.53	528.58	1.99	0.03	1.41	4.10	36.50	5.41	48.10	2.32	14.48
02-Mar	4	1630	2.4	660	4.48	0.07	7.19	535.77	1.44	0.03	1.61	2.20	38.70	2.90	51.00	3.27	13.84
03-Mar	5	2120	2.4	675	4.48	0.03	9.43	545.20	1.08	0.08	1.94	2.10	40.80	2.77	53.77	4.49	13.36
04-Mar	6	2830	2.4	640	4.48	0.00	12.68	557.88	0.69	0.05	2.68	1.70	42.50	2.24	56.00	7.47	13.13
05-Mar	7	1940	2.4	670	4.48	0.00	8.69	566.57	0.59	0.03	2.74	0.97	43.47	1.28	57.28	8.96	13.03
06-Mar	8	2220	2.3	670	4.48	0.00	9.95	576.51	0.51	0.05	2.83	0.93	44.40	1.23	58.51	10.67	12.98
07-Mar	9	2030	2.3	680	4.48	0.03	9.03	585.55	0.46	0.03	2.84	0.75	45.15	0.99	59.50	12.03	12.97
08-Mar	10	2190	2.3	660	4.48	0.80	8.06	593.61	0.40	0.03	2.84	0.68	45.83	0.89	60.40	11.87	12.95
09-Mar	11	2260	2.3	660	4.48	0.00	10.12	603.73	0.36	0.03	3.29	0.61	46.44	0.80	61.20	16.59	13.00
10-Mar	12	2200	2.2	675	4.48	0.19	9.44	613.17	0.32	0.03	3.98	0.51	46.95	0.67	61.87	18.65	13.06
11-Mar	13	2140	2.2	685	4.48	0.10	9.37	622.54	0.31	0.03	3.75	0.47	47.42	0.62	62.49	19.91	13.13
12-Mar	14	2220	2.2	680	4.48	0.39	9.08	631.62	0.29	0.03	3.63	0.44	47.86	0.59	63.07	20.45	13.20
13-Mar	15	2150	2.2	690	4.48	0.34	8.90	640.52	0.26	0.03	3.28	0.37	48.23	0.48	63.55	24.35	13.28
14-Mar	16	2140	2.2	690	4.48	0.39	8.75	649.28	0.26	0.03	3.51	0.36	48.59	0.48	64.03	24.06	13.36
15-Mar	17	2210	2.2	685	4.48	0.25	9.35	658.63	0.26	0.03	3.39	0.38	48.97	0.50	64.53	24.88	13.45
16-Mar	18	2490	2.1	680	4.48	0.36	10.26	668.88	0.24	0.03	3.00	0.37	49.34	0.49	65.02	27.47	13.56
17-Mar	19	2200	2.1	685	4.48	0.48	8.80	677.68	0.24	0.03	3.31	0.33	49.67	0.43	65.46	26.67	13.64
18-Mar	20	2435	2.1	690	4.48	0.43	9.86	687.55	0.23	0.03	2.89	0.34	50.01	0.45	65.91	28.93	13.75
19-Mar	21	1820	2.1	700	4.48	0.53	7.19	694.73	0.22	0.03	3.01	0.24	50.25	0.31	66.22	30.38	13.83
20-Mar	22	2350	2.1	690	4.48	0.34	9.73	704.46	0.23	0.03	2.49	0.33	50.58	0.43	66.65	29.57	13.93
21-Mar	23	2190	2.1	680	4.48	0.48	8.76	713.22	0.22	0.03	3.20	0.28	50.86	0.38	67.03	30.77	14.02
22-Mar	24	2230	2.0	660	4.48	0.48	8.92	722.14	0.22	0.03	3.31	0.29	51.15	0.38	67.41	30.77	14.12
23-Mar	25	2560	2.0	650	4.48	0.39	10.47	732.61	0.21	0.03	3.28	0.31	51.46	0.40	67.81	34.08	14.24
24-Mar	26	2800	2.0	660	4.48	0.56	10.98	743.59	0.20	0.03	3.20	0.31	51.77	0.41	68.22	35.64	14.36
25-Mar	27	2450	2.0	650	4.48	0.63	9.43	753.02	0.19	0.03	3.19	0.25	52.01	0.32	68.54	38.50	14.48
26-Mar	28	1550	2.0	670	4.48	0.73	5.81	758.83	0.19	0.03	3.19	0.16	52.17	0.20	68.75	37.50	14.55
27-Mar	29	2360	2.0	680	4.48	0.78	8.73	767.57	0.18	0.01	3.30	0.21	52.38	0.28	69.03	41.11	14.65
28-Mar	30	2300	2.0	675	4.48	0.71	8.67	776.24	0.19	0.03	3.29	0.23	52.61	0.30	69.33	37.70	14.75
29-Mar	Drain	360	2.0	670	4.48	1.00	1.25	777.49	0.20	0.03	3.29	0.07	52.68	0.09	69.42	17.40	14.76
30-Mar	Wash	1675	2.1	630	0.84	0.46	0.71	778.20	0.19	0.08	2.68	0.36	53.04	0.47	69.89	2.00	14.67
02-Apr	Drain	660	2.1	610	0.00	0.90	-0.59	777.61	0.16	0.05	1.86	0.11	53.14	0.14	70.03	-5.63	14.63
07-Apr	31	2050	2.3	630	6.04	0.24	11.89	789.50	0.15	0.03	0.68	0.12	53.27	0.16	70.19	96.67	14.82
08-Apr	32	1940	2.1	640	6.04	0.24	11.25	800.75	0.20	0.03	2.48	0.21	53.48	0.28	70.48	52.73	14.97
09-Apr	33	1900	2.0	650	6.04	0.44	10.64	811.39	0.20	0.03	4.17	0.21	53.69	0.28	70.75	50.91	15.11
10-Apr	34	2850	1.7	635	6.04	0.85	14.79	826.18	0.19	0.03	4.37	0.29	53.97	0.38	71.13	51.90	15.31
11-Apr	35	2550	1.7	645	6.04	0.95	12.98	839.16	0.18	0.03	4.46	0.23	54.20	0.30	71.43	56.56	15.48
12-Apr	36	2550	1.7	630	6.04	1.34	11.99	851.15	0.17	0.01	4.43	0.20	54.41	0.27	71.70	58.75	15.64
13-Apr	37	2770	1.7	650	6.04	1.56	12.41	863.56	0.18	0.01	4.39	0.25	54.66	0.33	72.03	49.78	15.80
14-Apr	38	2525	1.8	650	6.04	1.43	11.64	875.20	0.17	0.01	4.11	0.20	54.86	0.27	72.29	57.62	15.95
15-Apr	39	2850	1.7	655	6.04	1.58	12.71	887.91	0.17	0.01	4.36	0.23	55.09	0.30	72.59	55.75	16.12
16-Apr	40	2230	1.8	660	6.04	1.44	10.26	898.17	0.18	0.01	4.63	0.20	55.29	0.26	72.86	51.11	16.25
17-Apr	41	2700	1.6	630	0.68	1.49	-1.65	896.52	0.18	0.01	4.49	0.24	55.53	0.32	73.18	-6.78	16.14
18-Apr	Wash	2460			0.00	1.29	-3.17	893.35	0.16	0.13	2.99	0.39	55.92	0.52	73.70	-8.06	15.97
19-Apr	Wash	2100			0.00	0.77	-1.62	891.73	0.10	0.01	1.23	0.21	56.13	0.28	73.97	-7.70	15.89

