



CONTACT INFORMATION
Mining Records Curator
Arizona Geological Survey
3550 N. Central Ave, 2nd floor
Phoenix, AZ, 85012
602-771-1601
<http://www.azgs.az.gov>
inquiries@azgs.az.gov

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PERCOLATION LEACHING OF COPPER ORE
FROM BLUEBIRD MINE
FOR
RANCHERS EXPLORATION AND DEVELOPMENT CORPORATION

HAZEN RESEARCH, INC.

HAZEN RESEARCH, INC.

TELEPHONE 279-4549
4601 INDIANA STREET
GOLDEN, COLORADO

H.R.I. Project No. 53

Copy No. 3

PERCOLATION LEACHING OF COPPER ORE
FROM BLUEBIRD MINE

for

Ranchers Exploration and Development Corporation
4204 Coal Avenue, S.E.
Albuquerque, New Mexico

June 9, 1964

By:

A. V. Henrickson

A. V. Henrickson, Vice President

F. C. Haas

F. C. Haas, Chief Chemist

Roland Schmidt

Roland Schmidt, Microscopist

Wilson T. Fossey

Wilson T. Fossey, Technician

Approved by:

Wayne C. Hazen

Wayne C. Hazen, President

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INTRODUCTION

This report covers laboratory tests made by Hazen Research, Inc. for Ranchers Exploration and Development Corporation on ore from the Bluebird Mine near Miami, Arizona. The work included was conducted during March, April and May, 1964 at the Hazen laboratory, Golden, Colorado.

The objective of this work was to establish the basic metallurgical factors for evaluating vat percolation leaching. The most important metallurgical questions have been studied and monthly progress reports were issued for March and April. This final report brings together all of the test work to date, including that previously issued as letter reports. It is in the form of a final report divided into sections of metallurgical significance.

In vat percolation leaching there are two major areas in which information must be obtained: (1) chemical factors, and (2) physical factors. The chemical factors such as acid strength, temperature, time, etc. were the subject of the study made in this laboratory.

The physical factors, which are as important in the final results as the chemical factors, are concerned with channelling, solution flow rates, agglomeration, etc., and cannot be studied effectively in small size laboratory test equipment. These factors are being studied by Ranchers Exploration at the Bluebird property, and are being executed under the direction of Mr. R. E. Chilson.

It is not anticipated that much more laboratory work would be needed in order to evaluate the possibilities of vat leaching. The conclusions drawn from the work are presented in the summary immediately following, while the detailed data may be found in the main body of the report.

SUMMARY AND CONCLUSIONS

Samples of ore from the Bluebird Mine were examined petrographically and were tested for amenability to acid percolation leaching. The more important conclusions derived from the work are as follows:

1. The major copper mineral is chrysocolla with some azurite. No diopside or other silicate copper minerals were found. The gangue is predominantly quartz and feldspar with some clay alteration products of the feldspar. A screen analysis showed a high copper content in the -200 mesh fraction which assayed three times the average, contained 7% of the weight and 21% of the copper.
2. Acid percolation leaching results showed that 3/4" pieces leached as swiftly and completely as finer sizes, indicating that the ore does not need to be crushed finer than this. The -200 mesh fraction was more difficult to leach than the coarser material.
3. Leach tests were made on .8% Cu heads, using the same flow-sheet and cycle as used at Yerington, Nevada. With 4.5% acid at 70^oF, 85% of the Cu was dissolved in an 8-day leach cycle with an acid consumption of 64 pounds of sulfuric acid.
4. Acid strength of 7% gave no better copper extraction than 2.2% acid strength.
5. Higher temperature gave higher copper extraction but also materially increased acid consumption. This effect was so pronounced that it may be economic to cool the solutions through spray evaporation to take advantage of the decreased acid consumption. For example, a leach at 40^oF gave an extraction of 84% and acid consumption of 33 pounds of acid per ton of ore, while 90^oF gave 92% extraction but consumption was doubled to 72 pounds per ton of ore.

6. Examination of a sample of residue from a heap which had been leached for about a year showed that about 68% of the total copper had been dissolved. Acid leach treatment of the very fine (-200 mesh) fraction of the sample (containing half of the remaining copper in only 12% of the weight) showed that approximately half of this copper was still acid soluble.

3. HEAD SAMPLES

Five samples of material were received from the property.

No.	Description	Assay % Cu
HRI-127	This consisted of 60 pounds of rock received at the laboratory on January 28, described by letter from R. E. Chilson as being "a general sample of the ore of the Bluebird Mine", maximum size 1 inch.	.55
HRI-133	100 pounds of ore received March 13, 1964, maximum particle size 6 inches, described in letter from R. E. Chilson dated March 3 as follows: "The sample was taken over a wide area, thus incorporating various rock phases but the grade is probably above average".	.81
HRI-134	Sample from pile which had been heap leached for one year. Delivered by R. E. Chilson on April 17, 1964.	.245
HRI-135A	66 pounds of "high grade", maximum particle size 6 inches, delivered by R. E. Chilson on April 17, 1964.	.70
HRI-135B	37-1/2 pounds of "low grade", delivered to the laboratory by R. E. Chilson on April 17, 1964, maximum particle size 1/2 inch.	.41

A screen analysis was made of HRI-133 after crushing to 3/4" in a jaw crusher, with the following results:

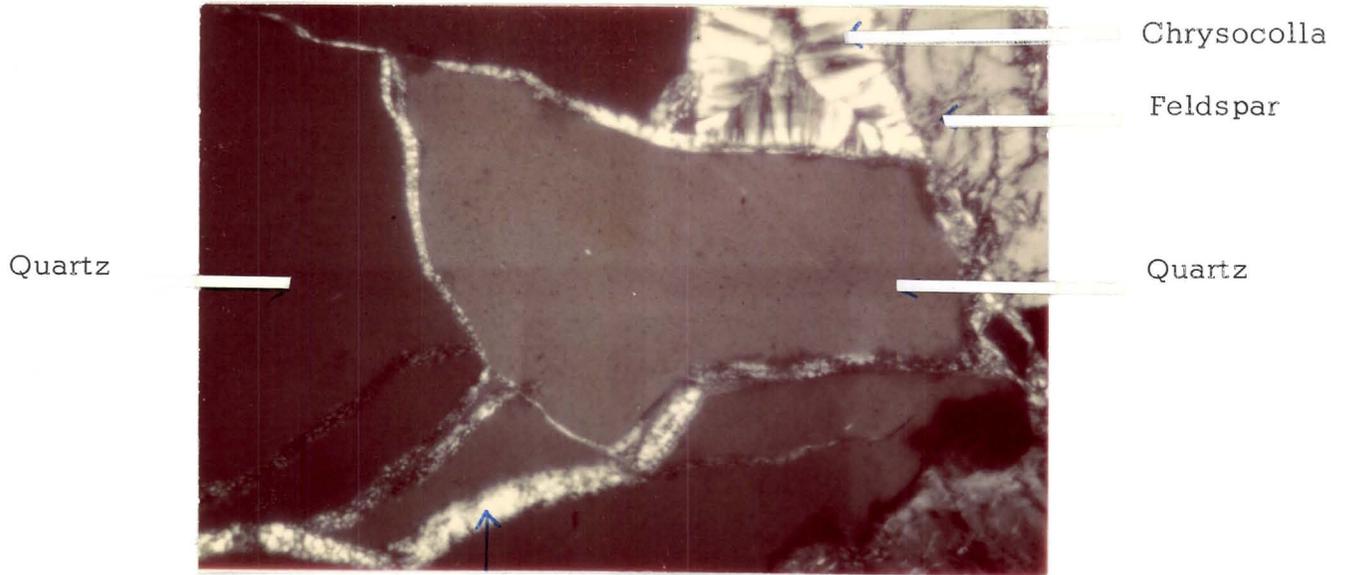
Size Fraction	Wt. %	Assay % Cu	Distribution of Cu %
-3/4" +1/2"	3.3	.64	2.5
-1/2" +1/4"	44.7	.64	35.8
-1/4 +10 mesh	23.3	.66	18.5
-10 +200 mesh	21.6	.83	22.2
-200 mesh	7.1	<u>2.40</u>	21.0
	Avg.	.81%	

There is no information in this laboratory as to the sampling methods used to obtain the samples received. No assumption can be made that these are representative of the deposit although they all have the same general appearance. It may be that the mineralization is so uniform that these samples are indeed valid, but this is not certain by any means.

3.1 MINERALOGY

All of these ores were of the same type of material consisting of a granite rock with a small amount of dark gray biotite schist. There were obvious stains of chrysocolla and a few pieces of azurite in all samples. Some seemed to contain harder rock than others, and there was evidence of a variation in clay content.

Thin sections were made of sample HRI-127 and examined under the petrographic microscope. These thin sections showed that the ore consisted primarily of quartz, feldspar with clay alteration products, and biotite. Chrysocolla occurred as veinlets in the quartz and feldspar, and as a coating on grains. The veinlets vary from a few microns to about 1 mm in thickness. No copper sulfides were noted. Figure 1 is a photomicrograph with polarized light of a thin section of the ore at 200 power magnification. This shows a typical area containing copper minerals as veinlets and coating.



Chrysocolla

Thin Section of Sample HRI-127
(Taken at 200X magnification with polarized, transmitted light.)

Figure 1

4. LEACHING TESTS

Of major importance in deciding what metallurgical flowsheet to use in the acid leaching of copper are the variables such as the particle size, the strength of the acid to be used, the leaching cycle time, and temperature.

Although the physical factors which affect solution flow rate such as method of loading and agglomeration procedure, are equally important, these are factors which must be worked out on a larger scale and are not as amenable to the small scale work upon which decisions concerning the other variables can be based.

The following tests were run either in a 3-inch diameter glass tube, 3 feet deep, or in 5-inch diameter glass jars with 4" to 5" depth of ore.

