# METALLURGY OF THE BLACKBIRD COBALT ORE

A THESIS

SUBMITTED TO THE FACULTY OF THE UNIVERSITY OF NEVADA

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By

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## Introduction

The Blackbird mine is located in Lemhi County, Idaho, about 20 miles west-southwest of Salmon. It is owned and operated by the Calera Mining Co., a subsidiary of the Howe Sound Co.

Cobalt was originally discovered in the area in 1901, but there was little interest in the metal until 1917. At that time the Haynes - Stellite Co. mined and milled about 4000 tons of the ore, producing 55 tons of concentrate assaying 17.7% cobalt. There was little activity in the area after this until 1938 when the Uncle Sam Mining Co. constructed a 75-ton flotation mill. No attempt was made to recover the cobalt, and this enterprise also proved unprofitable.

The Howe-Sound Co. became interested in the district in 1943, and through its subsidiary undertook a mapping and drilling program. World War II curtailed any extensive exploration, but at the close of the European fighting work in the area was begun in earnest. By 1949 enough ore had been blocked out to justify full-scale operation and construction was started that year.1/ 2/

## General Geology

Geology of the area has been adequately described by Mr. E. B. Douglas as follows: 2/

"The rocks of the Blackbird District are Pre-Cambrian quartzites and metamorphosed sediments. The sediments strike northwest-southeast and dip 30 to 40 degrees north. Many basic dikes and at least one acid dike intrude the sedimentary rocks. The district is bounded on the west and east by quartzites; on the north by granites; and on the south by argillite.

"Known commercial orebodies occur as hydrothermal replacements of predominately schistose rocks along shear zones. Underground workings have indicated the presence of two sizeable orebodies, the Chicago and the Brown Bear.

"The Chicago is a high sulfide ore and has been indicated to be 1800 feet along the strike, at least 350 feet in depth, and with an average width of 15 feet. The Brown Bear is characterized by a series of mineralized schistose zones with the cobaltite as finely disseminated grains in the schist. Massive sulfides occur in only a few spots. The Brown Bear has been developed along a 1000-foot length and a vertical distance of 550 feet.

"The basic mining method used at the Blackbird mine is a horizontal cut and fill, with deslimed mill tails used as the fill material. This method is very successful in the Chicago orebody. In the Brown Bear it has met with only partial success, and even with close sand filling, timbering is necessary to support the weak walls."

## Present Milling Practice 3/

At present the mill is treating 1000 tons of ore per day. Grinding is carried out in a rod mill in open circuit and one ball mill in closed circuit. Classifier overflow is 38% solids and 64% -200 mesh. With the present flowsheet a second ball mill is out of operation.

The classifier overflow is the feed to the bulk rougher flotation section (reagents and amounts fed to each section are shown opposite the flowsheet in Appendix C). This bulk rougher concentrate is cleaned twice. The bulk rougher tail goes to mill tails, and the cleaner tails are recycled to the bulk rougher heads.

The re-cleaned bulk concentrate is thickened and conditioned. During this conditioning the temperature of the pulp is maintained at about 140 degrees F. Lime is added and high pressure air is introduced. Total conditioning time at this point is approximately five hours.

This conditioned bulk concentrate forms the feed for the copper section. The pH at the copper head is 8.5 and the pulp density is 35% solids. The copper concentrate is cleaned once. A final copper concentrate of 20% - 25% copper is produced representing a recovery of 90% - 95% of the total copper in the ore.

Tailings from the copper rougher section are the heads for the iron flotation section. Iron is floated in rougher and scavenger cells. The iron concentrate goes to

mill tails and the scavenger concentrate is recycled to the head of the differential float. The tailing from the iron scavenger is the cobalt concentrate.

Grade of the cobalt concentrate varies between 14 and 17 pct., representing a recovery of 70% to 75% of the total cobalt.

Concentration of the cobalt, a normally difficult task, is complicated by the requirements of the refinery at Salt Lake City, Utah. A chemical process is used which depends to a large degree on the correct ratio of iron and arsenic in the concentrate. The refinery requires a cobalt concentrate grade of about 17.5% cobalt. This adds the problem of separating the right amount of iron pyrites from the cobaltite.

Present cost of the milling is $2.98 per ton. Flotation represents 42% of this cost and grinding 14%.

## Purpose of this Thesis

The ore of the Blackbird mine has presented many perplexing problems. Besides those encountered in mining the irregularly shaped orebodies, there has been the problem of separating the cobaltite from the worthless iron pyrites. Because of the extreme fineness of some of the cobalt minerals, gravity methods have not been effective.

The present solution to the ore dressing problem has been long conditioning with lime at elevated temperatures. However, even with this method the recovery of the cobalt has been low. Up to the present it has not been possible to make a cold pulp separation with required grade of concentrate and high extraction.

The object of this work is to effect a concentration of the cobaltite in this ore by differential flotation from a cold pulp, producing a concentrate of the required grade with a high recovery.

## Preliminary Examination of the Ore

A representative portion of the sample was cut out for mineralogical examination and chemical analysis. Results of these are shown in tables 1 and 2.

---- Table 1 ----

Mineralogical Composition of the Ore

| | |
|---|---|
| Cobaltite | Quartz |
| Chalcopyrite | Mica |
| Erythrite* | Tourmaline |
| Pyrrohotite | Vivianite |
| Pyrite | Iron Oxides |

* minor amount only

The principal ore minerals are cobaltite and chalcopyrite. Erythrite was found in such a small quantity as to be considered a trace mineral. The texture of the ore sample ranges from a fine grained quartzite with massive sulfides to a mica schist with the sulfides finely disseminated in the schist.

Specific gravity of the ore was determined to be 2.85. This figure converted to a tonnage factor gives 11.2 cu. ft. per ton, or 2.4 tons per cu. yard.

---- Table 2 ----

Partial Chemical Analysis of the Ore

| | |
|---|---|
| Au | Trace |
| Ag | 0.80 oz/ton |
| Co | 0.80% |
| Cu | 1.4 % |
| Fe | 17.8 % |
| Ni | Trace |
| As | 1.1 % |
| $Al_2O_3$ | 13.0 % |
| CaO | 0.1 % |
| S | 10.6 % |
| Insoluble | 52.7 % |
| | 97.5 % |

Results of the above analyses indicated that the sulfide minerals comprised about 20% of the ore.

Based on the current market values of copper at 39¢ per lb. and cobalt at $2.60 per lb. the value of the ore is $55.50 per ton. This does not take into account the silver value in the ore which would raise the value per ton to $56.25.

## Method of Analysis

Gravimetric, volumetric, and colorimetric methods of cobalt analysis were tried. The method that was found

to be the quickest and most reliable for this ore was the colorimetric method of Young and Hall.[6] The procedure is given in Appendix A.

General Testing Procedure

The ore sample as received from the Blackbird mine was approximately 4" material. This was crushed through a jaw and roll crusher to minus 10 mesh. The minus 10 mesh charges were ground for flotation in a laboratory batch ball mill. Lime was the only reagent added to the ball mill.

Flotation was done in a laboratory size Fagergren Flotation machine. Conditioning of the pulp was done in the flotation cell by running the machine with the air valve closed. Aeration during all flotation tests was standard.

During the flotation tests certain factors were held constant. These constants were: (1) pulp density - 60% solids during grinding; 20% solids during flotation, (2) pulp temperature - 65° to 70° F, (3) machines used in the tests, and (4) water - Reno city water.

A survey of available literature furnished little information concerning the flotation of cobaltite. The only article that did deal with this subject was the one written about the Blackbird ore. With minor changes in reagents, the flotation scheme mentioned as in use at that time was taken as a starting point. The major difference was the

pulp temperature during flotation.

After preliminary tests were made, tests were run in series of 4 to 6 to investigate the effect of certain variables upon the concentration and recovery of the cobalt minerals.

## FLOTATION TEST SUMMARIES

Preliminary Tests: Tests nos. 1 through 11 were conducted varying the reagents and flotation method. This was to determine a set of reagents and method of flotation that appeared to offer the most promise for further tests. Both differential flotation of the copper, iron, and cobalt minerals, and bulk sulfide flotation with cleaning of the bulk concentrate were tried. The differential float gave a better separation of the sulfide minerals than did attempts to clean a bulk concentrate.

Various aerofloats, xanthates, and acids were used in different combinations. Test no. 9, with a cobalt concentrate of 5.5% Co representing a recovery of 86.5%, was chosen as the base for further tests. Tables 3 and 4 show the reagents and results of test no. 9. Points of reagent addition are shown on the flotation log sheets in Appendix B.

Lime was used as the alkalinity regulator in all tests because of its depressant effect on iron pyrites. In the copper flotation sodium aerofloat was used because of

its low collecting power. It does not actively promote pyrites in an alkaline circuit, yet is an excellent promoter for chalcopyrite.

---- Table 3 ----

Reagents and Quantities Used -- Test #9

| Reagent | lbs. per ton |
|---|---|
| Lime | 8.0 |
| Na Aero | 0.10 |
| X- 325 | 0.20 |
| $CuSO_4$ | 0.20 |
| HCl | * |
| Y-F | 0.16 |

* to lower pH to 3

---- Table 4 ----

Products and Assays -- Test #9

| Product | % Co | % distribution |
|---|---|---|
| Cu Conc | 0.28 | 1.8 |
| Fe Conc | 0.28 | 5.5 |
| Co Conc | 5.5 | 86.5 |
| Tails | 0.06 | 6.2 |

For the iron flotation a promoter strong enough to activate the slow floating pyrrohotite, but not powerful

enough to float the cobaltite in the alkaline pulp, was needed. Of the xanthates tried, sodium ethyl xanthate gave the best results.

Sulfuric and hydrochloric acids were tried as pH regulators for the cobalt flotation. A greater amount of hydrochloric than sulfuric was necessary to lower the pH to the desired point. However, the grade of the cobalt concentrate and the cobalt recovery were both increased when HCl was used. It was noticed that when using hydrochloric acid a considerable amount of $H_2S$ was liberated in the flotation cell. This might have had a sulphidizing effect on the cobaltite. A possible explanation for the $H_2S$ formation would be the decomposition of xanthate under the slightly reducing conditions of the hydrochloric acid.

Although the xanthate appeared to work well in the acid pulp, when conditioning time with the acid and xanthate was increased more xanthate was necessary to maintain a mineralized froth. In order to keep xanthate consumption in the cobalt circuit low, the reagent was added to the cell just prior to flotation.

Copper sulfate was added to the third conditioning as an activator for the cobaltite. Subsequent tests showed this reagent to be unnecessary.

Yarmour-F was the standard frother used in all tests. The amount was varied slightly as needed to maintain a suitable froth.

Conditioning times are shown on the flotation log sheets. The flotation time varied slightly from test to test. In each float the froth was removed until it became barren of sulfide mineral.

Effect of Grinding Time: After selection of a suitable set of reagents, tests were made in which the time of grinding was varied. Times of 10, 16, and 20 minutes were chosen (tests nos. 9, 12, and 13). Screen analyses made of the 10 and 20 minute grinds are given in table 5.

---- Table 5 ----

Screen Analyses of 10 and 20 Minute Grinds

| mesh | 10 min grind % retained | 10 min grind Cum % | 20 min grind % retained | 20 min grind Cum % |
|---|---|---|---|---|
| 65 | 0 | 0 | - | - |
| 100 | 1.4 | 1.4 | 0.2 | 0.2 |
| 150 | 2.9 | 4.3 | 1.4 | 1.6 |
| 200 | 7.3 | 11.6 | 5.2 | 7.8 |
| 325 | 88.4 | 100.0 | 14.7 | 22.5 |
| -325 | - | - | 78.5 | 100.0 |

Although the grade of the cobalt concentrate decreased in test no. 13, recovery of the cobalt increased. This was apparently due to insufficient scalping of the iron pyrites. Test no. 15 was made with the same grind as no. 13, but the amount of xanthate to the iron circuit was increased.

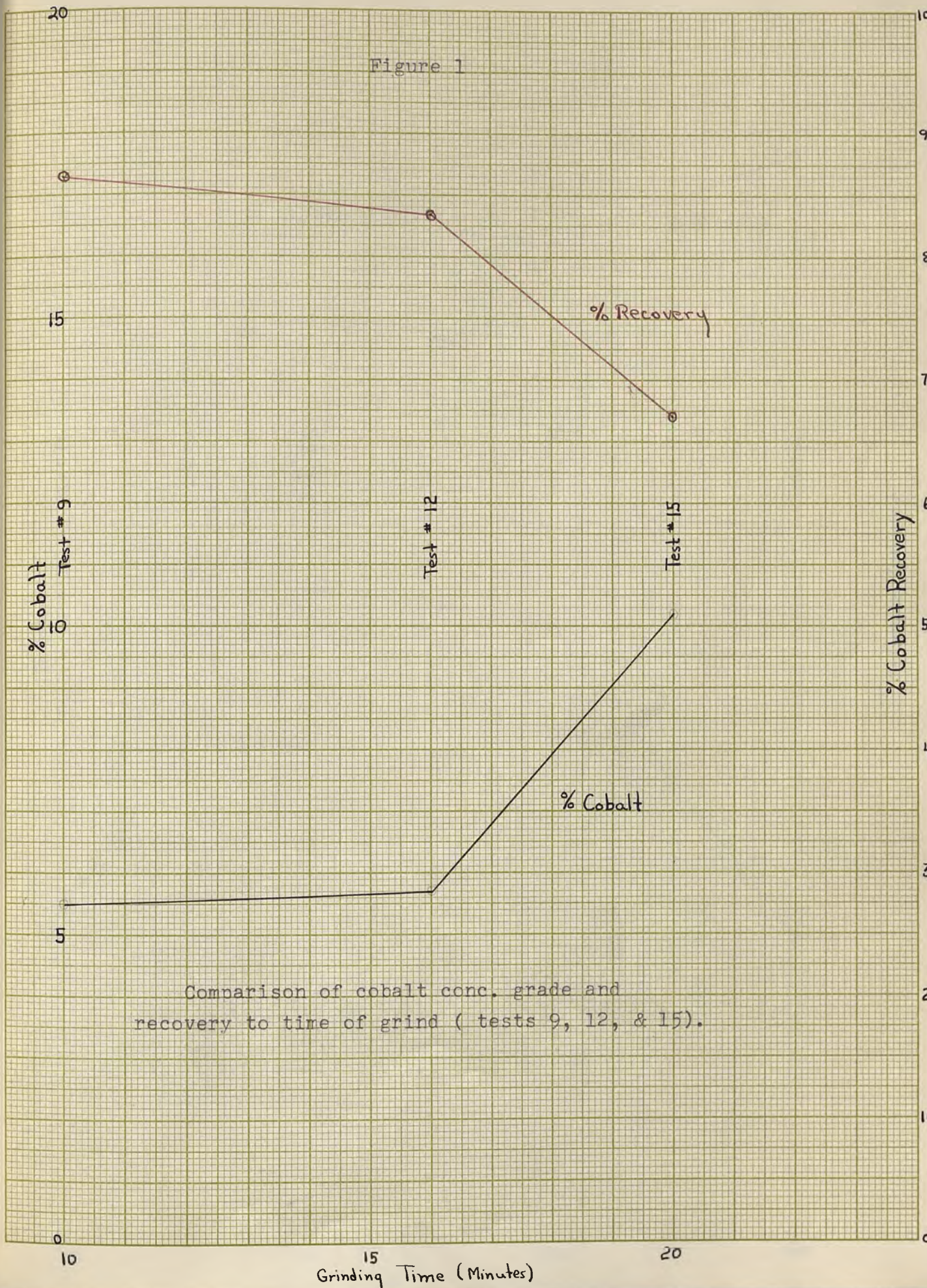
In this test the grade of the cobalt concentrate was markedly improved, but with a decrease in the recovery of the cobalt. The lowered recovery in test no. 15 is probably because of an improper reagent balance. Results of the grinding tests are shown graphically on figure 1.

