LIX® 34. (ISN'T NEW REAGENT EVALUATION FUN!)

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The Mineral Industries Group of General Mills Chemicals, Inc., had the pleasure of introducing LIX® 34, "A New Generation Copper Extractant", at the AIME Annual Meeting in February of 1976.[1] The paper discussed the behavior of LIX 34 with respect to a variety of copper containing feed solutions and in some cases direct comparisons with the behavior of LIX® 64N were made. Since that time we have had the opportunity to examine the behavior of LIX 34 in much greater detail. Furthermore, we have produced several pilot plant size batches of LIX 34 as a prelude to commercial scaleup. This paper covers our subsequent work; pointing out some of the problems encountered; how we solved or attempted to solve them; and where these adventures have led us. We apologize for the places where details may be lacking, but the confidentiality of our customers and our own confidentiality for competative purposes dictate this discretion.

Before discussing our recent work with LIX 34, some background on the reagent will be presented. LIX 34 operates on a hydrogen ion cycle with the equation below representing the loading $\leftrightarrows$ stripping reactions:

$$2\ R\text{-}H(org.) + M^{2+}(aq.) \rightleftharpoons R_2M(org.) + 2H^{+}(aq.)$$

We have previously reported that LIX 34 is comparable to LIX 64N in extraction strength when the reagents are evaluated on a molar basis and indeed presented several independent experiments as evidence[1] (Figure 1. Tables I and II). We also reported that LIX 34 had good phase separation properties and showed excellent copper selectivity over iron. In fact, we had never measured any iron loading on the reagent by atomic absorption regardless of the feed. Furthermore, we showed evidence that LIX 34 loaded and stripped copper only slightly slower than LIX 64N. Finally, we reported that LIX 34 showed no acid loading under typical tankhouse conditions.

Recent Work

As our work with LIX 34 progressed we noted some interesting behavioral differences between LIX 34 and our normal frame of reference, LIX 64N. First of all, even though mixer box kinetics of LIX 34 are nearly as fast as those of LIX 64N the approach to equilibrium in a circuit can be much slower if care is not taken to run the circuit properly. The LIX 34 - aqueous feed emulsion is apparently more prone to short circuiting than a similar LIX 64N emulsion. These LIX 34 emulsions also show a much stronger tendency to run organic continuous at O/A ratios of one in our small laboratory units than do comparable LIX 64N emulsions. In fact, it is possible to run organic continuous even at A/O ratios of 1.5/1 and under these conditions nice, thick emulsions which result in high stage efficiencies are obtained. Thus, the apparent disadvantage of LIX 34 running organic continuous at an O/A = 1 turns out to be an advantage at the higher O/A $\sim$1.5. Will this behavior remain the same in commercial size mixers? We think not. Does the problem then have a solution? Three are readily apparent: A) faster extraction kinetics would lessen the chances for and effect of short circuiting, B) care in the mixer design to give better mixing and, C) close circuit control to maintain the best mixing possible. We have studied several additives which accelerate closed mixer box kinetics considerably yet show no adverse affects on extraction, stripping, selectivity or phase separation. These help considerably the approach to equilibrium in a circuit. Our laboratory has not studied mixer designs, but work in this area has been reported(2) and I am sure is continuing. Good circuit control should be a part of normal operating procedure at all times.

A second behavioral characteristic we found was in the phase separation characteristics of the first pilot plant batch. All previously prepared lab samples exhibited quite good phase separation, but the first pilot plant batch of LIX 34 displayed poor initial phase separation. After running in a circuit for 16 - 24 hours phase separation did become nearly as good as that of the original laboratory batches of LIX 34. We felt though, that good phase separation from the beginning was important and, thus, our research staff began to study the problem. At about the same time several companies were looking at LIX 34 with respect to their needs. In particular, one company experienced severe phase separation problems when trying to run aqueous continuous in the extraction side of the circuit when using their actual feed solution with LIX 34. However, another company with a feed produced in much the same way as the first company did not see the very poor phase separation in their studies. As this oddity was being digested, our research staff discovered process changes in the production of LIX 34 such that phase separation improved dramatically. In a standard type of a phase separation test we normally run on a variety of reagents we noted phase separation times at levels as low as 1/3 to 1/2 of what is considered acceptable for LIX 64N. Of course, we felt confident that the problems experienced by the one company would now be solved, but a quick phase disengagement experiment showed this not to be true. We were still looking at phase separation 8 to 10 times longer than considered acceptable. However, by treating the aqueous feed under study with a method known to remove impurities and then filtering, a feed could be produced which gave acceptable phase separation when running aqueous continuous. We concluded the feed was causing the problem and indeed, since this feed had been treated with a flocculent prior to the solvent extraction, this conclusion seems justified. The strange thing, however, is that with LIX 64N or with a 50/50 mixture of LIX 64N/LIX 34 and the feed in question no phase separation problems are encountered. An even with LIX 34 phase problems are severe only when operating under aqueous continuous conditions. Why this type of behavior? How can the flocculent cause this type of problem when it is there in very low (.5 - 1 ppm*) levels?

While our laboratory was worrying about some of the problems just discussed, our research people were trying to identify the villain(s) causing the phase separation problems in the original pilot plant batch of LIX 34. To date, we have been somewhat successful not only in identifying the undesireable constituents, but also in finding they are present at levels of 50 ppm or less.

Finally, we worried that the newly processed LIX 34 which showed such fast phase separation under our standard tests and with a variety of actual feed solutions might actually phase separate so fast that the mixer short circuiting problem might worsen - sort of damned if you do

*.5 - 1 ppm represent 10 - 20% of the total flocculent used to treat the leach liquor.

and damned if you don't. Long term phase separation studies on the newly processed LIX 34 relieved these worries as the extremely fast phase separation was somewhat shortlived. The LIX 34 emulsion band equilibrated at a height somewhat greater than the initial phase band, but still a little lower than that shown by LIX 64N under similar conditions.

From the discussion I am sure you can appreciate the difficulties that can arise in phase separation. The very low levels of some contaminants that will cause severe phase separation problems often times makes detection and identification a difficult and exasperating chore. Each feed is unique and may present problems not previously encountered, each new reagent may do the same and the behavior of a given feed with one reagent may not necessarily be the same as with another reagent. Our work indicates that competitive reagents may face real problems in this area.

A third behavioral characteristic which has been noted can readily be seen by comparing the isotherm data plotted in Figures 2, 3, 4 and 5. Note that at the lowest concentration of reagents LIX 64N is clearly the stronger extractant, but that the extraction power of the reagents becomes more nearly equal as the concentrations of the reagents increase. Now consider the isotherm data plotted in Figures 6, 7 and 8. Note that in this case at lowest concentrations LIX 64N is again the stronger extractant, but that at 6 V/V% reagent both LIX 64N and LIX 34 exhibit identical extraction isotherms with respect to the particular aqueous feed that was used in this comparison. Why do the reagents give identical isotherms with one feed at 6 V/V% while from another feed LIX 64N is the stronger extractant at 6.7 V/V%, the two reagents show similar isotherms at 20 V/V% and at 30 V/V% LIX 34 is the stronger extractant? We are just not sure.

The V/V% of the reagents used in these isotherm comparisons is based on the fact that a 10 V/V% solution of the respective reagent loads 2.50 g/1 Cu under specified conditions. This does not mean, however, that two reagents, each of which loads 2.50 g/1 Cu under the same specified conditions, are present in the exact same concentrations. One reagent may be loading to 80% of the total reagent present and another may be loading to only 60% of the total reagent present. Ideally, one would like a simple loading test that could be related directly to the total reagent present. In some instances (we believe LIX 34 is an example) the reagent will load copper from a Cu - ammonia solution such that all of the reagent present is in the form of a CuR_2 complex, and thus copper loading is a direct measure of the total reagent concentration. With other reagents (LIX 64N may be an example) CuR_2, CuR_3 and bridged complexes of variable stoichiometry can be made depending upon conditions and thus copper loading may not be a direct measure of reagent concentrations. If 100% pure reagent were available then comparisons based on exact reagent concentrations obtained by weighing out the proper amount of reagent could be run. This may not provide a solution to the problem of the changing extraction strength of LIX 64N and LIX 34, but at least the experiments would help to better define the problem. We are hoping to run these experiments in the near future.

The last problem we encountered that I am going to discuss deals with the stripping stages in an operating laboratory circuit. While running a long term phase separation circuit a small amount of gray solid with some blue speckling was noted above the emulsion on the mixer walls. The gray solid was shown to be the hydrogen sulfate complex of the reagent while the blue speckling was shown to be copper sulfate. The hydrogen sulfate complex! But we stated the reagent does not load acid. The acid loading on the reagent was determined in the following manner. A 10 V/V% solution of copper loaded LIX 34 was stripped at an O/A = 1 with 150 g/l H_2SO_4 and then filtered. Next, the organic was washed with deionized water at an O/A of 1 and the pH of the resulting water wash was measured and found to be 6.6. This means that $[H^+] = 2.5 \times 10^{-7}$ and gives a ratio of LIX 34 to H^+ in the neighborhood of 100,000 to 1. Hence, we say the reagent does not load acid. After identifying the gray solid as the hydrogen sulfate complex we tried to generate the solid by mixing a LIX 34 solution with 150 g/l H_2SO_4 in a closed glass vessel - no solid could be generated in this fashion. We also ran a long term circuit to see if the formation of the solid caused a loss in the loading power of the solvent. Over a 20 day period running 24 hours per day, the loading on 20 V/V% LIX 34 solution remained constant using a standard loading procedure. It is possible there was a loss of kerosene due to evaporation and we should have seen a slight increase in the loading, thus, there may have been a slight loss of reagent, but I doubt if the loss was too great. The gray solid will readily redissolve in kerosene when shaken with a typical copper dump leach solution and in the process also extract copper thus the reagent is readily recoverable from the gray solid. Because we could not generate the hydrogen sulfate salt in a closed system we ran several circuits with partial covers on the mixers and noted that the formation of the solid was significantly reduced almost to the point of seeing no solid at all. While all this was taking place, we ran several circuits using 100 g/l H_2SO_4 and 30 g/l Cu as the stripping electrolyte for LIX 34. It was found that with the low grade solutions we examined successful circuits could be run using the lower acid strip solutions and little or no gray solid was formed even with uncovered mixers. With some of these feeds the concentration of reagent had to be increased slightly but economic advantages gained in the tankhouse by electrowinning from a much lower acid solution may more than offset the slight increase in reagent make-up costs. Thus, with low grade feed the problem of the hydrogen sulfate reagent complex may prove to be a blessing in disguise. However, for high copper containing feeds it may not be feasible to run with the 100 g/l H_2SO_4 strip solution as the reagent concentration may have to be increased to such an extent as to be uneconomical. This can easily be determined though with a lab circuit run on any particular feed in question.

We feel the problem of the formation of the hydrogen sulfate salt of the reagent is due mainly to locally higher than normal acid concentrations. The small lab circuit motors we use are cooled by pulling room air into the top and pushing it out the bottom of the motor. This warm dry air passes over drops of emulsion which have splashed onto the sides of the mixer causing evaporation of water and kerosene. This increases the acid concentration of the aqueous drop and the reagent concentration of kerosene drop and we get formation of very small amounts of the acid sulfate complex. Over a long period of time this builds to a noticeable level. At sometime or another the solid will wash into the mixer disperse in the emulsion and get washed into the settler where a small amount may settle on the organic overflow weir.

I hope this paper gives you a feel for some of the kinds of problems encountered in developing a new solvent extraction reagent. We have really only talked about the applications of the reagent to the copper industry. When you consider the reagent has potential applications in Co - Ni separations, Zn^{2+} extractions, Hg^{2+} extractions and possibly others you can appreciate the efforts required to fully research and hopefully understand the behavior of any solvent extraction reagent.

To this you can then add another full dimension: the production of a reagent which has an acceptable cost. Our synthetic organic chemists have the ability to construct molecules which possess just about any desired properties, i.e., extraction strength, proper solubility, selectivity, etc., but when you have to do this for a low cost many if not most synthetic routes are not feasible. Also, optimizing one desired property may cause a loss in another desired property and the ballgame starts anew; more loading and stripping isotherms, phase separation studies, circuits to be run, etc.

Where does LIX 34 stand as of now? The reagent has several outstanding and many good properties with respect to copper extraction from typical dump leach, agitation leach and vat leach liquors. We have encountered problems as discussed, but we have also been able to work some of the problems out. We feel the reagent has strong potential especially with respect to high iron feeds. What is needed is a well planned pilot study extending over a reasonably long period of time so that if there are any long term problems with the reagent they can be identified and solved. We at General Mills Chemicals, Inc., are evaluating various proposals to conduct such a pilot study.

FIGURE 1

Cu pH ISOTHERM COMPARISON
OF LIX® 34 AND LIX® 64N

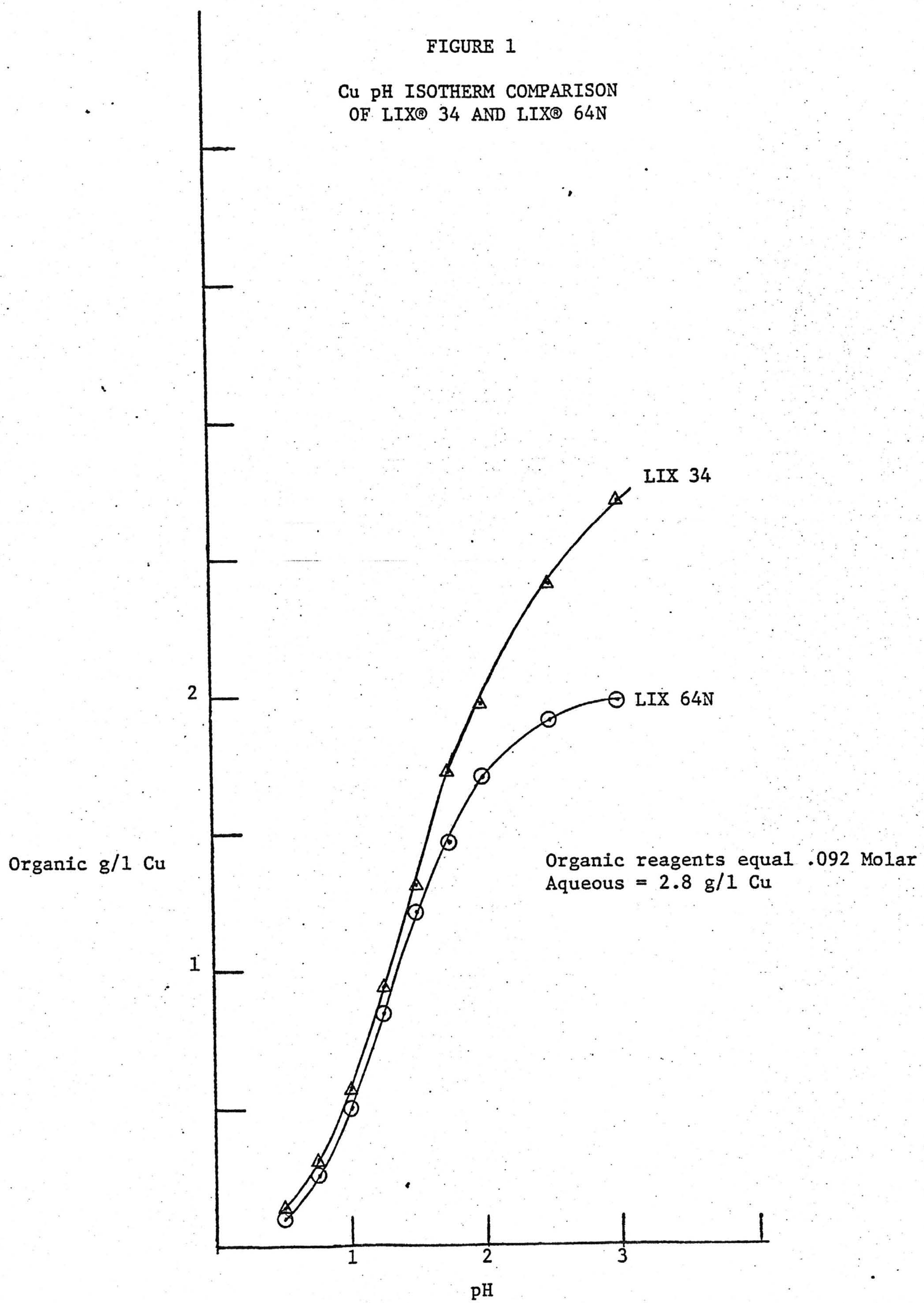


TABLE I

Circuit: 2 extraction and 2 stripping stages at 50°C. Mixer residence time = 3 minutes.
Recycles for O/A = 1 in mixers.

Feed: 10 g/l Cu^{2+}, 2 g/l Fe^{3+}, 10 g/l H_2SO_4 (synthetic).

Strip Electrolyte: 29 g/l Cu, 0.040 g/l Fe, 148 g/l H_2SO_4.

The carrier is Kermac 470B.

ORGANIC	MAXIMUM LOAD*	O/A EXT'N	O/A STRIP	PREGNANT ELECT.		LOADED ORGANIC		STRIPPED ORGANIC		RAFFINATE
	Cu g/l from NH_3			g/l Cu	g/l Fe	g/l Cu	g/l Fe**	g/l Cu	g/l Fe	g/l Cu
1) LIX 65N	14.6	1.6	3.6	49.8	.108	6.50	.0030	1.11	ND	1.12
2) LIX 34	11.7	1.6	3.6	46.3	--	6.35	--	.96	--	1.15
3) LIX 34	14.5	1.6	3.6	50.0	.055	7.68	ND	2.08	ND	.84

*Two contacts O/A = 1, with an aqueous solution containing 15 g/l Cu and 45 g/l NH_3.
**ND = not detected.

TABLE II

Circuit: 4 extraction and 3 stripping stages at 23°C. Mixer residence time = 3 minutes.
Recycles for O/A = 1 in mixers.

Feed: 4.42 g/l Cu, 2.07 g/l Fe, pH = 1.66 (Combination of 2 actual feeds).

Strip Electrolyte: 30 g/l Cu, 0.036 g/l Fe, 150 g/l H_2SO_4.

The carrier is Kermac 470B.

ORGANIC	MAXIMUM LOAD*	O/A EXT'N	O/A STRIP	PREGNANT ELECT.		LOADED ORGANIC		STRIPPED ORGANIC	RAFFINATE
	g/l Cu			g/l Cu	g/l Fe	g/l Cu	g/l Fe**	g/l Cu	g/l Cu
1) 22 v/v% LIX 64N	5.74	1	4/1	44.2	.046	4.50	.0020	.28	.38
2) 20 v/v% LIX 34	5.20	1	4/1	46	.038	4.40	ND	.28	.37

*Maximum Load - 5 two minute contacts of loaded organic from the circuit with fresh feed at O/A = 1.
**ND = not detected.