4.1 EFFECT OF ACID STRENGTH

A sample of Bluebird ore, HRI-135A, was ground to -1/2". A portion of this was split out for a head analysis and found to contain .70 percent Cu on a total copper basis. Approximately 1-1/2 kilogram samples were split out, agglomerated with water, and loaded into 5-inch diameter percolation leach jars.

The ore was flooded from the bottom with sulfuric acid of the proper strength (2.2 percent in Test 1, 4.5 percent in Test 2, 7 percent in Test 3). The solution was then percolated downward and recycled at a flow rate equivalent to 0.10 gallons per minute per square foot of area for 24 hours, after which it was replaced with fresh acid of the same strength as the original solution. This procedure was continued for a period of ten days. The copper and acid content of the leach liquor were determined at regular intervals. At the end of the run the residue was washed once with water which was recycled through the bed for 24 hours. The solids were removed from the percolation leach jar, dried, weighed, and assayed for

copper content. The results are tabulated below in Table 1, and graphed in Figure 2.

An inspection of the data obtained in these three parallel tests brings out a very significant and rather surprising fact; high acid strength did not increase the percent extraction obtainable in this sample. It appears that the higher strength of sulfuric acid merely increased the acid consumption slightly without increasing the dissolution of copper.

Table 1
Percolation Leaching at Various Acid Strengths
Bluebird Ore - Sample HRI-135A

Test No.	1 (2.2% H ₂ SO ₄)	2 (4.5% H ₂ SO ₄)	3 (7.0 % H ₂ SO ₄)
Days	% Extraction	% Extraction	% Extraction
1	46.7	46.5	46.4
2	67.0	67.3	67.8
3	78.4	76.3	76.7
4	--	82.0	82.5
5	85.6	--	--
6	86.4	84.1	84.7
7	--	84.8	84.9
8	87.0	--	--
9	--	--	--
10	87.3	86.5	87.9

Continued---

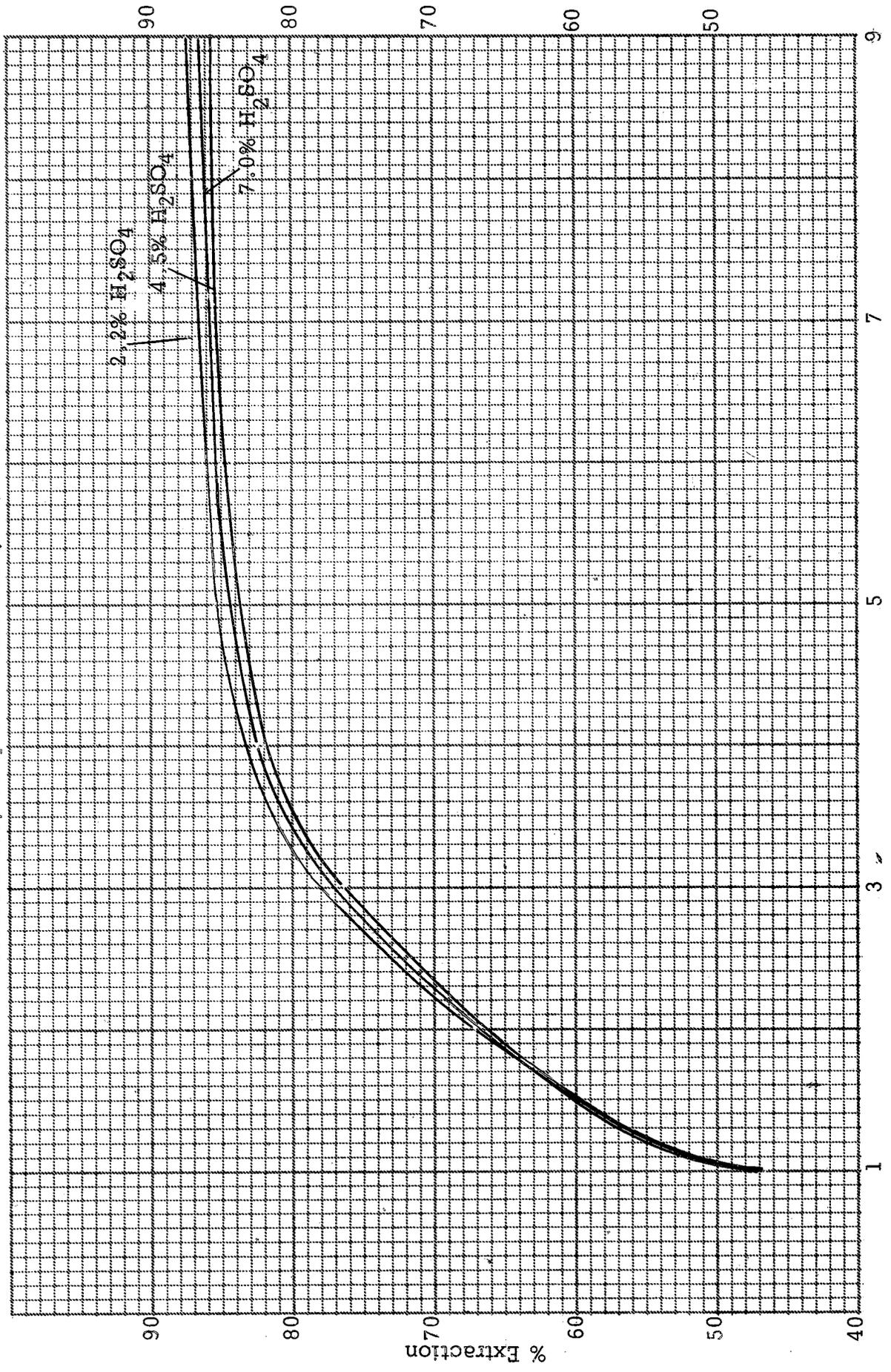
Table 1 Cont'd.

<u>Acid Consumption versus Time</u>			
Test No.	1 (2.2% H ₂ SO ₄)	2 (4.5% H ₂ SO ₄)	3 (7.0% H ₂ SO ₄)
Days	Lbs. H ₂ SO ₄ / Ton of Ore	Lbs. H ₂ SO ₄ / Ton of Ore	Lbs. H ₂ SO ₄ / Ton of Ore
1	17.4	20.5	23.1
2	24.6	30.3	31.9
3	27.7	36.0	34.8
4	--	40.8	41.4
5	32.6	43.0	45.3
6	34.7	--	--
7	36.7	49.5	51.0
8	39.3	--	--
9	--	--	--
10	41.5	56.2	58.0

Material Balance

Test No.	1 (2.2% H ₂ SO ₄)	2 (4.5% H ₂ SO ₄)	3 (7.0% H ₂ SO ₄)
Head, Grams	1400	1540	1517
Grams of Cu in Solution	8.05	8.72	9.04
Residue, Grams	1348	1507	1474
% Cu in Residue	0.087	0.09	0.085
Grams Cu in Residue	1.17	1.36	1.25
Grams of Cu	9.22	10.08	10.29
Calculated Head % Cu	0.66	0.65	0.68
Assayed Head % Cu	0.70	0.70	0.70

Percolation Leaching at Various Acid Strengths
Bluebird Ore, Sample No. HRI-135A, -1/2"



Days
Figure 2

4.2 EFFECT OF TEMPERATURE

Higher temperatures ordinarily accelerate the rate of chemical reactions. Since the operating plant will be subject to variable solution temperatures, it was felt necessary to determine what this influence would be on the extraction of copper and on acid consumption.

A sample of the ore was ground to $-1/2$ " and approximately 1-kilogram samples were split out, agglomerated with water, and loaded into the 5-inch diameter percolation leach jars. The ore was flooded from the bottom with a 4.5 percent sulfuric acid solution, followed by a continuous recycle in downward percolation of this solution for 24 hours. At the end of each 24-hour period the solution was replaced with fresh acid, and this procedure was continued for a period of ten days. The residue was washed once with water, recycled for 24 hours, after which the solids were removed from the glass jar, dried, and assayed for copper.

The temperature in Test No. 1 was 90°F , in Test No. 2 75°F , and in Test No. 3 the temperature was held below room temperature and just above the freezing point at 40°F .

The solutions were analyzed each day for copper content and from this solution analysis the percent extracted in the 24-hour period could be calculated. These percent extractions are tabulated in Table 2. The acid consumption was also determined each day. Extractions are also plotted in Figure 3.

Inspection of these data show that the rate of copper extraction as well as the total percent extracted was markedly accelerated by increasing the temperature. For example, at the end of six days the 90° temperature had given 88.7% extraction, while the leach at 75° gave 84.9%, and that at 40° gave 82.5%. However, upon examining the increased acid consumption caused by the higher

