Flotation of a Complex Sulphide Ore Containing Tetrahedrite

James C. O'Dea
Lorimer W. Hoar

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FLOTATION OF A COMPLEX SULPHIDE ORE
CONTAINING TETRAHEDRITE

by

James C. O’Lea, Anaconda, Montana

and

Lorimer W. Hoar, Butte, Montana

A Thesis
Submitted to the Department of Mineral Dressing
in Partial Fulfillment of the
Requirements for the Degree of
Bachelor of Science in Metallurgical Engineering

MONTANA SCHOOL OF MINES
Butte, Montana

May, 1943
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</table>
FLOTATION OF A COMPLEX SULPHIDE ORE
CONTAINING TETRAHEDRITE

Introduction

The ore investigated in this thesis is a zinc-copper-lead ore which comes from near the Comet Mine near Basin, Montana. No data are available concerning the geology of the ore body.

Microscopic analysis of this complex sulphide ore showed it to contain pyrite, sphalerite, arsenopyrite, galena, chalcopyrite, tetrahedrite, and covellite, with quartz as the gangue constituent. It also contains gold and silver and bismuth and antimony in minor amounts. The gold occurs with the iron minerals and the silver occurs with the lead and copper minerals. The marketing of concentrates produced from this ore may be affected by the bismuth and antimony present.

Flotation consists of separating the valuable minerals from each other, and from the non-economic gangue minerals, this in effect giving concentration of each of the valuable products. In this process particles of one mineral are provided with a coating that enables it to be floated if the mass of the particle is not too great, the limit of particle size at the present time being minus 35 mesh. It may be necessary to grind as fine as
200 mesh to obtain satisfactory liberation. The coating on the mineral gives the particle the property of being air-avid and water-repellant, thereby causing it to attach itself to bubbles. These bubbles, with their captive mineral load, will rise to the surface and be floated.

This process is effected by the use of collectors and frothers. Collectors are the reagents which provide the coatings that enable the desired minerals to attach themselves to the air bubbles in the pulp and thereby float. The correct choice of collecting reagents, therefore, is an important factor in the flotation of minerals.

Frothing reagents are necessary to produce the mineral-carrying froth. Pine oil has been found to be the most practical frother in the flotation of sulphide ores. Other frothers are also in use, the most prominent being cresylic acid. Pine oil and cresylic acid were used throughout this investigation.

Care must be exercised in the amounts of reagents used, small quantities being preferred because excess will usually give "dirty" concentrates.

Soluble salts and colloids may interfere with flotation by reacting with the valuable minerals and preventing them from floating, and by reacting with reagents added and causing excessive reagent consumption.
The purpose of this investigation was to effect a separation of the zinc, copper, lead, and iron minerals and to produce marketable concentrates of each.
ACKNOWLEDGEMENTS

Acknowledgement is gratefully made to Dr. S. R. B. Cooke, Research Professor of Mineral Dressing at the Montana School of Mines, under whose direction this work was done, for his aid and assistance and for the reading of this manuscript.

The writers are also indebted to Assistant Professor W. Smith of the Metallurgy Department of the Montana School of Mines for the use of equipment without which the assaying work could not have been carried out.
GRINDING PROCEDURE

Charges weighing approximately 600 grams were cut from the sample of ore and stage-ground in a steel ball mill in preparation for each flotation test.

In the tests which follow, the entire sample was placed in the ball mill, along with the required amount of balls and water, and ground. The usual practice of dry screening first was not followed in this investigation for in the flotation of sulphide ores freshly fractured particles give the best results.

The sample was usually ground in the first stage for five minutes. After the first grinding period, the contents of the mill were screened and the balls were washed and returned to the mill along with the oversize for the second grinding. When all the ore was finally ground so that it went through a 65 mesh screen in some tests and a 100 mesh screen in others, the pulp was then ready for flotation. The grinding was adjusted so as to give two and sometimes three grinding stages, thereby reducing overgrinding. In some tests certain reagents were added during grinding.
FLotation Technique

After being ground, the pulp was then transferred to a Fagergren flotation cell and diluted to a pulp density of 23 per cent solids.