Residue weight 14739 grams, residue 0.134 % Cu 19.75
TOTAL 75.88

Feed starting weight 15000 grams

Calculated head = 0.506 % Cu
Assayed head = 0.538 % Cu

Table III

Summary of Column Leach Test Results

Recovery %	Time, Days		Ave. Preg., gpl Cu		Incremental Preg Grade, gpl Cu		Ave. Acid Cons. Lb./Lb. Cu		Incremental Acid Cons. Lb./Lb. Cu	
	BM-1	BM-2	BM-1	BM-2	BM-1	BM-2	BM-1	BM-2	BM-1	BM-2
43	2	2	10.3	9.3	4.74	4.64	15	16	—	—
48	3	3	6.9	6.4	1.92	1.99	14	14	2.4	2.3
51	4	4	5.3	5.3	1.22	1.44	13	14	3.9	3.3
55	6	5	3.5	4.3	0.58	1.08	13	13	9.1	4.5
60	12	9	2.0	2.4	0.35	0.46	13	13	17	12
65	22	17	1.13	1.36	0.24	0.26	14	13	26	25
70	40	31	0.68	0.80	0.20	0.20	16	15	47	32

FIGURE 1

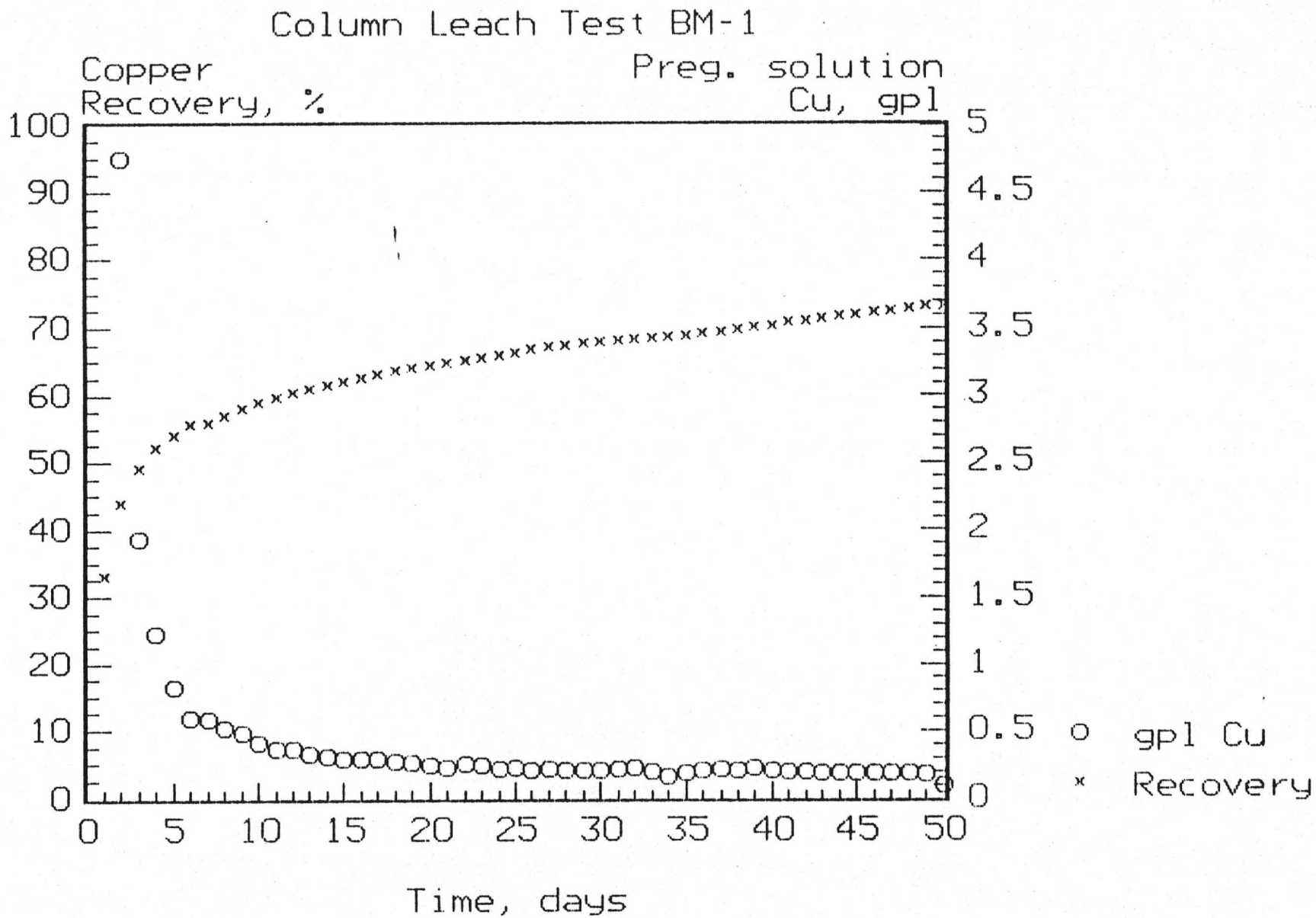
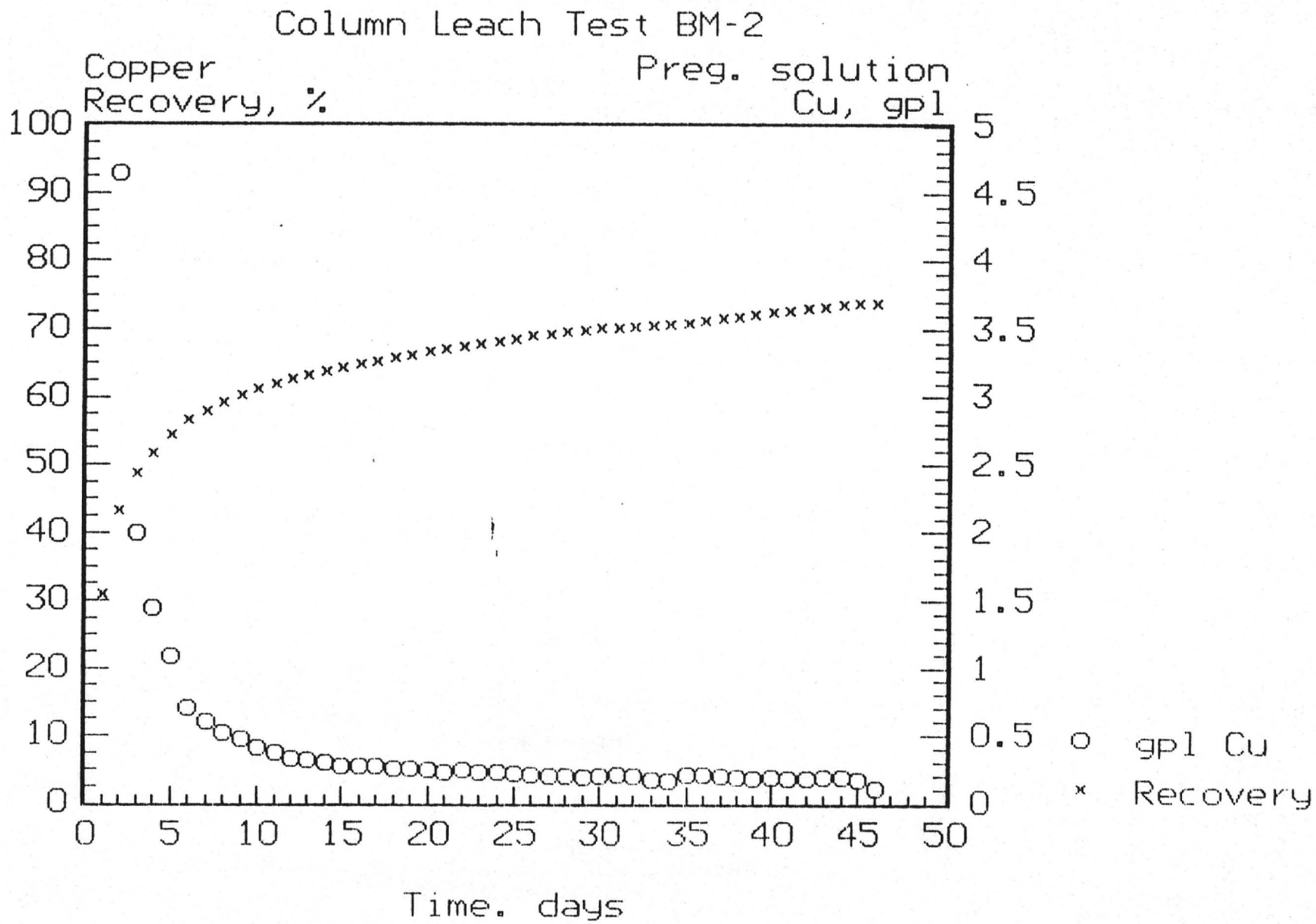