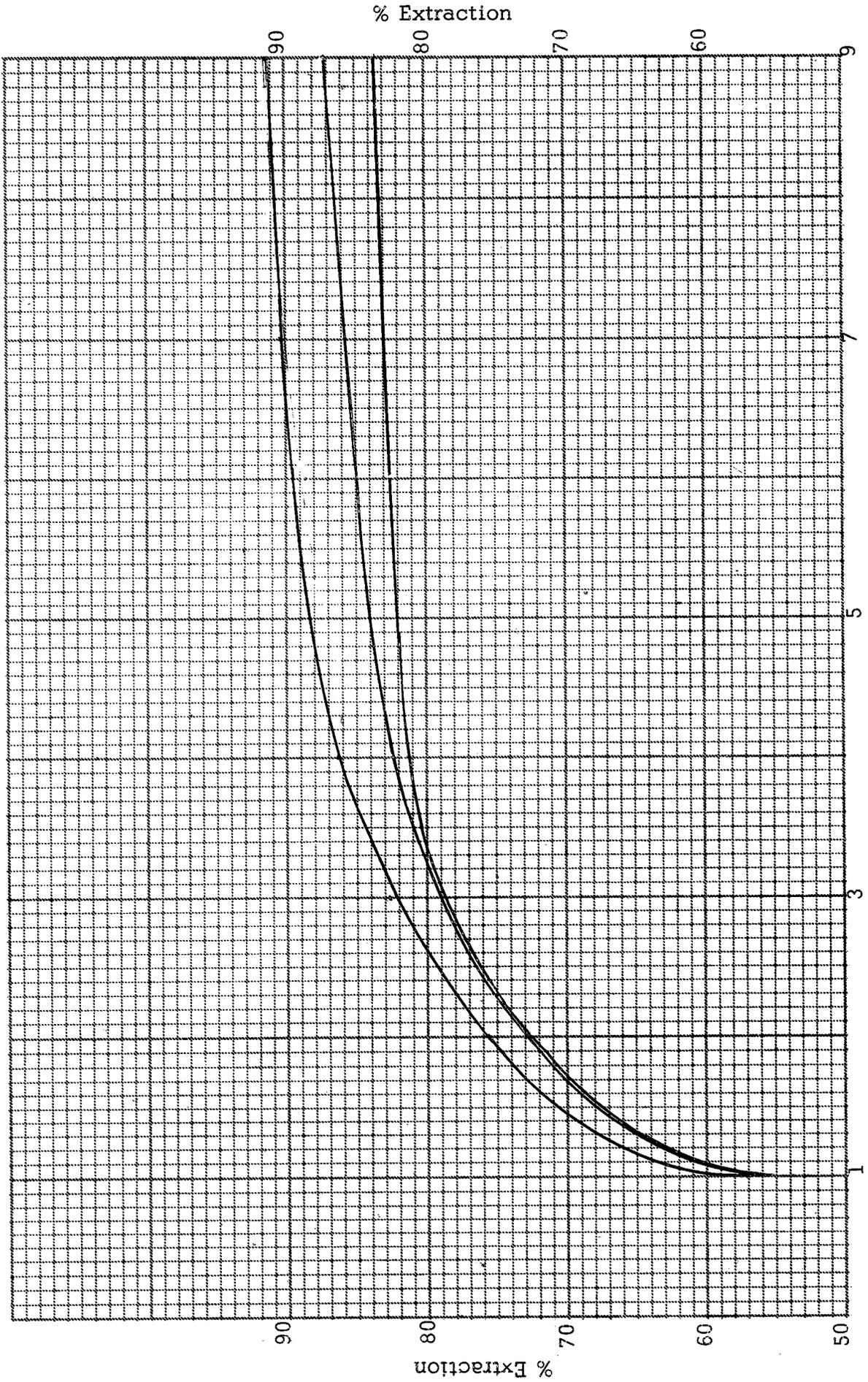
temperature it can be observed that the acid consumed per pound of copper extracted was nearly doubled by leaching at 90°F compared with leaching at 40°F.

Taking the results at the end of ten days, it is seen that the 90°F leach at 92 percent extraction would dissolve 14.7 pounds of copper per ton of ore (assuming .80% Cu heads), with an acid consumption of 72.3 pounds of sulfuric acid. The 40°F leach at 84% extraction would dissolve 13.45 pounds of copper per ton of ore at an acid consumption of ^(*)32.6 pounds of sulfuric acid. Taking these figures at face value, this means that at 90°F an additional 1.25 pounds of copper were extracted per ton of ore, but this required 39.7 pounds of additional sulfuric acid.

Although it is sometimes dangerous to extrapolate a general result such as this which is obtained on only one sample which may not be representative, it is nevertheless important to recognize the economic impact of this test. If water supply and other factors will permit, it would seem highly desirable to deliberately keep the solution temperatures low through means such as spray evaporation in order to take advantage of the decreased sulfuric acid consumption.

$$\begin{aligned} 40^{\circ}\text{F} (*) 1) \quad \frac{32.6}{13.45} &= 2.42 \# \text{ of } \text{H}_2\text{SO}_4 / \# \text{ of Cu} && \text{Acid Cost} \\ & && 2.42 \times 1.25 \$/\# = \$.032 / \# \text{ Cu} \\ 90^{\circ}\text{F} (*) 2) \quad \frac{72.3}{14.7} &= 4.92 \# \quad " \quad / \# \text{ of Cu} \\ & && 4.92 \times 1.25 \$/\# = \$.0614 / \# \text{ Cu} \\ \text{Additional } 1.25 \# \text{ Cu } @ 39.7 \# \text{ H}_2\text{SO}_4 \text{ cost } && \$.495 \end{aligned}$$

Percolation Leaching at Various Temperatures
Bluebird Ore, Sample No. HRI-133, -1/2"



Days
Figure 3

Table 2

Percolation Leaching at Various Temperatures
Bluebird Ore Sample HRI-133

Days	Test No. 34-146-1 (90°F)	Test No. 34-146-2 (75°F)	Test No. 34-146-3 (40°F)
	% Extraction	% Extraction	% Extraction
1	57.1	55.1	55.5
2	75.6	73.0	72.7
3	82.8	79.5	79.3
4	86.4	82.5	81.7
5	--	--	--
6	88.7	84.9	82.5
7	90.3	86.1	83.3
8	90.8	86.7	--
9	91.2	87.2	--
10	92.0	87.9	84.0

Acid Consumption

Days	34-146-1 (90°F)		34-146-2 (75°F)		34-146-3 (40°F)	
	# H ₂ SO ₄ /					
	Ton Ore	# Cu Extracted	Ton Ore	# Cu Extracted	Ton Ore	# Cu Extracted
1	30.7	3.05	27.5	2.84	30.1	2.85
2	43.2	3.25	35.8	2.78	34.7	2.51
3	51.9	3.56	41.3	2.95	35.2	2.34
4	59.8	3.93	45.9	3.16	36.3	2.34
5	--	--	--	--	--	--
6	73.1	4.68	54.6	3.65	--	--
7	77.2	4.86	56.3	3.72	38.5	2.46
8	78.0	4.88	56.5	3.70	38.5	2.43
9	78.9	4.91	57.2	3.73	--	--
10	79.5	4.91	57.4	3.71	38.7	2.43

Continued---

Table 2 Cont'd.

Material Balance, Copper

<u>Test No.</u>	<u>34-146-1 (90°F)</u>	<u>34-146-2 (75°F)</u>	<u>34-146-3 (40°F)</u>
Head, grams	1194	1249	1113
Grams of Cu in Solution	9.70	9.62	8.94
Residue, grams	1142	+200 1066 -200 122	1067
% Cu in Residue	.073	+200 .055 -200 .62	.16
Grams Cu in Residue	.83	1.33	1.70
Grams of Copper	10.53	10.95	10.64
Calculated Head	.88	.88	.96

The inference from this test is that higher temperature accelerates the rate of attack of sulfuric acid upon other constituents in the ore such as iron. In order to verify that this is so, a composite of all of the leach liquor and wash solution from the tests was analyzed for copper and iron with the following results.

Table 3

Copper to Iron Ratio in Leach Liquor

Leach Temp. °F	Iron gpl	Copper gpl	Ratio Iron Dissolved/ Copper Dissolved
90	.48	1.84	.26
75	.26	1.83	.14
40	.07	1.83	.04

It can be seen from the above that six times as much iron per pound of copper was dissolved at the temperature of 90°F than was dissolved at 40°F. It is probable that the attack on other minerals such as alumina is accelerated by the higher temperature also, although this was not verified in any analytical way.

4.3 EFFECT OF PARTICLE SIZE

Because the ore breaks rather easily and shatters along planes and cracks, which also are the site of the major part of the copper mineral deposition, it seemed reasonable to expect the coarser sizes to leach easily.

This is important not only from the standpoint of avoiding the cost of crushing if this is unnecessary, but also because a coarser feed should permit easier percolation of solutions in a deep vat.

In order to determine the rate of extraction of copper in various particle sizes, a sample of ore No. HRI-133 was stage crushed to -3/4 inch and a screen analysis obtained.

Separate portions were then placed dry in 3-inch diameter glass columns with a bed depth of approximately 3 feet. The loaded columns were then filled upflow with 1.33% sulfuric acid and allowed to stand stagnant for five hours, after which percolation was started downflow with 1.25% sulfuric acid at a rate equal to one ton of solution per ton of ore per day. The solution was not recirculated.

Fresh sulfuric acid was fed continuously to the top of the column and removed by an overflow jackleg which kept the ore bed flooded. Column No. 1 was terminated at 48 hours, Column 2 at 96 hours, and Column 3 at 192 hours. Each of the ore beds was then washed with one column volume of water, drained and discharged. The leached residues were wet screened, and the screen fractions dried, weighed and analyzed for copper.

The extraction of copper after the termination of the 8-day cycle was calculated from the analysis of the screen fraction as being 78.4 percent of the total copper contained. The heads for this test assayed .81% Cu, and the overall acid consumed was 40 pounds per ton of ore, which is 3.16 pounds of sulfuric acid consumed per pound of copper dissolved.

Analysis of the screen fractions showed that the -200 mesh fraction which was the richest in copper is also the most difficult to leach. The leaching rate and extraction efficiency of the larger fractions was found to be reasonably uniform, indicating that the solution finds its way through crevices rather easily in the large particles and that a crush finer than $-3/4$ inch is not necessary in vat leaching. Table 4 gives the analyses and weight distribution of the size fractions of the percolation leach tails.

Figure 4 is a graph showing the percent extraction of the size fraction plotted as a function of time.

It is interesting to note that the leaching rate of the particles which were in the 3/4"-1/2" size range was exactly the same as particles which were in the 1/2"-1/4" size range. Since the mass of a 1/2" particle is 8 times the mass of a 1/4" particle, it is obvious that the size of the particle has not seriously impeded the flow of solution. It is tempting to speculate on how far upward in size range this constancy of leach rate will continue.