For certain periods of time, the cell was operated with the air off and used as a conditioner after the addition of various activating and conditioning reagents. Upon completion of the conditioning, the collecting and frothing reagents were added to remove the desired concentrate. Concentrates from what appeared to be the best separations were dried in a gas-heated oven and assayed.

Altogether, ten flotation tests were made. These are presented in the following pages, together with assays (where made) and remarks concerning each test.

Hydrogen ion concentrations were measured in some cases colorimetrically and in others with a Coleman pH meter.

Tap water was used in the grinding circuit in the first eight tests and distilled water was used in the last two tests.
TEST NO. 1

Object: To float a lead-copper rougher concentrate and depress the zinc and iron with the first addition of reagents; to activate the zinc and depress the iron by raising the pH of the solution; to float a zinc rougher concentrate, leaving the iron in the tails.

Sample: 600 grams ground through 65 mesh.

Reagents:

Ball mill—nothing.

Conditioning

<table>
<thead>
<tr>
<th>Reagent</th>
<th>Amount</th>
</tr>
</thead>
<tbody>
<tr>
<td>Potassium cyanide</td>
<td>1.5 lbs. / ton</td>
</tr>
<tr>
<td>Zinc sulphate</td>
<td>2.0 lbs. / ton</td>
</tr>
<tr>
<td>Lime</td>
<td>1.0 lbs. / ton</td>
</tr>
</tbody>
</table>

(After conditioning here, pH is 8)

Lead-copper rougher concentrate

<table>
<thead>
<tr>
<th>Reagent</th>
<th>Amount</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lime</td>
<td>2.0 lbs. / ton</td>
</tr>
<tr>
<td>Aerofloat 51</td>
<td>0.05 lbs. / ton</td>
</tr>
<tr>
<td>Cresylic acid</td>
<td>0.05 lbs. / ton</td>
</tr>
</tbody>
</table>

(After this extraction, pH is 9.4)

Zinc conditioner

<table>
<thead>
<tr>
<th>Reagent</th>
<th>Amount</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lime</td>
<td>1.0 lbs. / ton</td>
</tr>
<tr>
<td>Copper sulphate</td>
<td>1.5 lbs. / ton</td>
</tr>
</tbody>
</table>
Zinc rougher

Cresylic acid.................................. 0.10 lbs. / ton
Sodium Aerofloat................................. 0.05 lbs. / ton
Sodium Aerofloat-B.............................. 0.05 lbs. / ton

(pH—7.1)

Results of assay:

<table>
<thead>
<tr>
<th></th>
<th>Wt.</th>
<th>Wt. %</th>
<th>Assay %</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Pb  Cu  Zn</td>
</tr>
<tr>
<td>Tails</td>
<td>513.0</td>
<td>84.7</td>
<td>1.9  1.4  1.4</td>
</tr>
<tr>
<td>Pb-Cu Rougher</td>
<td>25.6</td>
<td>4.2</td>
<td></td>
</tr>
<tr>
<td>Zn Concentrates</td>
<td>67.1</td>
<td>11.1</td>
<td>6.7</td>
</tr>
<tr>
<td></td>
<td>605.7</td>
<td>100.0</td>
<td></td>
</tr>
</tbody>
</table>

Remarks:

The tails from this test were assayed for their lead, copper, and zinc content. The lead-copper rougher concentrate was assayed for its zinc content. The results showed a considerable loss in the tails and also a fairly large amount of zinc in the copper-lead rougher.
TEST NO. 2

Object: To float a bulk concentrate containing the lead, copper, and zinc and to depress the pyrite by maintaining a high pH; to separate the pyrite from the gangue; to depress the sphalerite by the use of sodium sulfite and to float a lead-copper concentrate from the bulk concentrate.

Sample: 600 grams ground through 65 mesh.