FIGURE 2

EXTRACTION ISOTHERMS

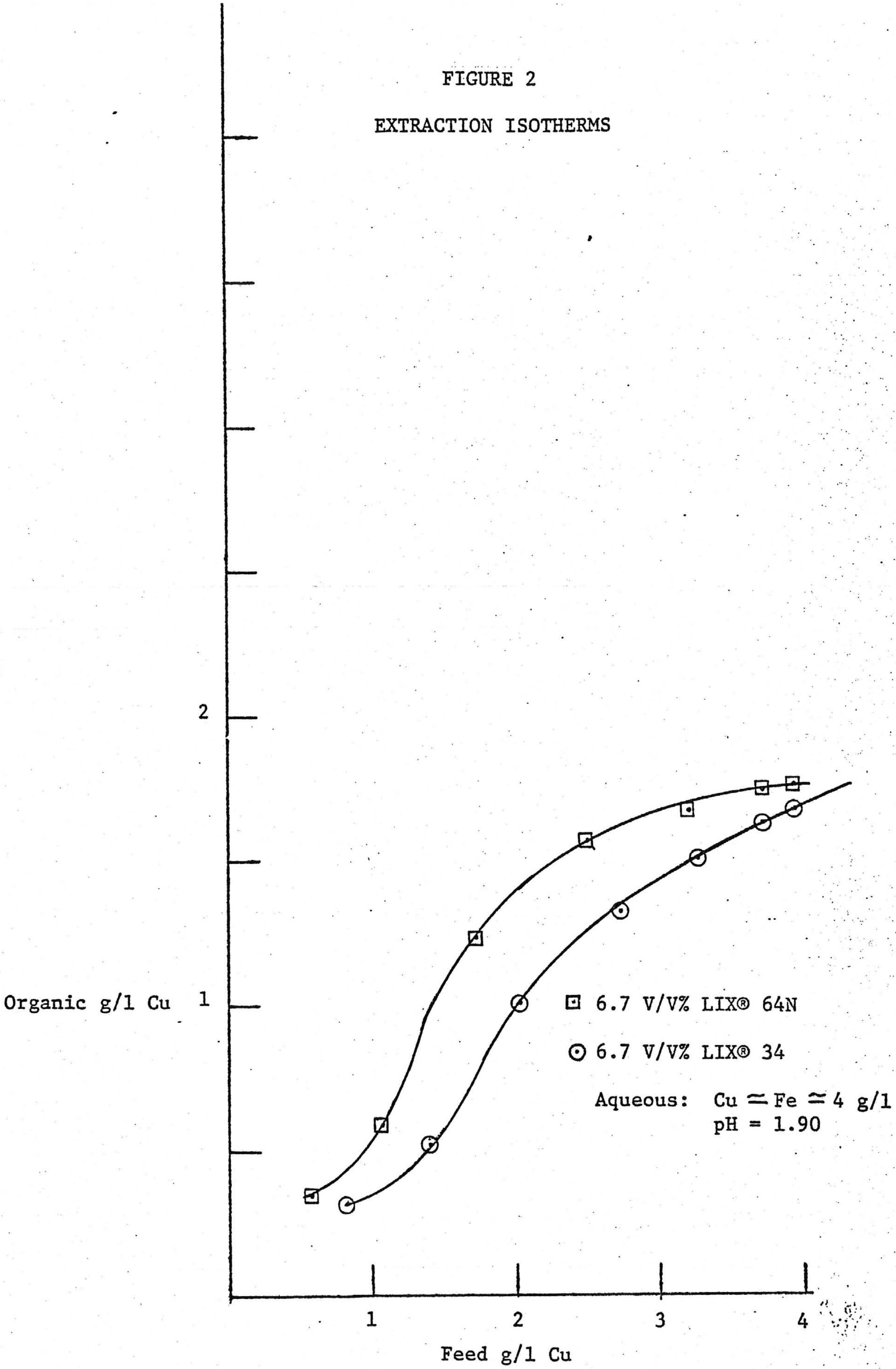


FIGURE 3

EXTRACTION ISOTHERMS

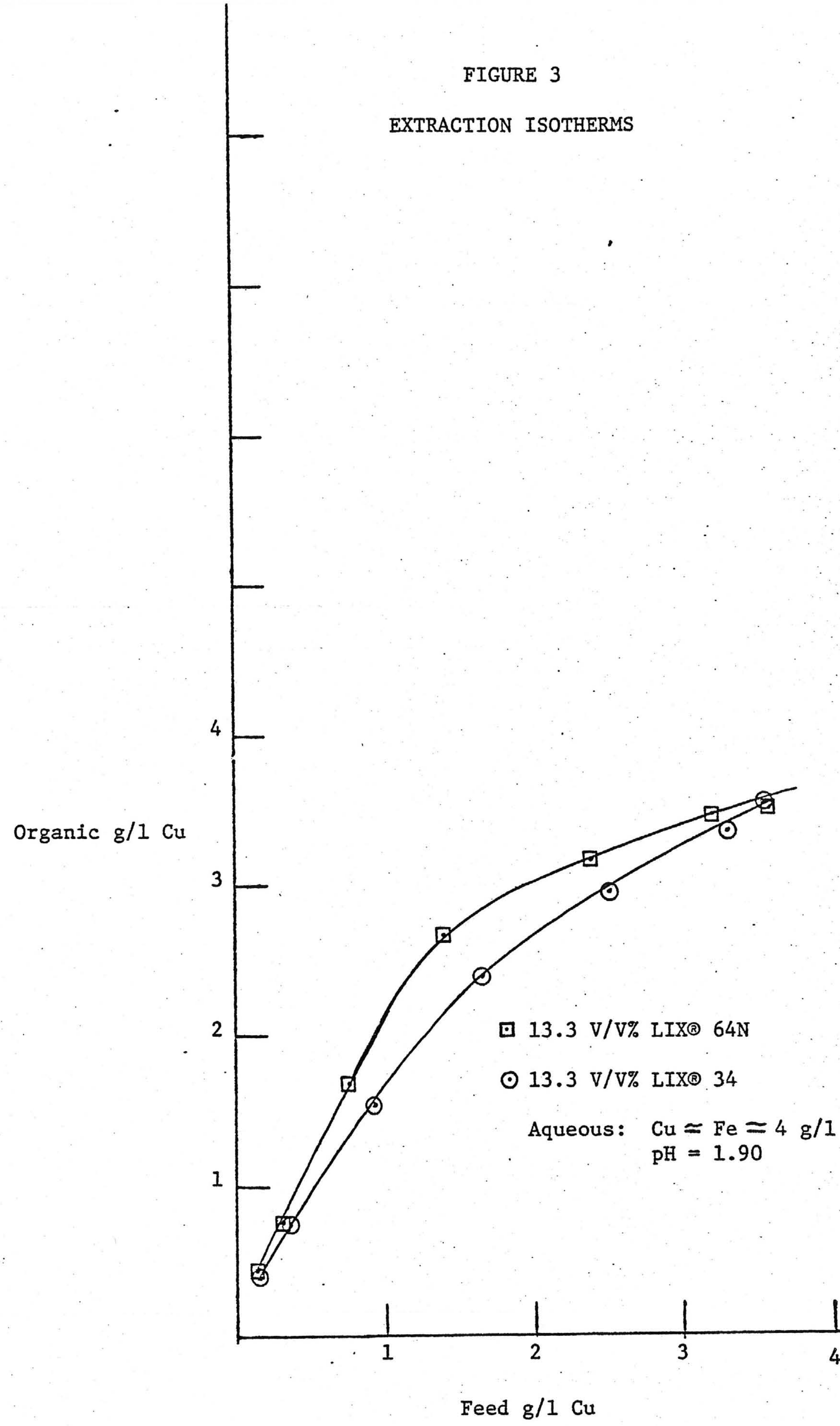


FIGURE 4

EXTRACTION ISOTHERMS

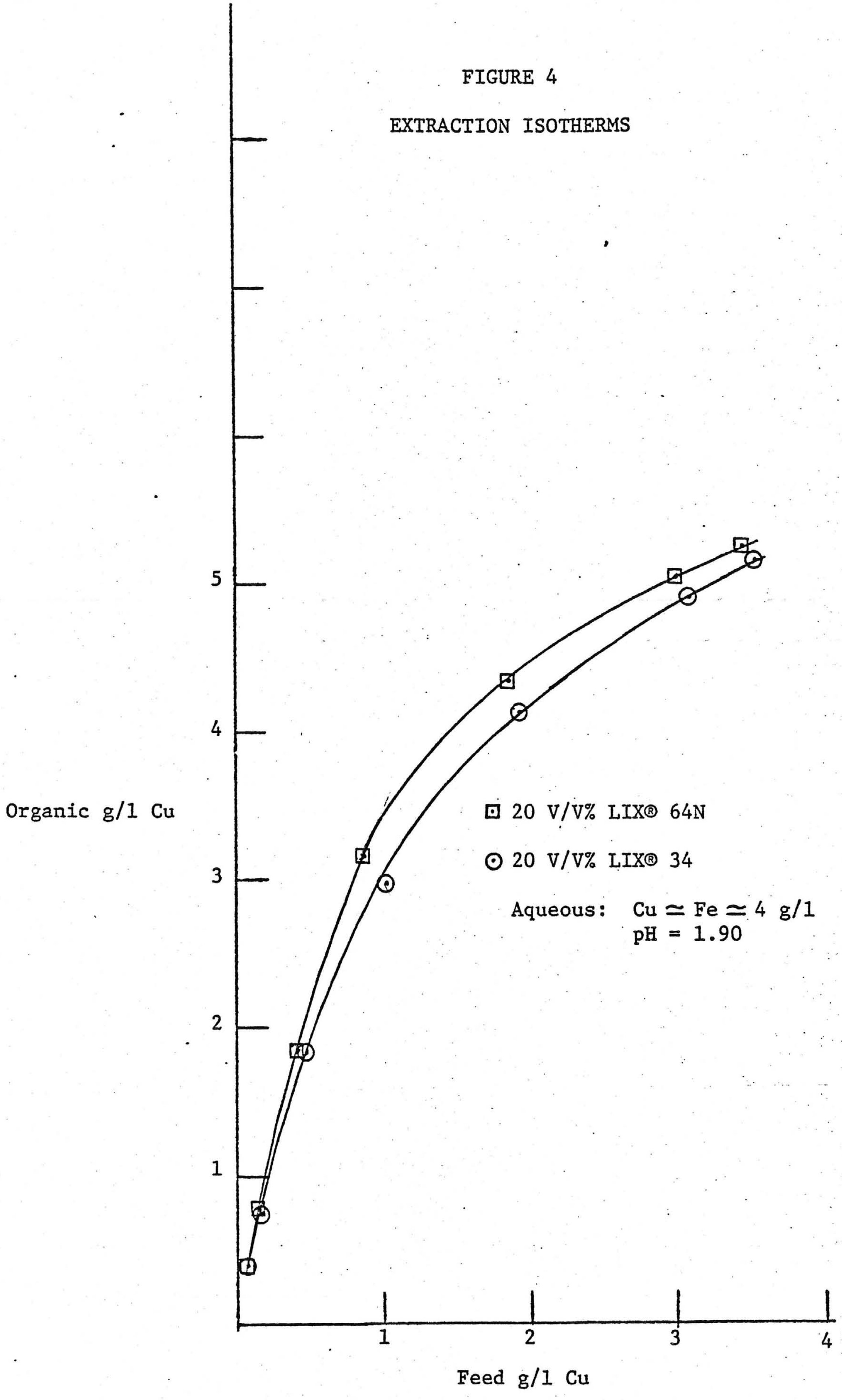


FIGURE 5

EXTRACTION ISOTHERMS

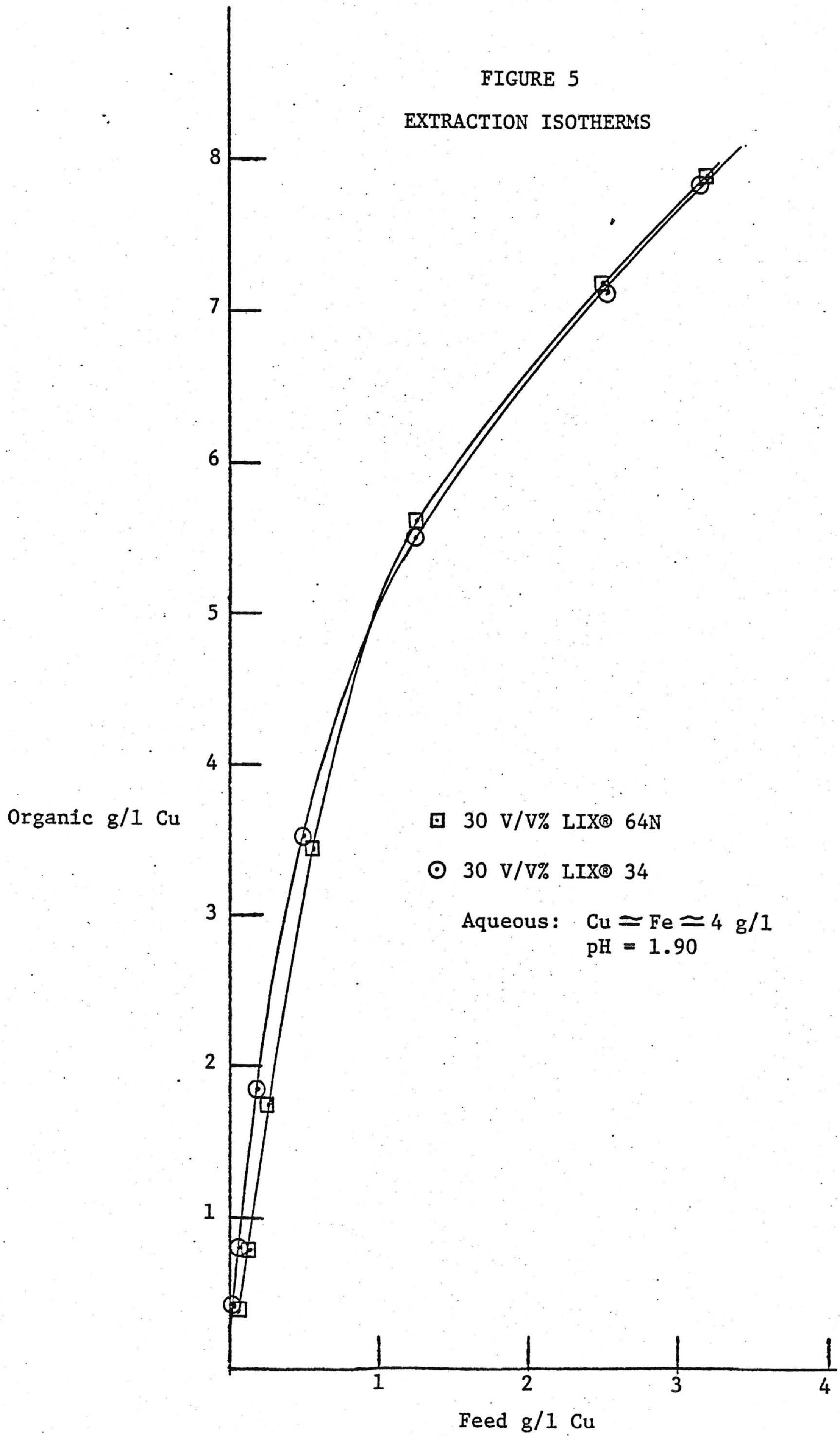


FIGURE 6

EXTRACTION ISOTHERMS

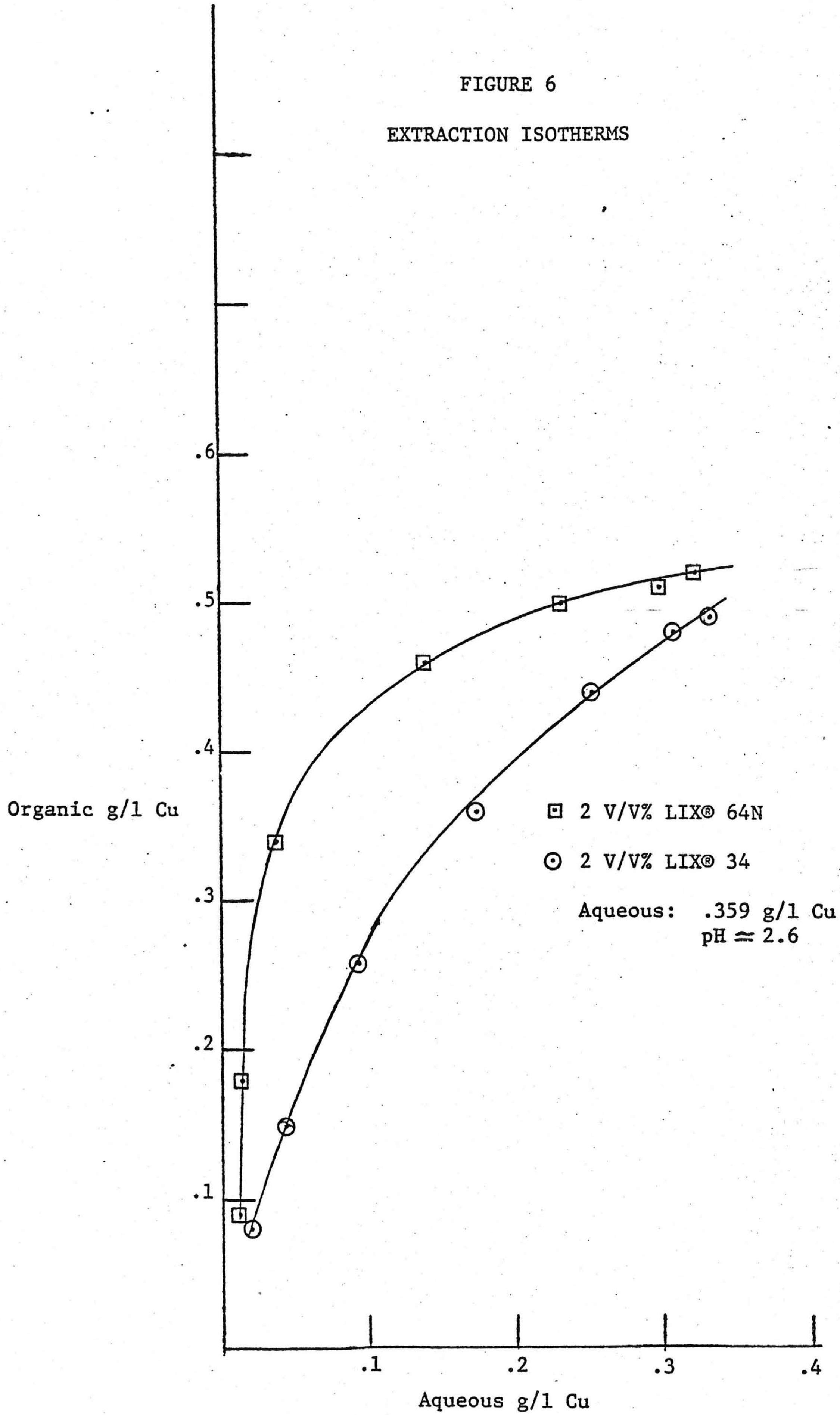


FIGURE 7

EXTRACTION ISOTHERMS

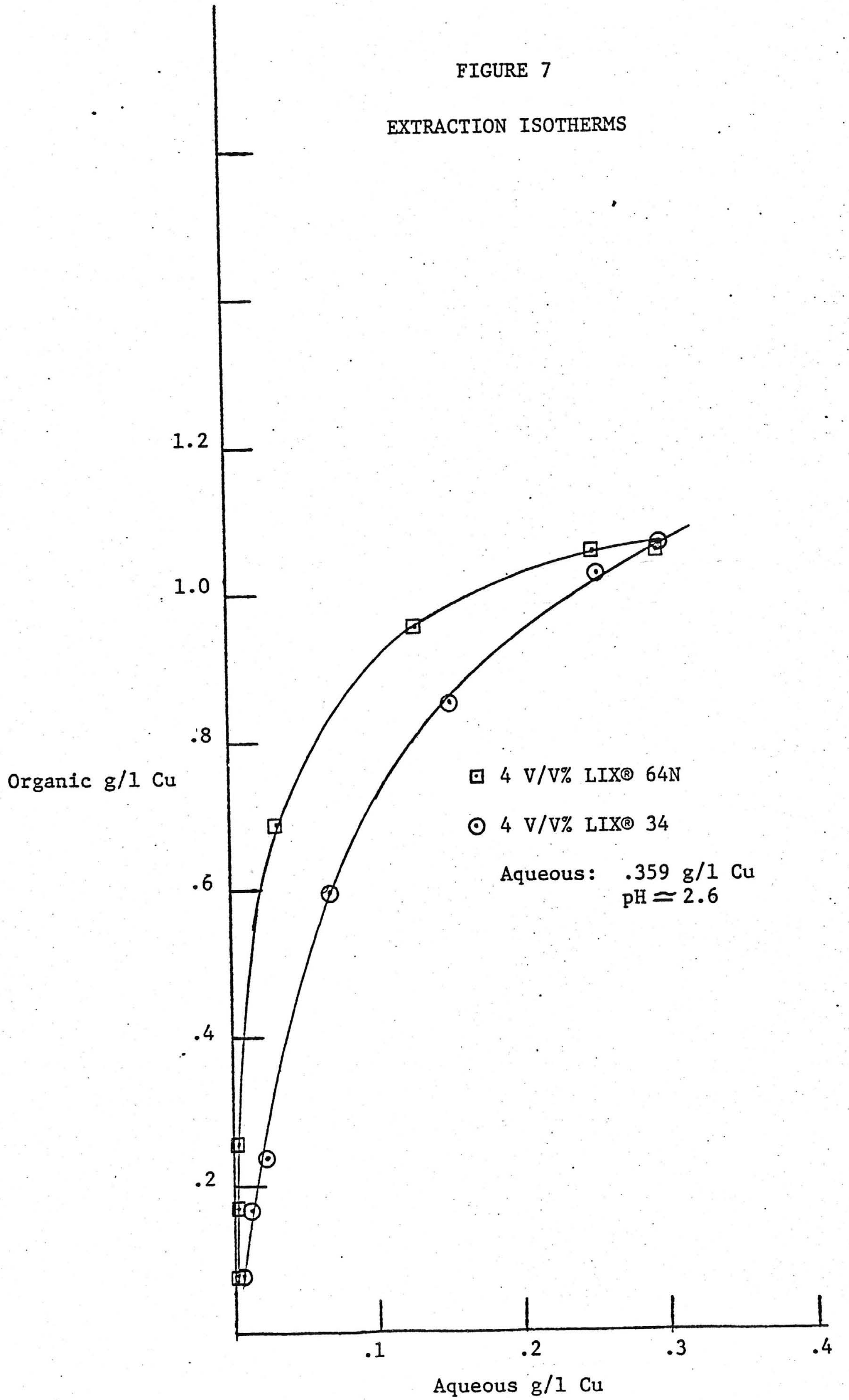
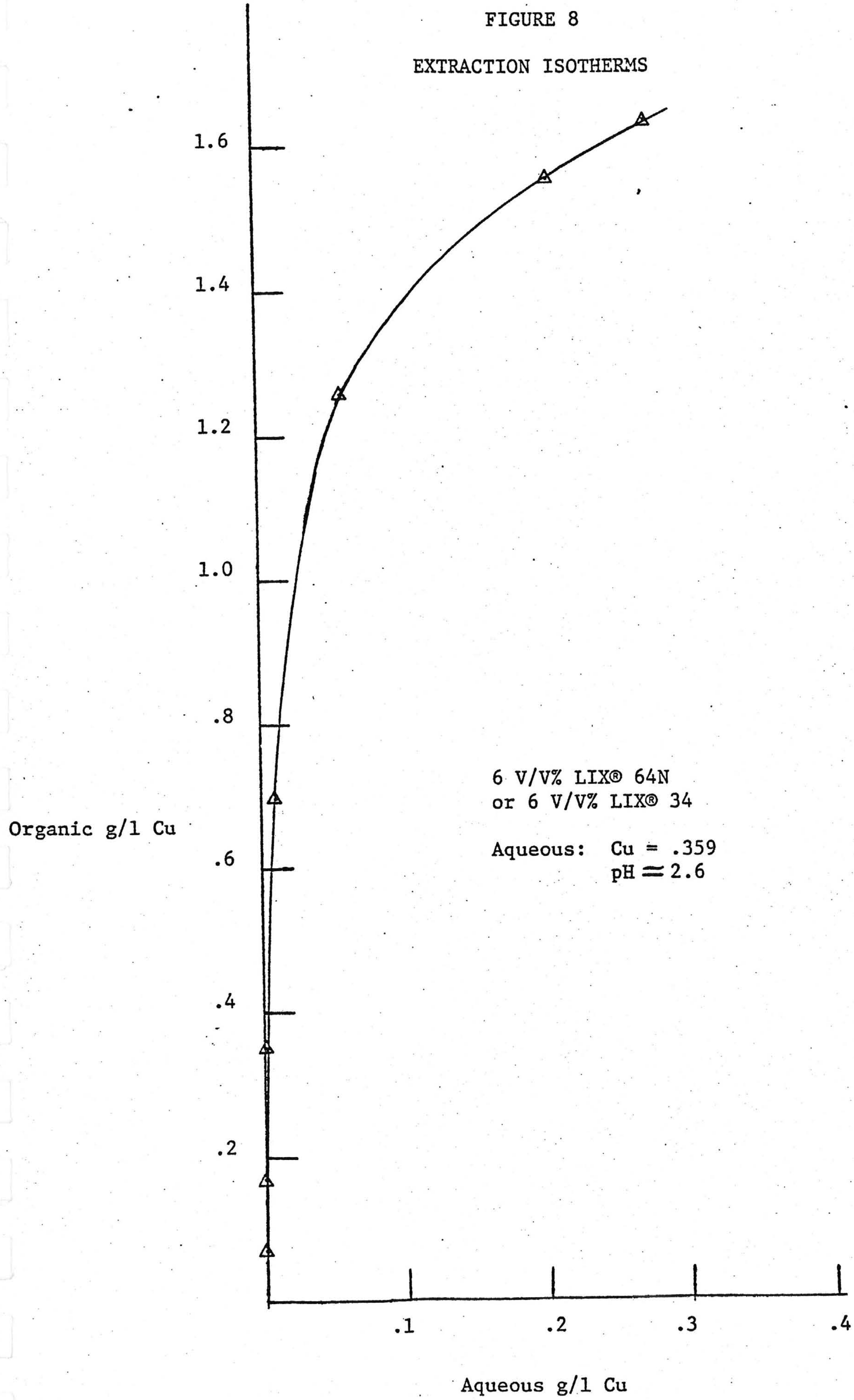


FIGURE 8

EXTRACTION ISOTHERMS



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2. C. N. Wright, K. J. Richards, C. D. Carey and T. I Probert, "The Application of Solvent Extraction for Recovering Copper from Very Dilute Leach Solutions - The Economic Constraints and Potential Technical Solutions", AIME Annual Meeting, Las Vegas, Nevada, February 22 - 26, 1976.

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Before discussing our recent work with LIX 34, some background on the reagent will be presented. LIX 34 operates on a hydrogen ion cycle with the equation below representing the loading ⇋ stripping reactions:

$$2\ R\text{-}H(org.) + M^{2+}(aq.) \rightleftharpoons R_2M(org.) + 2H^{+}(aq.)$$

We have previously reported that LIX 34 is comparable to LIX 64N in extraction strength when the reagents are evaluated on a molar basis and indeed presented several independent experiments as evidence[1] (Figure 1. Tables I and II). We also reported that LIX 34 had good phase separation properties and showed excellent copper selectivity over iron. In fact, we had never measured any iron loading on the reagent by atomic absorption regardless of the feed. Furthermore, we showed evidence that LIX 34 loaded and stripped copper only slightly slower than LIX 64N. Finally, we reported that LIX 34 showed no acid loading under typical tankhouse conditions.

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As our work with LIX 34 progressed we noted some interesting behavioral differences between LIX 34 and our normal frame of reference, LIX 64N. First of all, even though mixer box kinetics of LIX 34 are nearly as fast as those of LIX 64N the approach to equilibrium in a circuit can be much slower if care is not taken to run the circuit properly. The LIX 34 - aqueous feed emulsion is apparently more prone to short circuiting than a similar LIX 64N emulsion. These LIX 34 emulsions also show a much stronger tendency to run organic continuous at O/A ratios of one in our small laboratory units than do comparable LIX 64N emulsions. In fact, it is possible to run organic continuous even at A/O ratios of 1.5/1 and under these conditions nice, thick emulsions which result in high stage efficiencies are obtained. Thus, the apparent disadvantage of LIX 34 running organic continuous at an O/A = 1 turns out to be an advantage at the higher O/A $\sim$1.5. Will this behavior remain the same in commercial size mixers? We think not. Does the problem then have a solution? Three are readily apparent: A) faster extraction kinetics would lessen the chances for and effect of short circuiting, B) care in the mixer design to give better mixing and, C) close circuit control to maintain the best mixing possible. We have studied several additives which accelerate closed mixer box kinetics considerably yet show no adverse affects on extraction, stripping, selectivity or phase separation. These help considerably the approach to equilibrium in a circuit. Our laboratory has not studied mixer designs, but work in this area has been reported[2] and I am sure is continuing. Good circuit control should be a part of normal operating procedure at all times.

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The last problem we encountered that I am going to discuss deals with the stripping stages in an operating laboratory circuit. While running a long term phase separation circuit a small amount of gray solid with some blue speckling was noted above the emulsion on the mixer walls. The gray solid was shown to be the hydrogen sulfate complex of the reagent while the blue speckling was shown to be copper sulfate. The hydrogen sulfate complex! But we stated the reagent does not load acid. The acid loading on the reagent was determined in the following manner. A 10 V/V% solution of copper loaded LIX 34 was stripped at an O/A = 1 with 150 g/l H_2SO_4 and then filtered. Next, the organic was washed with deionized water at an O/A of 1 and the pH of the resulting water wash was measured and found to be 6.6. This means that $[H^+] = 2.5 \times 10^{-7}$ and gives a ratio of LIX 34 to H^+ in the neighborhood of 100,000 to 1. Hence, we say the reagent does not load acid. After identifying the gray solid as the hydrogen sulfate complex we tried to generate the solid by mixing a LIX 34 solution with 150 