Effect of Lime: In tests 16 through 19 the quantity of lime added to the ball mill was varied. The amounts of the other reagents used remained the same as given in table 3, with the exception of xanthate which had been increased to 0.30 lbs. per ton. Figure 2 shows the relationship of lime (pH) upon the grade of the cobalt concentrate and cobalt recovery.

Below a pH of 9.0 both the cobalt concentrate grade and recovery drop sharply. Assay of the other flotation products shows that the cobalt mineral is not sufficiently depressed and is floated with both the copper and iron. Above a pH of 10.0 the grade of the cobalt concentrate decreases with an increase in the recovery of the cobalt. This is because of the over depression of iron minerals which are later floated with the cobalt, lowering the concentrate grade.

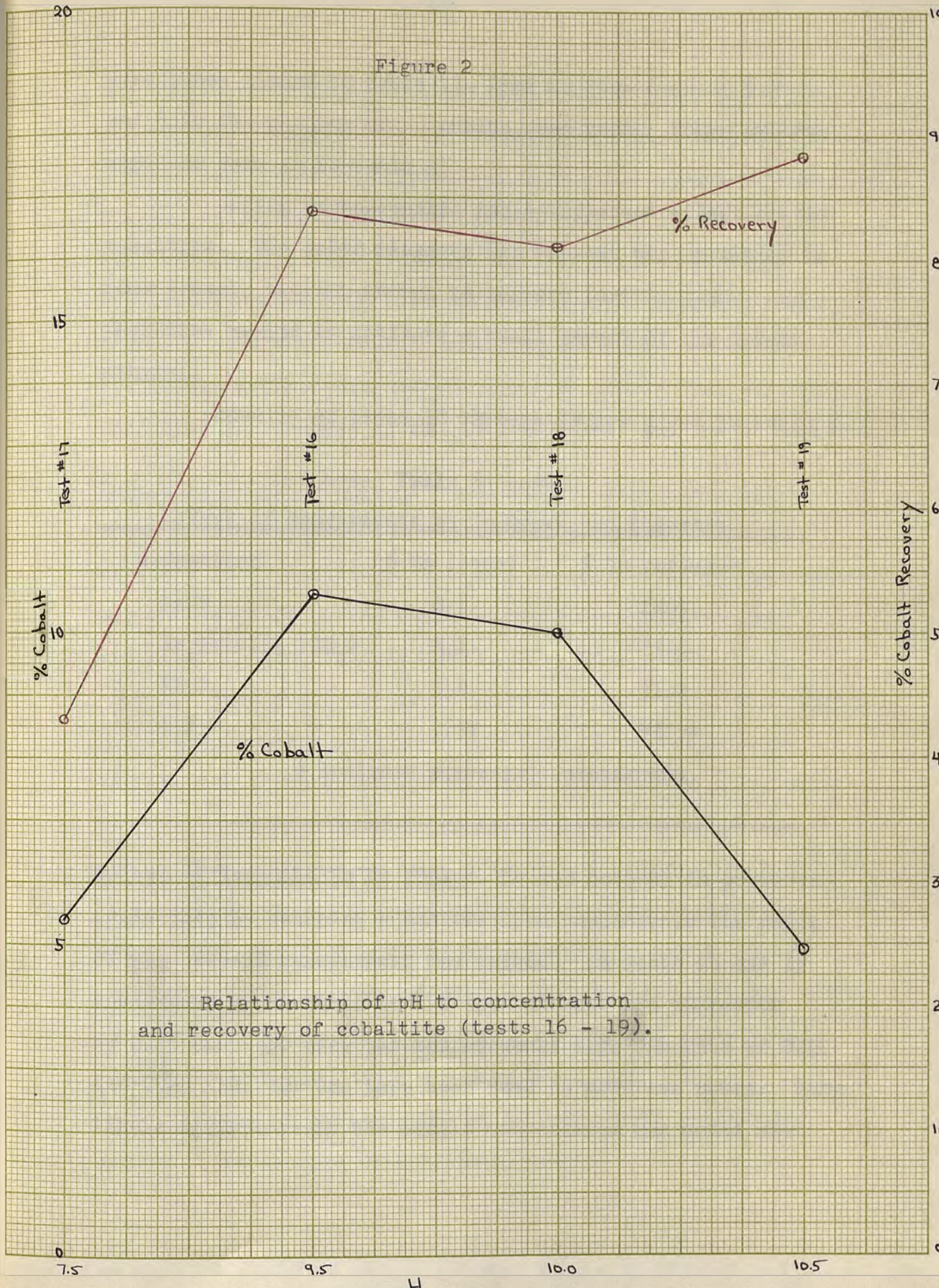
Effect of Depressants: After determining the optimum alkalinity for the ore, tests were made using various depressants. The effects of sodium cyanide, sodium ferro-cyanide, potassium permanganate, and Reagent 610 on the flotation and recovery of cobaltite were investigated. The other reagents used

Figure 1




Comparison of cobalt conc. grade and recovery to time of grind ( tests 9, 12, & 15).

Figure 2




Relationship of pH to concentration and recovery of cobaltite (tests 16 - 19).

were those listed in table 3. Lime to give a pH of 9.5 and 0.30 lbs per ton of xanthate were used. Other amounts were the same as in table 3.

Sodium ferro-cyanide had no apparent effect on the cobaltite. The other reagents did depress the cobaltite to some extent, but not enough to warrant further study. In fact they seemed to activate a small amount of the cobalt mineral.

Results of tests 20 through 23 are given in table 6.

---- Table 6 ----

Effect of Depressants on Co grade and Recovery

| Depressant | % Co (conc) | % Co recovery |
|---|---|---|
| NaCN | 0.5 | 12.3 |
| $Na_4Fe(CN)_6$ $10H_2O$ | 8.1 | 85.4 |
| $KMnO_4$ | 5.2 | 31.2 |
| 610 | 5.5* | 38.7* |

* includes scavenger concentrate

Effect of Xanthate in Fe Float: It was noticed in previous tests that by scalping a heavier iron concentrate the grade of the cobalt concentrate was raised. In tests 24 and 25 the amount of xanthate to the iron circuit was increased to 0.25 and 0.30 lbs. per ton respectively. Amounts of 0.10 and 0.20 lbs. per ton have been used in previous tests. Very little difference in the cobalt concentrate was noted when

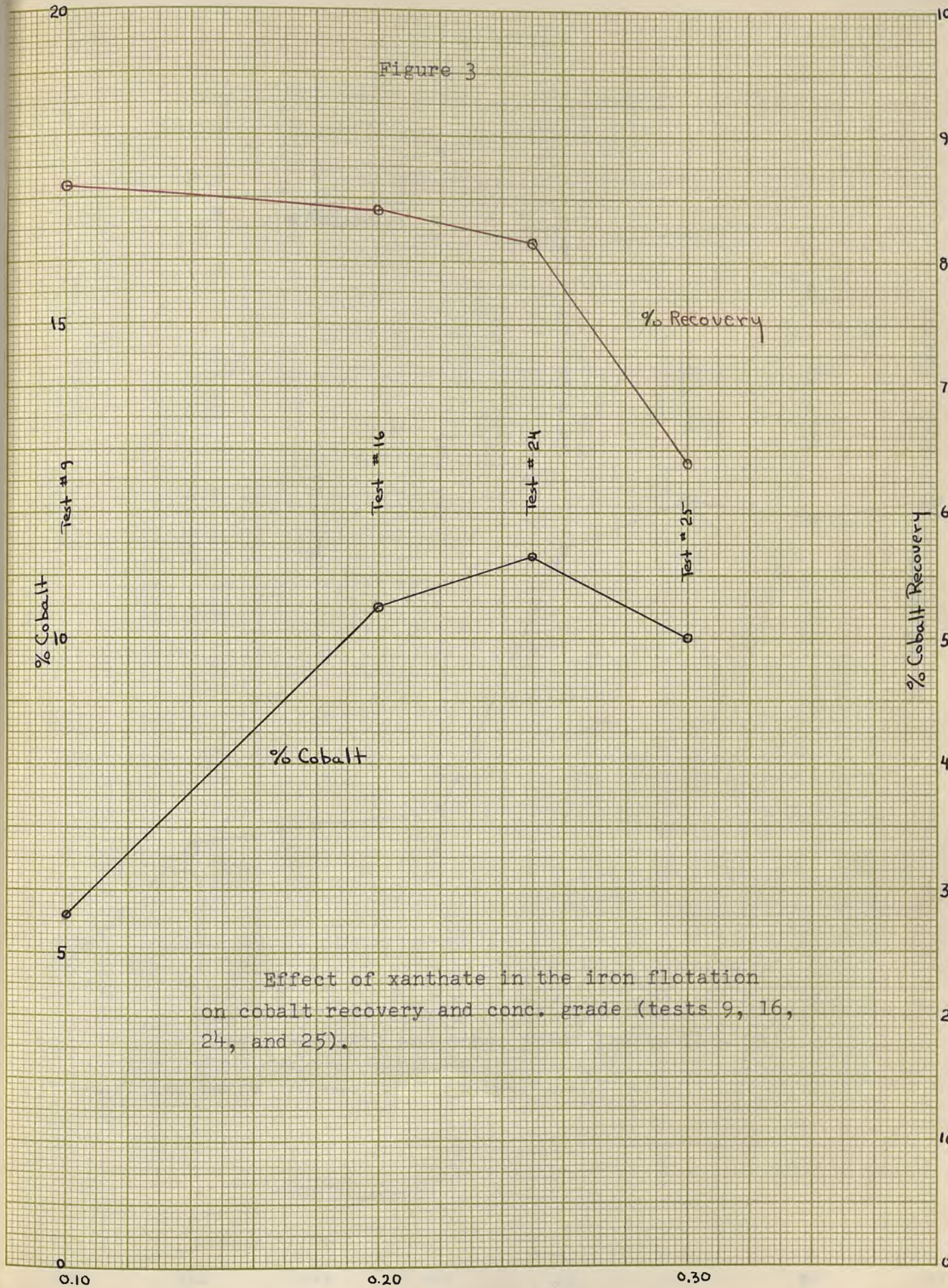
the amount of xanthate was 0.20 and 0.25 lbs. per ton. The use of less xanthate does not scalp enough iron from the circuit and leaves the pyrites to dilute the cobalt concentrate. Larger amounts of xanthate float the cobalt mineral with the iron concentrate with resulting loss in cobalt recovery. For further tests 0.20 lbs. per ton was used because of the slightly higher recovery of the cobalt. Figure 3 compares the grade of the cobalt concentrate and cobalt recovery with variation in xanthate in the iron circuit.

Change in Cobalt Promoter: Work done on other ores had shown Aerofloat 33 to be an excellent promoter of sulfide minerals in an acid pulp. In test no. 26 the cobalt promoter was changed from sodium ethyl xanthate to Aerofloat 33. Two other reagent changes were made at this point.

During the series of tests made with various depressants and xanthate additions, the lime consumption varied to maintain a pH of 9.5. The cause for this was attributed to the lime used. Several sources had been used and the CaO availability varied from 7% to 40%. A change was made to quicklime with a CaO availability of 60%. In order to re-evaluate the lime consumption a series of tests (27-33) varying the lime amount was again run. Results of these tests are shown in figure 4. As before, the optimum alkalinity was at a pH of 9.5.

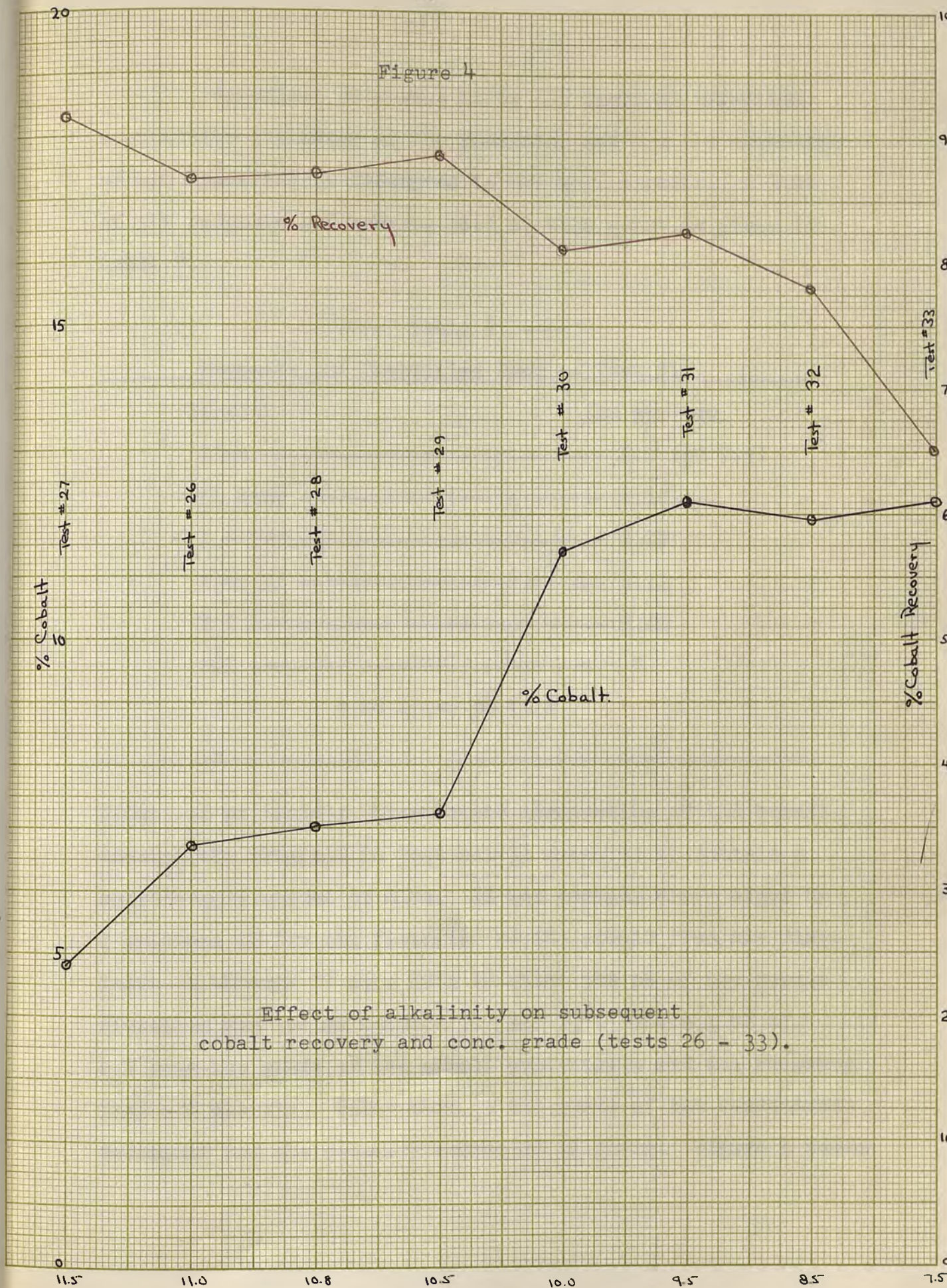
Also in test no. 26 the use of copper sulfate was dropped. No changes were noticed.