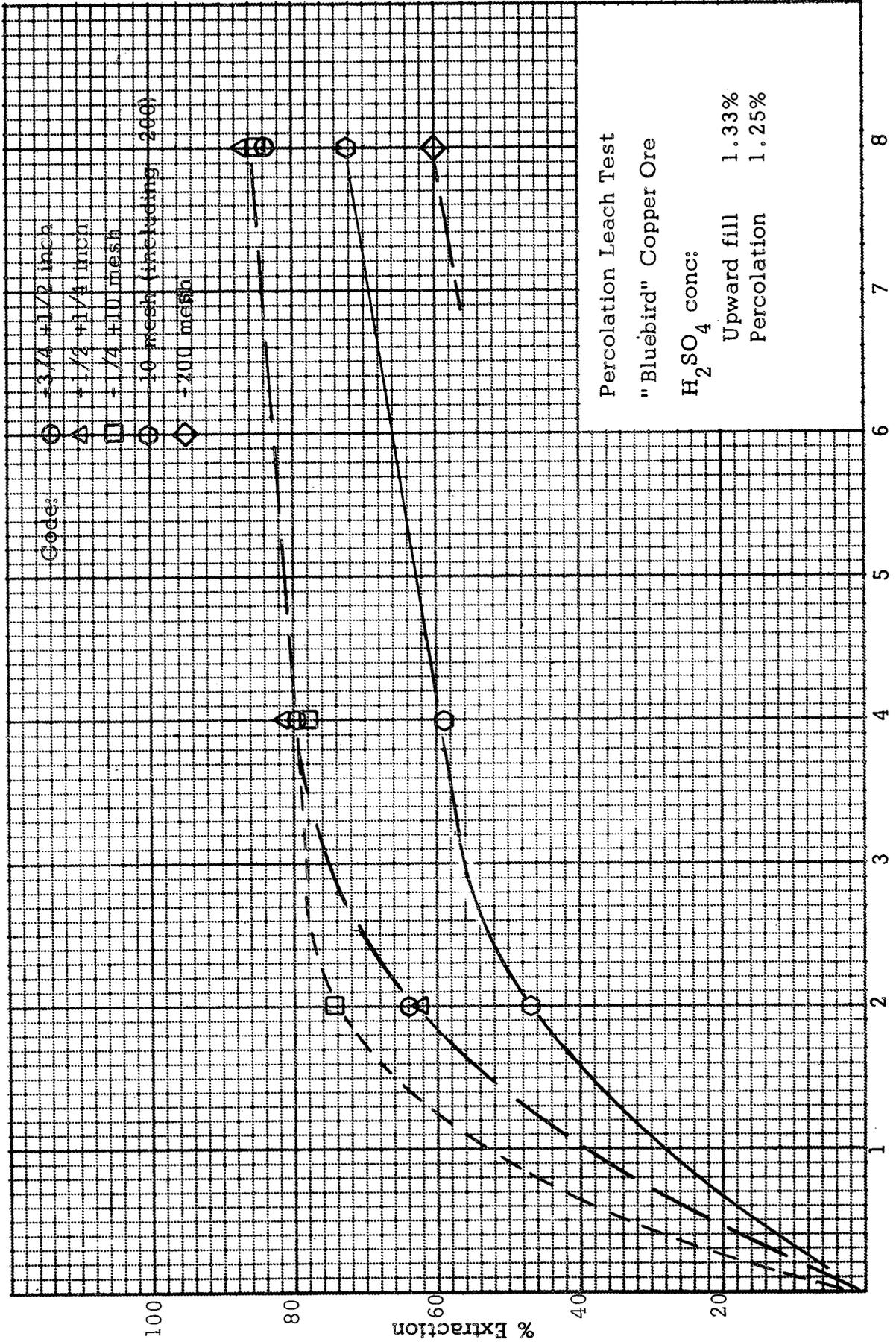
If this sample can be considered to be representative of the entire ore body, then it is entirely reasonable to expect relatively fast leaching rates on particles of much larger diameter as, for example, 3". Testing of such large particles will have to be done in large diameter columns.

Table 4

Bluebird Ore - Tailings from Percolation Leaching with 1.25% Sulfuric Acid. Weight Distribution and Copper Analysis of Screen Fractions

Leaching Time (Hrs.)	Size	Distribution Wt. %	Assays, Head	% Cu Tails	% Extraction
24	-3/4 +1/2	3.3	0.64	0.23	64.0
48	"	"	"	0.13	79.7
172	"	"	"	0.098	84.7
24	-1/2 +1/4	37.2	0.64	0.23	64.0
48	"	"	"	0.12	81.3
172	"	"	"	0.083	87.2
24	-1/4 +10	21.2	0.66	0.17	74.2
48	"	"	"	0.14	78.7
172	"	"	"	0.10	84.9
24	-10	38.3	1.32	0.70	46.9
48	"	"	"	0.54	59.1
192	"	"	"	0.36	72.7*
192	-10 +200	26.9	0.83	0.11	86.7
192	-200	11.4	2.40	0.96	60.0

* The -10 +200 and the -200 mesh fractions from the 172 hr. leach were analyzed separately to determine more nearly where the unleached copper occurs.



Time - Days
Figure 4

4.4 EFFECT OF WETTING AGENTS

It has sometimes been observed in leaching that a wetting agent which lowers the surface tension of the leach solution permits it to penetrate crevices more readily and thereby dissolves minerals more swiftly.

In order to see if this was the case, a percolation leach test was run in which Aerosol OT was added to the sulfuric acid solution which percolated through the charge. The amount added was equal to .05 pounds per ton of ore.

The ore was crushed to $-1/2$ inch, agglomerated with water and loaded into the 5-inch diameter percolation leach jars. It was flooded from the bottom with a 4.5% sulfuric acid solution, after which downward percolation was started. Solutions were recycled for ten days and the acid strength was adjusted at the end of each 24 hours to bring it back to the 4.5% strength.

An exact duplicate was run in parallel with this test, using a solution of the same strength of acid to which no wetting agents were added.

The data from these two parallel tests is given in the table below, and show quite clearly that there was absolutely no benefit obtained from the addition of the wetting agent and the lowering of the surface tension. This tends to confirm the observations that the solution can penetrate rather easily into the interior of this ore. The sample used was HRI-135A which had a head analysis of .70% Cu.

The copper extraction at the end of ten days was 85.3%, with an acid consumption of 53.6 pounds for the test with Aerosol, and 85.6% with an acid consumption of 54.8 pounds per ton of ore for the leach without the Aerosol. Provided fracturing is as common for the entire ore body as it was for this sample, there would seem to be no purpose in pursuing the use of wetting agents further.

Table 5

Percolation Leaching with Aerosol Added
Bluebird Ore Sample 135A

Test No.	40-8-3 (.05# Aerosol/Ton)	40-8-4
Days	Lbs. H ₂ SO ₄ /Ton of Ore	Lbs. H ₂ SO ₄ /Ton of Ore
1	28.3	27.7
2	31.8	31.8
3	36.9	37.3
4	39.2	39.5
5	--	--
6	42.0	42.7
7	44.8	46.0
8	--	--
9	51.7	52.2
10	53.6	54.8

Material Balance, Copper

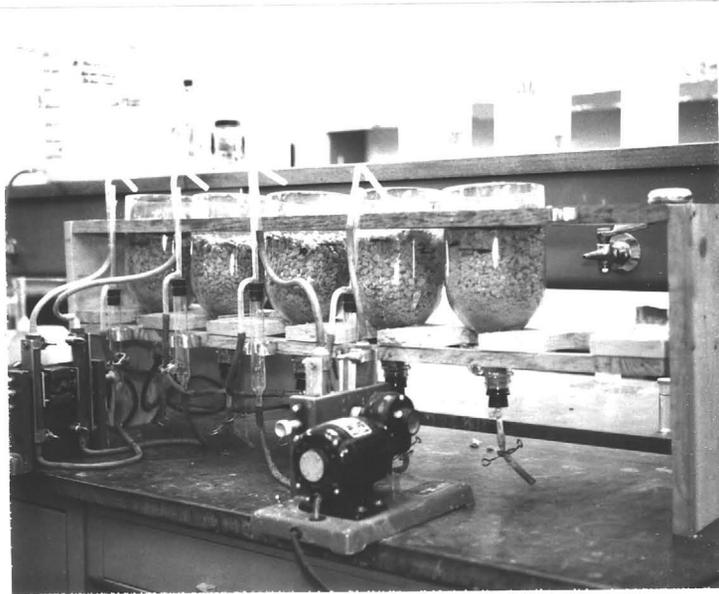
Test No.	40-8-3 (.05# Aerosol/Ton)	40-8-4
Head, grams	1420	1460
Grams Cu in Solution	8.00	8.06
Residue, grams	1381	1421
% Cu in Residue	0.10	0.096
Grams Cu in Residue	1.38	1.36
Grams of Cu	9.38	9.42
Calculated Head % Cu	0.66	0.65
Assayed Head % Cu	0.70	0.70
% Cu Extraction	85.3	85.6

4.5 SIMULATED YERINGTON FLOWSHEET

Because the leaching operation of the Anaconda Company at Yerington, Nevada uses percolation leaching in vats to dissolve the copper, it appeared desirable to run a test in which the solutions were advanced from one ore charge to the next and in which a regular cycle of operations could be carried out comparable to the Yerington cycle. The purpose of such a test would be not only to demonstrate the feasibility of continued cycling, but it would also permit the buildup of other impurities dissolved from the ore in correct proportion to the copper. In order to demonstrate this flow-sheet, the series of percolation leach jars were set up as shown in the photograph of Figure 5 and operated with the time cycle according to the schematic diagram shown in Figure 6.