Column Leach Test BM-1
Copper Recovery, %
Preg. solution Cu, gpl
100
90
80
70
60
50
40
30
20
10
0
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
0 5 10 15 20 25 30 35 40 45 50
Time, days
o gpl Cu
x Recovery

FIGURE 2


Column Leach Test BM-2
Copper Recovery, %
Preg. solution Cu, gpl
100
90
80
70
60
50
40
30
20
10
0
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
0 5 10 15 20 25 30 35 40 45 50
Time. days
o gpl Cu
x Recovery

2. Pregnant solution grades were above 10 gpl copper initially then drop to below 0.3 gpl as recovery exceeds 60 percent. The average pregnant solution grade is about 4 gpl until the recovery exceeds 45 percent. The incremental pregnant solution grade is shown in Figures 1 an 2.

3. Incremental acid consumption is initially about 14 pounds of acid per pound of copper but increases to above 30 pounds of acid per pound of copper as copper recovery exceeds 60 percent. The acid cure enhances the initial copper recovery and can be credited for the high average pregnant solution grades.

   Figures 3 and 4 show the relationship between the incremental acid consumption and copper recovery. Data for those days following column shut down were not included in the figures as they do not represent typical data. The curve drawn is an exponential curve and slightly exaggerates the trend.

4. Even in the later stages of leaching, acid in the leach solution was almost completely consumed as the leach solution passed though the column. Increasing the height of the column would allow a higher strength leach solution to be used and a higher grade pregnant solution to be obtained. This would have a tendency to increase the acid consumption but the trade off would be the higher grade pregnant solution at recoveries above 60 percent.