Figure 3




Effect of xanthate in the iron flotation on cobalt recovery and conc. grade (tests 9, 16, 24, and 25).

Figure 4




Effect of alkalinity on subsequent cobalt recovery and conc. grade (tests 26 - 33).

Aerofloat 33 proved to be at least as effective a cobaltite collector as the xanthate, and had the advantage of not appearing to decompose in the acid circuit. A list of the reagents and amounts used at this point is given in table 7.

---- Table 7 ----

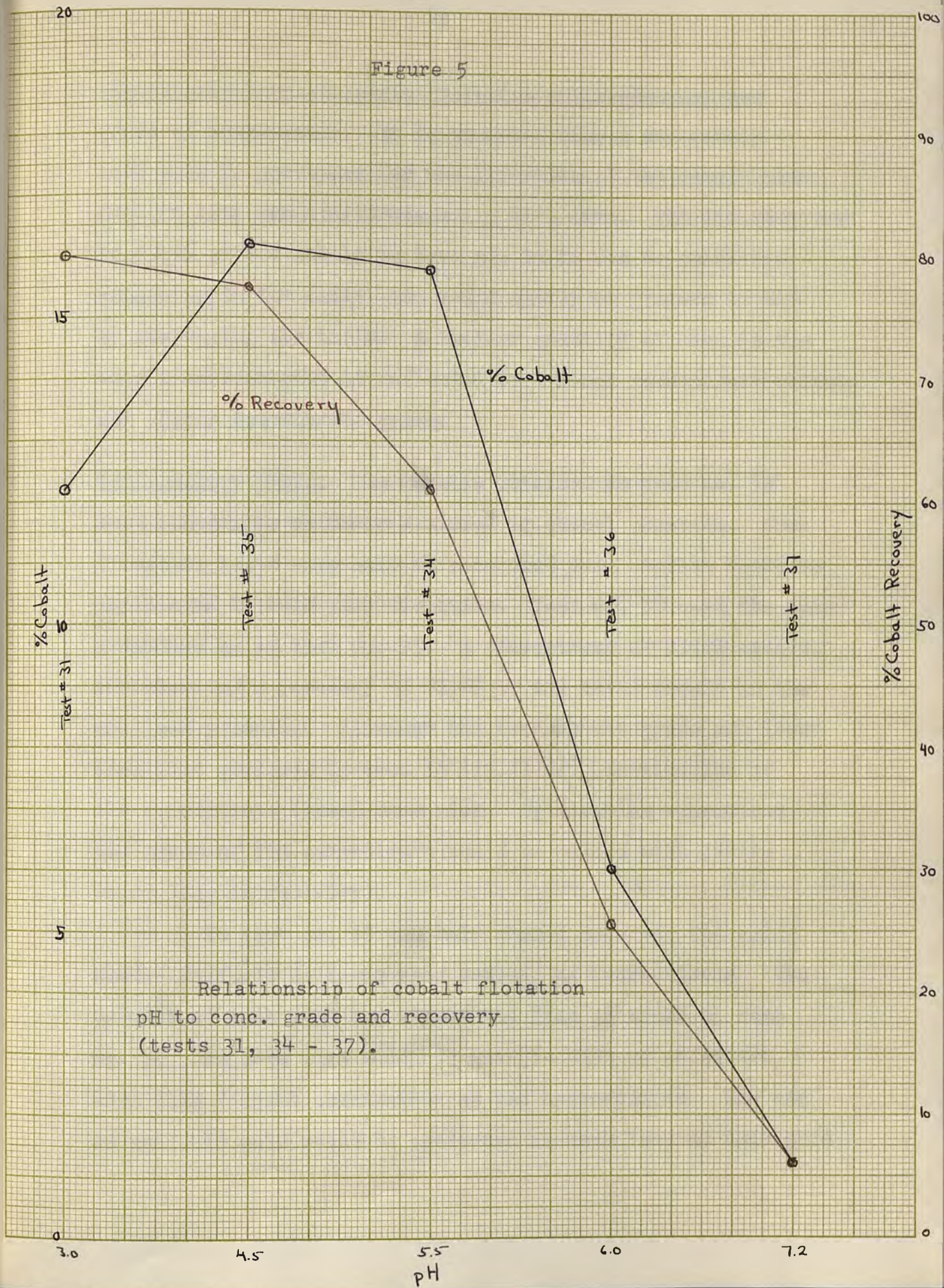
Reagents and Quantities Used -- Test 31

| Reagent | lbs per ton |
|---|---|
| Lime | 8.0 (pH 9.5) |
| Na Aero | 0.10 |
| X - 325 | 0.20 |
| Aero 33 | 0.11 |
| Y-F | 0.16 |
| HCl | * |

* to lower pH to 3

Effect of pH (acid): Microscopic examination of the cobalt concentrate obtained in test no. 31 showed it to contain a considerable amount of mica. It was thought there might be a critical pH for the flotation of the cobalt from the mica. Tests 34 through 37 were made in which the pH of the cobalt flotation was varied between 3.0 and 7.5. Above a pH of 4.5 both the grade of the cobalt concentrate and the recovery drop off sharply. Below this pH the grade of the concentrate decreases and the recovery increases slightly. Figure 5 shows

Figure 5




Relationship of cobalt flotation pH to conc. grade and recovery (tests 31, 34 - 37).

the relationship of cobalt flotation pH to recovery and grade of concentrate. It is apparent that a moderately acid pulp is necessary for the flotation of the cobalt mineral in this ore after depression with lime. The low recovery of 77.5% of the cobalt in test no. 35 is due to cobaltite remaining in the tails, and could easily be raised to 84% by scavenging the tails. A smaller quantity of mica in the cobalt concentrated is reflected in a lower concentrate weight, and higher concentrate grade.

Confirmatory Tests: The results obtained in test no. 35 were comparable to those achieved in actual practice. Confirmatory tests were made to show that such results could be duplicated by cold pulp flotation. Test no. 38 used the same procedure as in test no. 35. A concentrate of 15.0% cobalt, representing a recovery of 84.6% of the total cobalt in the ore, was produced. Although the concentrate grade was lower than that produced in test 35 (16.2% Co), examination of the concentrate showed some mica. By cleaning operations the grade of the concentrate could be raised with little or no loss in recovery.

In test no. 39 the only change made was the acid used. Sulfuric acid was used instead of hydrochloric. The results of this test are almost the same as those of test no. 35, and show that sulfuric acid is just as effective with this reagent combination as the hydrochloric. The use of sulfuric acid would be preferred as much less of this acid

is required to lower the pH to the desired point, and it is less expensive than hydrochloric acid.

The log sheet for test no. 38 gives a more complete analysis of the products than has been given previously.

## SUMMARY

The results of tests nos. 35, 38, and 39 indicate that the cobaltite in the Blackbird ore can be concentrated from a cold pulp by selective flotation. The grade of the cobalt concentrate and the recovery of the cobalt about equal that now obtained commercially. By complete scavenging of the tails, recovery of the cobalt can be raised to approximately 85%. Generally, the results obtained in a laboratory can be improved upon in a plant because circuits and reagents can be more closely balanced.

No attempt has been made in these tests to recover the copper in a high grade concentrate. However, a good grade of copper concentrate is produced, and it was noticed during the test work that the copper in the iron concentrate could be recovered easily by cleaning with a standard copper reagent. This copper cleaned from the iron concentrate, added to the copper rougher concentrate, would give a copper recovery of about 90% to 95%.

Beneficiation of this ore seems to depend largely on two critical pH's. Too high a pH in the copper and iron circuits over-depresses the pyrites and results in a low grade cobalt concentrate. If this initial pH is too low the cobaltite is not sufficiently depressed and floats with the iron, lowering the cobalt recovery.

In the cobalt circuit if the pH is not acid enough it appears that the cobaltite is not activated. However, a pH too low at this point will result in a low grade concentrate, which seems to be due to flotation of more of the gangue material.

The optimum pH ranges are 9.0 to 9.5 for the copper and iron floats, and 3.5 to 4.5 for the cobalt flotation.

By the use of low strength promoters in the copper and iron circuits the flotation of the cobaltite with these products can be kept to a minimum.

From the study made of this ore it appears that the cobalt content of the copper and iron products is due to one, or both, of two causes. Either the cobalt is present as very fine inclusions of the mineral in the pyrites, or it is present as cobaltiferrous pyrite. In the first case it could be liberated by finer grinding, but as the grind used in these tests is 78% -325 mesh, finer grinding would appear uneconomical. If the cobalt is present as cobaltiferrous pyrite only a chemical or pyrometallurgical treatment would recover it.

A detailed flowsheet based on the results of this paper is not proposed. A general flowsheet which could be used is given in Appendix C. With minor changes, this could be accomplished from the present flowsheet and equipment.

# APPENDIX A

## Method of Cobalt Analysis Used

COLORIMETRIC DETERMINATION OF COBALT 5/

"Cobalt forms a complex with ammonium thiocyanate which can be extracted with amyl alcohol and ether, and the blue cobaltothiocyanate color measured in a colorimeter.

$$CoCl_2 + 4\ NH_4CNS \rightarrow (NH_4)_2(Co(CNS)_4) + 2NH_4Cl$$

"Decompose the sample with $HNO_3$ and HCl, adding a few drops of bromine or HF if necessary. For high iron material use $HNO_3$ and $KClO_3$. Evaporate the sample to dryness, but do not bake. Traces of $HNO_3$ have no effect on the formation of the thiocyanate complex.

"Dissolve the samples in approximately 25 ml of water, and add exactly 1 ml of HCl for every 50 ml of subsequent dilution of the sample. Boil, cool, and wash out into appropriate measuring cylinders or calibrated flasks. The amount of dilution depends on the amount of cobalt present and can be read off from the following table.

---- Table 8 ----

| Co in Sample % | weight of sample (gm) | dilution ml | aliquot taken (ml) | factor for % Co |
|---|---|---|---|---|
| 0.01 - 0.20 | 2.0 | 50 | 5 | 0.5 |
| 0.16 - 0.80 | 0.5 | 50 | 5 | 2 |
| 0.80 - 3.20 | 0.5 | 50 | 5 | 8 |

"(a) Cobalt Samples With Less Than 36 Mg Iron.
Measure out 5 ml of sodium thiosulfate solution, 3 ml of

sodium phosphate solution, and 10 ml of ammonium thiocyanate solution. Add with vigorous agitation 5 ml of the solution of the sample. The pH is now 3.5 to 4.0 and the concentration of the ammonium thiocyanate is 26%.

"Add 10 ml of the amyl alcohol-ether mixture and shake the whole thoroughly again. Transfer to a separatory funnel, run off the lower layer, and discard. Transfer the solution of the cobalt complex to a test tube or 1-cm absorptiometer cell. For visual comparison, match the intensity of the color of the test solution with the standard copper sulfate solutions. The comparisons may be carried out in a La Motte comparator for hydrogen-ion determinations with a source of artificial light, or the tube may be simply held against a white background out of direct sunlight. It will be possible to take a reading half way between any two of the standards if the color of the test solution lies between them.

"In the photoelectric comparison, absorption of the test solution is compared with an amyl alcohol-ether blank. The amount of cobalt present in the test solution is then read off from the calibration curve.

"(b) Cobalt Samples With More Than 36 Mg Iron. Carry out the analysis in exactly the same way as for those under (a), but in this case add 2 ml of ammonium acetate solution. The pH is still 3.5 to 4.0 and the concentration of ammonium thiocyanate is 24%. Unless iron is known to be absent it is preferable in all cases to add 2 ml of ammonium

acetate as routine procedure. Copper does not interfere with the production of the blue color even when present to the extent of 60%. Iron, if present in amount greater than about 36 mg, will interfere unless ammonium acetate is used. Vanadium forms a blue complex which is extracted with the amyl alcohol-ether solution. If, however, ammonium acetate and a few drops of tartaric acid are added to the reagents this blue complex is not formed, and vanadium will not interfere. The following do not give colored complexes which are soluble in amyl alcohol-ether: Cr, Mn, Zn, Ti, Mo, U. Other common elements such as Al, Si, Mg, P, Bi, As, Pb, and the alkalies are without effect.

"This rapid procedure is very satisfactory for a range of 0.02 to 0.50 mg of cobalt or 0.0 to 4% Co.

Reagents

Ammonium thiocyanate: Dissolve 600 gm of $NH_4CNS$ in 1 liter of water

Sodium phosphate: Dissolve 83.3 gm of $Na_3PO_4 \cdot 12H_2O$ in 1 liter of water

Sodium thiosulfate: Dissolve 200 gm of $Na_2S_2O_3 \cdot 5H_2O$ in 1 liter of water

Ammonium acetate: Dissolve 700 gm of $NH_4C_2H_3O_2$ in 1 liter of water

Tartaric acid: Dissolve 50 gm of $C_4H_6O_6$ in 1 liter of water

Amyl alcohol-ether mixture: Mix 3 parts by volume of amyl alcohol with 1 volume of ethyl ether

"For visual comparisons a solution of copper sulfate in water containing 8 gm of $CuSO_4$ $5H_2O$ per liter will match an extract containing 0.02 mg of Co per 10 cc. For colorimetric comparison a calibration curve for the colorimeter is established giving colorimeter readings against mg of cobalt."

Figure 6 and table 9 are the calibration curve used and a list of factors for converting curve readings to pct cobalt.