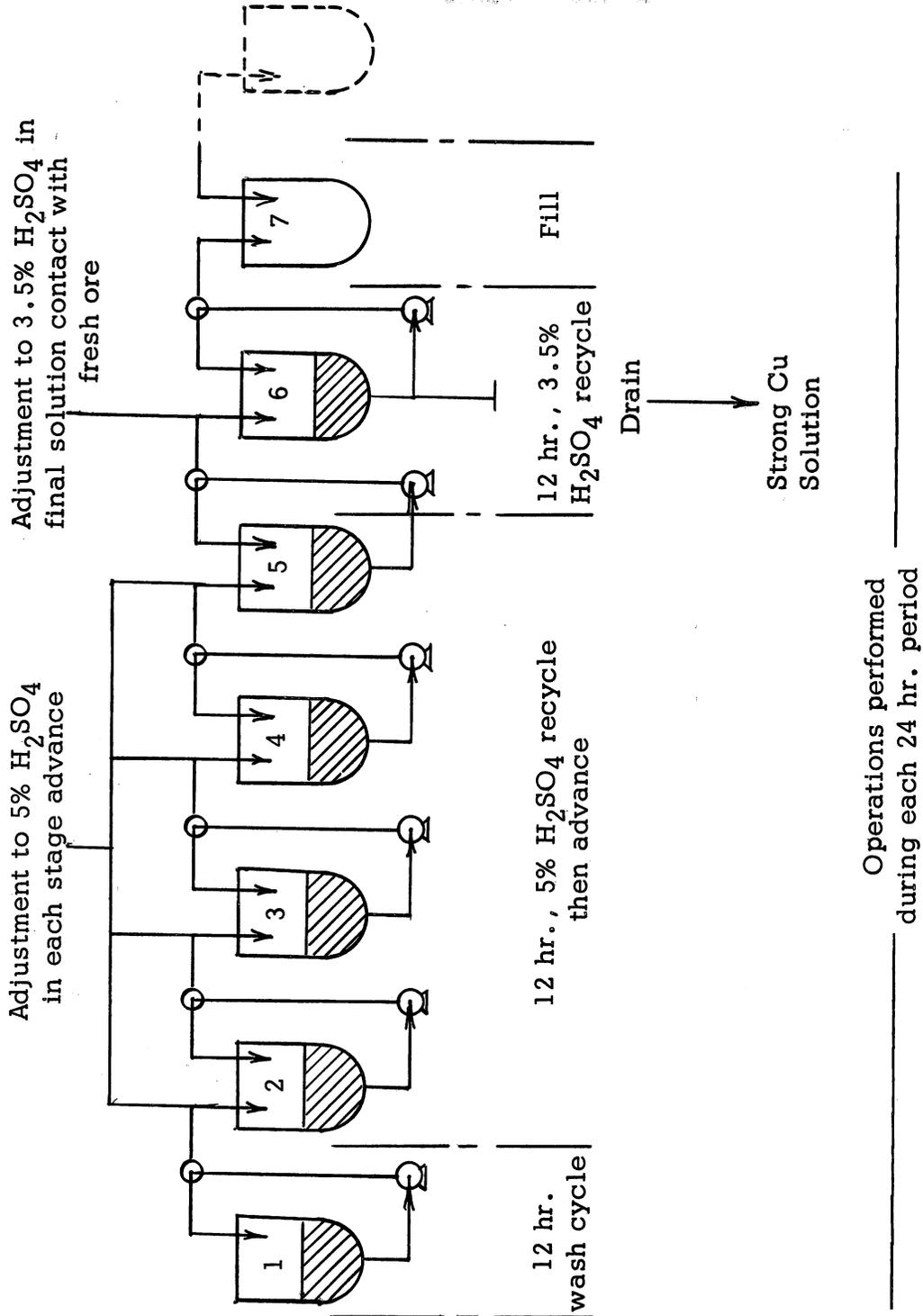
One kilogram charges of $-3/4$ " crushed ore (HRI-133) were prepared for leaching by agglomerating with enough water so that the fines were collected by the coarser material into about $1/4$ " agglomerates mixed with the coarser pieces of ore. These were loaded into the series of columns with a bed depth of 5 inches. These were then leached using the countercurrent system which followed the Yerington flowsheet as closely as possible with respect to time cycle and acid concentration.

Some departure from the Actual Yerington time cycles was caused principally by the shorter time required for advancing the solutions in these small vessels compared to that required for a large tank. This time difference in transfer was included in an extended recycle time to give effectively the same contact time with the acid. It also necessitated some idle time in each 24-hour period. However, the overall cycle was adjusted so that one lot of pregnant solution was produced and one new batch of ore went on-stream in each 24-hour period.



Percolation Leach Jars Used to
Simulate the Yerington Leaching Cycle

Figure 5



hri

Schematic Diagram and Time Cycles of Yerington Countercurrent Leach Test

Figure 6

The sulfuric acid quantity was carefully measured as it was introduced into the test circuit, and the free acid remaining in the solution was analyzed whenever it was removed from the circuit. Acid consumption was calculated as being the difference between the sulfuric acid added to the circuit and that which was removed from solution.

This test was continued until three of the batches of ore had been through the entire cycle and had been removed as being leached. When the test was stopped all of the ore from all leach vessels was removed and analyzed. In addition, one of the completely leached samples was screened and the screen fractions analyzed. The complete data on these tests is given in Table 6.

The average extraction of copper in three lots which had been through the complete leach cycle was 84.0%, with an average acid consumption of 64.5 pounds of acid per ton of ore, which is 4.75 pounds of sulfuric acid consumed per pound of copper dissolved. The pregnant solution produced in this test was analyzed for the various impurities with the results given in Table 7. It can be seen from this table that there is apparently no difficulty in producing solutions containing 18 grams per liter of copper, and that the aluminum and iron dissolution from the ore is not serious.

Table 6

Countercurrent Percolation Leach Test of
Bluebird Ore, HRI-133, Using Yerington
Acid Concentration and Time Cycles

Extraction Data

<u>Column</u>	<u>#1</u>	<u>#2</u>	<u>#3</u>	<u>#4</u>	<u>#5</u>	<u>#6</u>	<u>#7</u>
Head, grams	1180	1050	1058	1169	1212	1173	1170
Residue, grams	1142	1021.6	1044	1144	1185	1150	1136
Residue, % Cu	0.12	0.137	0.15	0.19	0.25	0.29	0.58
Head, grams Cu	9.79	8.72	8.78	9.70	10.1	9.74	9.71
Residue, grams Cu	1.37	1.40	1.57	2.17	2.96	3.33	6.59
% Extraction	86.0	83.9	82.1	77.6	70.7	65.8	32.2
Leach Time	5 days	5 days	5 days	4 days	3 days	2 days	1 day

Screen Analysis on Residue from Column #2

<u>Fraction</u>	<u>Grams</u>	<u>% Distribution</u>	<u>% Copper</u>	<u>Grams Copper</u>	<u>% Copper Distribution</u>	<u>Calculated % Extraction</u>
-3/4 +1/2"	40.8	4.0	0.070	0.028	2.0	89.1
-1/2 +1/4"	391.1	38.3	0.060	0.234	16.7	90.6
-1/4 +10 M	249.8	24.4	0.045	0.112	8.0	93.2
-10 +200 M	234.0	22.9	0.090	0.210	15.0	89.2
-200 M	<u>105.9</u>	<u>10.4</u>	0.77	<u>0.815</u>	<u>58.3</u>	67.9
	1021.6	100.0		1.399	100.0	

Continued---

Table 6 Cont'd.

Copper Material Balance

Sample		Vol. or Wt. (cc or grams)	Cu Assay (g/l or %)	Wt. Cu Grams
1	Tailings	1142	0.12	1.37
2	"	1022	0.137	1.40
3	"	1044	0.15	1.56
	Preg. Solution	315	18.3	5.76
	Col. Drain	310	1.00	0.31
	Col. Wash	305	0.83	0.25
4	Tailings	1144	0.19	2.17
	Preg. Solution	280	20.4	5.71
	Col. Drain	290	2.58	0.75
	Col. Wash	355	1.30	0.46
5	Tailings	1185	0.25	2.96
	Preg. Solution	345	17.5	6.04
	Col. Drain	235	6.74	1.58
	Col. Wash	540	1.95	1.05
6	Tailings	1150	0.29	3.33
	Preg. Solution	280	17.1	4.79
	Col. Drain	270	18.9	5.10
	Col. Wash	350	4.33	1.51
7	Tailings	1136	0.58	6.59
	Preg. Solution	235	15.4	3.62
	Col. Drain	365	13.3	4.85
	Col. Wash	350	6.68	2.33
Samples for Assay		390	4.10	1.60
Total Cu accounted for				65.09
Ore feed to leach 8012 grams @ 0.81% Cu				64.90
Difference				+0.19

Acid Consumption

Total acid added	296.7 grams
Free acid remaining after leach	<u>38.2</u> "
Net acid consumed	258.5 "
Total weight of ore feed	8.01 kg
Grams acid/kg ore	32.23
Lbs. acid/ton ore	64.5

Table 7

Typical Analysis of Strong Copper Solution
Produced in the Yerington Leach Test

<u>Element</u>	<u>Analysis g/l</u>
Copper	18.3
Iron	0.43
Aluminum	0.88
Sulfate	39.6
Free H ₂ SO ₄	5.2
Total Solids	63.8

4.6 LEACHING OF SAMPLE FROM STOVALL HEAP LEACH

On the property at the Bluebird Mine is a heap which was subjected to leaching for approximately a year. In an effort to make an estimate of the efficiency of heap leaching, samples were taken by R. E. Chilson and brought to the Hazen Research laboratory in Golden. These samples were in 1-quart cardboard containers and each sample contained one large 3-inch rock and a portion of considerably finer material.

It was not proper to include the 3-inch rocks in a composite because they would outweigh the other fractions, and would not be proportional to their percentage in the heap. Therefore, a composite was made of the remainder of the material excluding these 3-inch pieces. Several of the 3-inch lumps were analyzed by themselves, however. The remainder of the material was screened, and analyzed for copper content with results given in Table 8. The composite assayed .26% Cu excluding the 3-inch pieces.