FIGURE 3

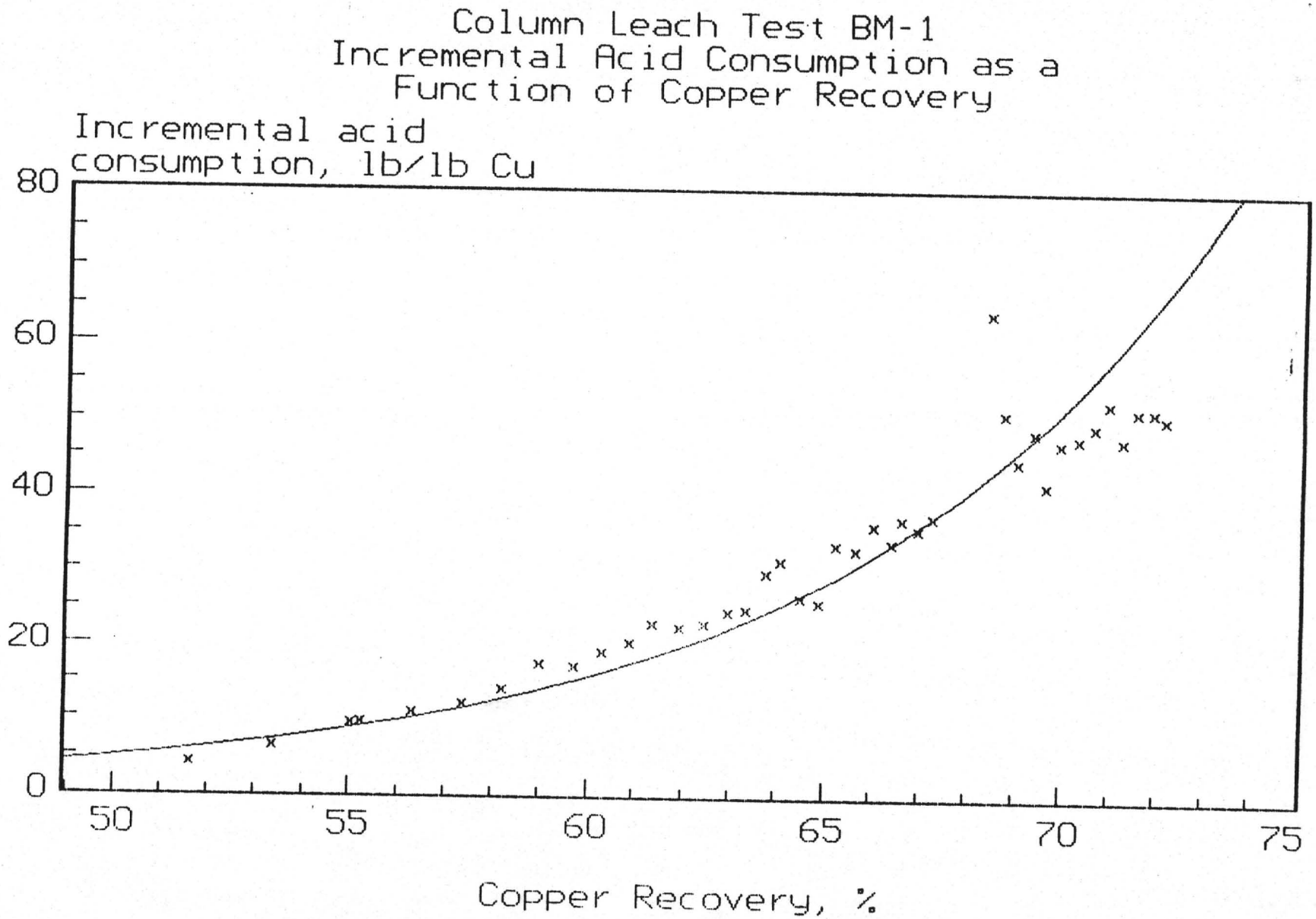