---- Table 9 ----

Factors for Converting mg Co (from graph Fig. 6) to % Co *

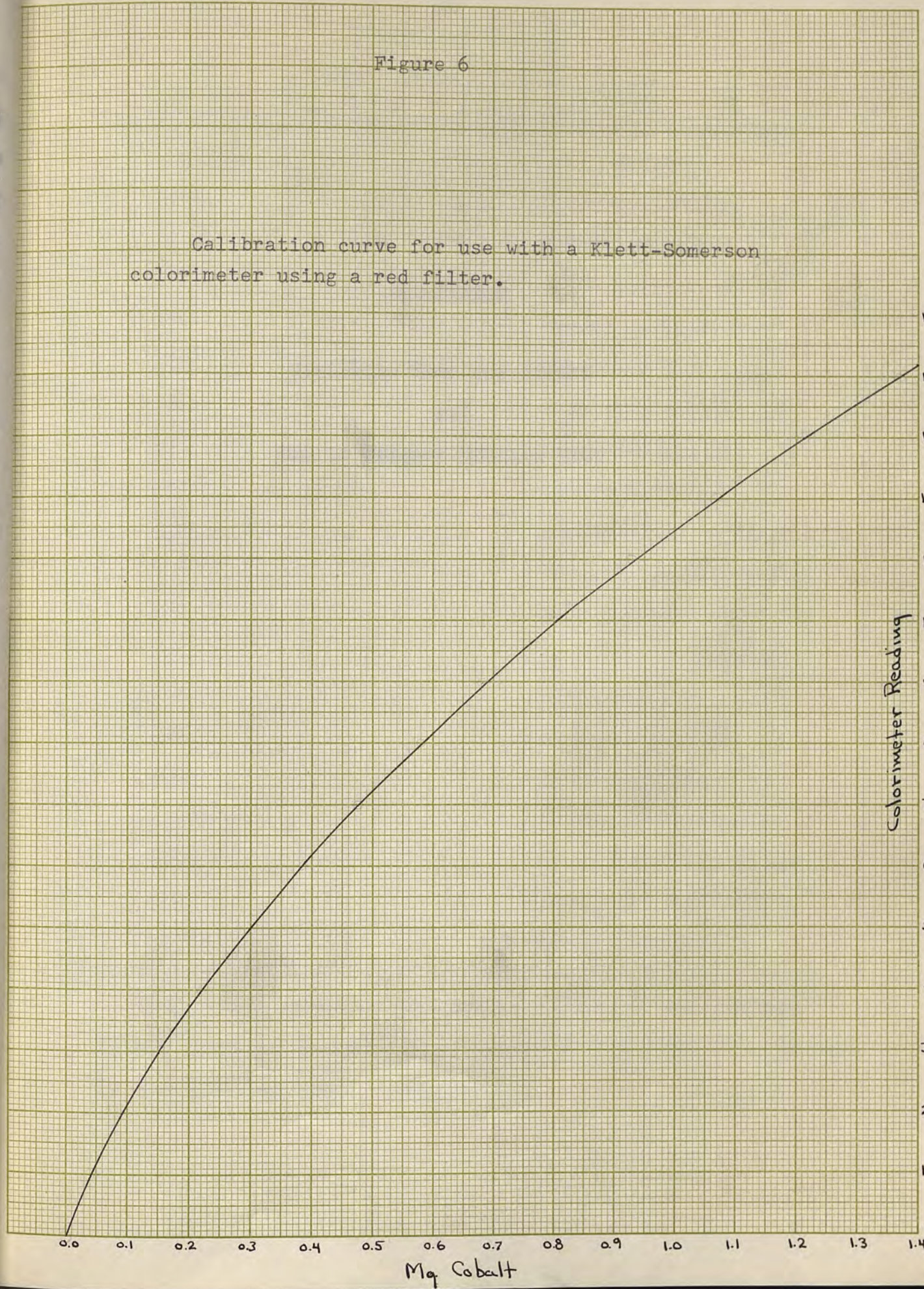
| Sample wt (gms) | Dilution (mls) 50 | 100 | 200 | 250 | 500 | 1000 |
|---|---|---|---|---|---|---|
| 2.00 | 0.5 | 1 | 2 | 2.5 | 5 | 10 |
| 1.00 | 1 | 2 | 4 | 5 | 10 | 20 |
| 0.50 | 2 | 4 | 8 | 10 | 20 | 40 |
| 0.25 | 4 | 8 | 16 | 20 | 40 | 80 |
| 0.20 | 5 | 10 | 20 | 40 | 80 | 160 |
| 0.10 | 10 | 20 | 40 | 80 | 160 | 320 |

* 5 ml aliquots taken for complexing

By the selection of the proper dilution, samples containing any amount of cobalt can be analyzed. To get the % cobalt in a sample multiply mg of cobalt in 5 ml aliquot (from calibration curve) by the appropriate factor in table 9.

Figure 6

Calibration curve for use with a Klett-Somerson colorimeter using a red filter.



# APPENDIX B

## Flotation Test Log Sheets

## and

## Key to Reagent Symbols Used

---- Table 10 ----

Key to Reagent Symbols *

| Symbol | Reagent |
|---|---|
| Lime | Commercial Lime |
| Na Aero | Sodium Aerofloat |
| X 325 | Aero xanthate 325 |
| Y-F | Yarmour F Pine Oil |
| 208 | Aerofloat 208 |
| 301 | Aero xanthate 301 |
| 350, Z-6 | Aero xanthate 350 |
| $CuSO_4$ | copper sulfate |
| $H_2SO_4$ | concentrated sulfuric acid |
| HCl | Conc. Hydrochloric acid |
| 404 | Aero promoter 404 |
| 77 | Aerofroth 77 frother |
| A 238 | Aerofloat 238 |
| 303 | Aero xanthate 303 |
| NaCn | Sodium cyanide |
| Na-Fe-CN | Sodium ferro-cyanide |
| $KMnO_4$ | Potassium permanganate |
| 610 | Aero depressant 610 |
| $Fe_2(SO_4)_3$ | Ferrous sulfate |

* All reagents used except Yarmour F are products of the American Cyanamid Co. Yarmour F is a pine oil supplied by the Hercules Powder Company.

3861 PTD.IN U.S.A. 11/52

# ITATION TEST LOG SHEET

TABLE NO. Blackbird

TEST NO. 1

## CONDITIONS AND REAGENTS

| POINT OF ADDITION | CONDITIONS | | | REAGENTS POUNDS PER TON | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | TIME MINS | % SOLIDS | PH | lime | 208 | 301 | Z-6 | $CuSO_4$ | $H_2SO_4$ | Y-F | | | |
| Grind | 10 | 60 | 10.5 | 8.0 | | | | | | | | | |
| Cond #1 | 2 | 20 | 10.5 | | 0.08 | 0.12 | | | | | | | |
| Flot | | " | " | | | | | | | 0.04 | | | |
| Cond #2 | 2 | " | " | | | | 0.08 | | | | | | |
| Flot | | " | " | | | | | | | 0.04 | | | |
| Cond #3 | 3 | " | 2.5 | | | | 0.12 | 0.15 | 12.0 | | | | |
| Flot | | " | " | | | | | | | 0.04 | | | |
| | | | | | | | | | | | | | |

MARKS

## METALLURGICAL RESULTS

| PRODUCT | % WEIGHT | ASSAYS | | | | | % DISTRIBUTION | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Co | | | | | Co | | | | |
| C-1 (Cu) | | 0.35 | | | | | 2.8 | | | | |
| C-2 (Fe) | | 0.58 | | | | | 8.3 | | | | |
| C-3 (Co) | | 6.80 | | | | | 85.3 | | | | |
| Tails | | 0.04 | | | | | 3.6 | | | | |
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ATIO OF CONCENTRATION

EMARKS

9861 PTD. IN U.S.A. 11/52

# TATION TEST LOG SHEET

TABLE NO. Blackbird

TEST NO. 2

## CONDITIONS AND REAGENTS

| POINT OF ADDITION | CONDITIONS | | | REAGENTS POUNDS PER TON | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | TIME MINS | % SOLIDS | PH | lime | 301 | 208 | Z-6 | $CuSO_4$ | $H_2SO_4$ | Y-F | | | |
| Grind | 10 | 60 | 10.5 | 8.0 | | | | | | | | | |
| Cond #1 | 3 | 20 | " | | 0.08 | 0.08 | | | | | | | |
| Flot | | " | " | | | | | | | 0.04 | | | |
| Cond #2 | 2 | " | " | | | | 0.08 | | | | | | |
| Flot | | " | " | | | | | | | | | | |
| Cond #3 | 3 | " | " | | | | 0.12 | 0.20 | 11.0 | | | | |
| Flot | | " | " | | | | | | | 0.04 | | | |
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MARKS

## METALLURGICAL RESULTS

| PRODUCT | % WEIGHT | ASSAYS | | | | | % DISTRIBUTION | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Co | | | | | Co | | | | |
| Conc #1 | 7.5 | 0.44 | | | | | 4.2 | | | | |
| Conc #2 | 7.6 | 0.56 | | | | | 7.6 | | | | |
| Conc #3 | 10.7 | 4.7 | | | | | 45.8 | | | | |
| Tails | 74.0 | 0.45 | | | | | 42.6 | | | | |
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ATIO OF CONCENTRATION

EMARKS

.3861 PTD. IN U.S.A. 11/52

# OTATION TEST LOG SHEET

TABLE NO. Blackbird

TEST NO. 3

## CONDITIONS AND REAGENTS

| POINT OF ADDITION | CONDITIONS | | | REAGENTS POUNDS PER TON | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | TIME MINS | % SOLIDS | PH | 404 | 301 | Z-6 | $CuSO_4$ | $H_2SO_4$ | 77 | | | | |
| Grind | 10 | 60 | 5 | | | | | | | | | | |
| Cond #1 | 2 | 20 | " | 0.25 | 0.10 | | | | | | | | |
| Rougher Flot | | " | " | | | | | | 0.08 | | | | |
| Cond #2 | 2 | 10 | 3 | | | 0.10 | 0.20 | 5.0 | | | | | |
| Flot | | 10 | " | | | | | | 0.04 | | | | |
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MARKS

## METALLURGICAL RESULTS

| PRODUCT | % WEIGHT | ASSAYS | | | | | % DISTRIBUTION | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Co | | | | | Co | | | | |
| Cleaner Conc | 13.8 | 3.4 | | | | | 82.8 | | | | |
| Cleaner Tail | 4.7 | 1.2 | | | | | 7.3 | | | | |
| Rougher Tail | 76.0 | 0.1 | | | | | 9.3 | | | | |
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ATIO OF CONCENTRATION

EMARKS

61 PTD. IN U.S.A. 11/52

ATION TEST LOG SHEET

TABLE NO. Blackbird

TEST NO. 4

CONDITIONS AND REAGENTS

| POINT OF ADDITION | CONDITIONS | | | REAGENTS POUNDS PER TON | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | TIME MINS | % SOLIDS | PH | lime | 208 | 301 | $NaCNH_2SO_4$ | | $(SO_4)_3$ | Y-F | | | |
| Grind | 12 | 60 | 9.5 | 8.0 | | | | | | | | | |
| Cond #1 | 4 | 20 | " | | 0.12 | 0.08 | 0.12 | | | | | | |
| Flot | | " | " | | | | | | | 0.04 | | | |
| Cond #2 | 3 | " | 2.5 | | | 0.08 | | 12.0 | 0.12 | | | | |
| Flot | | " | " | | | | | | | 0.04 | | | |
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METALLURGICAL RESULTS

| PRODUCT | % WEIGHT | ASSAYS | | | | | % DISTRIBUTION | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Co | | | | | Co | | | | |
| Cu Conc | 7.5 | 0.24 | | | | | 2.2 | | | | |
| Co-Fe Conc | 18.9 | 3.48 | | | | | 83.8 | | | | |
| Tails | 73.6 | 0.15 | | | | | 14.0 | | | | |
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IO OF CONCENTRATION

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GOF-3861 PTD. IN U.S.A. 11/52

# FLOTATION TEST LOG SHEET

TABLE NO. Blackbird

TEST NO. 5

## CONDITIONS AND REAGENTS

| POINT OF ADDITION | CONDITIONS | | | REAGENTS POUNDS PER TON | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | TIME MINS | % SOLIDS | PH | lime | 208 | 301 | 610 | $H_2SO_4$ | $CuSO_4$ | A-25 | Y-P | | |
| Grind | 10 | 60 | 9.5 | 8.0 | | | | | | | | | |
| Cond #1 | 3 | 20 | " | | 0.08 | 0.16 | 0.20 | | | | | | |
| Cu Flot | | " | " | | | | | | | | 0.04 | | |
| Cond #2 | 3 | " | 6.0 | | 0.06 | | | 9.0 | 0.10 | 0.15 | | | |
| Fe-Co Flot | | " | 6.0 | | | | | | | | 0.04 | | |
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REMARKS

## METALLURGICAL RESULTS

| PRODUCT | % WEIGHT | ASSAYS | | | | | % DISTRIBUTION | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Co | | | | | Co | | | | |
| Conc #1 | 7.8 | 0.36 | | | | | 3.6 | | | | |
| Conc #2 | 19.5 | 2.88 | | | | | 71.4 | | | | |
| Tails | 72.7 | 0.30 | | | | | 25.0 | | | | |
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RATIO OF CONCENTRATION

REMARKS

GOF-3861 PTD. IN U.S.A. 11/52

# FLOTATION TEST LOG SHEET

June 15, 1956 | TABLE NO. Blackbird | TEST NO. 6

## CONDITIONS AND REAGENTS

| POINT OF ADDITION | CONDITIONS | | | REAGENTS POUNDS PER TON | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | TIME MINS | % SOLIDS | PH | lime | 208 | 301 | 350 | H-80 | Y.F | | | | |
| Grind | 10 | 60 | 9.5 | 8.0 | | | | | | | | | |
| Cond #1 | 4 | 20 | " | | 0.08 | 0.12 | | | | | | | |
| Flot | | " | " | | | | | | 0.04 | | | | |
| Cond #2 | 3 | " | 2.5 | | | | 0.20 | 11.0 | | | | | |
| Flot | | " | " | | | | | | 0.08 | | | | |
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REMARKS

## METALLURGICAL RESULTS

| PRODUCT | % WEIGHT | ASSAYS | | | | | % DISTRIBUTION | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Co | | | | | Co | | | | |
| Conc 1 | 6.8 | 0.36 | | | | | 3.0 | | | | |
| Conc 2 | 19.2 | 3.80 | | | | | 88.8 | | | | |
| Tails | 74.0 | 0.09 | | | | | 8.2 | | | | |
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RATIO OF CONCENTRATION

REMARKS

GOF-3861 PTD. IN U.S.A. 11/52

# FLOTATION TEST LOG SHEET

June 21. 1956 | TABLE NO. Blackbird | TEST NO. 7

## CONDITIONS AND REAGENTS

| POINT OF ADDITION | CONDITIONS | | | REAGENTS POUNDS PER TON | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | TIME MINS | % SOLIDS | PH | lime | $H_2SO_4$ | $CuSO_4$ | Z-6 | 301 | Y-F | 208 | | | |
| Grind | 13 | 60 | 5 | | | | | | | | | | |
| Cond #1 | 5 | 20 | 5 | | 3.0 | 0.10 | 0.25 | | | | | | |
| Bulk Flot | | " | 5 | | | | | | 0.08 | | | | |
| Cond #2 | 5 | 10 | 10.5 | 6.6 | | | | 0.12 | | 0.08 | | | |
| Flot | | " | 10.5 | | | | | | 0.04 | | | | |
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REMARKS

## METALLURGICAL RESULTS

| PRODUCT | % WEIGHT | ASSAYS | | | | | % DISTRIBUTION | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Co | | | | | Co | | | | |
| Rougher Tail | 72.9 | 0.36 | | | | | 31.3 | | | | |
| Cleaner Tail | 5.3 | 1.60 | | | | | 10.8 | | | | |
| Cleaner Conc | 21.8 | 2.04 | | | | | 55.9 | | | | |
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RATIO OF CONCENTRATION

REMARKS

GOF-3861 PTD. IN U.S.A. 11/52

# FLOTATION TEST LOG SHEET June 21, 1956

TABLE NO. Blackbird

TEST NO. 8

## CONDITIONS AND REAGENTS

| POINT OF ADDITION | CONDITIONS | | | REAGENTS POUNDS PER TON | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | TIME MINS | % SOLIDS | PH | $H_2SO_4$ | A-33 | A-238 | lime | Y-F | | | | | |
| Grind | 12 | 60 | 6 | | | | | | | | | | |
| Cond #1(a) | 10 | 20 | 4 | * | | | | | | | | | |
| (b) | 2 | " | 4 | | 0.25 | | | | | | | | |
| Flot (bulk) | | " | 4 | | | | | 0.04 | | | | | |
| Cond #2(a) | 10 | 10 | 10 | | | | 10.4 | | | | | | |
| (b) | 2 | " | " | | | 0.10 | | | | | | | |
| Flot | | " | " | | | | | 0.04 | | | | | |
| | | | | | | | | | | | | | |

REMARKS

A-33 stage added 0.08 ea.

