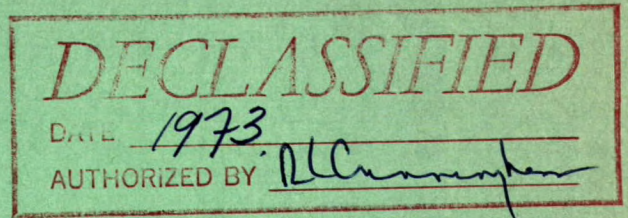


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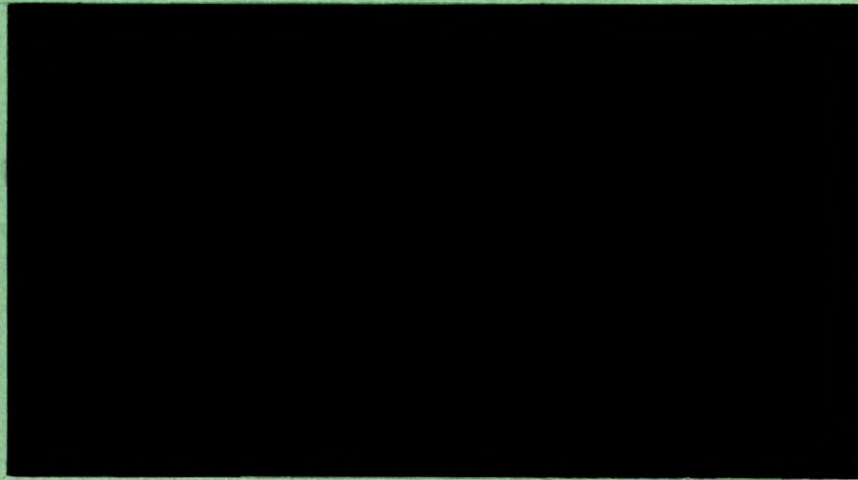
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BACTERIAL LEACHING OF OXIDIZED COPPER
ORE FROM CAMPBELL CHIBOUGAMAU
MINES, LTD., QUEBEC

H. W. Parsons
EXTRACTION METALLURGY DIVISION

Mines Branch Investigation Report IR 72-55

BACTERIAL LEACHING OF OXIDIZED COPPER
ORE FROM CAMPBELL CHIBOUGAMAU
MINES, LTD., QUEBEC

by

H. W. Parsons *

SUMMARY

Oxidized copper ore from the Henderson Mine, Campbell Chibougamau Mines, Limited, is amenable to leaching with the aid of bacteria in an acid-sulphate medium. About 85 % of the copper was leached in 24 weeks with a consumption of about 1.5 pounds of sulphuric acid per pound of copper extracted.

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INTRODUCTION

Campbell Chibougamau Mines, Limited, is interested in applying bacterial leaching to more than one million tons of highly oxidized copper ore at their Henderson mine. To determine the feasibility of such treatment, the company requested help from the Mines Branch in Ottawa, and submitted a sample of ore to be tested for its amenability to bacterial leaching.

Copper has been commercially extracted from its minerals by heap leaching operations by many companies, some of which, such as Rio Tinto Mines in Spain, are centuries old. However, it has been known for only about the past quarter of a century that bacteria have an active fundamental role in the alteration of sulphide minerals. The complex chemical and biological reactions involved in the dissolution of metal sulphides are not completely understood. However, sufficient data have been obtained from numerous investigations to enable the prediction of close to optimum conditions for maximum bacterial efficiency.

One species of bacteria which reacts with most metallic sulphides of commercial importance (excluding lead sulphides) is called *Thiobacillus ferrooxidans*. Studies have been made of the oxidative action of these bacteria on the copper minerals chalcopyrite (CuFeS_2) (1-17), chalcocite (Cu_2S) (5,7,10,13,17,18), bornite (Cu_3FeS_4) (5,7,13,19), covellite (CuS) (5,13,18,19), tetrahedrite ($\text{Cu}_8\text{Sb}_2\text{S}_7$) (13) and enargite ($3\text{Cu}_2\text{S} \cdot \text{As}_2\text{S}_5$) (20).

Thiobacillus ferrooxidans cells are rod-shaped, and measure from 1.0 to 1.6 microns in length, and 0.6 to 1.0 microns in width. The species is the chemosynthetic autotrophic type, and derives its

energy from the oxidation of reduced sulphur compounds and ferrous iron. Nutrients needed for its metabolism include nitrogen (utilized from ammonium ions), phosphate, potassium, magnesium and calcium. A nutritive solution containing these salts, called Silverman 9K solution (21) is widely used as both a culture medium and as a leaching solution. An adequate supply of air is needed by the bacteria, as a source of oxygen and carbon dioxide. The bacteria obtain their carbon only from carbon dioxide. It has been reported that in the leaching of mineral sulphides with water containing nitrogen and phosphorus ions, in the presence of adequate oxygen and carbon dioxide, the gangue may supply the other necessary nutrients (10). In leaching with these bacteria it has been determined that they perform best at a temperature of about 35°C, at a pH of from 1.5 to 3.5.