Three of the 3-inch chunks were pulverized and assayed individually. It is reported that a head analysis of .82% Cu is correct for the material which was placed on this heap. If this is the case, then the analysis of the residue remaining showed that

the overall extraction of copper from the material during the one year of heap leaching was 68.2%.

Table 8
Screen Analysis of One Year Leached Material

<u>Mesh Size</u>	<u>Weight</u> <u>%</u>	<u>Assay</u> <u>Cu %</u>	<u>Distribution</u> <u>% of Copper</u>
-1" +1/2"	34.1	0.17	22.2
-1/2" +1/4"	18.3	0.14	9.8
-1/4 +10 mesh	13.6	0.11	5.7
-10 +200 mesh	21.6	0.16	13.3
-200 mesh	12.4	<u>1.03</u>	<u>49.0</u>
		0.26	100.0

Analysis of three samples of 3" pieces from one year leached material.

<u>Hole 4</u>	<u>% Cu</u>
5-10 ft.	0.13
15-20 ft.	0.19
20-25 ft.	0.45

It can be seen from the table that the coarser material is fairly well leached, and that approximately one-half of the copper which had not dissolved during the one year was in the -200 mesh fraction which constituted 12.4% by weight of the residue.

There is no way of knowing whether this fine fraction did not leach well because of channeling and failure of the acid solution to contact the fine material, or whether there was something about the copper minerals present in the very fine fraction which made leaching difficult.

In order to shed some light on this problem, the -200 mesh fraction of a portion of this leached tails was agitated in a 4.5% sulfuric acid solution at 70°F for a period of six days. Each 24 hours the leach liquor was replaced with fresh solution. The solution was analyzed at the end of each day and the results are shown in

Table 9. It can be seen from these results that 56% of the copper which remained in this -200 mesh fraction was soluble in sulfuric acid. Of this copper which was soluble in the -200 mesh fraction, the major portion (80%) dissolved in the first two days of agitation leaching.

If this additional dissolving obtained in the -200 mesh fraction by agitation had been obtained while it was in the heap, it would have increased the percent extraction of the heap leaching to 76% of the total copper.

Table 9

Agitation Leaching of -200 Mesh Portion of
Sample of One Year Leached Heap from Stovall Operation

Ore 200 grams of -200 mesh
Dilution 1:1
Acidity 4.5% H₂SO₄
Temperature 70°F

Fraction	Amount g or ml	Assay, Cu % or g/l	Grams	Distribution % of Cu
Heads, Assayed	200	1.03	2.06	
Heads, Calculated		1.07	2.14	
Leach Liquor, 1st Day	165	4.08	0.67	
Leach Liquor, 2nd Day	200	1.44	0.28	
Leach Liquor, 4th Day	220	0.72	0.16	
Leach Liquor, 5th Day	230	0.27	0.06	56.1
Wash, 6th Day	290	0.12	0.03	
Residue	185	0.51	0.94	43.9

Acid consumption 98 lbs. H₂SO₄/ton of -200 mesh fraction.

5. ANALYSIS FOR ACID SOLUBLE COPPER (OXIDE COPPER)

It has been customary in analytical work concerned with the determination of oxide copper versus sulfide copper to use a dilute sulfuric acid or sulfurous acid leaching technique in the laboratory. By agitating a pulverized sample for a prescribed period of time with a certain strength sulfuric acid, or by introducing a certain concentration of SO_2 into a leaching system, that portion of the copper which is in oxide minerals ordinarily dissolves, while that portion which is present as a sulfide does not.

These analytical methods have been used to determine what is called oxide copper. It is not necessarily true, however, that any copper mineral which does not dissolve in any particular acid leach analytical procedure is not oxide copper. It may be merely difficultly soluble.

Bluebird ore contains no sulfide copper, but it does contain some form of oxide copper which is not readily attacked by sulfuric or sulfurous acid. It was necessary, therefore, to use a standard procedure which would have meaning for this particular ore. This difficulty is shown best by results in Table 10 in which the screen fractions of one of the leach tests from the "Yerington flowsheet" were analyzed by three different procedures for the determination of acid soluble copper. The first procedure used 6% sulfuric acid for 2 hours at room temperature, the second used 6% sulfurous acid (SO_2) for 2 hours, and the third used sulfurous acid for 88 hours. It can be seen that there is such a wide variance between the results obtained by the three different systems that they would not be of much value in the test work.

The procedure given by Mr. A. J. Gould on May 3, which was the one standardized for Anaconda operations, was then used in comparison with sulfurous acid and also in comparison with a very long digestion period on five samples of drill holes supplied by R. E. Chilson. These results

are given in Table 11. It can be seen from this that the SO₂ leach procedure, which is frequently given in text books on analytical procedures, is of little use for this problem and that the 2-hour leach with 6% sulfuric acid appears to be the proper method.

Because this method is recommended for all future metallurgical test work and plant control, the procedure is given in detail in the Appendix.

As a double check on these analyses for copper, the total Cu was analyzed in duplicate by a colorimetric method and once by the volumetric iodide method. Results given in Table 12 confirm the accuracy of the total copper assays.

Table 10

Analysis of Residue from
Column #2 of "Yerington Flowsheet"

Sample No.	Total Cu	% Acid Soluble Cu		
		6% H ₂ SO ₄ (2 hr. leach)	6% H ₂ SO ₃ (2 hr. leach)	6% H ₂ SO ₃ (88 hr. leach)
34-142 Col. #2 +1/2"	0.070	0.028	∠0.01	0.017
+1/4"	0.060	0.021	∠0.01	0.012
+10 M	0.045	0.015	∠0.01	0.022
+200 M	0.090	0.027	∠0.01	0.054
-200 M	0.77	0.070	0.051	0.18

Table 11

Comparison of Total Copper and
"Acid Soluble Copper"

Sample No.	Total Cu	Acid Soluble 6% H ₂ SO ₄ (2 hrs.)	Acid Soluble 6% H ₂ SO ₃ (2 hrs.)	Acid Soluble 6% H ₂ SO ₄ (144 hrs.)
Hole #4 (0 to 265)	0.60	0.50	0.34	0.52
#6 (6 to 182)	0.53	0.43	0.31	0.43
#9 (5 to 231)	0.68	0.53	0.38	0.59
#18 (0 to 106)	0.24	0.13	0.11	0.13
#19 (0 to 162)	0.57	0.40	0.29	0.43

Table 12

Total Copper Analysis

<u>Sample No.</u>	<u>Colorimetric Method</u> <u>% Cu</u>	<u>Volumetric Method</u> <u>% Cu</u>
Hole #4 (0-265)	0.59; 0.60	0.58
#6 (6-182)	0.53; 0.53	0.53
#9 (5-231)	0.68; 0.72	0.72
#18 (0-106)	0.24; 0.26	0.27
#19 (0-162)	0.57; 0.56	0.59; 0.57

6. PETROGRAPHIC STUDY OF -200 MESH LEACHED RESIDUE

Because the evidence seems to be strong that the copper present in the fine slimes is difficult to dissolve in sulfuric acid, a study was made of a fraction of -200 mesh material using an optical microscope.

This sample was from the heap leach pile and had undergone one year of leaching.

Thin sections and grain mounts of this material showed the presence of quartz, feldspar, clay, biotite, and a small amount of chrysocolla. This chrysocolla seemed to have a variable refractive index which would indicate probably a variation in the chemical composition which might affect the solubility. Several standard sections of chrysocolla from other localities were studied and compared with the small particles of chrysocolla seen in this fine material. There was no obvious difference in this fine chrysocolla and that from other localities, or in the chrysocolla in the coarse fraction of this same ore. No copper silicate minerals other than chrysocolla were found.

A sample of the -200 mesh material which had been agitation leached with acid for 6 days was also examined microscopically. Even though the chrysocolla was gone and no copper minerals were visible at a magnification of 200X, the sample still assayed .51% Cu.

As a further step the -200 mesh material was screened on 325 mesh, and the undersize and oversize assayed. The +325 mesh fraction analyzed .38% copper, while the -325 mesh analyzed 1.53% copper. Since there was not sufficient visible chrysocolla in the -325 mesh fraction to explain an assay as high as 1.53%, it is strong indication that the clay, and possibly the biotite, which are present in the very fine fractions of the ore contain copper which was probably adsorbed from solutions at some time.

This problem may warrant further study at some time in the future to verify this tentative conclusion that the copper is in the very fine sizes by adsorption on clay.

APPENDIX

Analytical Method for the Determination of Acid Soluble Copper

1. Weigh out a 2 gram sample which has been dried and pulverized to 100 mesh. Transfer to a 250-ml bottle.
2. Add 50 ml of 6% H_2SO_4 .
3. Shake the bottles on any suitable shaker for 2 hours at 80°F.
4. Filter the sample through a #1 Whatman filter paper, wash the residue four times with hot water.
5. Determine copper in the filtrate by any suitable means, such as a volumetric, electrolytic or colorimetric finish. The colorimetric finish is described below.
6. Dilute the filtrate to a definite volume. Pipet an aliquot containing from 20 to 70 micrograms of copper into a 50 ml beaker. Add 5 ml of 10% tartaric acid solution and 5 ml of 10% hydroxylamine hydrochloride solution.
7. Adjust the pH to 5 to 6 with ammonium hydroxide.
8. Transfer the solution to a 60-ml separatory funnel, keeping the total volume to 40 ml.
9. Add by pipet 10.0 ml of 1% cuproine in iso-amyl alcohol. Shake the mixture for 1 to 2 minutes.
10. Allow the layers to separate and draw off the aqueous phase. Transfer the alcohol layer to a centrifuge tube and centrifuge for 1 minute.
11. Measure the absorbancy at a wave length of 546 mu against a reagent blank.
12. From a previously prepared calibration curve calculate percent Cu.

4.4 EFFECT OF WETTING AGENTS

It has sometimes been observed in leaching that a wetting agent which lowers the surface tension of the leach solution permits it to penetrate crevices more readily and thereby dissolves minerals more swiftly.