* Acid quantity - to give desired pH

## METALLURGICAL RESULTS

| PRODUCT | % WEIGHT | ASSAYS | | | | | % DISTRIBUTION | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Co | | | | | Co | | | | |
| Rougher Tail | 72.1 | 0.05 | | | | | 4.7 | | | | |
| Cleaner Conc | 18.3 | 3.40 | | | | | 82.7 | | | | |
| Cleaner Tail | 9.6 | 1.0 | | | | | 12.6 | | | | |
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RATIO OF CONCENTRATION

REMARKS

BOF-3861 PTD. IN U.S.A. 11/52

# FLOTATION TEST LOG SHEET

July 1, 1956 | TABLE NO. Blackbird | TEST NO. 9

## CONDITIONS AND REAGENTS

| POINT OF ADDITION | CONDITIONS | | | REAGENTS POUNDS PER TON | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | TIME MINS | % SOLIDS | PH | lime | Na [illegible] | [illegible] 325 | HCl | $CuSO_4$ | Y-F | | | | |
| Grind | 10 | 60 | 10.0 | 8.0 | | | | | | | | | |
| Cond #1 | 10 | 20 | 10.0 | | 0.10 | | | | | | | | |
| Flot | | " | " | | | | | | 0.08 | | | | |
| Cond #2 | 3 | " | 8.0 | | | 0.10 | * | | | | | | |
| Flot | | " | " | | | | | | 0.01 | | | | |
| Cond #3 | 3 | " | 3 | | | 0.10 | * | 0.20 | | | | | |
| Flot | | " | " | | | | | | 0.01 | | | | |
| | | | | | | | | | | | | | |

REMARKS

## METALLURGICAL RESULTS

| PRODUCT | % WEIGHT | ASSAYS | | | | | % DISTRIBUTION | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Co | | | | | Co | | | | |
| C-1 | | 0.28 | | | | | 1.8 | | | | |
| C-2 | | 0.28 | | | | | 5.5 | | | | |
| C-3 | | 5.5 | | | | | 86.5 | | | | |
| Tails | | 0.06 | | | | | 6.2 | | | | |
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RATIO OF CONCENTRATION

REMARKS

DOF-3861 PTD. IN U.S.A. 11/52

FLOTATION TEST LOG SHEET July 6. 1956 | TABLE NO. Blackbird | TEST NO. 10

CONDITIONS AND REAGENTS

| POINT OF ADDITION | CONDITIONS | | | REAGENTS POUNDS PER TON | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | TIME MINS | % SOLIDS | PH | lime | NaCN aero | Y-F | X 325 | $CuSO_4$ | HCl | | | | |
| Grind | 10 | 60 | 10.5 | 9.0 | | | | | | | | | |
| Cond #1 | 10 | 20 | 10.5 | | 0.15 | | | | | | | | |
| Flot | | " | " | | | 0.04 | | | | | | | |
| Cond #2 | 3 | " | 4 | | 0.10 | | | | * | | | | |
| Flot | | " | " | | 0.10 | 0.04 | | | | | | | |
| Cond #3 | 2 | " | 3 | | | | 0.10 | 0.20 | * | | | | |
| Flot | | " | " | | | 0.04 | | | | | | | |
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REMARKS

METALLURGICAL RESULTS

| PRODUCT | % WEIGHT | ASSAYS | | | | | % DISTRIBUTION | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Co | | | | | Co | | | | |
| C-1 | 7.1 | 0.36 | | | | | 4.5 | | | | |
| C-2 | 13.5 | 1.80 | | | | | 43.6 | | | | |
| C-3 | 7.2 | 3.3 | | | | | 42.8 | | | | |
| Tails | 72.2 | 0.07 | | | | | 9.1 | | | | |
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RATIO OF CONCENTRATION

REMARKS

GOF-3861 PTD. IN U.S.A. 11/52

# FLOTATION TEST LOG SHEET

July 6, 1956 | TABLE NO. Blackbird | TEST NO. 11

## CONDITIONS AND REAGENTS

| POINT OF ADDITION | CONDITIONS | | | REAGENTS POUNDS PER TON | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | TIME MINS | % SOLIDS | PH | lime | aero | 303 | 350 | Y-P | $CuSO_4$ | HCl | | | |
| Grind | 10 | 60 | 10.5 | 9.0 | | | | | | | | | |
| Cond #1 | 10 | 20 | 10.5 | | 0.15 | | | | | | | | |
| Flot | | " | " | | | | | 0.04 | | | | | |
| Cond #2 | 3 | " | 8.0 | | | 0.10 | | | | * | | | |
| Flot | | " | " | | | | | 0.04 | | | | | |
| Cond #3 | 2 | " | 3 | | | | 0.10 | | 0.20 | * | | | |
| Flot | | " | " | | | | | 0.06 | | | | | |
| | | | | | | | | | | | | | |

REMARKS

## METALLURGICAL RESULTS

| PRODUCT | % WEIGHT | ASSAYS | | | | | % DISTRIBUTION | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Co | | | | | Co | | | | |
| C-1 | 5.4 | 0.40 | | | | | 3.8 | | | | |
| C-2 | 10.3 | 0.28 | | | | | 5.4 | | | | |
| C-3 | 13.6 | 3.4 | | | | | 83.3 | | | | |
| Tails | 70.2 | 0.06 | | | | | 7.5 | | | | |
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RATIO OF CONCENTRATION

REMARKS

GOF-3861 PTD. IN U.S.A. 11/52

FLOTATION TEST LOG SHEET Sept. 13. 1956 | TABLE NO. Blackbird | TEST NO. 12

CONDITIONS AND REAGENTS

| POINT OF ADDITION | CONDITIONS | | | REAGENTS POUNDS PER TON | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | TIME MINS | % SOLIDS | PH | lime | Na aero | X 325 | HCl | CuSO4 | Y-F | | | | |
| Grind | 16 | 60 | 9 | 8.0 | | | | | | | | | |
| Cond #1 | 10 | 20 | 9 | | 0.10 | | | | | | | | |
| Flot | | " | " | | | | | | 0.04 | | | | |
| Cond #2 | 3 | " | 7.5 | | | 0.10 | * | | | | | | |
| Flot | | " | " | | | | | | 0.04 | | | | |
| Cond #3 | 2 | " | 3 | | | 0.10 | * | 0.20 | | | | | |
| Flot | | " | " | | | | | | 0.04 | | | | |
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REMARKS

METALLURGICAL RESULTS

| PRODUCT | % WEIGHT | ASSAYS | | | | | % DISTRIBUTION | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Co | | | | | Co | | | | |
| C-1 | 4.2 | 0.48 | | | | | 2.8 | | | | |
| C-2 | 9.8 | 0.44 | | | | | 6.0 | | | | |
| C-3 | 10.8 | 5.70 | | | | | 84.0 | | | | |
| Tails | 75.2 | 0.07 | | | | | 7.2 | | | | |
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RATIO OF CONCENTRATION

REMARKS

GOF-3861 PTD. IN U.S.A. 11/52

# FLOTATION TEST LOG SHEET

Sept. 17, 1956 | TABLE NO. Blackbird | TEST NO. 13

## CONDITIONS AND REAGENTS

| POINT OF ADDITION | CONDITIONS | | | REAGENTS POUNDS PER TON | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | TIME MINS | % SOLIDS | PH | lime | Na aero | X 325 | HCl | CuSO4 | Y-F | | | | |
| Grind | 20 | 60 | 8.0 | 8.0 | | | | | | | | | |
| Cond #1 | 10 | 20 | 9.0 | 2.0 | 0.10 | | | | | | | | |
| Flot | | " | " | | | | | | 0.04 | | | | |
| Cond #2 | 3 | " | 7.5 | | | 0.10 | * | | | | | | |
| Flot | | " | " | | | | | | 0.04 | | | | |
| Cond #3 | 2 | " | 3 | | | 0.10 | * | 0.20 | | | | | |
| Flot | | " | " | | | | | | 0.08 | | | | |
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REMARKS

## METALLURGICAL RESULTS

| PRODUCT | % WEIGHT | ASSAYS | | | | | % DISTRIBUTION | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Co | | | | | Co | | | | |
| C-1 | 2.0 | 0.40 | | | | | 0.9 | | | | |
| C-2 | 3.5 | 0.40 | | | | | 1.5 | | | | |
| C-3 | 22.6 | 3.7 | | | | | 94.4 | | | | |
| Tails | 73.9 | 0.04 | | | | | 3.2 | | | | |
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RATIO OF CONCENTRATION

REMARKS

GOF-3861 PTD. IN U.S.A. 11/52

FLOTATION TEST LOG SHEET Sept. 19, 1956 | TABLE NO. Blackbird | TEST NO. 14

CONDITIONS AND REAGENTS

| POINT OF ADDITION | CONDITIONS | | | REAGENTS POUNDS PER TON | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | TIME MINS | % SOLIDS | PH | lime | Na pero | X 325 | HCl | Y-F | $KMnO_4$ | 77 | | | |
| Grind | 20 | 60 | 8 | 8.0 | | | | | | | | | |
| Cond #1 | 10 | 20 | 9 | 2.0 | 0.10 | | | | | | | | |
| Flot | | " | " | | | | | 0.04 | | | | | |
| Cond #2 | 3 | " | 7.5 | | | 0.10 | * | | | | | | |
| Flot | | " | " | | | | | 0.04 | | | | | |
| Cond #3 | 2 | " | 3 | | | 0.10 | * | | | | | | |
| Flot | | " | " | | | | | 0.04 | | | | | |
| #3 Conc: Cl 1x | | | 5 | | | | | | 0.3 | 0.6 | | | |
| REMARKS Cl 2x | | | 5 | | | | | | 0.2 | | | | |

2000 gm test charge
$KMnO_4$ to depress pyrite in cleaner - unsuccessful
77 - used as froth modifier.

METALLURGICAL RESULTS

| PRODUCT | % WEIGHT | ASSAYS | | | | | % DISTRIBUTION | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Co | | | | | Co | | | | |
| Combined C-1; C-2 | 5.5 | 0.60 | | | | | 3.9 | | | | |
| #1 Cl Tails | 2.9 | 2.76 | | | | | 9.4 | | | | |
| #2 Cl Tails | 1.0 | 5.8 | | | | | 6.4 | | | | |
| #2 Cl Conc | 16.8 | 3.88 | | | | | 76.8 | | | | |
| Tails | 73.8 | 0.04 | | | | | 3.5 | | | | |
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RATIO OF CONCENTRATION

REMARKS

GOF-3861 PTD. IN U.S.A. 11/52

# FLOTATION TEST LOG SHEET Sept. 20. 1956

TABLE NO. Blackbird

TEST NO. 15

## CONDITIONS AND REAGENTS

| POINT OF ADDITION | CONDITIONS | | | REAGENTS POUNDS PER TON | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | TIME MINS | % SOLIDS | PH | lime | Na aero | Y 325 | HCl | CuSO4 | Y-F | | | | |
| Grind | 20 | 60 | 8.0 | 8.0 | | | | | | | | | |
| Cond #1 | 10 | 20 | 9.0 | 2.0 | 0.10 | | | | | | | | |
| Flot | | " | " | | | | | | 0.04 | | | | |
| Cond #2 | 3 | " | " | | | 0.10 | | | | | | | |
| Flot | | " | " | | | 0.10 | | | 0.04 | | | | |
| Cond #3 | 2 | " | 3 | | | 0.10 | * | 0.20 | | | | | |
| Flot | | " | " | | | | | | 0.04 | | | | |
| | | | | | | | | | | | | | |

REMARKS

## METALLURGICAL RESULTS

| PRODUCT | % WEIGHT | ASSAYS | | | | | % DISTRIBUTION | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Co | | | | | Co | | | | |
| C-1 | 5.0 | 0.64 | | | | | 3.7 | | | | |
| C-2 | 16.9 | 1.12 | | | | | 22.1 | | | | |
| C-3 | 5.5 | 10.2 | | | | | 65.7 | | | | |
| Tails | 72.6 | 0.10 | | | | | 8.5 | | | | |
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RATIO OF CONCENTRATION

REMARKS

OF-3861 PTD. IN U.S.A. 11/52

# FLOTATION TEST LOG SHEET Sept. 24, 1956

TABLE NO. Blackbird

TEST NO. 16

## CONDITIONS AND REAGENTS

| POINT OF ADDITION | CONDITIONS | | | REAGENTS POUNDS PER TON | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | TIME MINS | % SOLIDS | PH | lime | Na [illegible] | 325 | HCl | CuSO4 | Y.F | | | | |
| Grind | 20 | 60 | 8.0 | 8.0 | | | | | | | | | |
| Cond #1 | 10 | 20 | 9.5 | 3.0 | 0.10 | | | | | | | | |
| Flot | | " | " | | | | | | 0.04 | | | | |
| Cond #2 | 3 | " | " | | | 0.10 | | | | | | | |
| Flot | | " | " | | | 0.10 | | | 0.04 | | | | |
| Cond #3 | 2 | " | 3 | | | 0.10 | * | 0.20 | | | | | |
| Flot | | " | " | | | | | | 0.08 | | | | |
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REMARKS

## METALLURGICAL RESULTS

| PRODUCT | % WEIGHT | ASSAYS | | | | | % DISTRIBUTION | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Co | | | | | Co | | | | |
| C-1 | 3.6 | 0.40 | | | | | 1.7 | | | | |
| C-2 | 16.4 | 0.52 | | | | | 10.6 | | | | |
| C-3 | 6.4 | 10.5 | | | | | 84.0 | | | | |
| Tails | 73.6 | 0.04 | | | | | 3.7 | | | | |
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RATIO OF CONCENTRATION

REMARKS

F-3861 PTD. IN U.S.A. 11/52

# FLOTATION TEST LOG SHEET

TABLE NO. Blackbird

TEST NO. 17

## CONDITIONS AND REAGENTS

| POINT OF ADDITION | CONDITIONS | | | REAGENTS POUNDS PER TON | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | TIME MINS | % SOLIDS | PH | lime | Na aero | I 325 | HCl | $CuSO_4$ | Y-F | | | | |
| Grind | 20 | 60 | 7.5 | 6.0 | | | | | | | | | |
| Cond #1 | 10 | 20 | 7.5 | | 0.10 | | | | | | | | |
| Flot | | " | " | | | | | | 0.04 | | | | |
| Cond #2 | 3 | " | " | | | 0.10 | | | | | | | |
| Flot | | " | " | | | 0.10 | | | 0.04 | | | | |
| Cond #3 | 2 | " | 3 | | | 0.10 | * | 0.20 | | | | | |
| Flot | | " | " | | | | | | 0.08 | | | | |
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REMARKS

## METALLURGICAL RESULTS

| PRODUCT | % WEIGHT | ASSAYS | | | | | % DISTRIBUTION | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Co | | | | | Co | | | | |
| C-1 | 4.0 | 0.88 | | | | | 4.4 | | | | |
| C-2 | 16.8 | 1.80 | | | | | 40.2 | | | | |
| C-3 | 6.7 | 5.4 | | | | | 46.2 | | | | |
| Tails | 72.5 | 0.10 | | | | | 9.2 | | | | |
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RATIO OF CONCENTRATION