Thiobacillus ferrooxidans bacteria, from underground mine water from the Elliot Lake area (22), were used in this investigation of copper leaching.

PROCEDURE

The ore, which had the analysis shown in Table 1, was crushed to minus 1/2 inch, and 500 grams were placed in the apparatus shown in Figure 1. The solution in the reservoir below the ore column was air-lifted at a rate of about 10 ml/minute to the top of the column, and allowed to percolate through the ore back to the reservoir.

This leaching medium was an aqueous solution of sulphuric acid, pH 1.8, which contained the salts shown in Table 2. This so-called 9K Medium was inoculated with 5 mls of

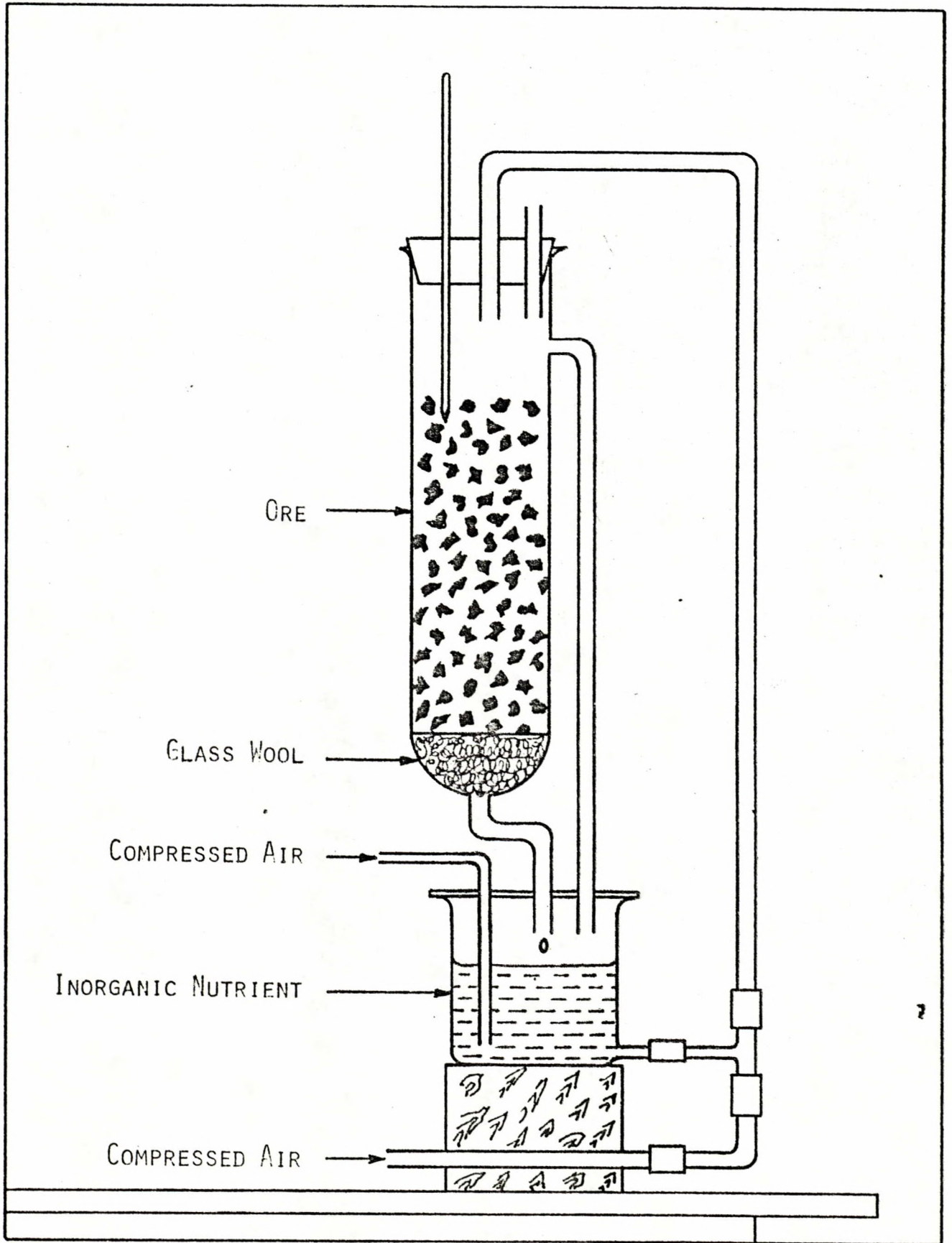


FIGURE 1. PERCOLATION LEACHING APPARATUS

Thiobacillus ferrooxidans serum concentrate. The bacteria were cultivated by aerating the solution at 35°C for five days. The amount of solution used was 800 mls, maintained at pH 1.8 by the addition of sulphuric acid; loss by evaporation was compensated for by the addition of distilled water acidified to pH 1.8 with sulphuric acid.