g/l H_2SO_4 in a closed glass vessel - no solid could be generated in this fashion. We also ran a long term circuit to see if the formation of the solid caused a loss in the loading power of the solvent. Over a 20 day period running 24 hours per day, the loading on 20 V/V% LIX 34 solution remained constant using a standard loading procedure. It is possible there was a loss of kerosene due to evaporation and we should have seen a slight increase in the loading, thus, there may have been a slight loss of reagent, but I doubt if the loss was too great. The gray solid will readily redissolve in kerosene when shaken with a typical copper dump leach solution and in the process also extract copper thus the reagent is readily recoverable from the gray solid. Because we could not generate the hydrogen sulfate salt in a closed system we ran several circuits with partial covers on the mixers and noted that the formation of the solid was significantly reduced almost to the point of seeing no solid at all. While all this was taking place, we ran several circuits using 100 g/l H_2SO_4 and 30 g/l Cu as the stripping electrolyte for LIX 34. It was found that with the low grade solutions we examined successful circuits could be run using the lower acid strip solutions and little or no gray solid was formed even with uncovered mixers. With some of these feeds the concentration of reagent had to be increased slightly but economic advantages gained in the tankhouse by electrowinning from a much lower acid solution may more than offset the slight increase in reagent make-up costs. Thus, with low grade feed the problem of the hydrogen sulfate reagent complex may prove to be a blessing in disguise. However, for high copper containing feeds it may not be feasible to run with the 100 g/l H_2SO_4 strip solution as the reagent concentration may have to be increased to such an extent as to be uneconomical. This can easily be determined though with a lab circuit run on any particular feed in question.

We feel the problem of the formation of the hydrogen sulfate salt of the reagent is due mainly to locally higher than normal acid concentrations. The small lab circuit motors we use are cooled by pulling room air into the top and pushing it out the bottom of the motor. This warm dry air passes over drops of emulsion which have splashed onto the sides of the mixer causing evaporation of water and kerosene. This increases the acid concentration of the aqueous drop and the reagent concentration of kerosene drop and we get formation of very small amounts of the acid sulfate complex. Over a long period of time this builds to a noticeable level. At sometime or another the solid will wash into the mixer disperse in the emulsion and get washed into the settler where a small amount may settle on the organic overflow weir.

I hope this paper gives you a feel for some of the kinds of problems encountered in developing a new solvent extraction reagent. We have really only talked about the applications of the reagent to the copper industry. When you consider the reagent has potential applications in Co - Ni separations, Zn^{2+} extractions, Hg^{2+} extractions and possibly others you can appreciate the efforts required to fully research and hopefully understand the behavior of any solvent extraction reagent.

To this you can then add another full dimension: the production of a reagent which has an acceptable cost. Our synthetic organic chemists have the ability to construct molecules which possess just about any desired properties, i.e., extraction strength, proper solubility, selectivity, etc., but when you have to do this for a low cost many if not most synthetic routes are not feasible. Also, optimizing one desired property may cause a loss in another desired property and the ballgame starts anew; more loading and stripping isotherms, phase separation studies, circuits to be run, etc.

Where does LIX 34 stand as of now? The reagent has several outstanding and many good properties with respect to copper extraction from typical dump leach, agitation leach and vat leach liquors. We have encountered problems as discussed, but we have also been able to work some of the problems out. We feel the reagent has strong potential especially with respect to high iron feeds. What is needed is a well planned pilot study extending over a reasonably long period of time so that if there are any long term problems with the reagent they can be identified and solved. We at General Mills Chemicals, Inc., are evaluating various proposals to conduct such a pilot study.

FIGURE 1

Cu pH ISOTHERM COMPARISON
OF LIX® 34 AND LIX® 64N

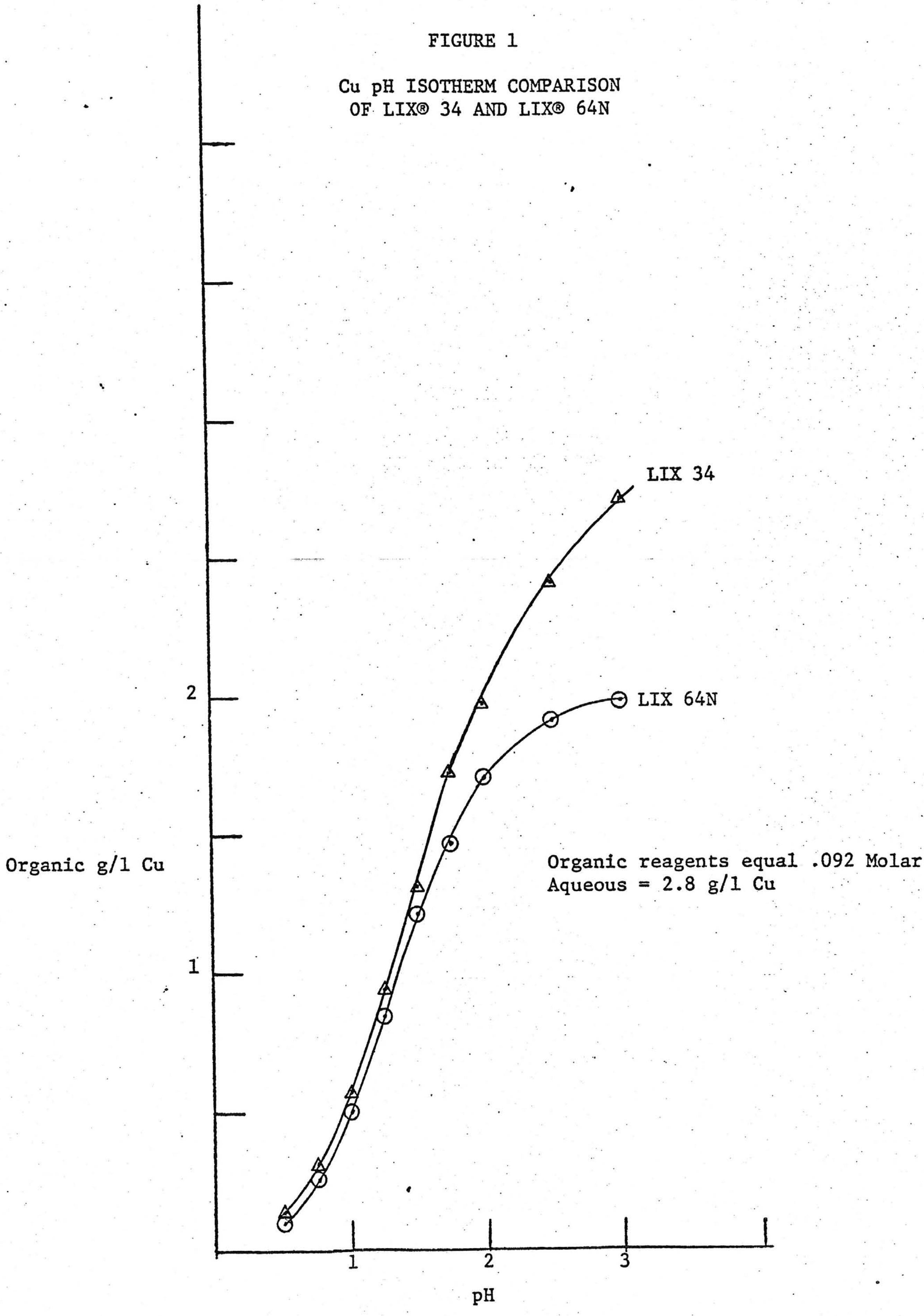


TABLE I

Circuit: 2 extraction and 2 stripping stages at 50°C. Mixer residence time = 3 minutes.
Recycles for O/A = 1 in mixers.