REMARKS

IOF-3861 PTD. IN U.S.A. 11/52

FLOTATION TEST LOG SHEET Sept. 26. 1956 | TABLE NO. Blackbird | TEST NO. 18

CONDITIONS AND REAGENTS

| POINT OF ADDITION | CONDITIONS | | | REAGENTS POUNDS PER TON | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | TIME MINS | % SOLIDS | PH | Limehero | Na | X 325 | HCl | $CuSO_4$ | Y-F | | | | |
| Grind | 20 | 60 | 8.5 | 8.0 | | | | | | | | | |
| Cond #1 | 10 | 20 | 10.0 | 6.0 | 0.10 | | | | | | | | |
| Flot | | " | " | | | | | | 0.04 | | | | |
| Cond #2 | 3 | " | " | | | 0.10 | | | | | | | |
| Flot | | " | " | | | 0.10 | | | 0.03 | | | | |
| Cond #3 | 2 | " | 3 | | | 0.10 | * | 0.20 | | | | | |
| Flot | | " | " | | | | | | 0.04 | | | | |
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REMARKS

METALLURGICAL RESULTS

| PRODUCT | % WEIGHT | ASSAYS | | | | | % DISTRIBUTION | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Co | | | | | Co | | | | |
| C-1 | 4.6 | 0.34 | | | | | 2.1 | | | | |
| C-2 | 17.1 | 0.36 | | | | | 8.4 | | | | |
| C-3 | 6.0 | 10.0 | | | | | 82.6 | | | | |
| Tails | 72.3 | 0.07 | | | | | 6.9 | | | | |
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RATIO OF CONCENTRATION

REMARKS

30F-3861 PTD. IN U.S.A. 11/52

FLOTATION TEST LOG SHEET Sept. 26. 1956. | TABLE NO. Blackbird | TEST NO. 19

CONDITIONS AND REAGENTS

| POINT OF ADDITION | CONDITIONS | | | REAGENTS POUNDS PER TON | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | TIME MINS | % SOLIDS | PH | lime | Na meta | X 325 | HCl | $CuSO_4$ | Y-F | | | | |
| Grind | 20 | 60 | 8.0 | 8.0 | | | | | | | | | |
| Cond #1 | 10 | 20 | 10.5 | 10.0 | 0.10 | | | | | | | | |
| Flot | | " | " | | | | | | 0.04 | | | | |
| Cond #2 | 3 | " | " | | | 0.10 | | | | | | | |
| Flot | | " | " | | | 0.10 | | | 0.04 | | | | |
| Cond #3 | 2 | " | 3 | | | 0.10 | * | 0.20 | | | | | |
| Flot | | " | " | | | | | | 0.04 | | | | |
| | | | | | | | | | | | | | |

REMARKS

METALLURGICAL RESULTS

| PRODUCT | % WEIGHT | ASSAYS | | | | | % DISTRIBUTION | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Co | | | | | Co | | | | |
| C-1 | 4.0 | 0.40 | | | | | 2.1 | | | | |
| C-2 | 9.4 | 0.36 | | | | | 4.3 | | | | |
| C-3 | 14.0 | 4.9 | | | | | 88.5 | | | | |
| Tails | 72.6 | 0.03 | | | | | 5.1 | | | | |
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RATIO OF CONCENTRATION

REMARKS

GOF-3861 PTD. IN U.S.A. 11/52

# FLOTATION TEST LOG SHEET Sept. 28, 1956

TABLE NO. Blackbird

TEST NO. 20

## CONDITIONS AND REAGENTS

| POINT OF ADDITION | CONDITIONS | | | REAGENTS POUNDS PER TON | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | TIME MINS | % SOLIDS | PH | lime | Na aero | X 325 | HCl | $CuSO_4$ | Y-F | NaCN | | | |
| Grind | 20 | 60 | 8.5 | 8.0 | | | | | | | | | |
| Cond #1 | 10 | 20 | 9.5 | 3.0 | 0.10 | | | | | 0.11 | | | |
| Flot | | " | " | | | | | | 0.04 | | | | |
| Cond #2 | 3 | " | " | | | 0.10 | | | | | | | |
| Flot | | " | " | | | 0.10 | | | 0.04 | | | | |
| Cond #3 | 2 | " | 3 | | | 0.10 | * | 0.20 | | | | | |
| Flot | | " | " | | | | | | 0.08 | | | | |
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REMARKS

## METALLURGICAL RESULTS

| PRODUCT | % WEIGHT | ASSAYS | | | | | % DISTRIBUTION | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Co | | | | | Co | | | | |
| C-1 | 1.3 | 1.04 | | | | | 2.1 | | | | |
| C-2 | 7.3 | 0.44 | | | | | 4.9 | | | | |
| C-3 | 16.2 | 0.5 | | | | | 12.5 | | | | |
| Tails | 75.2 | 0.7 | | | | | 80.5 | | | | |
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RATIO OF CONCENTRATION

REMARKS

GOF-3861 PTD. IN U.S.A. 11/52

FLOTATION TEST LOG SHEET Sept. 28, 1956 | TABLE NO. Blackbird | TEST NO. 21

CONDITIONS AND REAGENTS

| POINT OF ADDITION | CONDITIONS | | | REAGENTS POUNDS PER TON | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | TIME MINS | % SOLIDS | PH | lime | Na aero | X 325 | HCl | CuSO4 | Na-Fe | Y-F | | | |
| Grind | 20 | 60 | 8.5 | 8.0 | | | | | | | | | |
| Cond #1 | 10 | 20 | 9.5 | 4.0 | 0.10 | | | | 0.10 | | | | |
| Flot | | " | " | | | | | | | 0.04 | | | |
| Cond #2 | 3 | " | " | | | 0.10 | | | | | | | |
| Flot | | " | " | | | 0.10 | | | | 0.04 | | | |
| Cond #3 | 2 | " | 3 | | | 0.10 | * | 0.20 | | | | | |
| Flot | | " | " | | | | | | | 0.08 | | | |
| | | | | | | | | | | | | | |

REMARKS

METALLURGICAL RESULTS

| PRODUCT | % WEIGHT | ASSAYS | | | | | % DISTRIBUTION | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Co | | | | | Co | | | | |
| C-1 | 3.6 | 0.42 | | | | | 2.0 | | | | |
| C-2 | 15.3 | 0.44 | | | | | 8.9 | | | | |
| C-3 | 8.0 | 4.1 | | | | | 85.5 | | | | |
| Tails | 73.1 | 0.04 | | | | | 3.6 | | | | |
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RATIO OF CONCENTRATION

REMARKS

COF. 5861 PTD. IN U.S.A. 11/52

FLOTATION TEST LOG SHEET — Oct. 2, 1956 — TABLE NO. Blackbird — TEST NO. 22

CONDITIONS AND REAGENTS

| POINT OF ADDITION | CONDITIONS | | | REAGENTS POUNDS PER TON | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | TIME MINS | % SOLIDS | PH | lime | Na aero Y 325 | | HCl | $CuSO_4$ | Y-F | $KMnO_4$ | | | |
| Grind | 20 | 60 | 8.5 | 8.0 | | | | | | | | | |
| Cond #1 | 10 | 20 | 9.5 | 3.0 | 0.10 | | | | | 0.10 | | | |
| Flot | | " | " | | | | | | 0.04 | | | | |
| Cond #2 | 3 | " | " | | | 0.10 | | | | | | | |
| Flot | | " | " | | | 0.10 | | | 0.04 | | | | |
| Cond #3 | 2 | " | 3 | | | 0.10 | * | 0.20 | | | | | |
| Flot | | " | " | | | | | | 0.08 | | | | |
| | | | | | | | | | | | | | |

REMARKS

METALLURGICAL RESULTS

| PRODUCT | % WEIGHT | ASSAYS | | | | | % DISTRIBUTION | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Co | | | | | Co | | | | |
| C-1 | 6.5 | 0.68 | | | | | 6.6 | | | | |
| C-2 | 14.8 | 0.96 | | | | | 21.0 | | | | |
| C-3 | 5.0 | 4.2 | | | | | 31.1 | | | | |
| Tails | 73.7 | 0.38 | | | | | 41.3 | | | | |
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RATIO OF CONCENTRATION

REMARKS

GOF-5861 PTD. IN U.S.A. 11/52

FLOTATION TEST LOG SHEET Oct. 2, 1956 | TABLE NO. Blackbird | TEST NO. 23

## CONDITIONS AND REAGENTS

| POINT OF ADDITION | CONDITIONS | | | REAGENTS POUNDS PER TON | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | TIME MINS | % SOLIDS | PH | lime | Na aero | I 325 | HCl | $CuSO_4$ | 610 | Y-F | A-33 | | |
| Grind | 20 | 60 | 8.5 | 8.0 | | | | | | | | | |
| Cond #1 | 10 | 20 | 9.5 | 3.0 | 0.10 | | | | 0.5 | | | | |
| Flot | | " | | | | | | | | 0.04 | | | |
| Cond #2 | 3 | " | | | | 0.10 | | | | | | | |
| Flot | | " | | | | 0.10 | | | | 0.04 | | | |
| Cond #3 | 2 | " | 3 | | | 0.10 | * | 0.20 | | | | | |
| Flot | | " | | | | | | | | 0.08 | | | |
| Scavenge | | " | | | | | | | | | 0.20 | | |

REMARKS

A-33 stage added -- CoAsS still in tails
610 to depress As minerals

## METALLURGICAL RESULTS

| PRODUCT | % WEIGHT | ASSAYS | | | | | % DISTRIBUTION | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Co | | | | | Co | | | | |
| C-1 | 5.0 | 0.43 | | | | | 3.6 | | | | |
| C-2 | 16.0 | 1.02 | | | | | 24.9 | | | | |
| C-3 | 1.9 | 1.4 | | | | | 3.9 | | | | |
| Scav. Conc | 2.3 | 8.2 | | | | | 34.8 | | | | |
| Tails | 74.3 | 0.3 | | | | | 33.2 | | | | |
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RATIO OF CONCENTRATION

REMARKS

GOF-3861 PTD. IN U.S.A. 11/52

FLOTATION TEST LOG SHEET Oct. 8, 1956 | TABLE NO. Blackbird | TEST NO. 24

CONDITIONS AND REAGENTS

| POINT OF ADDITION | CONDITIONS | | | REAGENTS POUNDS PER TON | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | TIME MINS | % SOLIDS | PH | lime | Na aero | X 325 | HCl | X-F | $CuSO_4$ | | | | |
| Grind | 20 | 60 | 7.5 | 8.0 | | | | | | | | | |
| Cond #1 | 10 | 20 | 9.5 | 6.0 | 0.10 | | | | | | | | |
| Flot | | " | " | | | | | 0.04 | | | | | |
| Cond #2 | 3 | " | " | | | 0.10 | | | | | | | |
| Flot | | " | " | | | 0.25 | | 0.04 | | | | | |
| Cond #3 | 2 | " | 3 | | | 0.10 | * | | 0.20 | | | | |
| Flot | | " | " | | | | | 0.08 | | | | | |
| | | | | | | | | | | | | | |

REMARKS

METALLURGICAL RESULTS

| PRODUCT | % WEIGHT | ASSAYS | | | | | % DISTRIBUTION | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Co | | | | | Co | | | | |
| C-1 | 5.4 | 0.40 | | | | | 3.0 | | | | |
| C-2 | 16.1 | 0.52 | | | | | 11.9 | | | | |
| C-3 | 5.0 | 11.35 | | | | | 80.9 | | | | |
| Tails | 73.5 | 0.04 | | | | | 4.2 | | | | |
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RATIO OF CONCENTRATION

REMARKS

GOF-3861 PTD. IN U.S.A. 11/52

FLOTATION TEST LOG SHEET October 8, 1956 | TABLE NO. Blackbird | TEST NO. 25

CONDITIONS AND REAGENTS

| POINT OF ADDITION | CONDITIONS | | | REAGENTS POUNDS PER TON | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | TIME MINS | % SOLIDS | PH | lime | Na aero | I 325 | HCl | Y-F | CuSO4 | | | | |
| Grind | 20 | 60 | 8.0 | 8.0 | | | | | | | | | |
| Cond #1 | 10 | 20 | 9.5 | 6.0 | 0.10 | | | | | | | | |
| Flot | | " | " | | | | | 0.04 | | | | | |
| Cond #2 | 3 | " | " | | | 0.10 | | | | | | | |
| Flot | | " | " | | | 0.20 | | 0.04 | | | | | |
| Cond #3 | 2 | " | 3 | | | 0.10 | * | | 0.20 | | | | |
| Flot | | " | " | | | | | 0.08 | | | | | |
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REMARKS

* 325 in Fe float stage added 0.10#/ton ea. time

METALLURGICAL RESULTS

| PRODUCT | % WEIGHT | ASSAYS | | | | | % DISTRIBUTION | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Co | | | | | Co | | | | |
| C-1 | 4.5 | 0.44 | | | | | 2.9 | | | | |
| C-2 | 18.5 | 1.00 | | | | | 27.4 | | | | |
| C-3 | 4.3 | 9.9 | | | | | 64.1 | | | | |
| Tails | 72.7 | 0.05 | | | | | 5.6 | | | | |
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RATIO OF CONCENTRATION

REMARKS

GOF-3861 PTD. IN U.S.A. 11/52

# FLOTATION TEST LOG SHEET

Oct. 11, 1956 | TABLE NO. Blackbird | TEST NO. 26

## CONDITIONS AND REAGENTS

| POINT OF ADDITION | CONDITIONS | | | REAGENTS POUNDS PER TON | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | TIME MINS | % SOLIDS | PH | lime | Na aero | 325 | HCl | Y-7 | A-33 | | | | |
| Grind | 20 | 60 | 9.5 | 8.0 | | | | | | | | | |
| Cond #1 | 10 | 20 | 11.0 | 4.0 | 0.10 | | | | | | | | |
| Flot | | " | " | | | | | 0.04 | | | | | |
| Cond #2 | 3 | " | " | | | 0.10 | | | | | | | |
| Flot | | " | " | | | 0.10 | | 0.04 | | | | | |
| Cond #3 | 2 | " | 3 | | | | * | | 0.11 | | | | |
| Flot | | " | " | | | | | 0.08 | | | | | |
| | | | | | | | | | | | | | |

REMARKS

## METALLURGICAL RESULTS

| PRODUCT | % WEIGHT | ASSAYS | | | | | % DISTRIBUTION | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Co | | | | | Co | | | | |
| Cu Conc | 5.5 | 0.44 | | | | | 3.0 | | | | |
| Fe Conc | 12.7 | 0.36 | | | | | 5.9 | | | | |
| Co Conc | 10.0 | 6.70 | | | | | 86.6 | | | | |
| Tails | 71.8 | 0.05 | | | | | 4.5 | | | | |
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RATIO OF CONCENTRATION