TABLE 1

Chemical Analysis of Henderson Copper Ore

Cu	20.4%
Zn	0.011%
S	19.3%

TABLE 2

Composition of 9K Medium*

Constituent	g/l
FeSO ₄ · 7H ₂ O	44.2
(NH ₄) ₂ SO ₄	3.0
K ₂ HPO ₄	0.5
KCl	0.1
MgSO ₄ · 7H ₂ O	0.5
Ca(NO ₃) ₂ · 4H ₂ O	0.02
H ₂ SO ₄	0.5
pH	1.8

* after Silverman and Lundgren (21)

RESULTS AND OBSERVATIONS

The concentration of copper in solution increased rapidly for about the first 4 weeks of leaching to about 52 g/l. This is equivalent to about 41% copper extraction. Additional extraction during the next 4 weeks amounted to only about 2%. See Figures 2 and 3.

After this initial leach period of 8 weeks, the column was allowed to drain completely. The leach solution was then replaced by freshly prepared 9K, and the recycling resumed for an additional 7 weeks. As shown in Figure 2, an additional 35% of the copper was extracted, making a total extraction of 76% during the 15 weeks of leaching. Figure 3 shows that in this second cycle the copper increased to 45 g/l but at a slower rate than during the first cycle.

The leach solution was again replaced by freshly prepared 9K solution, and the recycle-leaching technique was repeated for another 9 weeks. Another 9% of the copper was extracted in this period to make a total copper extraction of 85% in the 24 weeks. During the third leach the dissolved copper increased slowly to only 18 g/l.

As is shown by Figure 4, the redox potential over the whole leaching period gradually increased from about 350 mV to about 520 mV. In the first leach, the initial value of 480 mV decreased to about 350 mV and fluctuated between this value and 400 mV. In the second leach period, the initial emf of 500 mV decreased to 420 mV on the second day of leaching, and fluctuated between 450 mV and 380 mV. During the final leach, the emf value fluctuated between 620 mV and 480 mV.