Reagents:

Ball mill

Potassium cyanide.................. 0.05 lbs./ ton
Lime.................................. 2.5 lbs./ ton
(pH—8.0)

Bulk concentrate

Potassium ethyl xanthate.......... 0.05 lbs./ ton
Aerofloat 31....................... 0.05 lbs./ ton
Cresylic acid....................... 0.10 lbs./ ton

Pyrite concentrate

Amyl xanthate..................... 0.10 lbs./ ton
Pine oil............................ 0.20 lbs./ ton
Sulphuric acid..................... till acid pH

Lead-copper concentrates

Sodium sulfite...................... 5.0 lbs./ ton
Sulphur dioxide gas.......................... for 30 minutes
Note: Gas from a sulphur dioxide container was
bubbled freely through the agitated pulp
for this length of time.

Potassium ethyl xanthate................. 0.05 lbs. / ton

Zinc rougher concentrate

Copper sulphate............................... 5.0 lbs. / ton
Sodium Aerofloat-B.......................... 0.05 lbs. / ton
Sodium Aerofloat............................. 0.05 lbs. / ton
Cresylic acid................................. 0.05 lbs. / ton

Products from this test were not assayed.

Remarks:

The zinc concentrates appeared to be quite clean but the
tails contained some coarse material that was either galena or
tetrahedrite. To determine whether this material was galena or
tetrahedrite, the same test was carried out on a similar, but
less complex ore which contained more galena. (Test No. 3)
TEST NO. 3

(Made on Missoula galena-sphalerite-chalcopyrite ore)

Object: To depress sphalerite and to float lead and copper concentrates; to activate and float sphalerite, giving particular attention to the zinc tails to determine the amount of lead therein.

Sample: 600 grams ground through 65 mesh.

Reagents:

Ball mill—nothing.

Bulk conditioner

- Sodium sulfite........................................ 5.0 lbs. / ton
- Sulphur dioxide gas.................................... 20 minutes
  Note: Gas from a sulphur dioxide container was bubbled freely through the agitated pulp for this length of time.

Lead-copper concentrate

- Pine oil.................................................. 0.10 lbs. / ton

Zinc conditioner

- Lime.......................................................... 5.0 lbs. / ton
- Copper sulphate.......................................... 3.0 lbs. / ton

Zinc concentrate

- Potassium ethyl xanthate............................... 0.1 lbs. / ton
- Sodium Aerofloat-B...................................... 0.05 lbs. / ton
- Sodium Aerofloat........................................ 0.05 lbs. / ton
Amyl Xanthate.......................... 0.05 lbs./ton

Products from this test were not assayed.

Remarks:

The galena as well as the sphalerite was depressed completely by the addition of sodium sulfite and sulphur dioxide gas.

The copper concentrate was very clean and floated readily. A zinc concentrate was finally obtained after a considerable conditioning time with the reagents listed. The zinc concentrates were fairly clean and the tails from the zinc flotation contained the galena with very little zinc.

It is obvious that the coarse grey residual mineral in Test No. 2 was galena.
TEST NO. 4
(Made on Missoula galena-sphalerite-chalcopyrite ore)

Object: To depress the sphalerite without the use of sulphur
dioxide gas but by using sodium bisulfite.
Sample: 600 grams ground through 65 mesh.
Reagents:
Ball mill—nothing.
Conditioner
Sodium bisulfite............................. 5.0 lbs. / ton
(Conditioning time, 10 minutes)
Copper concentrate
Potassium ethyl xanthate...................... 0.3 lbs. / ton
Pine oil........................................ 0.10 lbs. / ton
Lead concentrate
Aerofloat 3l.................................... 0.05 lbs. / ton
Zinc concentrate conditioner
Copper sulphate............................... 4.0 lbs. / ton
Sodium Aerofloat............................. 0.03 lbs. / ton
Sodium Aerofloat-B........................... 0.03 lbs. / ton
Amyl xanthate................................. 0.03 lbs. / ton
(Conditioning time, 5 minutes)
Zinc concentrate

Potassium permanganate till zinc floated

Products from this test were not assayed.

Remarks:

The sphalerite was depressed. The copper concentrate appeared to be relatively clean, some lead being present.
TEST NO. 5

(Made on original complex sulphide ore)

Object: To eliminate the flotation of a bulk concentrate by floating copper and pyrite together and depressing the sphalerite by the use of sodium bisulfite.