Feed: 10 g/l Cu^{2+}, 2 g/l Fe^{3+}, 10 g/l H_2SO_4 (synthetic).

Strip Electrolyte: 29 g/l Cu, 0.040 g/l Fe, 148 g/l H_2SO_4.

The carrier is Kermac 470B.

ORGANIC	MAXIMUM LOAD*	O/A EXT'N	O/A STRIP	PREGNANT ELECT.		LOADED ORGANIC		STRIPPED ORGANIC		RAFFINATE
	Cu g/l from NH_3			g/l Cu	g/l Fe	g/l Cu	g/l Fe**	g/l Cu	g/l Fe	g/l Cu
1) LIX 65N	14.6	1.6	3.6	49.8	.108	6.50	.0030	1.11	ND	1.12
2) LIX 34	11.7	1.6	3.6	46.3	--	6.35	--	.96	--	1.15
3) LIX 34	14.5	1.6	3.6	50.0	.055	7.68	ND	2.08	ND	.84

*Two contacts O/A = 1, with an aqueous solution containing 15 g/l Cu and 45 g/l NH_3.
**ND = not detected.

TABLE II

Circuit: 4 extraction and 3 stripping stages at 23°C. Mixer residence time = 3 minutes.
Recycles for O/A = 1 in mixers.

Feed: 4.42 g/l Cu, 2.07 g/l Fe, pH = 1.66 (Combination of 2 actual feeds).

Strip Electrolyte: 30 g/l Cu, 0.036 g/l Fe, 150 g/l H_2SO_4.

The carrier is Kermac 470B.

ORGANIC	MAXIMUM LOAD*	O/A EXT'N	O/A STRIP	PREGNANT ELECT.		LOADED ORGANIC		STRIPPED ORGANIC	RAFFINATE
	g/l Cu			g/l Cu	g/l Fe	g/l Cu	g/l Fe**	g/l Cu	g/l Cu
1) 22 v/v% LIX 64N	5.74	1	4/1	44.2	.046	4.50	.0020	.28	.38
2) 20 v/v% LIX 34	5.20	1	4/1	46	.038	4.40	ND	.28	.37

*Maximum Load - 5 two minute contacts of loaded organic from the circuit with fresh feed at O/A = 1.
**ND = not detected.