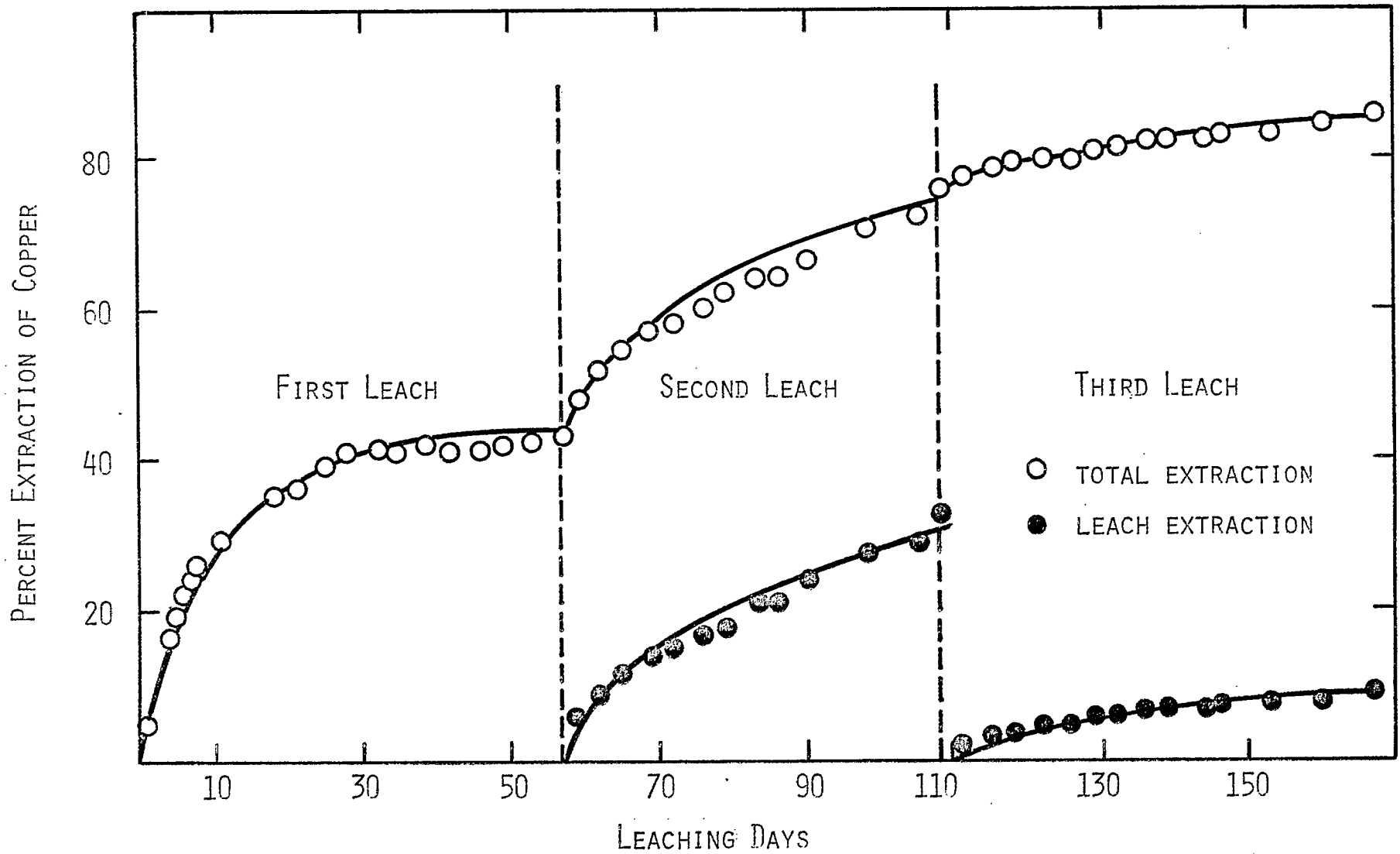


FIGURE 2. ACCUMULATIVE PERCENT EXTRACTION OF COPPER

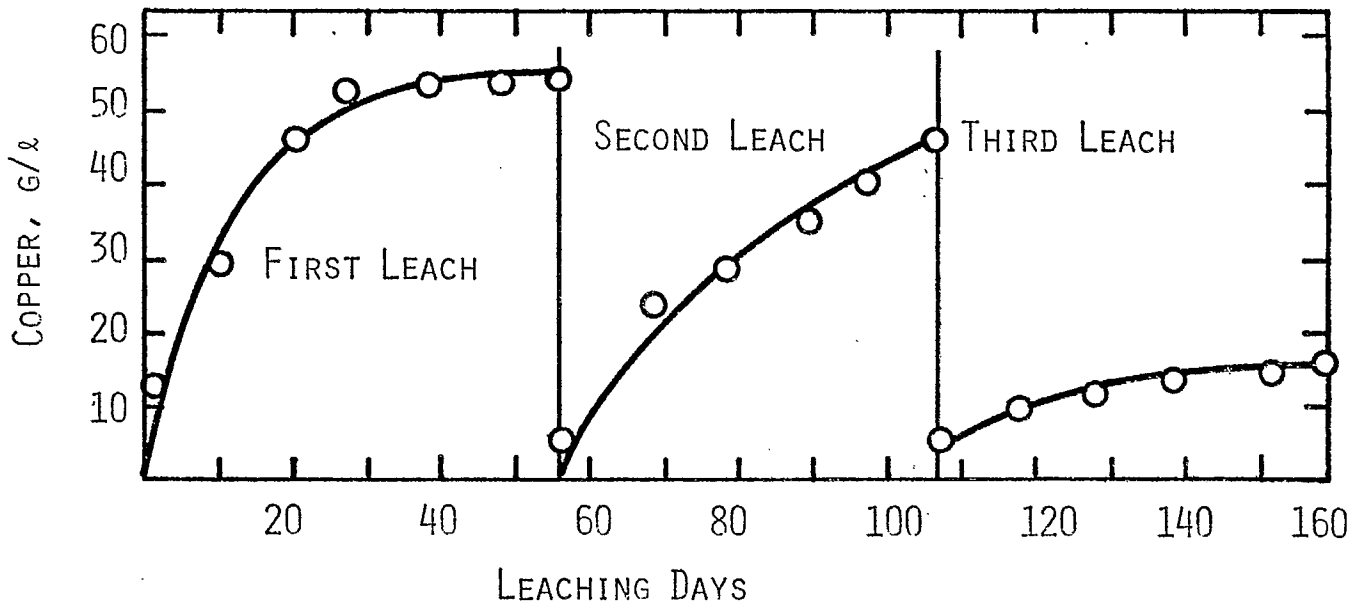


FIGURE 3. COPPER IN SOLUTION, g/l

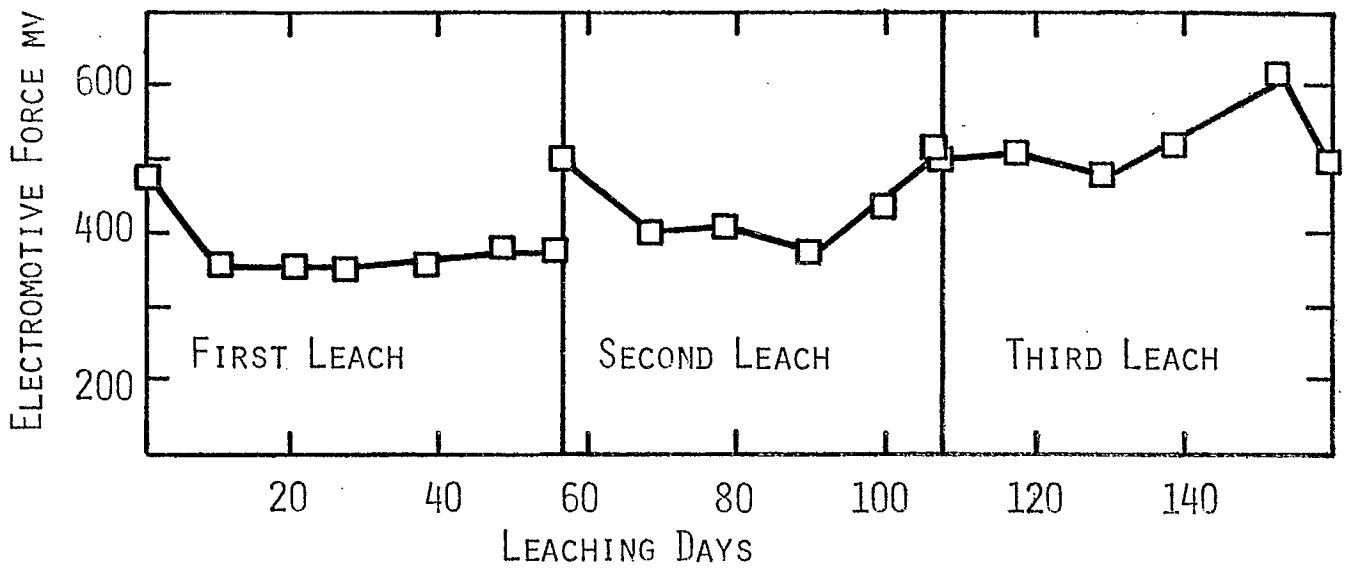


FIGURE 4. ELECTROMOTIVE FORCE OF RECYCLING SOLUTIONS

The rates of copper extraction, shown in Table 3 and Figure 5, varied from about 11 lbs Cu/day/ton of ore, over the first 11 days of leaching, to about 0.3 lb Cu/day/ton of ore during the period 30-56 days from the beginning of leaching.

A total of 135 grams of H_2SO_4 were added to the solutions in the extraction of 87 grams of copper. This is an overall consumption of about 1.5 pounds of acid per pound of copper extracted, or 540 pounds of acid per ton of ore treated. The consumption of acid in the three leaches is shown in Figure 6. In the first leach, over two pounds of acid were consumed for each pound of copper extracted. It was observed that in the period 30-56 days after the start of leaching, when the copper extraction did not increase, the acid continued to be consumed. In the second and third leaches, about one pound of acid was consumed for each pound of copper extracted.

DISCUSSION

As is shown by Figure 2, the copper extraction rate was satisfactory for the first month of operation. In the following thirty days, however, only a slight additional amount of copper dissolved. It is suspected that the increase in the strength of the copper in solution inhibited the activity of the bacteria, especially when the concentration of the copper was approximately 50 g/l. Copper is toxic to most organisms, but *Thiobacillus ferrooxidans* apparently can exist in fairly high concentrations of copper (18). Duncan et al (6) stated that "the production of copper concentrations ranging from 30 to 50 g/l has accrued as a result of experimentation and bacterial conditioning involving several years".