In order to see if this was the case, a percolation leach test was run in which Aerosol OT was added to the sulfuric acid solution which percolated through the charge. The amount added was equal to .05 pounds per ton of ore.

The ore was crushed to $-1/2$ inch, agglomerated with water and loaded into the 5-inch diameter percolation leach jars. It was flooded from the bottom with a 4.5% sulfuric acid solution, after which downward percolation was started. Solutions were recycled for ten days and the acid strength was adjusted at the end of each 24 hours to bring it back to the 4.5% strength.

An exact duplicate was run in parallel with this test, using a solution of the same strength of acid to which no wetting agents were added.

The data from these two parallel tests is given in the table below, and show quite clearly that there was absolutely no benefit obtained from the addition of the wetting agent and the lowering of the surface tension. This tends to confirm the observations that the solution can penetrate rather easily into the interior of this ore. The sample used was HRI-135A which had a head analysis of .70% Cu.

The copper extraction at the end of ten days was 85.3%, with an acid consumption of 53.6 pounds for the test with Aerosol, and 85.6% with an acid consumption of 54.8 pounds per ton of ore for the leach without the Aerosol. Provided fracturing is as common for the entire ore body as it was for this sample, there would seem to be no purpose in pursuing the use of wetting agents further.

Table 5

Percolation Leaching with Aerosol Added
Bluebird Ore Sample 135A

Test No.	40-8-3 (.05# Aerosol/Ton)	40-8-4
Days	Lbs. H ₂ SO ₄ /Ton of Ore	Lbs. H ₂ SO ₄ /Ton of Ore
1	28.3	27.7
2	31.8	31.8
3	35.9	37.3
4	39.2	39.5
5	--	--
6	42.0	42.7
7	44.8	46.0
8	--	--
9	51.7	52.2
10	53.6	54.8

Material Balance, Copper

Test No.	40-8-3 (.05# Aerosol/Ton)	40-8-4
Head, grams	1420	1460
Grams Cu in Solution	8.00	8.06
Residue, grams	1381	1421
% Cu in Residue	0.10	0.096
Grams Cu in Residue	1.38	1.36
Grams of Cu	9.38	9.42
Calculated Head % Cu	0.66	0.65
Assayed Head % Cu	0.70	0.70
% Cu Extraction	85.3	85.6

4.5 SIMULATED YERINGTON FLOWSHEET

Because the leaching operation of the Anaconda Company at Yerington, Nevada uses percolation leaching in vats to dissolve the copper, it appeared desirable to run a test in which the solutions were advanced from one ore charge to the next and in which a regular cycle of operations could be carried out comparable to the Yerington cycle. The purpose of such a test would be not only to demonstrate the feasibility of continued cycling, but it would also permit the buildup of other impurities dissolved from the ore in correct proportion to the copper. In order to demonstrate this flowsheet, the series of percolation leach jars were set up as shown in the photograph of Figure 5 and operated with the time cycle according to the schematic diagram shown in Figure 6.

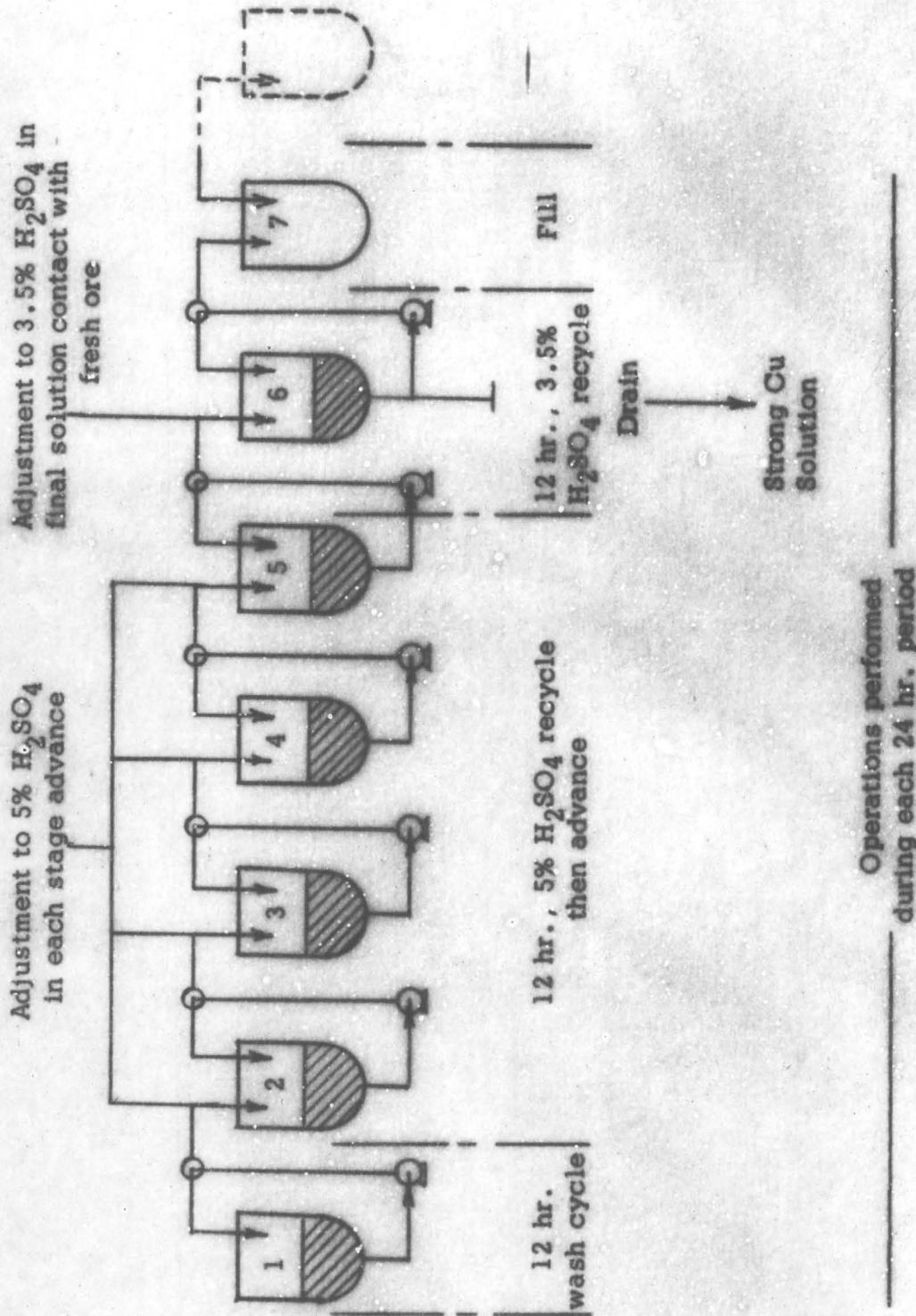
One kilogram charges of $-3/4$ " crushed ore (HRI-123) were prepared for leaching by agglomerating with enough water so that the fines were collected by the coarser material into about $1/4$ " agglomerates mixed with the coarser pieces of ore. These were loaded into the series of columns with a bed depth of 5 inches. These were then leached using the countercurrent system which followed the Yerington flowsheet as closely as possible with respect to time cycle and acid concentration.

Some departure from the Actual Yerington time cycles was caused principally by the shorter time required for advancing the solutions in these small vessels compared to that required for a large tank. This time difference in transfer was included in an extended recycle time to give effectively the same contact time with the acid. It also necessitated some idle time in each 24-hour period. However, the overall cycle was adjusted so that one lot of pregnant solution was produced and one new batch of ore went on-stream in each 24-hour period.



**Percolation Leach Jars Used to
Simulate the Yerington Leaching Cycle**

Figure 5



hri

Schematic Diagram and Time Cycles of Yerington Countercurrent Leach Test

Figure 6

The sulfuric acid quantity was carefully measured as it was introduced into the test circuit, and the free acid remaining in the solution was analyzed whenever it was removed from the circuit. Acid consumption was calculated as being the difference between the sulfuric acid added to the circuit and that which was removed from solution.

This test was continued until three of the batches of ore had been through the entire cycle and had been removed as being leached. When the test was stopped all of the ore from all leach vessels was removed and analyzed. In addition, one of the completely leached samples was screened and the screen fractions analyzed. The complete data on these tests is given in Table 6.

The average extraction of copper in three lots which had been through the complete leach cycle was 84.0%, with an average acid consumption of 64.5 pounds of acid per ton of ore, which is 4.75 pounds of sulfuric acid consumed per pound of copper dissolved. The pregnant solution produced in this test was analyzed for the various impurities with the results given in Table 7. It can be seen from this table that there is apparently no difficulty in producing solutions containing 18 grams per liter of copper, and that the aluminum and iron dissolution from the ore is not serious.

Table 6
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Bluebird Ore, HRI-133, Using Yerington
Acid Concentration and Time Cycles

<u>Extraction Data</u>							
<u>Column</u>	<u>#1</u>	<u>#2</u>	<u>#3</u>	<u>#4</u>	<u>#5</u>	<u>#6</u>	<u>#7</u>
Head, grams	1180	1050	1058	1169	1212	1173	1170
Residue, grams	1142	1021.6	1044	1144	1185	1150	1136
Residue, % Cu	0.12	0.137	0.15	0.19	0.25	0.29	0.58
Head, grams Cu	9.79	8.72	8.78	9.70	10.1	9.74	9.71
Residue, grams Cu	1.37	1.40	1.57	2.17	2.96	3.33	6.59
% Extraction	86.0	83.9	82.1	77.6	70.7	65.8	32.2
Leach Time	5 days	5 days	5 days	4 days	3 days	2 days	1 day

Screen Analysis on Residue from Column #2

<u>Fraction</u>	<u>Grams</u>	<u>% Distribution</u>	<u>% Copper</u>	<u>Grams Copper</u>	<u>% Copper Distribution</u>	<u>Calculated % Extraction</u>
-3/4 +1/2"	40.8	4.0	0.070	0.028	2.0	89.1
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-1/4 +10 M	249.8	24.4	0.045	0.112	8.0	93.2
-10 +200 M	234.0	22.9	0.090	0.210	15.0	89.2
-200 M	105.9	10.4	0.77	0.815	58.3	67.9
	<u>1021.6</u>	<u>100.0</u>		<u>1.399</u>	<u>100.0</u>	

Continued---

Table 6 Cont'd.