Sample: 600 grams ground through 65 mesh.

Reagents:

Ball mill—nothing.

Copper-lead concentrate

Sodium bisulfite.......................... 5.0 lbs. / ton
Potassium ethyl xanthate............... 1.5 lbs. / ton
Pine oil................................. 0.10 lbs. / ton

Products from this test were not assayed.

Remarks:

Most of the copper was depressed but the pyrite was floated.

The test was unsuccessful. A bulk concentrate of copper, lead, and zinc must be floated under high pH conditions to depress the pyrite.
Object: To produce a bulk concentrate, depressing the pyrite and gangue; to selectively float the minerals in the bulk concentrate by depressing sphalerite with sodium bisulfite.

Sample: 600 grams ground through 65 mesh.

Reagents:

Ball mill
- Potassium cyanide ........................................ 0.5 lbs. / ton
- Lime ..................................................................... 2.5 lbs. / ton

Bulk concentrate
- Potassium ethyl xanthate .................................... 0.05 lbs. / ton
- Aerofloat 51 .................................................... 0.05 lbs. / ton
- Cresylic acid ..................................................... 0.05 lbs. / ton

Copper-lead concentrate
- Sodium bisulfite ............................................... 10.0 lbs. / ton
- Potassium ethyl xanthate ................................... 0.6 lbs. / ton
- Pine oil .............................................................. 0.10 lbs. / ton

Products from this test were not assayed.

Remarks:
The bulk concentrate floated, the pyrite being depressed efficiently. The selective flotation of the bulk concentrates was very ineffective with a wide distribution of the valuable constituents.
TEST NO. 7

Object: To separate the copper, lead, and zinc without producing a bulk concentrate by using sodium carbonate and potassium cyanide.

Sample: 600 grams ground through 65 mesh.

Reagents:

Ball mill

- Sodium carbonate: 2.0 lbs./ton
- Potassium cyanide: 0.5 lbs./ton
- Zinc sulphate: 1.0 lbs./ton

Lead-copper rougher conditioner

- Potassium cyanide: 0.5 lbs./ton

Lead-copper rougher concentrate

- Potassium ethyl xanthate: 0.05 lbs./ton
- Pine oil: 0.05 lbs./ton

Zinc conditioner

- Potassium cyanide: 0.125 lbs./ton
- Pine oil: 0.05 lbs./ton
- Copper sulphate: 2.0 lbs./ton
- Lime: 2.0 lbs./ton
- Sodium Aerofloat: 0.05 lbs./ton
- Sodium Aerofloat-B: 0.05 lbs./ton
Zinc concentrate

Lime........................................ 2.0 lbs. / ton

Products from this test were not assayed.

Remarks:

The potassium cyanide was ineffective in depressing the pyrite during flotation of the sphalerite. Much pyrite appeared in the zinc rougher concentrate but was eliminated on cleaning the product. The pine oil seemed to promote flotation of the pyrite.

This test was carried out on the assumption that if the lead ions were activating the sphalerite in the presence of potassium cyanide, sodium carbonate would precipitate the lead and destroy its activating power.
Object: To eliminate bulk concentrate flotation and to effect a separation.

Sample: 600 grams ground through 65 mesh.

Reagents:

<table>
<thead>
<tr>
<th>Ball mill</th>
<th>Conditioner</th>
<th>Lead-copper rougher concentrate</th>
<th>Zinc conditioner</th>
<th>Zinc rougher concentrate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sodium carbonate</td>
<td>Sodium carbonate</td>
<td>Potassium ethyl xanthate</td>
<td>Copper sulphate</td>
<td>Lime</td>
</tr>
<tr>
<td>2.0 lbs. / ton</td>
<td>2.0 lbs. / ton</td>
<td>0.05 lbs. / ton</td>
<td>4.0 lbs. / ton</td>
<td>1.0 lbs. / ton</td>
</tr>
<tr>
<td>Potassium cyanide</td>
<td>Potassium cyanide</td>
<td>Pine oil</td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.05 lbs. / ton</td>
<td>0.5 lbs. / ton</td>
<td>0.05 lbs. / ton</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Zinc sulphate</td>
<td>Lime</td>
<td>Lime</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.0 lbs. / ton</td>
<td>1.0 lbs. / ton</td>
<td>1.0 lbs. / ton</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

-19-
Pyrite concentrate

Amyl xanthate................................. 0.10 lbs. / ton
Sulphuric acid................................. till acid

Zinc concentrate

Lime............................................... 4.0 lbs. / ton

Products from this test were not assayed.