TABLE 3

Rate of Extraction of Copper

Leach Period Day-to-Day	Cu Extraction lbs Cu/Day/Ton	Percent of Residual Cu Which was Leached		Percent of Heads Cu Extracted	Accumu- lative Percent Extraction
		% per period	% per day		
<u>First Leach</u>					
0-11	10.9	29.3	2.7	29.3	29.3
11-21	2.6	9.0	0.9	6.5	35.8
21-32	2.0	8.4	0.8	5.4	41.2
32-56	0.3	2.9	1.4	1.4	42.6
<u>Second Leach</u>					
0-9	5.1	19.7	2.2	11.2	53.8
9-20	2.0	11.7	1.1	5.3	59.1
20-30	1.7	10.4	1.0	4.3	63.4
30-42	2.2	17.8	1.5	6.6	70.0
42-51	2.3	17.0	1.9	5.1	75.1
<u>Third Leach</u>					
0-11	1.4	15.0	1.4	3.7	78.8
11-22	0.6	7.4	0.7	1.6	80.4
22-32	0.6	7.5	0.7	1.5	81.9
32-64	0.4	14.7	0.5	2.6	84.5

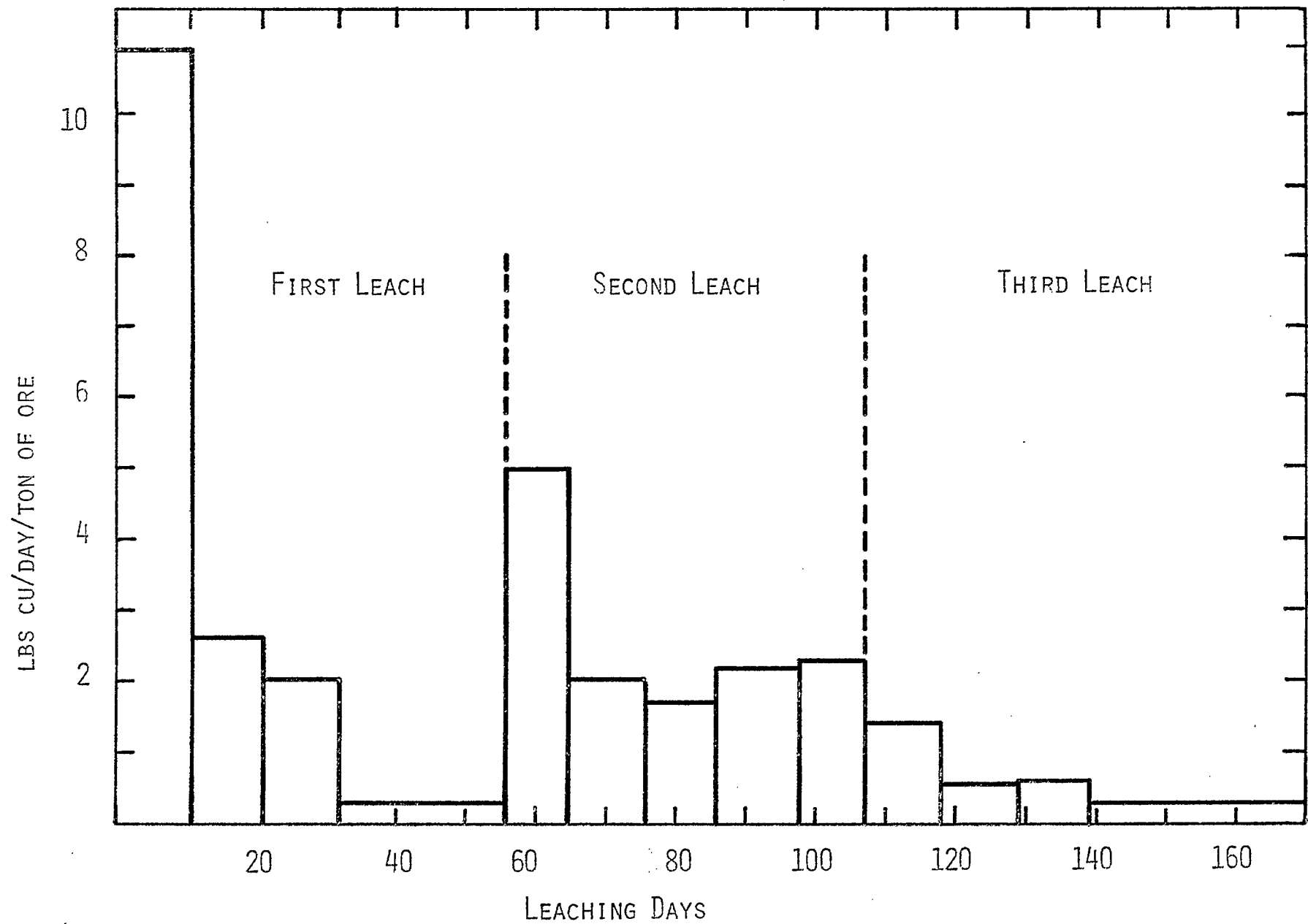


FIGURE 5. RATE OF COPPER EXTRACTION LBS CU/DAY/TON

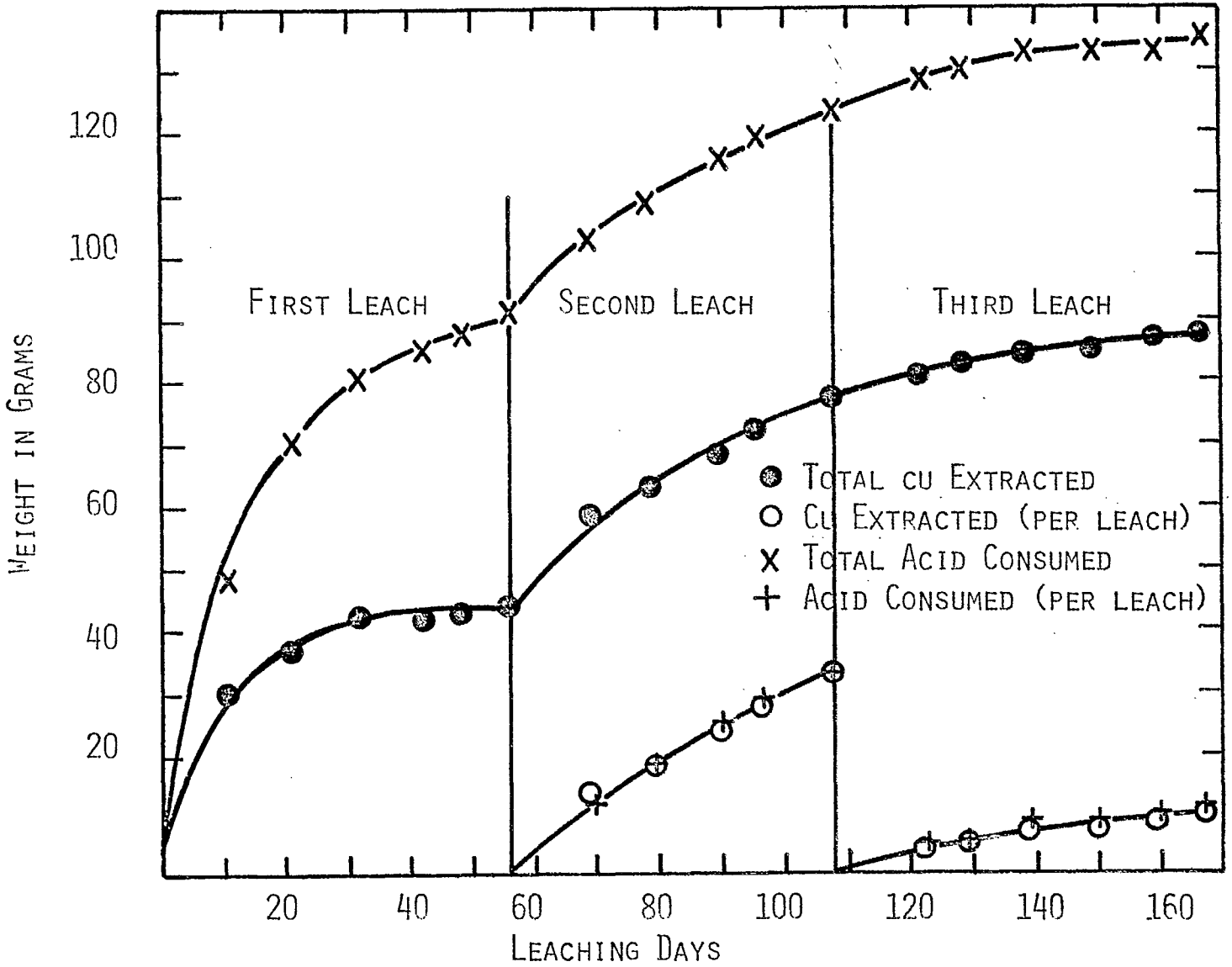


FIGURE 6. WEIGHT OF COPPER EXTRACTED AND WEIGHT OF ACID CONSUMED

In the second leach, the copper in solution did not reach the 46 g/l value (Figure 3), and it was observed that the extraction rate stayed fairly constant (Figure 5).