FIGURE 2

EXTRACTION ISOTHERMS

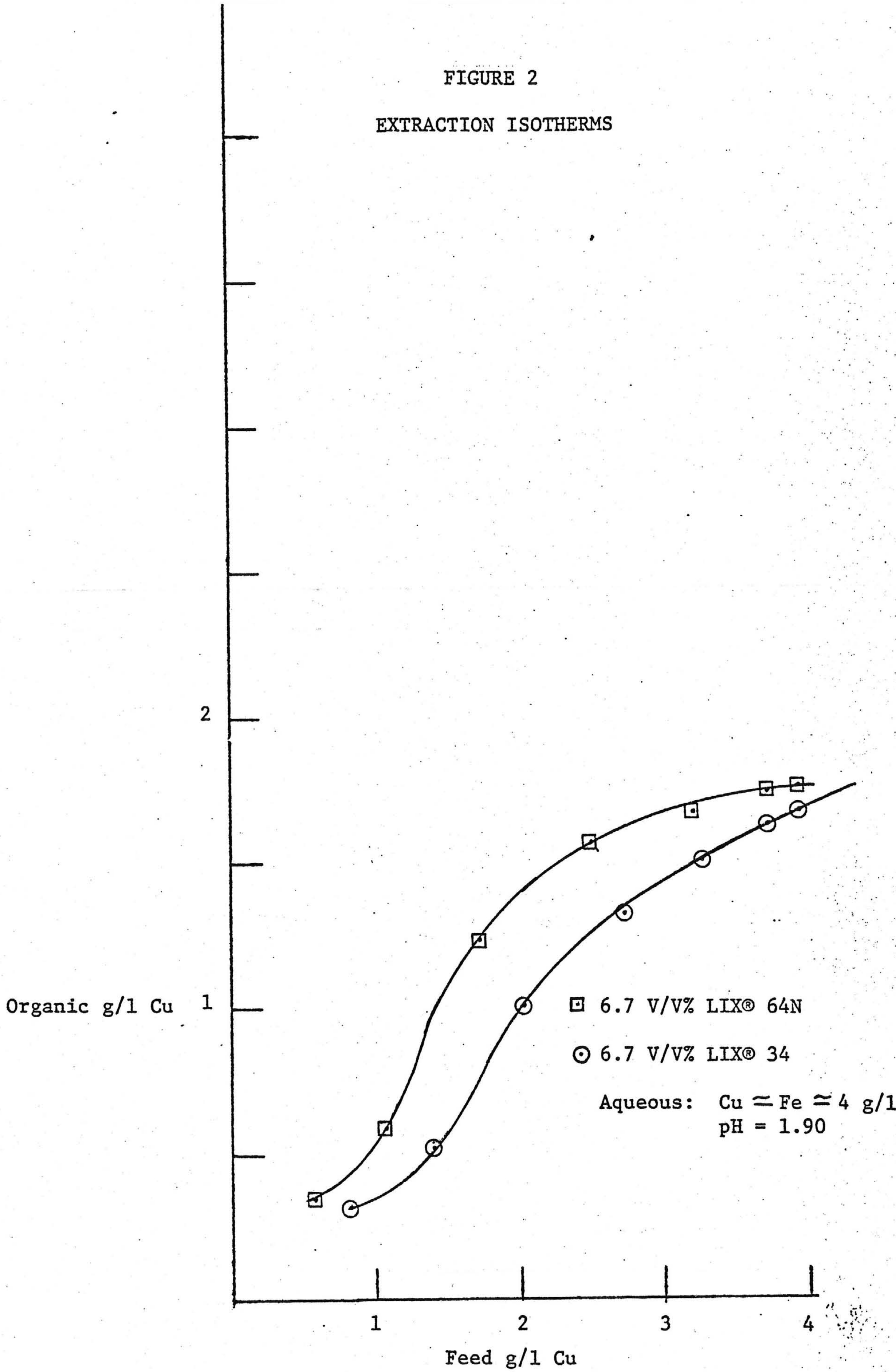


FIGURE 3

EXTRACTION ISOTHERMS

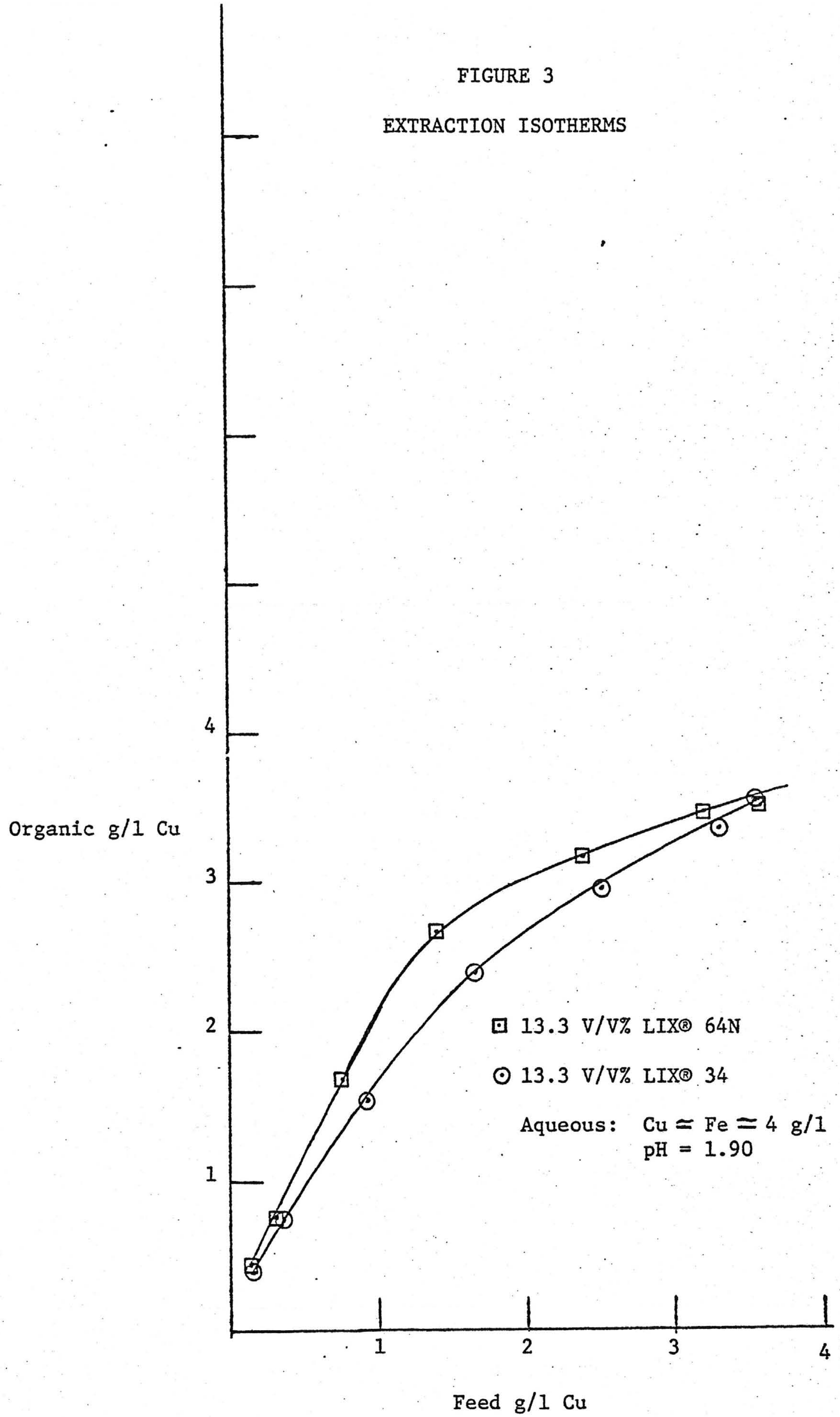


FIGURE 4

EXTRACTION ISOTHERMS

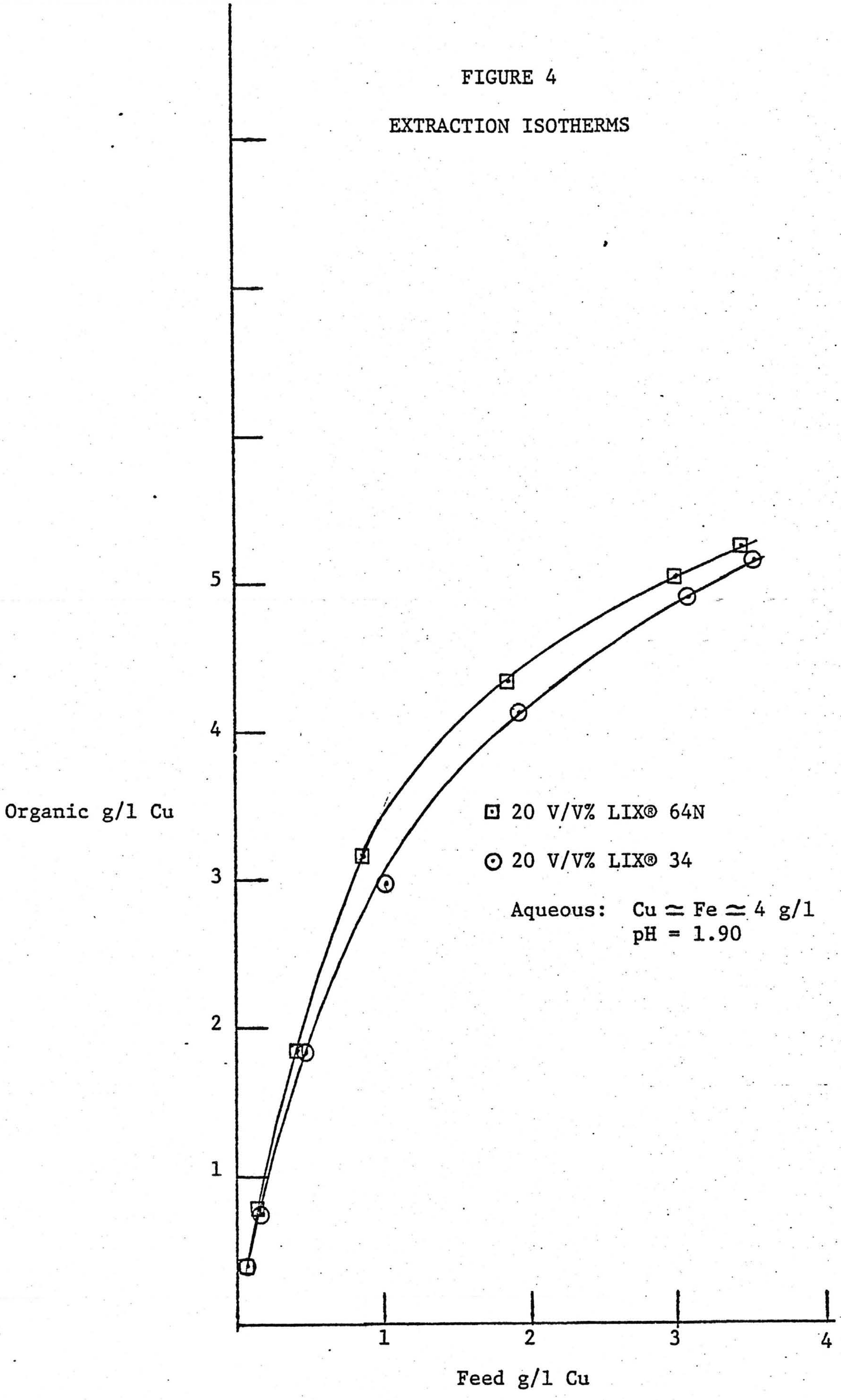


FIGURE 5

EXTRACTION ISOTHERMS

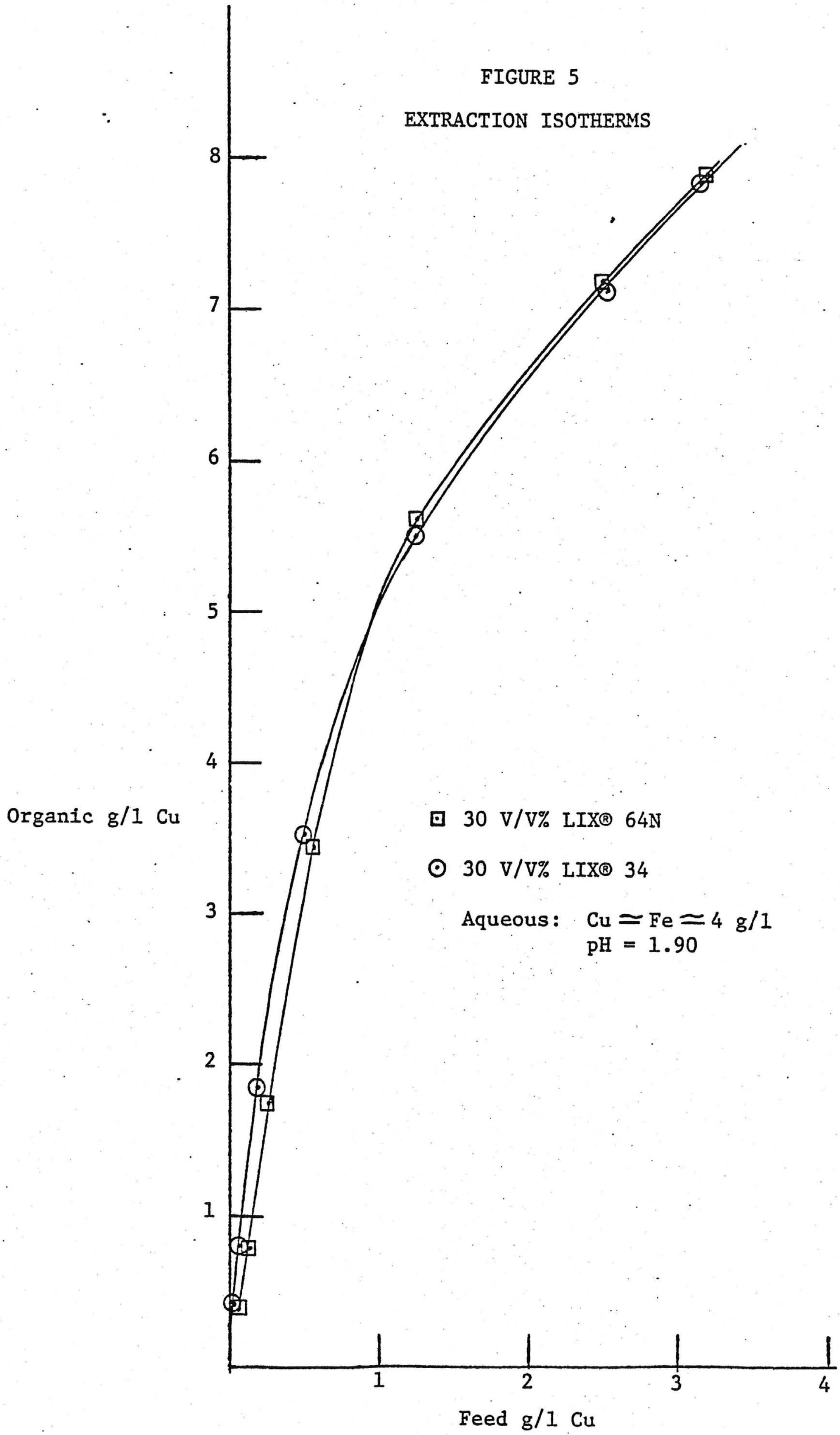


FIGURE 6

EXTRACTION ISOTHERMS

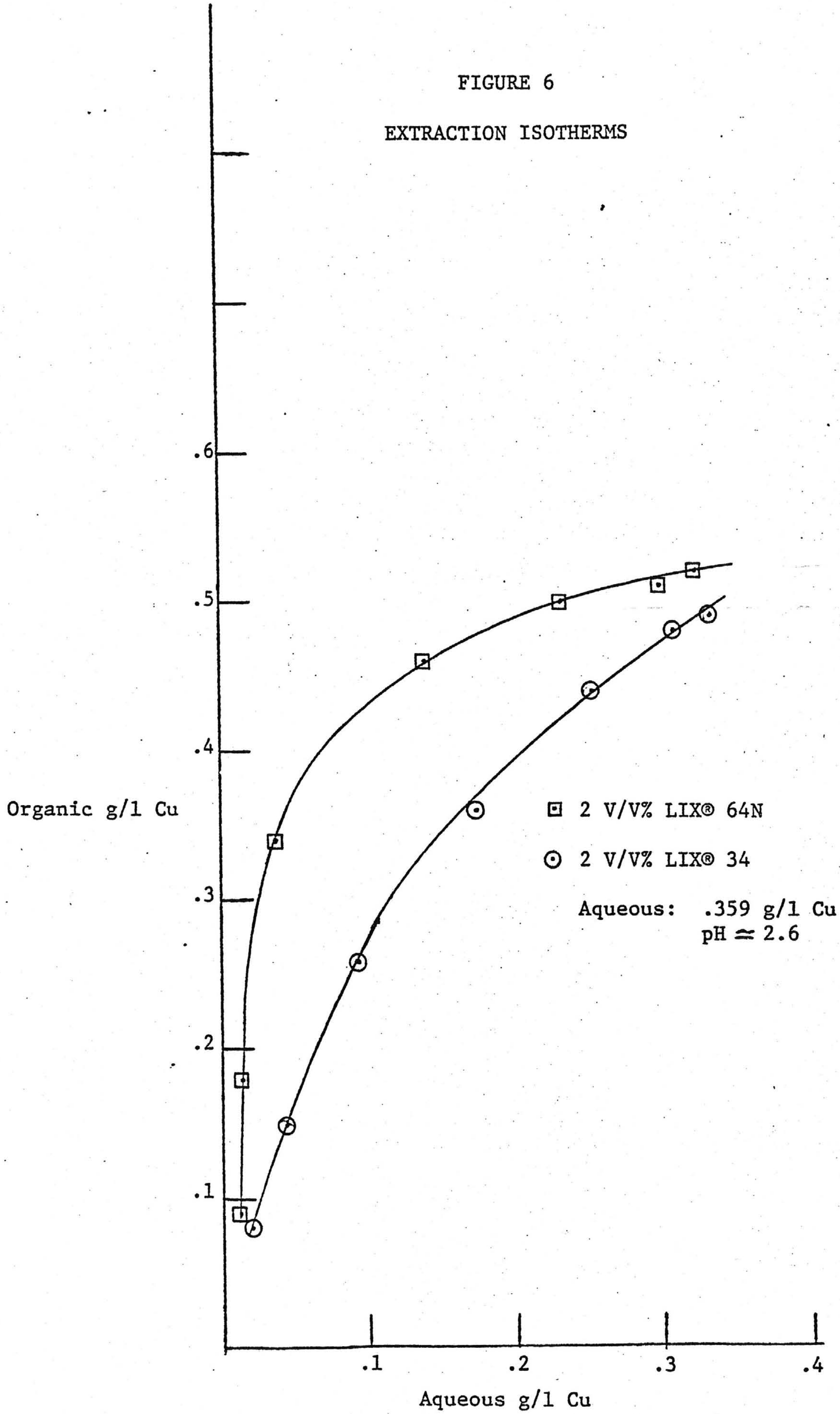


FIGURE 7

EXTRACTION ISOTHERMS

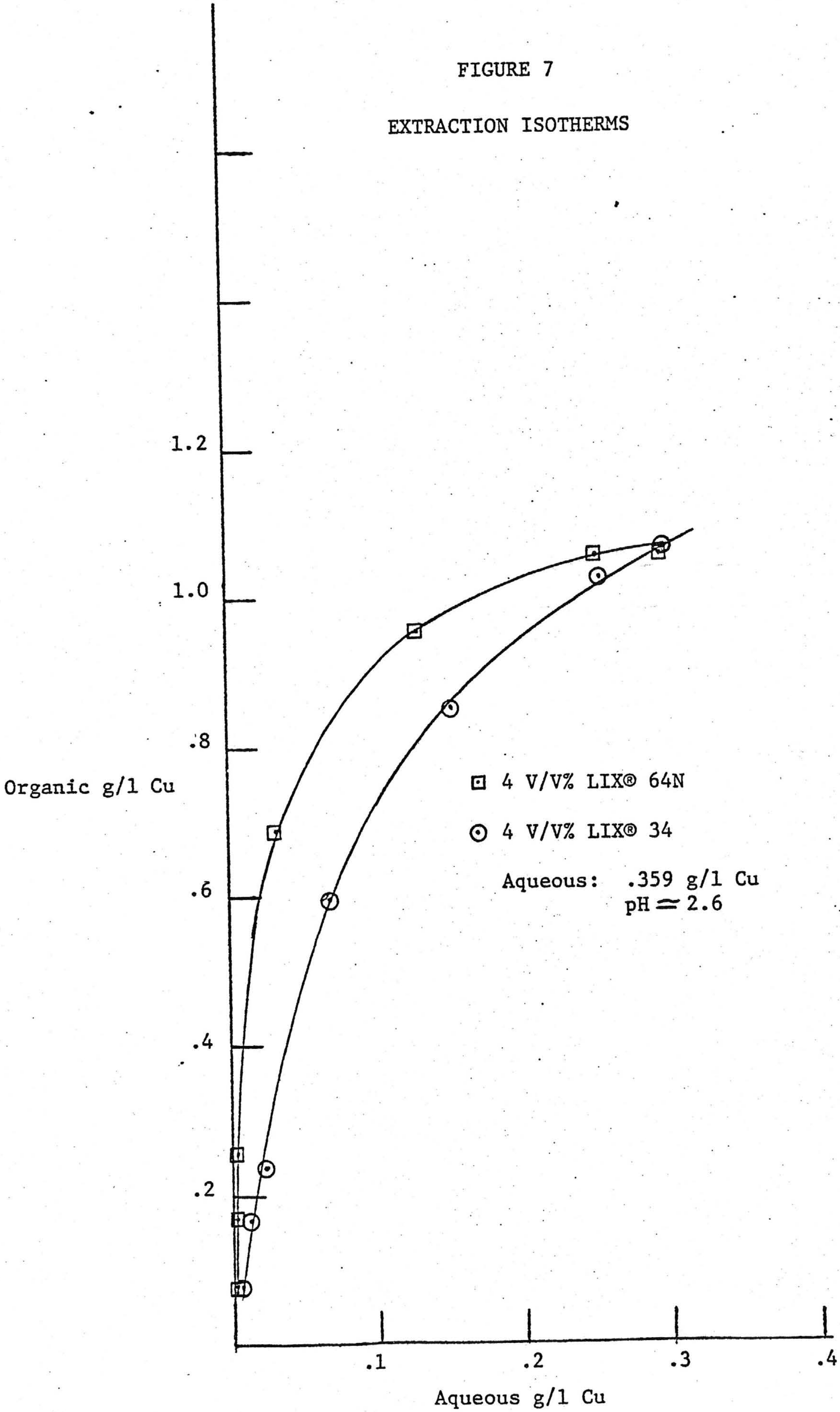
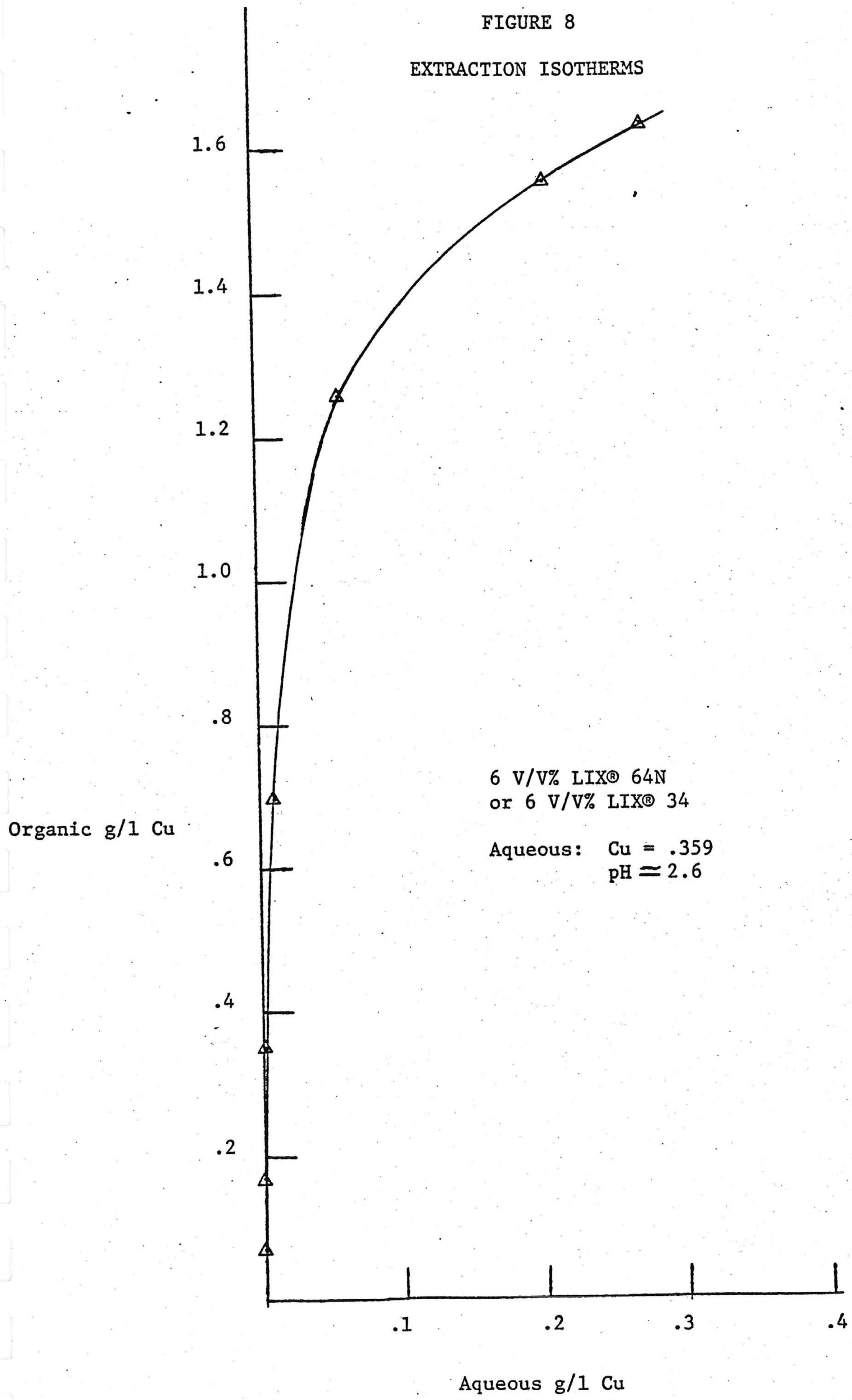


FIGURE 8

EXTRACTION ISOTHERMS



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COPY OF REPORTS IN BLUE FOLDER

REPORT

TWIN BUTTES GROUP COPPER MINES

Twin Buttes, Pima County, Arizona

By

Howard H. Fields

March, 1950

TWIN BUTTES

LOCATION:

The Twin Buttes Mining District lies in the Sierrita Mountains, about 6 miles West of Sahuarita, a station on the Southern Pacific Railroad, 25 miles South of Tucson, Arizona, toward Nogales. The Tucson-Nogales oiled highway also passes through Sahuarita. A very good graded, gravel road connects the camp with Sahuarita, so transportation is most economical. The following are the principal mines of the district:

Morgan, Minnie, Copper Buttes, Copper King, Copper Queen, Copper Glance and Copper Bullion

CLIMATE:

The climate is typically that of Tucson and southern Arizona--hot days, cool nights, with summer showers. The vegetation is sparce and that of the arid desert section. Water for domestic use and for mine operation is available at the Gladstone Shaft, which is under lease.

LABOR:

Labor is largely Mexica n and seems to be abundant in this particular section. The proxmity to the border assures a fair supply. The camp has practically all the buildings necessary to begin operation, though the ore bins, etc., will need repairs before commencement of operation.

HISTORY:

The known history of Twin Buttes mining district dates from the nineties, when four prospectors gophered various surface outcrops of copper carbonates, hauling same to Tucson by wagon. This continued up to the year 1905, when a group of men headed by David S. Rose, then Mayor of Milwaukee, formed the Twin Buttes Mining and Smelting Company, which acquired all the favorable property in the district. They built a standard gauge railroad from Tucson to Twin Buttes, 28 miles in length, and began mining operations in 1906, erecting a smelter near the Santa Cruz River, 9 miles from the mines. They operated until the spring of 1913, directing most of their attention on the Morgan Group, as this particular group had the best surface showing.

During these operations the Twin Buttes Mining and Smelting Company produced a gross of $3,110,000.00. Most of this came from the Morgan Mine, the balance from the Copper Glance, Copper Queen and Copper King, the latter group being on a different contact with very little surface showing, and was not worth considering at that time. However, later operations proved this contact to be the richest zone of this district higher grade ore and larger ore bodies. The gross production from this contact to date is $6,115,597.30. This, with the old company's produc-

tion of $3,110,000.00, makes a grand total of $9,225,597.30 for the district.

In 1913, after some of the older officials of the Company had died or passed out of the picture, operations ceased. From then on until 1918 the Morgan Mine was worked by leasers. In 1914 Ed. Bush of Butte, Montana, who had been leasing at the Morgan, took a lease and bond on the old Minnie Mine, which lay on the Glance-King contact adjoining the Copper Butte on the West. Bush and his partners netted over $400,000.00 in the years 1914-15 and 16. It was while operating the Minnie and seeing the possibilities of this contact that Bush took a lease and bond on the Copper Glance, which had been previously worked by the old company. This contract was for $300,000.00 for 3 years on a 10 % royalty basis, during 1916-17-18, until the drop of copper after the Armistice. Bush paid $233,796.16 in royalties to the old company and netted a substantial sum besides.

In 1917, being more convinced than ever of the possibilities of the Copper Queen, Bush took a 3 year lease and bond for $100,000.00 on this property. He paid this $100,000.00 in royalties after the second year and netted besides $180,643,72 for himself and partners.

W. F. Foy became associated with Bush in 1917, when they took over the Copper Queen, and Foy carried on operations after Bush's death in 1920, by reopening the Copper Queen, and during the 1923-26 period paid dividends totalling $412,000.00, besides sinking a 500' shaft on the Bullion and a 400' shaft on the Gladstone. This expense was absorbed in operating costs.

Foy purchased the properties from his associates in 1928, forming the Buttes Copper Company, embracing all the properties in the district, but the panic halted this project and the properties reverted to their original owners.

In 1938 Mr. Foy arranged a new deal and I became associated with him in 1942. A loan of $9,000.00 was granted by the R. F. C. to start unwatering the mines and show sufficient evidence to warrant additional funds to equip and place them in production. Due to difficult operating conditions, this was not sufficient, and I, personally, advanced some $15,000.00 to complete it. The Glance and Queen Mines were unwatered to the 525 level, where a personal examination showed the ore expected did exist. The shaft was re-timbered, the headframe repaired, two 310 cu. ft. Chicago Pneumatic air compressors were bought and installed, air and water lines installed in the shaft and a Cameron sinking pump obtained. The small amount of water remaining can be easily removed with this equipment and the mine equipped for production.

Mr. Foy eventually relinquished his contract so I could arrange a more favorable one. The mines held under the present lease and option are:

	Name	Survey No.
NORTHERN GROUP	Copper Prince (Dodge)	2641
	Senator Stewart	2642
	James G. Blaine	2640
	Garfield	2640
	Admiral Dewey	2640
	McKinley Lode	2640
	Hobson Copper	2640
	Copper Hill	2640

	Name	Survey
CENTRAL GROUP	Copper Butte	2643
	Copper King	2643
	Copper Glance	2643
	Copper Bullion	2643
	Bullion No. 2	2643
	Copper Eagle	2643
	Standard Copper	2643
SOUTHERN GROUP	Gladstone	2030
	Summit Fraction	2030
	Senator Morgan	2030
	Senator Morgan No. 2	2030
	Daily News	2030
	Nellie	2030
	Margaret or Margarita	2030

The terms of the lease-option from the owners, Twin Buttes Mining and Smelting Company, Room 1112, 229 East Wisconsin Avenue, Milwaukee 2, Wisconsin, are:

Date October 1, 1948. Term 5 years, Price $ 105,000.00
Minimum payments, $200.00 monthly.

W. F. Foy owns the Minnie and Copper Queen and will include either or both in any deal, under separate agreement.

The following gives details of shipments from the various mines. These were shipped to the Southern Pacific Railroad at Sahuarita over the Twin Buttes Railroad, a company road now abandoned and dismantled.

Mine	Date	Cu. Price	R.R. Cars	Dry Tons	% Cu.	Gross Cu. & Ag.	Net Profits
Minnie	1914 1918	22.73¢	1370	62,477	4.71	$1,282,202	$493,805
Queen	1917 1920	19.145¢	310	15,234	9.14	$ 556,396	$180,648
Queen	1923 1926	13.83	1078	59,952	6.55	$1,060,872	412,218
Glance	1916 1919	18.011¢	2432	118,066	6.72	2,786,126	629,282
		Total		255,729		$ 5,685,596	$1,715,953

Note: The Morgan Mine is reported to have produced previous to 1914, ore of a value of $ 3,110,000, but tonnage and profits are not available.

GEOLOGY:

In general, the geology is that common to replacement in a contact zone between bedded limestones and underlying granite. This contact has roughly an East-West strike and dips to the South at about 60 degrees. The contact lies in the form of a shallow arc, whose continuity is broken in several places by rolls, which are usually accompanied by cross fracturing. These rolls probably were occasioned by pressure due to the granite intrusions, which also may have caused the fracturing.

The lime is metamorphosed along the contact to a garnet and these garnet occurences extend into the limestone for considerable distances at the location of the rolls and fractures. All of the ore found to date occurs in the garnet in the "roll" area.

The lime beds have been tilted by the granite intrusion and faulting, but in general the contact crosses the beds, so there is a variation in the garnetization from the surface down, due to variations in the solubilities of the beds traversed.

The persistence of the lime is shown by a diamond drill hole, drilled vertically from the 625 level of the Glance Mine, which showed lime to a further depth of 500 feet, with the hole bottom still in lime.

The "Central" contact is known for a distance of 9,000 feet and the recognized "rolls" which have been named for the claims on which they occur, are, from East to West,: Copper Bullion, Copper Glance, Copper Queen, Copper King, Copper Buttes, and Minnie. The Copper Glance, Copper Queen and Minnie have been developed into good producing mines. The Copper King has produced an estimated $150,000.00 from a small fracture. The Copper Bullion has encountered a strong fracture filled with leached oxidized ore (not commercial). Neither of these developments has reached the contact so their present interesting showings warrant the expectance of ore bodies on the contact similar to those found in the other three mines.

There is an unprospected "roll" between the Glance and Queen, which could be prospected from the drift connecting these two shafts, and which was driven off the contact for permanence. Also, there are several other areas where "rolls" can be expected, as between the King, Buttes and Minnie.

The outcrops of contact garnet, or ore, are so inconspicuous as to have been practically non-existent. The small mineralized fracture on the surface at the King is the best. In the Queen and Glance the surface showed a very small fracture filled with oxidized ore but no commercial ore bodies were encountered until a depth of 300 feet was reached. However, from this point the ore has been practically continuous to their present bottoms, which are in ore.