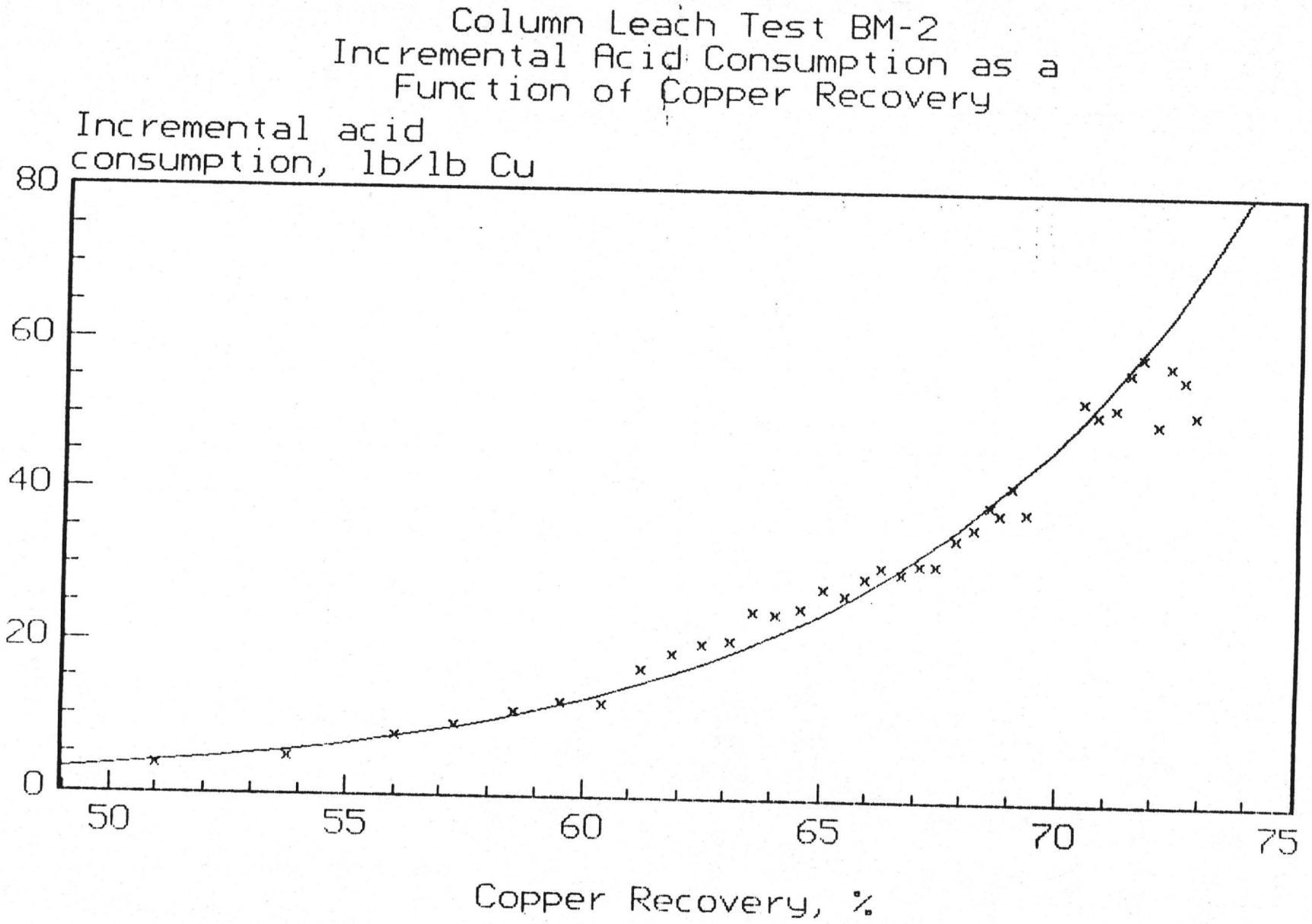