REMARKS

GOF-3861 PTD. IN U.S.A. 11/52

FLOTATION TEST LOG SHEET Oct. 11. 1956 | TABLE NO. Blackbird | TEST NO. 27

CONDITIONS AND REAGENTS

| POINT OF ADDITION | CONDITIONS | | | REAGENTS POUNDS PER TON | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | TIME MINS | % SOLIDS | PH | lime | Na aero | A 325 | HCl | Y-F | A-33 | | | | |
| Grind | 20 | 60 | 9.5 | 8.0 | | | | | | | | | |
| Cond #1 | 10 | 20 | 11.5 | 6.0 | 0.10 | | | | | | | | |
| Flot | | " | " | | | | | 0.04 | | | | | |
| Cond #2 | 3 | " | " | | | 0.10 | | | | | | | |
| Flot | | " | " | | | 0.10 | | 0.04 | | | | | |
| Cond #3 | 2 | " | 3 | | | | * | | 0.11 | | | | |
| Flot | | " | " | | | | | 0.08 | | | | | |
| | | | | | | | | | | | | | |

REMARKS

METALLURGICAL RESULTS

| PRODUCT | % WEIGHT | ASSAYS | | | | | % DISTRIBUTION | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Co | | | | | Co | | | | |
| Cu Conc | 3.7 | 0.44 | | | | | 1.9 | | | | |
| Fe Conc | 8.2 | 0.40 | | | | | 4.0 | | | | |
| Co Conc | 15.9 | 4.8 | | | | | 91.5 | | | | |
| Taila | 72.2 | 0.03 | | | | | 2.6 | | | | |
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RATIO OF CONCENTRATION

REMARKS

GOF-3861 PTD. IN U.S.A. 11/52

# FLOTATION TEST LOG SHEET Oct. 12, 1956

TABLE NO. Blackbird

TEST NO. 28

## CONDITIONS AND REAGENTS

| POINT OF ADDITION | CONDITIONS | | | REAGENTS POUNDS PER TON | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | TIME MINS | % SOLIDS | PH | lime | Na aero | ¾ 325 | HCl | Y-F | A-3 | | | | |
| Grind | 20 | 60 | 9.5 | 8.0 | | | | | | | | | |
| Cond #1 | 10 | 20 | 10.5-11.0 | 3.0 | 0.10 | | | | | | | | |
| Flot | | " | " | | | | | 0.04 | | | | | |
| Cond #2 | 3 | " | " | | | 0.10 | | | | | | | |
| Flot | | " | " | | | 0.10 | | 0.04 | | | | | |
| Cond #3 | 2 | " | 3 | | | | * | | 0.11 | | | | |
| Flot | | " | 0 | | | | | 0.08 | | | | | |
| | | | | | | | | | | | | | |

REMARKS

## METALLURGICAL RESULTS

| PRODUCT | % WEIGHT | ASSAYS | | | | | % DISTRIBUTION | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Co | | | | | Co | | | | |
| Cu Conc | 5.6 | 0.48 | | | | | 3.5 | | | | |
| Fe Conc | 11.8 | 0.40 | | | | | 6.1 | | | | |
| Co Conc | 9.6 | 7.0 | | | | | 86.6 | | | | |
| Tails | 73.0 | 0.04 | | | | | 3.8 | | | | |
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RATIO OF CONCENTRATION

REMARKS

GOF-3861 PTD. IN U.S.A. 11/52

# FLOTATION TEST LOG SHEET

Oct. 12, 1956 | TABLE NO. Blackbird | TEST NO. 29

## CONDITIONS AND REAGENTS

| POINT OF ADDITION | CONDITIONS | | | REAGENTS POUNDS PER TON | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | TIME MINS | % SOLIDS | PH | lime | Na aero | X 325 | HCl | Y-F | A-33 | | | | |
| Grind | 20 | 60 | 9.5 | 8.0 | | | | | | | | | |
| Cond #1 | 10 | 20 | 10.5 | 2.0 | 0.10 | | | | | | | | |
| Flot | | " | " | | | | | 0.04 | | | | | |
| Cond #2 | 3 | " | " | | | 0.10 | | | | | | | |
| Flot | | " | " | | | 0.10 | | 0.04 | | | | | |
| Cond #3 | 2 | " | 3 | | | | * | | 0.11 | | | | |
| Flot | | " | " | | | | | 0.08 | | | | | |
| | | | | | | | | | | | | | |

REMARKS

## METALLURGICAL RESULTS

| PRODUCT | % WEIGHT | ASSAYS | | | | | % DISTRIBUTION | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Co | | | | | Co | | | | |
| Cu Conc | 4.0 | 0.40 | | | | | 1.9 | | | | |
| Fe Conc | 13.9 | 0.36 | | | | | 6.1 | | | | |
| Co Conc | 10.2 | 7.2 | | | | | 88.5 | | | | |
| Tails | 71.9 | 0.04 | | | | | 3.5 | | | | |
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RATIO OF CONCENTRATION

REMARKS

GOF-3861 PTD. IN U.S.A. 11/52

# FLOTATION TEST LOG SHEET

Oct. 16. 1956 | TABLE NO. Blackbird | TEST NO. 30

## CONDITIONS AND REAGENTS

| POINT OF ADDITION | CONDITIONS | | | REAGENTS POUNDS PER TON | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | TIME MINS | % SOLIDS | PH | lime | Na aero 325 | A | HCl | Y-F | A-33 | | | | |
| Grind | 20 | 60 | 9.5 | 8.0 | | | | | | | | | |
| Cond #1 | 10 | 20 | 10.0 | 1.0 | 0.10 | | | | | | | | |
| Flot | | " | " | | | | | 0.04 | | | | | |
| Cond #2 | 3 | " | " | | | 0.10 | | | | | | | |
| Flot | | " | " | | | 0.10 | | 0.04 | | | | | |
| Cond #3 | 2 | " | 3 | | | | * | | 0.11 | | | | |
| Flot | | " | " | | | | | 0.04 | | | | | |
| | | | | | | | | | | | | | |

REMARKS

## METALLURGICAL RESULTS

| PRODUCT | % WEIGHT | ASSAYS | | | | | % DISTRIBUTION | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Co | | | | | Co | | | | |
| Cu Conc | 3.6 | 0.38 | | | | | 1.9 | | | | |
| Fe Conc | 16.6 | 0.44 | | | | | 10.1 | | | | |
| Co Conc | 5.1 | 11.4 | | | | | 80.6 | | | | |
| Tails | 74.5 | 0.10 | | | | | 7.4 | | | | |
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RATIO OF CONCENTRATION

REMARKS

GOF-3061 PTD. IN U.S.A. 11/52

# FLOTATION TEST LOG SHEET

Oct. 16. 1956 | TABLE NO. Blackbird | TEST NO. 31

## CONDITIONS AND REAGENTS

| POINT OF ADDITION | CONDITIONS | | | REAGENTS POUNDS PER TON | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | TIME MINS | % SOLIDS | PH | lime | Na aero | $\bar{X}$ 325 | HCl | Y-F | A-33 | | | | |
| Grind | 20 | 60 | 9.5 | 8.0 | | | | | | | | | |
| Cond #1 | 10 | 20 | " | | 0.10 | | | | | | | | |
| Flot | | " | " | | | | | 0.04 | | | | | |
| Cond #2 | 3 | " | " | | | 0.10 | | | | | | | |
| Flot | | " | " | | | 0.10 | | 0.04 | | | | | |
| Cond #3 | 2 | " | 3 | | | | * | | 0.11 | | | | |
| Flot | | " | " | | | | | 0.04 | | | | | |
| | | | | | | | | | | | | | |

REMARKS

## METALLURGICAL RESULTS

| PRODUCT | % WEIGHT | ASSAYS | | | | | % DISTRIBUTION | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Co | | | | | Co | | | | |
| Cu Conc | 4.1 | 0.32 | | | | | 1.7 | | | | |
| Fe Conc | 15.2 | 0.44 | | | | | 8.9 | | | | |
| Co Conc | 5.2 | 12.2 | | | | | 82.4 | | | | |
| Tails | 75.5 | 0.07 | | | | | 7.0 | | | | |
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RATIO OF CONCENTRATION

REMARKS

GOF-3861 PTD. IN U.S.A. 11/52

FLOTATION TEST LOG SHEET Oct. 18, 1956 | TABLE NO. Blackbird | TEST NO. 32

CONDITIONS AND REAGENTS

| POINT OF ADDITION | CONDITIONS | | | REAGENTS POUNDS PER TON | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | TIME MINS | % SOLIDS | PH | lime | Na aero | A 325 | HCl | Y-F | A-31 | | | | |
| Grind | 20 | 60 | 8.5 | 7.0 | | | | | | | | | |
| Cond #1 | 10 | 20 | " | | 0.10 | | | | | | | | |
| Flot | | " | " | | | | | 0.04 | | | | | |
| Cond #2 | 3 | " | " | | | 0.10 | | | | | | | |
| Flot | | " | " | | | 0.10 | | 0.04 | | | | | |
| Cond #3 | 2 | " | 3 | | | | * | | 0.11 | | | | |
| Flot | | " | " | | | | | 0.08 | | | | | |
| | | | | | | | | | | | | | |

REMARKS

METALLURGICAL RESULTS

| PRODUCT | % WEIGHT | ASSAYS | | | | | % DISTRIBUTION | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Co | | | | | Co | | | | |
| Cu Conc | 5.9 | 0.44 | | | | | 3.3 | | | | |
| Fe Conc | 14.9 | 0.52 | | | | | 9.4 | | | | |
| Co Conc | 5.2 | 11.9 | | | | | 77.6 | | | | |
| Tails | 74.0 | 0.10 | | | | | 9.7 | | | | |
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RATIO OF CONCENTRATION

REMARKS

GOF-3881 PTD. IN U.S.A. 11/52

# FLOTATION TEST LOG SHEET

Oct. 18, 1956 | TABLE NO. Blackbird | TEST NO. 33

## CONDITIONS AND REAGENTS

| POINT OF ADDITION | CONDITIONS | | | REAGENTS POUNDS PER TON | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | TIME MINS | % SOLIDS | PH | lime | Na aero | Y 325 | HCl | Y-F | A-33 | | | | |
| Grind | 20 | 60 | 7.5 | 6.0 | | | | | | | | | |
| Cond #1 | 10 | 20 | 7.5 | | 0.10 | | | | | | | | |
| Flot | | " | " | | | | | 0.04 | | | | | |
| Cond #2 | 3 | " | " | | | 0.10 | | | | | | | |
| Flot | | " | " | | | 0.10 | | 0.04 | | | | | |
| Cond #3 | 2 | " | 3 | | | | * | | 0.11 | | | | |
| Flot | | " | " | | | | | 0.08 | | | | | |
| | | | | | | | | | | | | | |

REMARKS

## METALLURGICAL RESULTS

| PRODUCT | % WEIGHT | ASSAYS | | | | | % DISTRIBUTION | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Co | | | | | Co | | | | |
| Cu Conc | 4.9 | 0.44 | | | | | 2.8 | | | | |
| Fe Conc | 16.5 | 0.80 | | | | | 17.2 | | | | |
| Co Conc | 4.1 | 12.2 | | | | | 64.6 | | | | |
| Tails | 74.5 | 0.16 | | | | | 15.5 | | | | |
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RATIO OF CONCENTRATION

REMARKS

GOF-3861 PTD. IN U.S.A. 11/52

FLOTATION TEST LOG SHEET Oct. 22, 1956 | TABLE NO. Blackbird | TEST NO. 34

## CONDITIONS AND REAGENTS

| POINT OF ADDITION | CONDITIONS | | | REAGENTS POUNDS PER TON | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | TIME MINS | % SOLIDS | PH | lime | Na aero | 325 | HCl | Y-F | A-33 | | | | |
| Grind | 20 | 60 | 9.5 | 8.0 | | | | | | | | | |
| Cond #1 | 10 | 20 | 9.5 | | 0.10 | | | | | | | | |
| Flot | | " | " | | | | | 0.04 | | | | | |
| Cond #2 | 3 | " | " | | | 0.10 | | | | | | | |
| Flot | | " | " | | | 0.10 | | 0.04 | | | | | |
| Cond #3 | 2 | " | 5.5 | | | | * | | 0.11 | | | | |
| Flot | | " | " | | | | | 0.08 | | | | | |
| | | | | | | | | | | | | | |

REMARKS

## METALLURGICAL RESULTS

| PRODUCT | % WEIGHT | ASSAYS | | | | | % DISTRIBUTION | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Co | | | | | Co | | | | |
| Cu Conc | 5.7 | 0.40 | | | | | 2.7 | | | | |
| Fe Conc | 16.4 | 0.52 | | | | | 10.4 | | | | |
| Co Conc | 3.3 | 15.8 | | | | | 60.6 | | | | |
| Tails | 74.6 | 0.30 | | | | | 26.3 | | | | |
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RATIO OF CONCENTRATION

REMARKS

GSP-3881 PTD. IN U.S.A. 11/52

# FLOTATION TEST LOG SHEET Oct. 22, 1956

TABLE NO. Blackbird

TEST NO. 35

## CONDITIONS AND REAGENTS

| POINT OF ADDITION | CONDITIONS | | | REAGENTS POUNDS PER TON | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | TIME MINS | % SOLIDS | PH | lime | Na aero 325 | | HCl | Y-F | A-31 | | | | |
| Grind | 20 | 60 | 9.5 | 8.0 | | | | | | | | | |
| Cond #1 | 10 | 20 | 9.5 | | 0.10 | | | | | | | | |
| Flot | | " | 9.5 | | | | | 0.04 | | | | | |
| Cond #2 | 3 | " | 8.5 | | | 0.10 | | | | | | | |
| Flot | | " | 8.5 | | | 0.10 | | 0.04 | | | | | |
| Cond #3 | 2 | " | 4.5 | | | | 15 cc | | 0.11 | | | | |
| Flot | | " | 4.5 | | | | | 0.08 | | | | | |
| | | | | | | | | | | | | | |

REMARKS

## METALLURGICAL RESULTS

| PRODUCT | % WEIGHT | ASSAYS | | | | | % DISTRIBUTION | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Co | | | | | Co | | | | |
| Cu Conc | 6.84 | 0.42 | | | | | 3.52 | | | | |
| Fe Conc | 15.18 | 0.48 | | | | | 8.95 | | | | |
| Co Conc | 3.90 | 16.2 | | | | | 77.53 | | | | |
| Tails | 74.08 | 0.11 | | | | | 10.00 | | | | |
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RATIO OF CONCENTRATION

REMARKS

GOF-3861 PTD. IN U.S.A. 11/52

FLOTATION TEST LOG SHEET Oct. 24, 1956 | TABLE NO. Blackbird | TEST NO. 36

CONDITIONS AND REAGENTS

| POINT OF ADDITION | CONDITIONS | | | REAGENTS POUNDS PER TON | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | TIME MINS | % SOLIDS | PH | lime | Na aero | Z 325 | HCl | Y-F | A-33 | | | | |
| Grind | 20 | 60 | 9.5 | 8.0 | | | | | | | | | |
| Cond #1 | 10 | 20 | 9.5 | | 0.10 | | | | | | | | |
| Flot | | " | 9.5 | | | | | 0.04 | | | | | |
| Cond #2 | 3 | " | 8.5 | | | 0.10 | | | | | | | |
| Flot | | " | 8.5 | | | 0.10 | | 0.04 | | | | | |
| Cond #3 | 2 | " | 6.0 | | | | 5 cc | | 0.11 | | | | |
| Flot | | " | 6.0 | | | | | 0.04 | | | | | |
| | | | | | | | | | | | | | |