In general, five "rolls" have been found in the 9,000 feet of known central contact, leaving a good chance for a similar number to be found by intelligent prospecting.

The "Morgan" contact lies about one mile South of Twin Buttes camp. Its productive life was from 1906--1913 and resulted in the production of ore valued at $ 3,110,000.00, construction of a 28 mile standard gauge railroad from Tucson and a small smelter. During this period the discovery of the "Central" contact occured. The Morgan Mine has been operated occasionally by leasers since 1913 but today is full of water. Mr. Foy states that it has some considerable promise for mill ore, which warrants serious study and unwatering and sampling.

The "North" group is purely prospective with little work and no production.

The ore found to date is almost entirely a massive pyrite containing bornite and chalcopyrite, there being almost no oxidized ore in any of the mines. These ore minerals are found in the garnet in irregular shaped ore bodies typical of replacement deposits. There has been no sign of dimunition in intensity of mineralization or grade to the present depth.

MINE WORKINGS:
Central Contact:

Copper Bullion:

This shaft is in solid limestone and is open all the way. It contains little seepage water and has no surface improvements at present.

Copper Glance:

The shaft has been retimbered to 525 level, which has been unwatered for inspection. The level is in fair shape, permitting access to all the stopes. The drift to connect with the Queen is open. The workings below the 525 level are probably all in good shape since they are relatively new. The headframe has been put in good shape and the shaft is operated by a 15 HP gasoline hoist.

On the 400 and 525 levels there exists ore faces which will mine 4% copper, making it possible to begin production at once. When we unwatered these levels, I had an opportunity to take a few check samples to confirm this.

Copper Queen:

The shaft has caved around the collar for a depth of 3-4 sets, requiring reopening to restore ventilation in the Glance and Queen Mines through the 525 deift, which is the 7th level of the Queen. Unwatering the Glance takes the Queen water to the 7th level, but supplementary equipment is needed in each case to unwater the bottom of the mine. It is confidently expected the Queen Mine will prove similar to the Glance in that fairly recent timbering, which has been under water, will be in such shape it will not have to be replaced. The Queen has a headframe, hoist house and a 50 HP hoist.

Copper King:

The shaft has been re-laddered and the timbering repaired. It has no surface improvement. The rehabilitation to the 200 level was for the purpose of preparing for diamond drilling to the contact.

ORE RESERVES:

The calculation of ore reserves in lime replacement bodies is a difficult matter, but the following is good practice and details the manner in which the Copper Glance reserves are estimated.

The ore occurs in connected lenses in a large mass of garnet, which occurs along the contact of the granite and overlying limestones. Using the known tonnage mined above the 525 level and below the 300 level from the garnet area there, we find a block of 100 feet by 200 feet extending from the 300 to the 525, an incline distance of 270 feet. This block contains 5,400,000 cubic feet of garnet or 540,000 tons of garnet zone, which actually has produced 118,066 tons of ore averaging 6.72 % copper.

From the 525 level to the bottom of the 626 winze, which is still in ore, using the same manner of calculation, we are justified in expecting 400,000 tons of garnet ore zine which could produce 87,400 tons of ore of similar grade. The partial development on these lower levels does not show any dimunition in size or grade.

An average of all the mine samples taken during the last 40 days' operation shows:

525 level workings assayed		6.80 % copper
625 level workings assayed		7.70 % copper
	Average	7.45 % Copper

There is no reason to expect the ore bodies to bottom at the present level as diamond drilling shows the limestones, which are essential to ore formation, continue at least 500 feet deeper.

This diamond drill hole was drilled from the 625 level so there is 400 feet of limestone below the 700 level. The 400 feet of limestone from the 300 to the 700 level produced 118,066 tons and is estimated to contain 87,400 tons more, a total of 205,466 tons. It is possible the succeeding 400 feet will contain a similar amount of similar grade.

Copper Queen:

The Queen has been mined to a greater depth than the Glance, but an estimate using similar reasoning shows approximately 40,000 tons reasonably expected, and a possible additional 50,000 tons averaging 6.50 % copper.

Copper Bullion:

Copper King:

These two areas have just as good a chance of developing substantial ore bodies as the Glance and Queen had, and of similar grade. It is remarkable that the three mines on this contact that were developed to the contact in the favorable "roll" area, all proved very profitable, and adds to the possibility of that two known areasalso developing similarly.

In addition to these, there are other likely "roll" areas between the Glance and the Queen, and the King and the Minnie.

Copper King: (continued)

	Production		Probable Ore		Possible Ore	
	Tons	% Cu.	Tons	% Cu.	Tons	% Cu.
Copper Glance	118,066	6.72	87,400	7.45	205,466	6.00
Copper Queen	75,086	7.08	40,000	7.00	50,000	6.50
Minnie	62,477	4.71	30,000	3.25	30,000	4.00
	255,629	6.35	157,400	6.53	285,466	6.23

In the unprospected "rolls", Copper King and Copper Bullion, it is possible they will each contain a somewhat similar tonnage to the average of the three, which is 232,830 tons, averaging 6.35 % copper.

There is a good "roll" between the Glance and the Queen Mines, which can be prospected from the 525 level of the Glance, and it also could develop a similar tonnage and grade like that estimated in the Copper King and Copper Bullion.

The property has an entirely possible chance of producing four or five times the quantity in the future that it has produced in the past.

COST OF PRODUCTION:

Since the Copper Queen mine was unwatered, rehabilitatated and put into production in 1919, under circumstances existing today in a similar way, costs and outcome could be very much alike. Mr. Foy started with a capital of $21,000.00, copper price averaged 13.83 ¢, shafts were caved and mine full of water. The net profits for 1923 to 1926 were $ 412,216.00 on 59,952 tons.

The detailed costs at that time were as follows:

Direct	Per Ton	Indirect	Per Ton
Labor	$ 1.686	Prospect Outside Mines	$ .688
Labor Ins.	.083	General	.062
Power	.097	Repairs Renewals	.112
Explosives	.179	Taxes--St. & Co.	.218
Smelter Represent.	.058	Taxes--Fed.	.476
Pumping	.076		
Timber	.022		
Total Direct	$ 2.372	Total Indirect	$1.556

Total all costs 3.928

Future costs of mining will not include "prospect outside mines", but labor will be higher, so a cost of $5.00 per ton is estimated.

Cost of Smelting--Transportation and Outcome:

Assuming the first production would come from the Copper Glance Mine, and using an approximation of the average assays of the last 58 railroad cars, 3,154.3 tons, namely, copper 6.0 %, Silver 2.0 oz., the following figures will show the outcome:

Pay			
Silver 2.0 oz. less 0.5 oz. at 90 ¢			$ 1.35
Copper 6.0 % 120 # - 12 # = 108 # at 18.5 - 2.8	15.7 ¢		16.96
			18.31
Deduct			
El Paso Smelting		$ 2.50	
R.R. Freight plus 5% H_2O		2.52	
Truck to R. R. " "		.84	
			5.86
Net Smelter Return			12.45
Royalty 10 %			1.24
			11.21
Mining			5.00
Net Profit			$ 6.21

The average grade shipped to date from the Glance was 6.72 % copper and the net profit with this grade is $ 8.04.

Similar profits should be available from the adjoining mines because ores are similar in grade and occurence, making similar mining costs probable.

All of the ores from the district are amenable to concentration by flotation but due to the prevalence of high grade ore, production until now has all gone direct to smelters. Proximity to the modern flotation mill of the Eagle Picher Company at Sahuarita, Arizona, makes milling the ores locally well worth investigating.

FUTURE OPERATIONS:

Considerable thought has been given to a diamond drilling campaign as the first step, but the locations for the most promising holes are at depth and largely under water, therefore a campaign to reopen the Glance and Queen Mines and make it possible to commence actual mining and at the same time permit the first diamond drill operations, is suggested.

The bulk of the water has been removed and now stands at about the 460 level. The mines only made 50 G P M when unwatered to present bottoms. The hoist, headframe and shaft on the Glance are in working order. There are two new 3" lines to the 525 and new guides to 500 ft. point. There are two Chicago Pneumatic Diesel (Hothead) 310 c f m compressors installed, renovated and ready with starting equipment. It is planned to take out the balance of the water with a No. 7 Cameron Pump to the 625 Glance, and then use it as a station pump while unwatering the mine workings with a Chicago Pneumatic pump. (air) It would be better to rent and install a deep well type pump to unwater to the 625 and then use the Cameron, etc.

At the same time pumping begins, reopening of the Queen shaft should be begun so when the 525 is unwatered a second escape and ventilation will be available. The two compressors will furnish enough air to operate the Cameron once the 625 is dry and will give some air for diamond drilling.

Mining can be started on the 525 and 625, but will be limited by the available air.

Some diamond drilling was done in the old operations but Mr. Foy says the holes all were into the H W or South. The first area to be drilled should be between the Glance and Queen Mines, where the long connecting drift is well in the lime hanging wall. These holes should have a downward inclination and be spaced about 100 feet apart. They should cut an ore body since there is a "roll" there and geo-physical tests are positive. The 525 drift should be extended East a couple of hundred feet and drilled similarly to the N or toward the contact.

The Copper Bullion shaft offers a good spot for a long hole from the bottom (500 level). This area shows ore according to the geo-physical tests. The shaft requires a hoist and tripod to make this drill station accessible. The Copper King area also has a positive geo-physical test, has had some production and is in a "roll" area. This warrants drilling.

There are several other likely areas in which extensions of known ore bodies might be found, but these are the main chances for finding ore bodies of the size known on the Glance and Queen.

The possibility of getting electric power should be investigated. The Trico Cooperative is considering entering the district and there is always power available from the Tucson-Nogales high tension line a few miles to the East.

In the past, Twin Buttes was a favorite camp for miners and probably will continue to be for particularly the Mexican type, due to its nearness to the border and good climate. Wages will probably be controlled to considerable extent by those at the Trench Mine at Patagonia and the San Xavier Mine at Olive Camp.

The estimated cost of rehabilitation and operating capital to get into production is as follows. This does not include diamond drilling, which could be paid out of operating income if the operation started well.

Hoist	Move 50 HP Diesel Hoist Queen Mine to Glance. Extend building foundations, small repairs..................................	$ 750.00
Shaft	Repair, tighten guides and sets, ladders to 625..............................	500.00
Levels	Clean up 525, 625. Repair, install track.....	1,000.00
Ore Bin	Repair..	250.00
Unwater	525, 625 levels, 625 winze with Cameron Pump..	1,000.00
A ir Receiver	Install	75.00
<u>Equipment:</u>		
	3 Jackhammer type drills, hoses, tanks, 1 cradle, 1 stoper, hose tank, line oilers...	2,000.00
	4000 # drill steel (use Contention sharpener or Throwaway Bits).......	750.00
	2500 Ft. 12# rail and spikes (5 ton)	300.00
	10 mine cars (used)	1,000.00
	2500 Ft. 2" pipe--21 ¢	525.00
	2500 Ft. 1/2" pipe--15 ¢	375.00
	1000 " 1" "-----12 ¢	120.00
	Fittings, valves, etc.	250.00
	Air Hoist--625 winze	500.00
	Air Pump--- " "	250.00
	Shovels, picks, wrenches, miscellaneous tools..	250.00
	Reopening Queen Shaft for ventilation..........	1,350.00
	Carload miscellaneous timber (repairs & operation	1,450.00
	30 day payroll--1,000 tons	5,000.00
	Pickup Truck	1,000.00
	Total	$ 18,695.00

In order to meet any unforeseen contingencies, a fund of $25,000.00 should be available.

All the maps and records were furnished by Mr. Foy, who was the manager under the last operations. When I was ore purchasing agent for the American Smelting and Refining Company, I bought the Copper Queen production from Mr. Foy during 1923--26. I saw his operations and was so very favorably impressed that I have confidence in all this data. The evidence disclosed in unwatering to date has confirmed his statements.

Aside from the Senator Morgan Mine, the main contact has a length of 8,000 feet, of which 6300 feet is open through existing shafts. Of this distance, 6300 feet, there remains 2500 feet of contact which has an excellent chance of containing similar ore bodies to those already discovered. The ore trend is raking to the East and probably will be found 500 feet deeper than at the Glance or at 800 feet.

While the ore in the Queen was much narrower at the 9th level, a winze below this level shows it is widening and has 4 feet of high grade copper. This is typical of replacement ore bodies and has occured many times in the mine before and definitely shows the Queen is not bottomed.

In the Glance there has been no dimunition in size of the ore on the lower level. Therefore, horizontally the end of the contact limits the extension but there is ample room for several large ore bodies. Vertically there has been no limit found as yet. The Twin Buttes Camp is still only partially prospected.

Considering the history of production and profits from these mines, and reviewing the maps and considering Mr. Foy's statements concerning the ore in the Glance Mine available for immediate production, it is entirely probable that more than enough ore can be easily and quickly produced to repay the capital investment, a drilling and development campaign, and furnish profits soon after production begins.

With intelligent management, the purchase price of the mines can be accomplished through royalty payments, ore can be developed for the future, and a long time mining operation of fair size can be developed.

Howard H. Fields

Howard H. Fields

March, 1950.

War Mineral Report
United States D. partment of the Interior---Bureau of Mines
W. M. R. 47--Copper, Zinc February 1943

Twin Buttes Camp

Pima County, Ariz.

SUMMARY

The mines of the Twin Buttes Camp are at contacts of intrusive granite with older sediments, largely limestone. The ores are principally the contact metamorphic type and are localized in the hanging-wall sediments at the junction of small fissure veins with the granite contact. No important ore bodies were exposed at the surface, but were discovered by sinking on the fissure veins to the contact zone. Masses of garnetized rock in the contact zone also serve as possible indicators of underlying ore bodies.

Five mines in the area--Minnie, Copper King, Copper Queen, Copper Glance, and Senator Morgan--have yielded 388,000 tons of ore averaging 6.17 percent copper and a small tonnage of high-grade oxidized zinc ore. Developed reserves in two of these mines amount to 30,000 tons of 6 percent copper ore. The Contention mine, on another segment of the granite contact, has 15,000 tons of developed zinc-copper ore averaging 17 percent zinc and 2 percent copper. Ore development is in progress at this mine, financed by a $20,000 Reconstruction Finance Corporation loan.

All of the copper mines except the Senator Morgan lie along an 8,000 foot east-west segment of the granite-sedimentary contact. Two other shafts, which yielded no production, were sunk on this contact, so that some 6,300 feet of the contact zone is accessible for underground exploration. Geologic conditions favorable to ore deposition are found along some 2,500 linear feet of unexplored portions of this contact zone.

All of these mines are controlled by the owner and operator of the Copper Queen and Contention mines, who holds the other mines under lease. Financing has been arranged for extracting shipping ore now exposed on the lower levels of the Copper Queen and Copper Glance mines and for continued development and mining. Preliminary rehabilitation is under way. Four of the shafts have been made accessible, and the lower levels of the Copper Queen and Copper Glance, now under water, will be unwatered soon.

Mining cost of shipping ore is estimated at $5.00 a ton. Ore of lower grade than 5 percent copper will yield little profit when shipped to the smelter.

The Bureau of Mines has begun an exploration program in which it is planning to include (1) mapping and geologic study, both at outcrop and underground; (2) sampling of underground workings and diamond-drill testing of parts of the Twin Buttes contact zone for extensions of known ore bodoes and search for new ones; and (3) sampling the Contention mine and diamond drilling to prove extensions of that ore body. About 4,000 feet of diamond drilling and 500 feet of underground drift-

ing will be needed. The total cost of the project is estimated at $45,000.00. This program has a dual purpose--first, to disclose additional reserves of shipping ore, and second, to estimate the tonnage of milling-grade ore and, if the available tonnage of the latter is sufficient to justify the erection of a mill, to make metallurgical tests and proposals for a custom mill in this camp.

This program offers an opportunity to disclose ore bodies that should yield copper ore and zinc-copper ore of shipping grade. The expectation is 25,000,000 pounds of copper to be produced from 1943 to 1947, inclusive.

INTRODUCTION

The Twin Buttes Camp embraces eight mines that lie along a contact of granite with Paleozoic limestones and quartzite. Five of these have been producers; another is in active development and has some zinc-copper ore blocked out. There is known reserve of some copper ore in two of the old producers.

In June, 1942, when a Bureau of Mines engineer investigated these mines, only one of them was accessible. Maps of the others are available, as well as records and smelter settlements covering the greater part of the copper produced from the camp, and a geological report on the Twin Buttes district by Ronald L Brown in the Univ. of Ariz. library. The present operator, who has been connected with these mines since 1916, supplied much information.

The Senator Morgan group, under lease to Charles Taylor of Tucson, Ariz., is owned by the Twin Buttes Mining and Smelting Co. of Milwaukee, Wis., which also owns the Copper Glance, Copper Buttes, Copper Bullion, and Copper King mines. These are leased to William Foy, of Twin Buttes, until 1948.

The Midland Copper Co., now defunct, owned the Copper Queen mine. William Foy, a former shareholder in that company, has been paying taxes on the mine for several years.

The Ariz. Buttes (Minnie) group of claims and the Contention group, all unpatented, are held by William Foy.

The Taurus claim (unpatented) is held by G. Gavin, Box 13, Ruby Star Route, Tucson, Ariz.

Work has been started at the Copper Glance to rehabilitate the shaft and unwater the mine and the Copper Queen, which is connected with the Copper Glance on the seventh level. William Foy has unwatered the Contention mine and is doing development work there.

HISTORY

The first locations are said to have been made in 1876. Little mining was done before 1905, when D. S. Rose, of Milwaukee, organized the Twin Buttes Mining and Smelting Co., and acquired the more promising claims in the area, exept the Minnie Group. This company built 28 miles of standard gage railroad from Twin Buttes to Tucson and erected a smelter on the Santa Cruz River. It operated from 1906 to 1913, but was not highly successful. It produced 132,500 tons of ore averaging 5.92 percent copper, mainly from the Morgan mine, but some of it from the Copper Glance and Copper King mines.

Ed Bush leased the Morgan mine in 1913 and produced a few carloads of low grade ore. He relinquished that lease in 1914 and took a lease and purchase option on the Minnie mine, which he developed and operated from 1914 to 1917.

Ed Bush and associates organized the Midland Copper Co. in 1917 and took the Copper Glance and Copper Queen mines under lease and purchase option. The Copper Queen was paid for out of royalties. The lease on the Copper Glance was surrendered in 1918, and the mine has since lain idle. It has produced 118,066 tons of ore, averaging 6.72 percent copper. Bush died in 1920. The company reopened the Copper Queen mine in 1922 under the management of William Foy, and shipped ore from 1923 to 1926. The Copper Queen produced 75,186 tons of 7.05 percent copper ore from 1917 to 1926. William Foy produced a little ore from the Minnie mine in 1928.