Column Leach Test BM-1
Incremental Acid Consumption as a
Function of Copper Recovery
Incremental acid
consumption, lb/lb Cu
80
60
40
20
0
50
55
60
65
70
75
Copper Recovery, %

FIGURE 4


Column Leach Test BM-2
Incremental Acid Consumption as a
Function of Copper Recovery
Incremental acid
consumption, lb/lb Cu
80
60
40
20
0
50
55
60
65
70
75
Copper Recovery, %

If the shrinking core model holds for this ore, several predictions as to the behavior of the ore under various leaching conditions can be made:

1) Increasing the acid strength of the leach solution will enhance the leaching rate but at the expense of higher acid consumption.

2) Increased leach solution flow rate will probably increase the recovery rate. Pregnant solution strength and acid consumption will remain the same.

3) Finer crushing of representative ore will markedly increase the rate of leaching for recoveries above 50 percent and at the same time reduce the acid consumption. The initial rate of leaching would not be affected as this is directly dependent only on the acid content of the leach solution.

4) Agitation leaching of the ore will result in the lowest acid consumption, however, the recovery will be limited to the acid soluble copper whereas in heap leaching some of the non-acid soluble copper does leach.

At the conclusion of the leach test it was planned to do an assay/screen analyses on the leached residue to determine the recovery as a function of particle size. The agglomeration resulted in hard lumps of agglomerated ore which would make the results of this test meaningless. The particle

size/recovery relationship can be predicted if the shrinking core model is assumed. The time to attain a given recovery would be proportional to the square of the particle diameter.

mountain states research & development

Project No. 5274

Date 2-23-90

Sample ID Kain Kob Ore

~~Test No.~~

METALLURGICAL RESULTS

Product	Weight (%)	% Cu	% Cu	Distribution % Cu
+ 3/4"	3.22	0.322	0.010	1.98
+ 1/2"	9.67	0.334	0.032	6.35
+ 1/4"	17.80	0.302	0.054	10.71
− 1/4"	69.31	0.588	0.408	80.76
Head (Calc)			0.504	100.00
Head Assay*			0.538	

Remarks: * [illegible] of four [illegible]