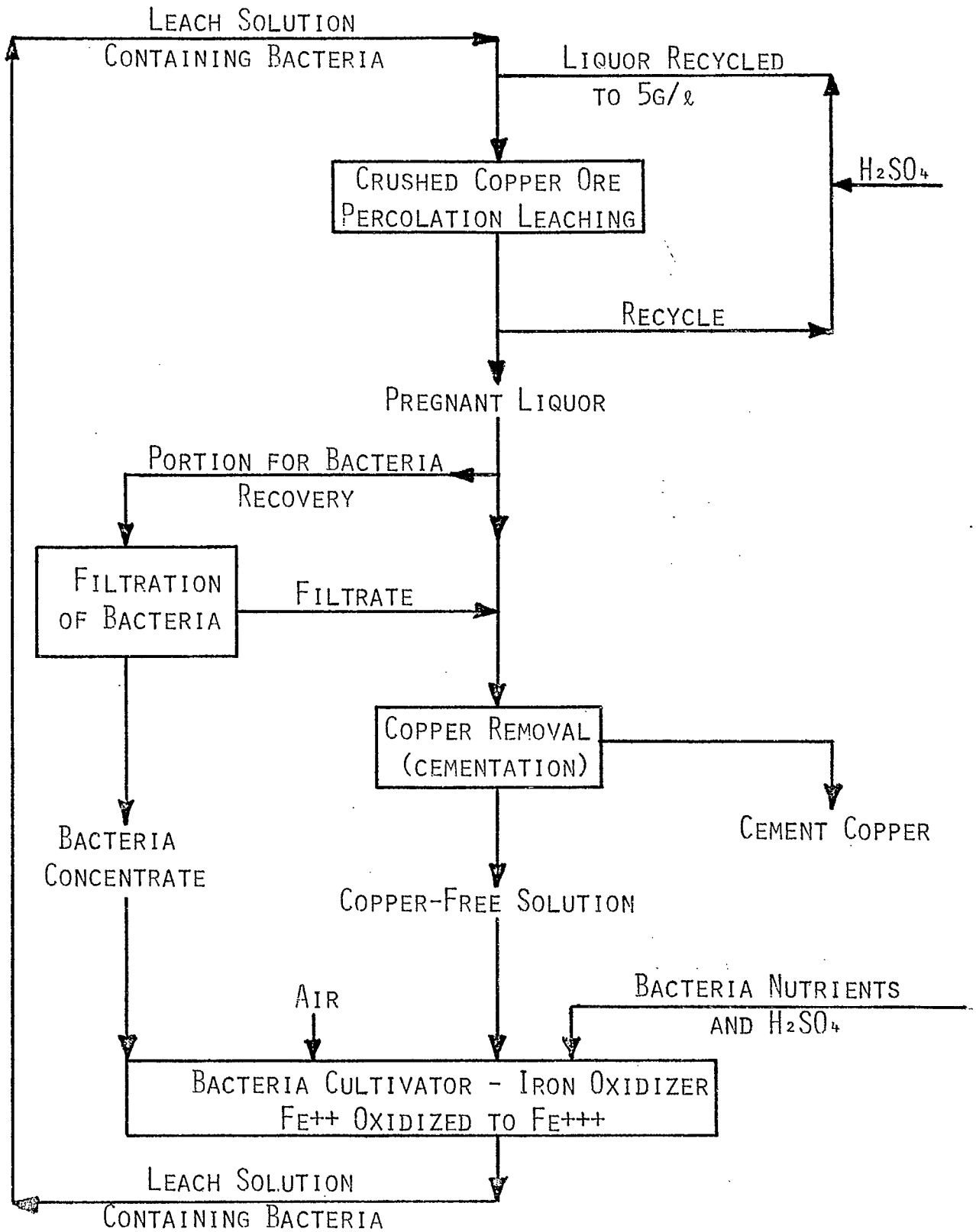
To circumvent the inhibitory effect of the high concentrations of copper ions in solution, the proposed procedure illustrated in Figure 7 could be followed. This is as follows:

The desired volume of leach liquor is percolated through the ore, and recycled, if necessary, until the copper content is say 5 g/l. A portion of this solution is then passed through a micro filter, to remove the bacteria in the form of a concentrate. The copper in the solution is then extracted by means of cementation with iron. The copper-free solution, containing the nutrients from the 9K salts, is then inoculated with the filtered bacteria. When the ferrous iron in solution is completely oxidized, the solution is then recycled over the heap.

By this method a constant production of copper from the heap will be obtained, thus avoiding the "tie-up" of copper entailed in recycling the whole solution until all the copper is leached.

CONCLUSIONS

The oxidized copper ore from the Henderson Mine, Campbell Chibougamau Mines, Limited, is amenable to bacterial leaching, with about 85% of the copper being leached in 166 days. The copper leaches quite rapidly at the beginning of leaching, at a rate of about 11 pounds of copper per day per ton of ore treated. The extraction rate declines, as the amount of copper available decreases, to a rate of about 0.3 pound Cu per day per



FLWSHEET FOR LEACHING COPPER ORE WITH BACTERIA LADEN SOLUTION

FIGURE 7.

ton of ore at the end of the experiment. The acid consumption is about 1.5 pounds of acid per pound of copper extracted.

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