Total production from the camp has amounted to 388,231 tons averaging 6.17 percent copper, contributed as follows:

Mine	Dry Tons	Copper, percent	Copper content, pounds
Senator Morgan[1]	132,502	5.92	15,688,237
Copper Glance	118,066	6.72	15,870,493
Copper Queen	75,186	7.05	10,608,048
Minnie	62,477	4.71	5,865,333
	388,231	6.17	48,032,111

[1]Production credited to the Senator Morgan mine includes all of the ore produced from the Copper King and the early production from the Copper Glance.

PHYSICAL FEATURES

The Twin Buttes Camp, in the Pima Mining District, is 28 miles south of Tucson on the Tucson-Continental County road. It is 6 miles south of Mineral Hill. Almost half of the road is paved and the remainder is well graded. A graded road 9 miles long connects the camp with Sahuarita, on the Nogales branch of the Southern Pacific Railroad and on paved U. S. Highway 89.

Topographic relief is not great. The altitude is about 3,400 feet, wherefore temperatures are somewhat lower than at Tucson.

Potable water is obtainable from three old prospect shafts in the area, but the nearest supply is rather scant in dry weather. Mine water is used for other than camp purposes.

Although labor is not abundant, a few experienced men are available, and some ordinary laborers can be obtained.

GEOLOGY

The ore deposits of the camp, as indicated by past development, are mainly the contact-metamorphic type and are at or near the contacts of intrusive granite with Paleozoic limestones and quartzites. The ore shoots lie in metamorphosed sediments adjacent to a zone of garnet rock that separates the ore from the footwall granite.

The principal group of copper mines lies along the north side of a sedimentary ridge that may be completely surrounded by granite. The greater part of the contact is masked by alluvium. The claims lie end to end, with their side lines roughly parallel to a nearly east-westsegment of the granite-sedimentary contact, which is about 8,000 feet long(fig. 1). From west to east the mines are Minnie (Arizona Buttes), Copper Buttes, Copper King, Copper Queen, Copper Glance, and Copper Bullion. The contact is approximately defined by outcrops toward the west but is masked by a thick mantle of alluvium toward the east. The dip of the contact is south. Some transverse faulting has been noted along this segment of the contact.

The Contention zinc-copper ore body on the North Star claim about 3,500 feet south of the Minnie mine, is on the granite sedimentary contact at the northeast side of another block of sediments. The intervening contact line between the mine and the Twin Buttes Group is several miles long, within which interval the granite presents many phases, grading from true granite to diorite. Quartz segregations and lamprophyric dikes also occur.

The old Senator Morgan mine, adjoining the Contention at the southeast, is near a faulted segment of the same granite-limestone contact that trends northwesterly. Several faults are noted in this general area.

ORE DEPOSITS

The Copper Bullion, Copper Glance, Copper Queen, Copper King, and Minnie form a geologic unit. Mining on the Glance, Queen, and Minnie has shown that these are contact-metamorphic deposits. Chalcopyrite, together with a little bornite, is the principal copper mineral, although copper carbonates and native copper are found. The gangue consists of garnet, epitodized limestone, and some specular hematite. The three mines have the following characteristics:

1. Initial work was on small-fissure veins containing copper-carbonate ore.

2. The veins led to contact-metamorphic deposits of economic importance.

3. The contact-metamorphic ore bodies did not outcrop.

4. The ore shoot developed, in each instance, has an easterly rake and consists of connected, irregularly shaped ore bodies within the contact zone. The shoots are lenticular in general outline, have an average thickness of 30--80 feet, and are about half replaced by copper ore above 5 percent grade.

5. At the surface and in the vicinity of the upward projection of the ore bodies, is a zone of garnetization, containing minor amounts of copper carbonates.

6. Progressively from west to east, the contact-metamorphic bodies occur at greater depth below the surface.

7. The depth of these bodies is a function of the horizontal distance between the granite contact and the fissure vein appearing over each body.

8. The importance of the underlying ore body appears to be reflected in the strength of garnetization, where the limestones are of equal amenability to contact metamorphism.

The water table is about 425 feet below the collar of the Copper Glance shaft. That mine makes 50 gallons of water a minute at the 625 foot horizon.

Description of Mines

Minnie (Arizona Buttes)--This was the first of the group to be explored. Most of the fissure vein over the ore shoot has been eroded, so that strong mineralization was evident at the surface. The ore shoot lies between limestone and a footwall wedge of quartzite, the thin edge of the wedge being towards the east. This was passed in drifting east on the 325 foot level, where granite was encountered on the footwall of the mineralized zone. The copper content there fell below 3 percent. Mineralization appears to have been localized by transverse fractures that pass from the granite through the quartzite into the limestone hanging wall. The quartzite is partly mineralized adjacent to these fractures and yielded some ore.

The ore shoot, as developed, is about 500' along its pitching axis, roughly oval in cross section and about 70' wide. Total production has amounted to 62,477 tons with average grade of 4.71 % copper. The ore diminished in grade on the lowest level; 5,100 tons mined there in 1929 averaged 3.15 percent copper. Ore of similar grade remains in the mine, according to assay maps, but the thickness of the ore shoot is decreasing downward. Future exploration in this mine had best be directed eastward along the granite-limestone contact toward the Copper Buttes shaft about 1,400 feet away. The 325 ' level was driven 375' east on this contact without encountering shipping ore. This exploration is not recommended at present.

Copper Buttes:

There is a moderate development of banded garnetization between the Minnie and the Buttes shaft. A small mineralized fissure vein outcrops at the Buttes shaft, which was sunk on this vein at an inclination of about 60° southerly. The shaft entered the footwall granite at 100' and was continued in granite to 300' on the slope. Crosscuts were driven to the hanging wall limestone at the 200 and 300' levels. Drifting along the contact on these levels aggregates about 225'. The contact, where exposed underground, shows a leached zone with some mineralization that averages about 5' in width. This zone contains some chalcopyrite in garnet rock, but the material is below commercial grade. Exploration, if undertaken, should be directed westward along the contact toward the Minnie; that is not contemplated as part of the Bureau's present work.

Copper King:

The King shaft was started early in the century on a fissure vein containing copper carbonates. The shaft was last used in 1913 and is reported to be 300 feet deep. The vein is in limestone and dips steeply toward the south. It is exposed for a length of 250 feet at the surface, where it pinches and swells along the strike; underground openings show the same variation in width down the dip. Average width is about 5 feet. Leasers are now mining at the surface, working westward toward the granite contact, which is masked by alluvium.

Mine records show that oxidized zinc ore was found in the footwall limestone a short distance north of the vein. Smelter settlements indicate that 2,183 tons of ore carrying 27 to 34 percent zinc was shipped to Kansas and Colorado smelters.

There is a moderate development of garnet in the hanging wall limestone over the King fracture. Eastwardly the surface trace of the fracture fades out into a heavy body of garnet rock overlying the Queen stopes. Although the King fissure is well within the hanging wall (perhaps 300 feet), relative to the Queen shaft, it is not unlikely that it connects with the Queen ore body. The intervening block of ground, about 400 feet measured along the rake of the Queen ore shoot, will be explored through stoping in the two mines.

The block of ground below the King workings is considered a promising potential souce of copper ore and possibly of zinc ore, also. An ore shoot should be found at the junction of the King fissure with the granite contact, assuming that ore deposition here followed the pattern, exposed by development, at the Minnie mine to the west and at the Queen and Glance Mines immediately to the east. The strike and the attitude of the granite footwall are unknown between the Queen mine and the Copper Butte shaft, so that the distance from the lowest level of the King workings to the granite footwall is unpredictable.

Copper Queen:

The first work at the Queen mine was on a small fracture filling of copper carbonate ore, as at the Minnie, King, and Glance mines. A shaft was sunk on the fracture about 100', almost vertically. In view of geologic conditions already proved at the Minnie and Glance mines, this shaft was abandoned and another was started, inclined 72° south. The second shaft intersected the hanging wall limestone and encountered the metamorphic ore body at 440 feet inclined depth, and has been sunk to 740 feet. Ore was stoped from above the 440 down to the 700 foot level. The ore body is said to diminish in thickness and grade in the backs of the stopes above the 440 foot level. Complete assay records of this last work indicate that the grade of ore is about the same as that of the ore mined above. Selective mining is necessary, as at the Glance and Minnie mines. About half the material in the ore shoot is shipping ore of 6 percent grade.

The shaft cut the granite contact at an inclined depth of 570 feet; on the 700 foot level it is 70 feet in the footwall granite. A wall of granite was encountered 175 feet west of the shaft on the 700 foot level. The calculated dip of the contact between these points is 45 ° south. Ore was mined from the reentrant angle, and the granite was followed 60 feet toward the hanging wall without finding its contact with the limestone. There is low grade mineralization along this crosscut. A similar granite projection was found east of the Queen stopes on the 650 foot level about 300 feet east of the shaft. Here it is clearly the result of transverse shearing. The ore continued well back into the footwall granite. Neither of these projections was found on the higher levels. If they continue downward, they may form the western and eastern limits of the Queen ore body. They are 500 feet apart where observed, but it is reported that they incline slightly toward wach other downward. The major ore shoot has a width of about 200 feet, although some ore has been mined along the entire strike length of 500 feet.

The Copper Queen could be explored at both upper and lower ends of the developed part of the ore zone. The upper and westerly projection would be difficult and costly to reach by diamond drilling. Continuation tod epth could be proved only by sinking on the ore body or crosscutting into the hanging wall and diamond drilling.

The Copper Queen has produced 75,186 tons of ore containing 7.05 percent copper and about 2 ozs. silver per ton.

Copper Glance:

The first work at the Copper Glance was an inclined shaft on a small fissure in limestone that strikes N. 60° W. and dips steeply south. Two ore shoots were found on opposite sides of the shaft, about 100 feet apart, on the 150 foot level. The first shaft was abandoned, and a vertical shaft was sunk, directed at the athe western ore shoot. This shaft entered the contact zone between granite and limestone at 330 feet. Two lobes of ore were developed, which join on the 400 level and connect with the eastern ore body found on the 150 foot level in the fissure vein. The ore in the contact zone was developed easterly and downward to a verticald epth of 550 feet.

The shaft intersected the granite contact at 380 feet and was sunk in the footwall granite to 625 feet, where the crosscut to the ore zone is 150 feet long. Two winzes were sunk in ore on the 625 foot level. The ore there is similar in grade to that mined at higher levels. The ore shoot rakes to the east. It has been developed for a length of 400 feet; it is about 200 feet wide and 60 feet thick. About half of the shoot is ore.

A west drift on the 525 foot level connects with workings of the Queen mine. This drift was carried along the granite footwall for 365 feet from the Glance workings, and thence, due to the undulating contact surface, in the limestone hanging wall for the final 1,000 feet.

Above the 450 foot level, the Glance stopes are almost entirely west of the shaft, but the ore body lies directly in front of the shaft on the 625 foot level.

Drifts were carried about 275 feet east of the shaft in the contact zone on the 450 foot and 525 foot levels. No profitable ore was found in these drifts nor in short crosscuts driven north and south from them.

Considerable diamond drilling has been done from underground stations in both the Glance and the Queen mines. These holes were all directed into the hanging wall at various angles, but, so far as known, none was directed toward the granite contact.

Copper Bullion:

A vertical shaft on the Copper Bullion claim was sunk 500 feet to explore a strong vein in the cherty Cambrian limestone known as the Abrigo formation. The vein has an average width of 18 feet, dips steeply northward, and strikes N. 60° W. in conformity with the bedding of the formation. The cherty country rock suffered little alteration, but there is some garnetization in the fissure filling. The shaft is in the vein to a depth of 50 feet and in the hard, cherty limestone footwall below the depth. Crosscuts were driven to the vein at the 100, 200 and 300 foot levels, and raises were carried up in the vein from these crosscuts. A 100 foot winze was sunk in the vein on the 300 foot level. A crosscut was started toward the vein on the 500 foot level but was not finished. A diamond drill hole 380 feet deep and almost horizontal was directed northeasterly and did not reach the granite contact.

The Copper Bullion vein filling is largely iron oxide, garnet, and partly garnetized limestone, with streaks of copper sulfide and oxide. A little shipping ore was mined from the upper part of the vein.

The Copper Bullion fissure appears to be on the projected strike of the Copper Glance fissure but in a different type of limestone. The horizontal distance between the shafts is about 1,300 feet. No ore exposures were observed except minor occurences of copper carbonates in garnet near the Glance shaft.

The granite contact north of the Copper Bullion shaft is masked by a heavy mantle of alluvium. The probable line of junction between the vein and the contact is indeterminate but is certainly at considerable depth. There appears to be ample room here for a deep deposit of copper ore.

Contention mine:

An exceptionally strong development of dark garnet rock occurs at the Contention mine. Thin beds of unreplaced limestone remain in the garnet zone, which is nearly 100 feet wide. The zone is separated from the granite here and there by unreplaced limestone and at some places by a thin bed of quartzite. The contact zone is irregular and is interrupted by faulting.

There is one vertical shaft 221 feet deep. A crosscut on the 150 foot level was driven southwesterly and encountered a thin vein at 100 feet from the shaft. This was drifted upon to the south for a distance of 157 feet and was crosscut at two places. Three raises were connected by a sublevel 80 feet above the drift. All of this work is in ore. One raise was continued to 60 feet above the subdrift, where its face is partly in ore. Two winzes were sunk in ore from the 150 foot level. It is reported that a crosscut was driven to the ore on the 210 foot levl (under water at date of examination) and that the vein was drifted on, in ore, for 150 feet. southward.

Development is insufficient to determine the structural relationship. The pitching of the ore to the north is probably related to a fault that outcrops a little north of the shaft. An east-west arroyo probably marks the trace of this fault. Beds on the two sides of the arroyo show almost no horizontal displacement but differ by 35° in strike.

The ore shoot contains masses of irregularly distributed garnet. It has a footwall slip, below which the beds have not been prospected. A zone of radially bladed actinolite may mark the hanging wall, but this has not been crosscut outward from the ore body. Widths across the ore range from 4 to 22 feet, but the average thickness is not less than 12 feet.

A class B development loan of $20,000 has been granted by the R. F. C. to be used to develop ore reserves to the south at a depth of 300 feet.

It is worthwhile noting that this ore body did not outcrop and that there were no prove ore bodies in the immediate vicinity. Ed Bush, following his experience at other mines in the district, sank 150 feet on the garnet zone and then crosscut toward the hanging wall limestone to discover the ore. A similar exploration program on the Gladstone claim, undertaken later, was unsuccessful.

Taurus:

This is an unpatented claim of irregular shape adjoining the North Star (Contention) claim on the southeast. The heavily garnetized contact zone on the North Star claim continues southeasterly across the Taurus claim but pinches out near the southeast end line of that claim. On the Taurus, about 800 feet southeast of the Contention shaft, measured along the contact (500 feet southeast of the nearest proposed diamond drill hole) is an outcrop containing copper carbonates enclosed in the garnetized and epidotized limestone. This copper streak is about 1 foot wide. There is no development except a few test pits.

ORE RESERVES

Minnie Mine:

Records and assay maps indicate that the developed ore shoot in the Minnie mine may be nearly exhausted. Both grade and thickness of the ore are diminishing at the edges of the stoped area. The last ore shipped averaged 3.15 percent copper, which is not shipping grade at this time. No reserves are credited to this mine.

Copper King Mine:

Ore probably remains in the King fracture. Both zinc and copper ores were being shipped from the mine when the Twin Buttes Mining and Smelting Co. suspended operation in 1913. No assay maps are available. The shaft has been cleaned out and retimbered.

Copper Queen Mine:

Assay records indicate that ore of the same grade as that mined above (about 6 percent copper) can be mined from the lowest levels. The thickness of the ore shoot diminishes within the lowest 100 feet of its depth.

Copper Glance Mine:

The Copper Glance ore shoot has been proved on the 525- and 625- foot levels but only partly extracted there. Reserve is estimated at 30,000 tons of 6 percent copper ore, based on past production from higher levels.

Contention Mine:

Proved reserve is about 15,000 tons of ore that will average about 17 percent zinc and 2 percent copper.

<u>Total reserves</u> are thus 30,000 tons of 6 percent copper ore and 15,000 tons of zinc-copper ore at 17 percent zinc and 2 percent copper.

MINING COSTS

Mining costs per ton of shipping ore at the Copper Queen mine from 1923 to 1926 were as follows:

Labor................$1.668
Insurance............ .083
Power and Air........ .097
Explosives........... .197
Smelter representation .058
Pumping.............. .076
Miscellaneous supplies .171
Timber............... .022

$2.372

Prospecting and Development... .688
Overhead:
General office expense .062
Repairs and renewals.. .112
Taxes, State and Co. .218
Taxes, Federal.Inc... .477

.869

Total cost per ton of
shipping ore................ 3.929

Estimated present cost....... 5.00

Smelter returns at the mine, according to American Smelting and Refining Co. schedule, on copper ore delivered at Hayden, are as follows:

Cu. 13.85 ¢ Ag. 70 ¢

On 4.5 percent copper, 2 oz. per ton silver $5.87
Less royalty 10% of net smelter returns .59
Net per ton at the mine.................. $5.28

On 5 percent copper ore, 2 oz per ton silver 7.48
Less royalty 10 percent of net smelter returns.................................. .75
Net per ton at the mine.................. $ 6.73

On 6 percent copper ore, 2 oz. per ton Ag. 11.10
Less royalty 10 % of net smelter returns 1.11

Net per ton at the mine....... $ 9.99

The lease terms under which the mines will be operated are not known, but a royalty of 10 percent of net smelter returns is a general standard on this grade of ore. According to the above calculations there will be no profit in shipping 4.5 percent ore, and 5 percent copper will be probable cutoff for shipping ore.

PROPOSED EXPLORATION BY BUREAU OF MINES

The complete program includes the following items, at their estimated costs:

1. Surveying and mapping surface and underground workings and preliminary character sampling............$4,000.00

2. Rehabilitation of mine to give access for drilling mapping, and cutting of underground drill stations 3,000.00

3. Surface trenching........................ 2,000.00

4. Diamond drilling, including supervision, sampling, and analyses, 4,000 feet at $6.00 per ft....24,000.00

5. Driving exploratory headings to favorable areas, 500 ft. at 14 dollars a ft.................. 7,000.00

6. Mine sampling.............................. 3,000.00

7. Contingencies.............................. 2,000.00

$ 45,000.00

For the immediate future, work will be limited to item 3, the results of which will largely determine the advisability of further procedure.

Copper King Mine:

Objectives are to extend the known ore reserve and determine its grade. Diamond drilling is proposed to test the Copper King fracture down to the granite contact and also the contact zone. It is proposed to drive a crosscut 100 ft. into the hanging wall on the 300 ft. level and to cut a diamond drill station at its end. Drill holes totalling 1,310 feet will be directed at different angles to crosscut the vein at intervals down to its junction with the contact and also to crosscut the contact zone. Some holes will be continued into the footwall of the vein to test the continuity downward of the footwall zinc-ore body, from which it is estimated that 1,100,000 lbs. of zinc has been shipped in ore.