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Total Solids	63.8

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Screen Analysis of One Year Leached Material

<u>Mesh Size</u>	<u>Weight %</u>	<u>Assay Cu %</u>	<u>Distribution % of Copper</u>
-1" +1/2"	34.1	0.17	22.2
-1/2" +1/4"	18.3	0.14	9.8
-1/4 +10 mesh	13.6	0.11	5.7
-10 +200 mesh	21.6	0.16	13.3
-200 mesh	12.4	<u>1.03</u>	<u>49.0</u>
		0.25	100.0

Analysis of three samples of 3" pieces from one year leached material.

<u>Hole 4</u>	<u>% Cu</u>
5-10 ft.	0.13
15-20 ft.	0.19
20-25 ft.	0.45

It can be seen from the table that the coarser material is fairly well leached, and that approximately one-half of the copper which had not dissolved during the one year was in the -200 mesh fraction which constituted 12.4% by weight of the residue.

There is no way of knowing whether this fine fraction did not leach well because of channeling and failure of the acid solution to contact the fine material, or whether there was something about the copper minerals present in the very fine fraction which made leaching difficult.

In order to shed some light on this problem, the -200 mesh fraction of a portion of this leached tails was agitated in a 4.5% sulfuric acid solution at 70°F for a period of six days. Each 24 hours the leach liquor was replaced with fresh solution. The solution was analyzed at the end of each day and the results are shown in

Table 9. It can be seen from these results that 56% of the copper which remained in this -200 mesh fraction was soluble in sulfuric acid. Of this copper which was soluble in the -200 mesh fraction, the major portion (80%) dissolved in the first two days of agitation leaching.

If this additional dissolving obtained in the -200 mesh fraction by agitation had been obtained while it was in the heap, it would have increased the percent extraction of the heap leaching to 76% of the total copper.

Table 9
Agitation Leaching of -200 Mesh Portion of
Sample of One Year Leached Heap from Stovall Operation

Ore 200 grams of -200 mesh
 Dilution 1:1
 Acidity 4.5% H₂SO₄
 Temperature 70°F

Fraction	Amount g or ml	Assay, Cu % or g/l	Grams	Distribution % of Cu
Heads, Assayed	200	1.03	2.06	
Heads, Calculated		1.07	2.14	
Leach Liquor, 1st Day	165	4.08	0.67	
Leach Liquor, 2nd Day	200	1.44	0.28	
Leach Liquor, 4th Day	220	0.72	0.16	
Leach Liquor, 5th Day	230	0.27	0.06	56.1
Wash, 6th Day	290	0.12	0.03	
Residue	185	0.51	0.94	43.9

Acid consumption 98 lbs. H₂SO₄/ton of -200 mesh fraction.

S. ANALYSIS FOR ACID SOLUBLE COPPER (OXIDE COPPER)

It has been customary in analytical work concerned with the determination of oxide copper versus sulfide copper to use a dilute sulfuric acid or sulfurous acid leaching technique in the laboratory. By agitating a pulverized sample for a prescribed period of time with a certain strength sulfuric acid, or by introducing a certain concentration of SO_2 into a leaching system, that portion of the copper which is in oxide minerals ordinarily dissolves, while that portion which is present as a sulfide does not.

These analytical methods have been used to determine what is called oxide copper. It is not necessarily true, however, that any copper mineral which does not dissolve in any particular acid leach analytical procedure is not oxide copper. It may be merely difficultly soluble.

Bluebird ore contains no sulfide copper, but it does contain some form of oxide copper which is not readily attacked by sulfuric or sulfurous acid. It was necessary, therefore, to use a standard procedure which would have meaning for this particular ore. This difficulty is shown best by results in Table 10 in which the screen fractions of one of the leach tests from the "Yerington flowsheet" were analyzed by three different procedures for the determination of acid soluble copper. The first procedure used 6% sulfuric acid for 2 hours at room temperature, the second used 6% sulfurous acid (SO_2) for 2 hours, and the third used sulfurous acid for 88 hours. It can be seen that there is such a wide variance between the results obtained by the three different systems that they would not be of much value in the test work.

The procedure given by Mr. A. J. Gould on May 3, which was the one standardized for Anaconda operations, was then used in comparison with sulfurous acid and also in comparison with a very long digestion period on five samples of drill holes supplied by R. E. Chilson. These results

are given in Table 11. It can be seen from this that the SO_2 leach procedure, which is frequently given in text books on analytical procedures, is of little use for this problem and that the 2-hour leach with 6% sulfuric acid appears to be the proper method.

Because this method is recommended for all future metallurgical test work and plant control, the procedure is given in detail in the Appendix.

As a double check on these analyses for copper, the total Cu was analyzed in duplicate by a colorimetric method and once by the volumetric iodide method. Results given in Table 12 confirm the accuracy of the total copper assays.

Table 10

Analysis of Residue from
Column #2 of "Yerington Flowsheet"

Sample No.	Total Cu	% Acid Soluble Cu*		
		6% H_2SO_4 (2 hr. leach)	6% H_2SO_3 (2 hr. leach)	6% H_2SO_3 (98 hr. leach)
34-142 Col. #2 +1/2"	0.070	0.028	<0.01	0.017
+1/4"	0.060	0.021	<0.01	0.012
+10 M	0.045	0.015	<0.01	0.022
+200 M	0.090	0.027	<0.01	0.054
-200 M	0.77	0.070	0.051	0.18

Table 11

Comparison of Total Copper and
"Acid Soluble Copper"

Sample No.	Total Cu	Acid Soluble 6% H_2SO_4 (2 hrs.)	Acid Soluble 6% H_2SO_3 (2 hrs.)	Acid Soluble 6% H_2SO_4 (144 hrs.)
Hole #4 (0 to 265)	0.60	0.50	0.34	0.52
#6 (6 to 182)	0.53	0.43	0.31	0.43
#9 (5 to 231)	0.68	0.52	0.38	0.59
#18 (0 to 106)	0.24	0.13	0.11	0.13
#19 (0 to 162)	0.57	0.40	0.29	0.43

Table 12
Total Copper Analysis

<u>Sample No.</u>	<u>Colorimetric Method</u> <u>% Cu</u>	<u>Volumetric Method</u> <u>% Cu</u>
Hole #4 (0-265)	0.59; 0.60	0.58
#6 (6-182)	0.53; 0.53	0.53
#9 (5-231)	0.68; 0.72	0.72
#18 (0-106)	0.24; 0.26	0.27
#19 (0-162)	0.57; 0.58	0.59; 0.57

6. PETROGRAPHIC STUDY OF -200 MESH LEACHED RESIDUE

Because the evidence seems to be strong that the copper present in the fine slimes is difficult to dissolve in sulfuric acid, a study was made of a fraction of -200 mesh material using an optical microscope.

This sample was from the heap leach pile and had undergone one year of leaching.

Thin sections and grain mounts of this material showed the presence of quartz, feldspar, clay, biotite, and a small amount of chrysocolla. This chrysocolla seemed to have a variable refractive index which would indicate probably a variation in the chemical composition which might affect the solubility. Several standard sections of chrysocolla from other localities were studied and compared with the small particles of chrysocolla seen in this fine material. There was no obvious difference in this fine chrysocolla and that from other localities, or in the chrysocolla in the coarse fraction of this same ore. No copper silicate minerals other than chrysocolla were found.

A sample of the -200 mesh material which had been agitation leached with acid for 6 days was also examined microscopically. Even though the chrysocolla was gone and no copper minerals were visible at a magnification of 200X, the sample still assayed .51% Cu.

As a further step the -200 mesh material was screened on 325 mesh, and the undersize and oversize assayed. The +325 mesh fraction analyzed .38% copper, while the -325 mesh analyzed 1.53% copper. Since there was not sufficient visible chrysocolla in the -325 mesh fraction to explain an assay as high as 1.53%, it is strong indication that the clay, and possibly the biotite, which are present in the very fine fractions of the ore contain copper which was probably adsorbed from solutions at some time.

APPENDIX

Analytical Method for the Determination of Acid Soluble Copper

1. Weigh out a 2 gram sample which has been dried and pulverized to 100 mesh. Transfer to a 250-ml bottle.
2. Add 50 ml of 6% H_2SO_4 .
3. Shake the bottles on any suitable shaker for 2 hours at 80°F.
4. Filter the sample through a #1 Whatman filter paper, wash the residue four times with hot water.
5. Determine copper in the filtrate by any suitable means, such as a volumetric, electrolytic or colorimetric finish. The colorimetric finish is described below.
6. Dilute the filtrate to a definite volume. Pipet an aliquot containing from 20 to 70 micrograms of copper into a 50 ml beaker. Add 5 ml of 10% tartaric acid solution and 5 ml of 10% hydroxylamine hydrochloride solution.
7. Adjust the pH to 5 to 6 with ammonium hydroxide.
8. Transfer the solution to a 60-ml separatory funnel, keeping the total volume to 40 ml.
9. Add by pipet 10.0 ml of 1% cuproine in iso-amyl alcohol. Shake the mixture for 1 to 2 minutes.
10. Allow the layers to separate and draw off the aqueous phase. Transfer the alcohol layer to a centrifuge tube and centrifuge for 1 minute.
11. Measure the absorbancy at a wave length of 546 mu against a reagent blank.
12. From a previously prepared calibration curve calculate percent Cu.