REMARKS

METALLURGICAL RESULTS

| PRODUCT | % WEIGHT | ASSAYS | | | | | % DISTRIBUTION | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Co | | | | | Co | | | | |
| Cu Conc | 4.74 | 0.38 | | | | | 2.4 | | | | |
| Fe Conc | 16.16 | 0.48 | | | | | 10.5 | | | | |
| Co Conc | 3.14 | 6.0 | | | | | 25.5 | | | | |
| Tails | 75.96 | 0.60 | | | | | 61.6 | | | | |
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RATIO OF CONCENTRATION

REMARKS

GOF-3861 PTD. IN U.S.A. 11/52

FLOTATION TEST LOG SHEET Oct. 24, 1956 | TABLE NO. Blackbird | TEST NO. T 37

## CONDITIONS AND REAGENTS

| POINT OF ADDITION | CONDITIONS | | | REAGENTS POUNDS PER TON | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | TIME MINS | % SOLIDS | PH | lime | Na aero | I 325 | HCl | Y-F | A-31 | | | | |
| Grind | 20 | 60 | 9.5 | 8.0 | | | | | | | | | |
| Cond #1 | 10 | 20 | 9.5 | | 0.10 | | | | | | | | |
| Flot | | " | 9.5 | | | | | 0.04 | | | | | |
| Cond #2 | 3 | " | 8.5 | | | 0.10 | | | | | | | |
| Flot | | " | 8.5 | | | 0.10 | | 0.04 | | | | | |
| Cond #3 | 2 | " | 7-7.5 | | | | 0 | | 0.11 | | | | |
| Flot | | " | 7-7.5 | | | | | 0.08 | | | | | |
| | | | | | | | | | | | | | |

REMARKS

## METALLURGICAL RESULTS

| PRODUCT | % WEIGHT | ASSAYS | | | | | % DISTRIBUTION | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Co | | | | | Co | | | | |
| Cu Conc | 5.6 | 0.38 | | | | | 2.8 | | | | |
| Fe Conc | 15.7 | 0.46 | | | | | 9.4 | | | | |
| Co Conc | 4.0 | 1.2 | | | | | 6.2 | | | | |
| Taile | 74.7 | 0.85 | | | | | 81.6 | | | | |
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RATIO OF CONCENTRATION

REMARKS

GOF-3861 PTD. IN U.S.A. 11/52

# FLOTATION TEST LOG SHEET

Oct. 26. 1956 | TABLE NO. Blackbird | TEST NO. 38

## CONDITIONS AND REAGENTS

| POINT OF ADDITION | CONDITIONS | | | REAGENTS POUNDS PER TON | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | TIME MINS | % SOLIDS | PH | lime | Na aero | A 325 | HCl | Y-F | A-3 | | | | |
| Grind | 20 | 60 | 9.5 | 8.0 | | | | | | | | | |
| Cond #1 | 10 | 20 | 9.5 | | 0.10 | | | | | | | | |
| Flot | | 20 | 9.5 | | | | | 0.04 | | | | | |
| Cond #2 | 3 | " | 8.5 | | | 0.10 | | | | | | | |
| Flot | | " | 8.5 | | | 0.10 | | 0.04 | | | | | |
| Cond #3 | 2 | " | 4.5 | | | | * | | 0.11 | | | | |
| Flot | | " | 4.5 | | | | | 0.08 | | | | | |
| | | | | | | | | | | | | | |

REMARKS

## METALLURGICAL RESULTS

| PRODUCT | % WEIGHT | ASSAYS | | | | | % DISTRIBUTION | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Co | Cu | Fe | Insol | S | Co | Cu | Fe | Insol | S |
| Cu Conc | 4.36 | 0.36 | 26.2 | 28.0 | 6.2 | 31.2 | 1.99 | 84.0 | 6.2 | 0.5 | 13.4 |
| Fe Conc | 15.45 | 0.44 | 1.4 | 39.2 | 5.9 | 44.8 | 8.62 | 15.9 | 30.9 | 1.7 | 68.1 |
| Co Conc | 4.46 | 15.0 | Tr. | 22.9 | 11.0 | 28.1 | 84.60 | - | 5.1 | 0.9 | 12.4 |
| Tails | 75.73 | 0.05 | Tr. | 12.0 | 68.4 | 0.81 | 4.79 | - | 45.5 | 96.9 | 6.1 |
| | | | | | | | | | | | |
| Calculated hds. | | 0.79 | 1.36 | 17.4 | 53.4 | 10.2 | | | | | |
| | | | | | | | | | | | |
| Co | | | | | | | | | | | |

RATIO OF CONCENTRATION = 19:1

REMARKS

GOF 3861 PTD. IN U.S.A. 11/52

FLOTATION TEST LOG SHEET Oct. 26, 1956 | TABLE NO. Blackbird | TEST NO. 39

CONDITIONS AND REAGENTS

| POINT OF ADDITION | CONDITIONS | | | REAGENTS POUNDS PER TON | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | TIME MINS | % SOLIDS | PH | lime | Na aero | ~~W~~ 325 | $H_2SO_4$ | A-33 | Y-F | | | | |
| Grind | 20 | 60 | 9.5 | 8.0 | | | | | | | | | |
| Cond #1 | 10 | 20 | 9.5 | | 0.10 | | | | | | | | |
| Flot | | 20 | 9.5 | | | | | | 0.04 | | | | |
| Cond #2 | 3 | " | 8.5 | | | 0.10 | | | | | | | |
| Flot | | " | 8.5 | | | 0.10 | | | 0.04 | | | | |
| Cond #3 | 2 | " | 3.5 | | | | 29.0 | 0.11 | | | | | |
| Flot | | " | 3.5 | | | | | | 0.08 | | | | |
| | | | 5.0 | | | | | | | | | | |

REMARKS

METALLURGICAL RESULTS

| PRODUCT | % WEIGHT | ASSAYS | | | | | % DISTRIBUTION | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Co | | | | | Co | | | | |
| Cu Conc | 5.66 | 0.36 | | | | | 2.7 | | | | |
| Fe Conc | 16.28 | 0.44 | | | | | 9.5 | | | | |
| Co Conc | 3.36 | 16.6 | | | | | 74.0 | | | | |
| Tails | 74.70 | 0.14 | | | | | 13.8 | | | | |
| | | | | | | | | | | | |
| Calculated hds. | | 0.755 | | | | | | | | | |
| | | | | | | | | | | | |
| Co | = | | | | | | | | | | |

RATIO OF CONCENTRATION = 2211

REMARKS

# APPENDIX C

Flowsheets

## Reagents -- Points of Addition and Amounts (lbs/ton)

| | |
|---|---|
| **Rod Mill** | |
| Sodium Sulfide | 0.9 |
| **Bulk Flotation** | |
| Potassium Amyl Xanthate | 0.25 |
| Sodium Sulfide | 0.30 |
| Potassium Ethyl Xanthate | 0.10 |
| Sodium Aerofloat | 0.10 |
| Methyl isobutyl Carbinol (frother) | as required |
| **Bulk Cleaner** | |
| Potassium Amyl Xanthate | 0.25 |
| Sodium Sulfide | 0.25 |
| Frother | |
| **Conditioner** | |
| Lime | |
| Steam and Compressed Air | 3.5 |
| **Copper Flotation** | |
| Ethyl Xanthate | 0.013 |
| Sodium Aerofloat | 0.013 |
| Frother | |
| **Iron Flotation** | |
| Potassium Amyl Xanthate | 0.02 |
| Sodium Sulfide | 0.50 |
| Aero Promoter 404 | 0.03 |
| Frother | |
| **Iron Scavenger** | |
| Potassium Amyl Xanthate | 0.03 |
| Sodium Sulfide | if required |
| Frother | |

Figure 7

Present Flowsheet --- Calera Mining Co. 3/

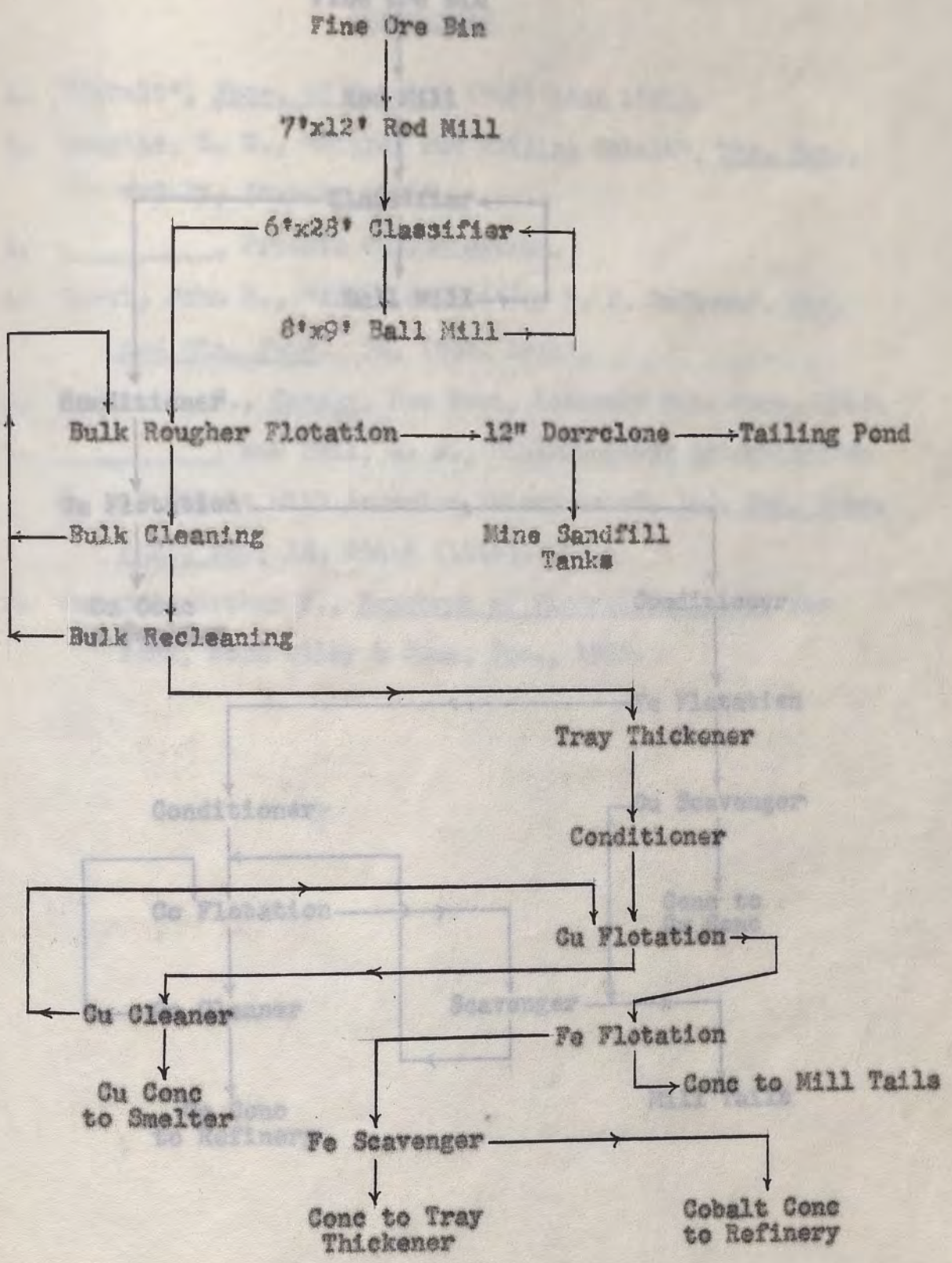
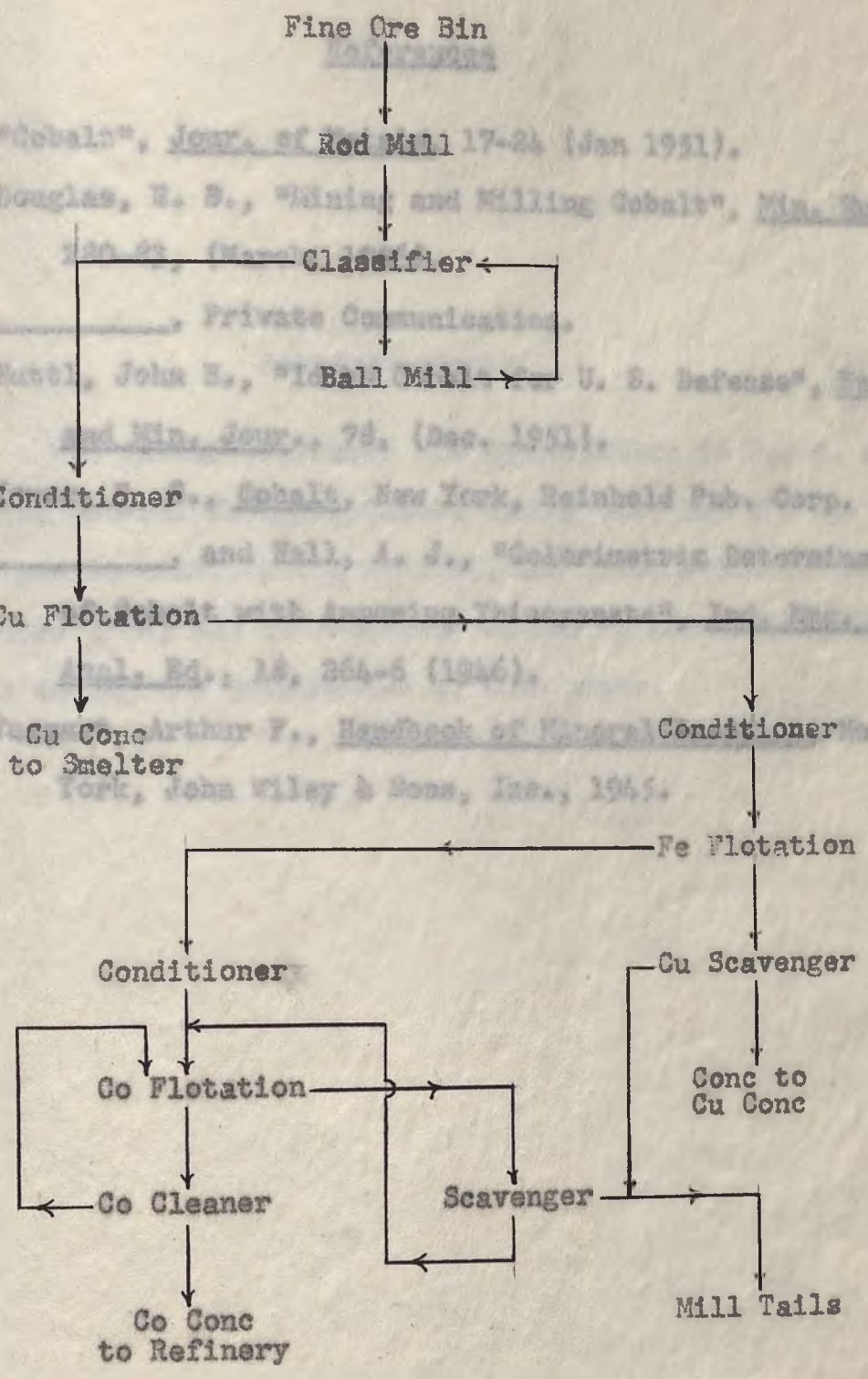


Figure 8

Proposed Flowsheet



## APPENDIX D

## References

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