Copper Queen and Copper Glance:

It is proposed to test a 1,000 ft. gap of unexplored contact zone between Copper Queen and Copper Glance workings by diamond drilling from stations in the long drift on the 525 ft. level of the Glance. The drill holes will be spaced at 100 ft. intervals and will be directed northeasterly with 45° downward inclination. The total footage to be drilled is estimated at 1,375 ft.

Copper Glance:

The operator proposes to extend the east drift on the 525ft. level 250 feet eastward, and to drive along the limestone hanging wall, thus leaving most of the contact zone unexplored. The contact zone contiguous to the proposed drift seems particularly promising because of its proximity to known ore and because it is under a very heavy mass of garnet rock at the surface. The Bureau of Mines proposes to drill five holes from this drift northerly to the granite footwall. The holes will be inclined about 45 ° downward and will be about 100 feet deep. The total drilling is estimated at 500 feet. This may disclose an ore shoot similar to the Glance ore body.

Copper Bullion:

The drilling proposed on this claim is to determine the copper content of an 18-ft vein at and below the 500 ft level. The vein has been exposed near the shaft to the 400 ft level. It is leached and oxidized and has spots of copper mineralization to that depth. The drill will be stationed at the bottom of the shaft. If the test holes find profitable ore, divergent holes will be drilled to explore the ore body along the strike as far as is practicable from one station. The proposal calls for 840 ft of initial and 845 feet of supplementary drilling. This work may disclose an ore body extending to considerable depth.

Contention:

The proposed drilling is dircted toward proving the continuation of this ore body in depth and along the strike. It will also test the zone between the footwall of the proved ore body and the granite contact. About 1,300 feet of drilling is required. This is expected to increase the present reserve of zinc-copper ore. It will also test the type of mineralization that prevails at greater depth. It is suspected that the copper content of the ore will increase and the zinc content decrease as depth is attained. If a fairly large tonnage of the zinc-copper ore should be developed, a mill will be required to beneficiate this ore.

Taurus:

It is proposed to drill two holes on the Taurus claim unless the results of drilling on the Contention are discouraging. The holes are designed to cut the contact at vertical depths of 150 and 250 feet under the surface showing of copper ore. This drilling may discover an ore shoot similar to those already proved along this contact.

CONCLUSIONS

It is believed that the above program should siclose additional ore bodies. The work will decide whether a custom mill should be built in the district. There are two possible sources of mill ore-copper ore at the Twin Buttes group of mines too low in grade to ship directly to a smelter and zinc-copper ore at the Contention mine that will need both concentration and separation.

The Bureau's sampling will determine the available tonnage of such ores. If the tonnage is high enough to justify a mill, then ore-dressing tests will be made by the Bureau of Mines metal-lurgical laboratory followed by proposals for a custom mill. It is probable, however, that enough mill ore will be indicated to recommend a 100 ton milling unit that can begin operation by the end of 1943.

EXPECTED PRODUCTION

	Copper, pounds	
	From smelting ore	From milling ore
1943	2,192,000	
1944	3,288,000	2,386,000
1945	3,288,000	2,386,000
1946	3,288,000	2,386,000
1947	3,288,000	2,386,000
	15,344,000	9,544,000

Production of zinc probably will not be high, its amount cannot be estimated at this time because it is likely that the zinc content of the Contention ore will decline as depth is attained.

Copper Oxide Ore Leaching and Electrowinning Plant

Anamax Mining Company
Sahuarita, Arizona

McKee's WKE Operations, as sponsor in a joint venture with another engineering company, provided facilities to process copper oxide ore and to produce commercial cathode copper for Anamax Mining Company, Sahuarita, Arizona.

Ore, reclaimed from stockpiles at a rate of 10,000 tons per day, is reduced to one-half inch size by three crushing stages. The fine ore is then reclaimed from a covered 15,000-ton live capacity storage pile for further reduction by grinding in two parallel rod and ball mills in open circuit.

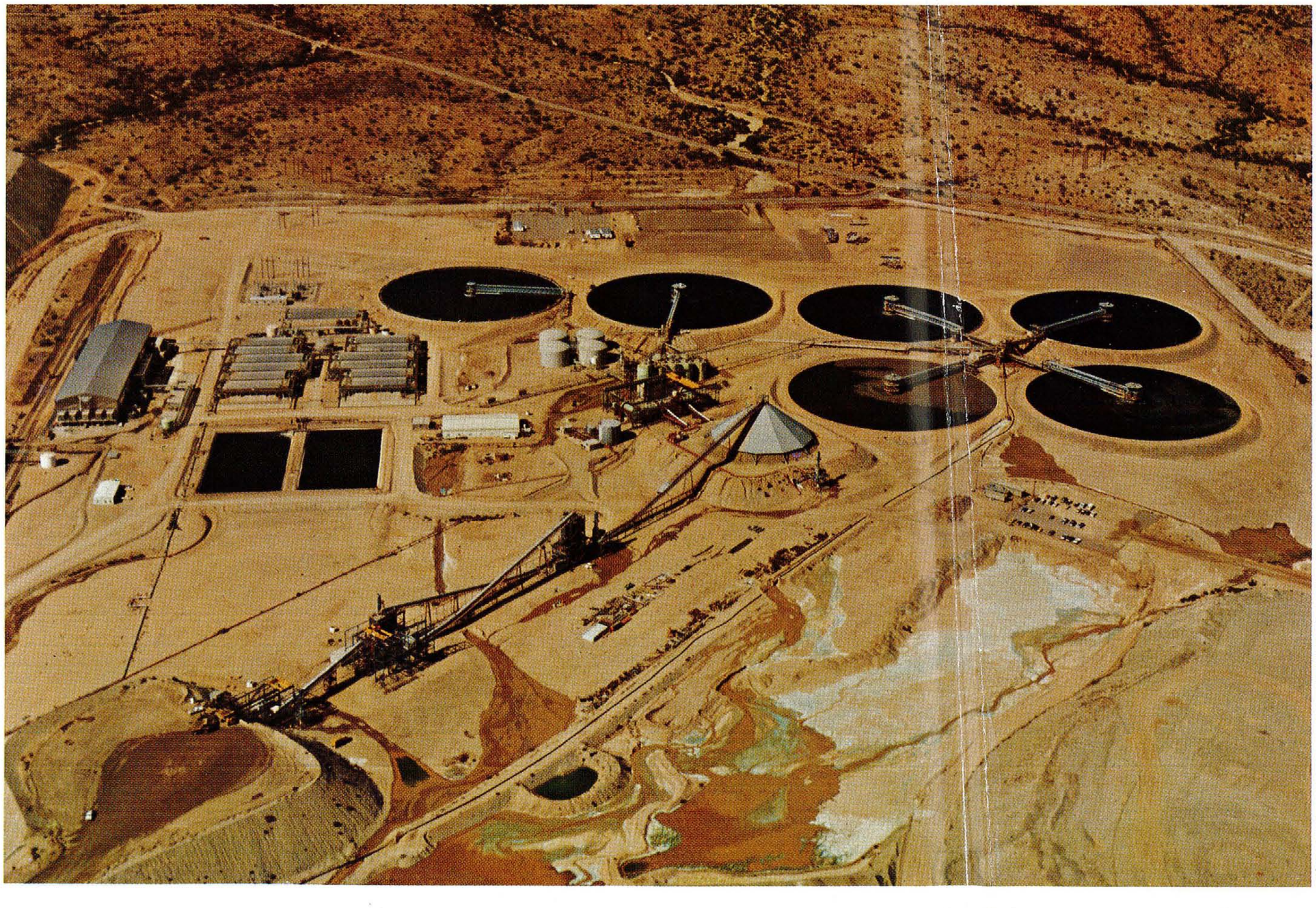
Fine ground ore passes to five agitation leach tanks where sulfuric acid solution leaches soluble copper oxide from the ore. The resultant slurry passes through four 400-foot-diameter countercurrent decantation thickeners. The copper bearing solution is then passed through a pH adjustment step and a 400-foot-diameter clarifier to produce a clarified leach liquor for the solvent extraction process.

The solution passes through polishing sand filters and into two separate circuits, each with six solvent extraction mixer-settler tanks. Electrowinning feed solution containing copper flows from the last two tanks in each circuit.

The electrowinning plant produces copper cathodes at the rate of 100 tons per day.

Scope of Project:
Copper oxide ore process plant with crushing, grinding, leaching, countercurrent decantation circuit, and solvent extraction facilities; electrowinning tank-house; and power plant.

McKee Services:
Engineering, procurement, construction.



Copper Oxide Ore Leaching and Electrowinning Plant

Anamax Mining Company
Sahuarita, Arizona

Legend:
Letter designation refers to photograph.
Color designation refers to processing area of flowsheet.

A B C D E F

A. Crushing plant, screening facility, dust collection system and fine ore storage building.

B. Grinding, agitation leach, sulfuric acid storage facilities and clarifier.

C. Four thickeners for countercurrent decantation, one for pH adjustment and one for clarification.

D. Solvent extraction facilities and electrowinning plant.

E. Electrolytic copper recovery cells.

F. Electrowinning plant cathode shipping area.

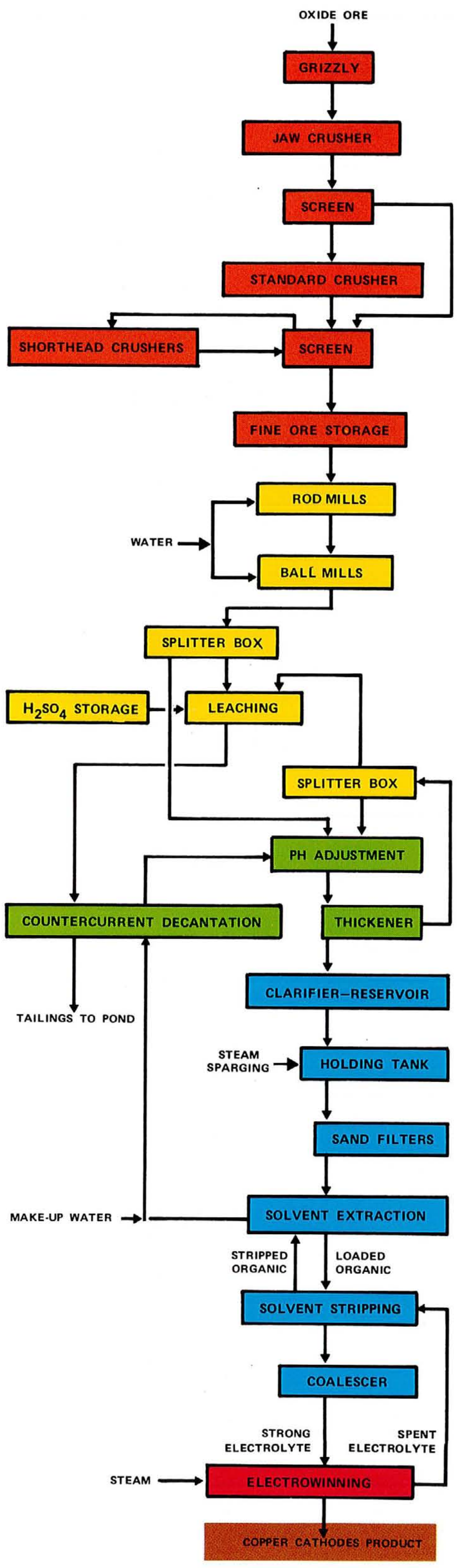
COVER ILLUSTRATION:

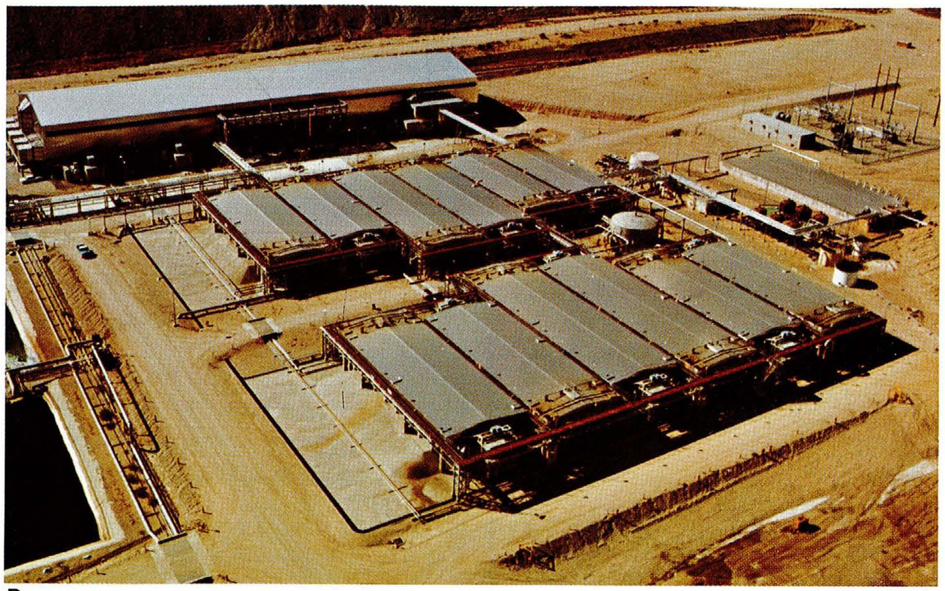
Overall view of copper oxide ore leaching and electrowinning plant.

A.

B.

C.


OXIDE ORE
GRIZZLY
JAW CRUSHER
SCREEN
STANDARD CRUSHER
SHORTHEAD CRUSHERS
SCREEN
FINE ORE STORAGE
ROD MILLS
WATER
BALL MILLS
SPLITTER BOX
H_2SO_4 STORAGE
LEACHING
SPLITTER BOX
PH ADJUSTMENT
COUNTERCURRENT DECANTATION
THICKENER
TAILINGS TO POND
CLARIFIER–RESERVOIR
STEAM SPARGING
HOLDING TANK
SAND FILTERS
MAKE-UP WATER
SOLVENT EXTRACTION
STRIPPED ORGANIC
LOADED ORGANIC
SOLVENT STRIPPING
COALESCER
STRONG ELECTROLYTE
SPENT ELECTROLYTE
STEAM
ELECTROWINNING
COPPER CATHODES PRODUCT



D.


P&H

E.

F.

Copper Oxide Ore Leaching and Electrowinning Plant

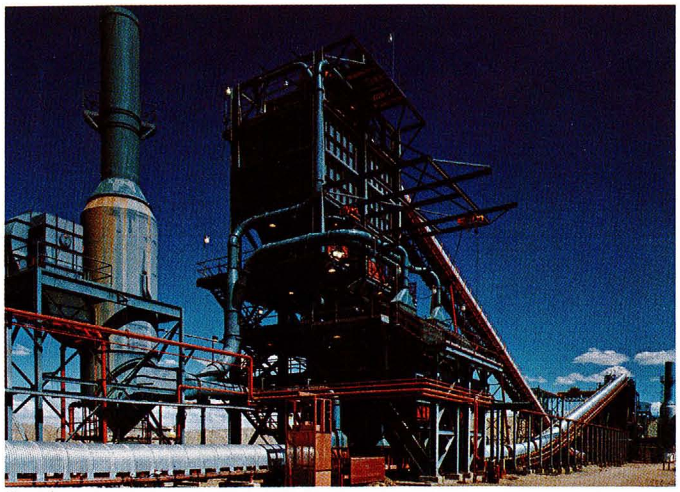
Anamax Mining Company
Sahuarita, Arizona

G. Fine crushing surge bins, screens and dust collection scrubber.

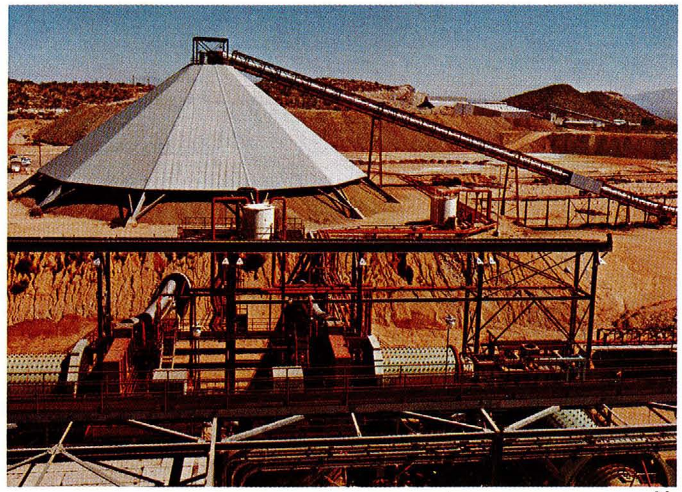
H. 15,000-ton live capacity fine ore storage building and reclaim conveyors to rod mills.

I. Control room for milling, leaching, acid storage and slurry thickening equipment.

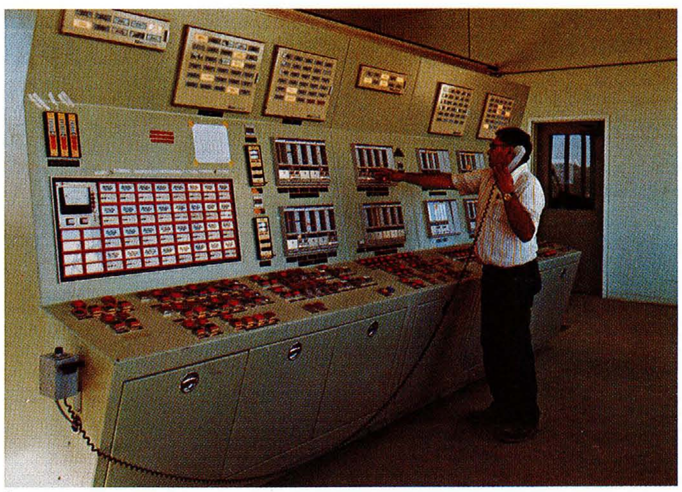
J. Power plant with nine 6.2 megawatt diesel generators.



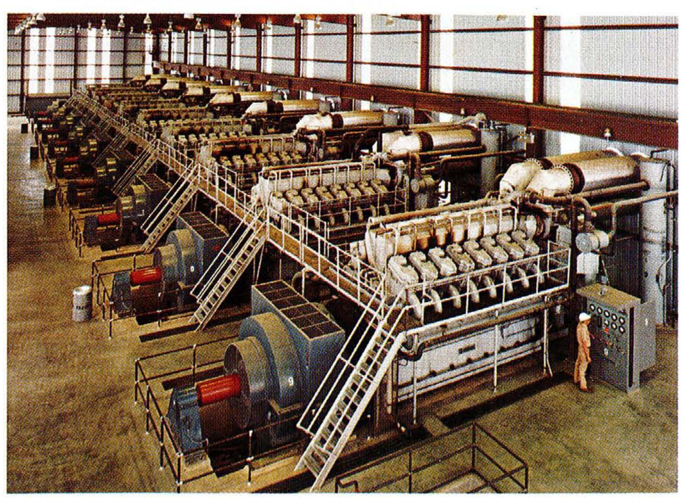
G.



H.



I.



J.