Remarks:

The pyrite showed a tendency to float upon the addition of potassium ethyl xanthate and pine oil, so lime was added to depress it. The chalcopyrite and galena then floated readily without contamination by pyrite. Most of the pyrite floated with the sphalerite.
TEST NO. 9

Object: To depress the pyrite and produce a bulk concentrate; to depress the sphalerite in the bulk concentrate with cyanide and zinc sulphate and also to prevent its activation by lead ions by the use of sodium carbonate.

Sample: 600 grams ground through 100 mesh.

Reagents:

Ball mill—nothing.

Bulk concentrate

- Lime .................................................. 3.0 lbs. / ton
- Copper sulphate ..................................... 0.5 lbs. / ton
- Potassium ethyl xanthate ......................... 0.1 lbs. / ton
- Pine oil ............................................... 0.05 lbs. / ton
  (pH——8.3)

Pyrine concentrate

- Pine oil ............................................... 0.20 lbs. / ton
- Sulphuric acid ...................................... to pH of 6.5

Bulk conditioner

- Potassium cyanide .................................. 2.0 lbs. / ton
- Zinc sulphate ...................................... 3.0 lbs. / ton
- Sodium carbonate .................................... 2.0 lbs. / ton
  (pH——8.0)
  Conditioning time——10 minutes
Lead-copper rougher

Potassium ethyl xanthate .................. 0.05 lbs. / ton
Aerofloat 31 ................................ 0.05 lbs. / ton
Pine oil ........................................ 0.05 lbs. / ton

Zinc rougher concentrate

Lime .............................................. to pH of 9.1
Copper sulphate .............................. 2.0 lbs. / ton
Potassium amyl xanthate .................... 0.05 lbs. / ton
Sodium Aerofloat ............................. 0.05 lbs. / ton

RESULTS OF ASSAY AND RECOVERIES

<table>
<thead>
<tr>
<th>Product</th>
<th>Wt. Gms.</th>
<th>Wt. %</th>
<th>Assay per cent (oz./ton)</th>
<th>Percent of total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Zn           Pb           Cu           Ag           Au           Zn           Pb           Cu</td>
<td></td>
</tr>
<tr>
<td>Fe Conc.</td>
<td>220.1</td>
<td>34.52</td>
<td>1.1          6.1          9.3</td>
<td>78.74 78.74 66.1</td>
</tr>
<tr>
<td>Zn R.</td>
<td>57.3</td>
<td>9.03</td>
<td>48.1         0.0          6.9</td>
<td>89.85 0.0 12.8</td>
</tr>
<tr>
<td>Zn Mids</td>
<td>12.9</td>
<td>2.02</td>
<td>5.7          1.8          5.1</td>
<td>2.52 1.40 1.29</td>
</tr>
<tr>
<td>Cu-Pb R.</td>
<td>29.2</td>
<td>4.60</td>
<td>0.0          11.5         17.7</td>
<td>0.0 19.86 16.75</td>
</tr>
<tr>
<td>Tails</td>
<td>317.5</td>
<td>49.83</td>
<td>0.0          0.0          0.3</td>
<td>0.0 0.0 3.06</td>
</tr>
<tr>
<td>Composite</td>
<td>637.0</td>
<td>100</td>
<td>6.8          3.4          2.3          3.1          0.1          100 100 100</td>
<td></td>
</tr>
</tbody>
</table>

Remarks:

The amount of potassium cyanide used is important, for if too little is used, sphalerite will float, and too much will depress
the copper-bearing minerals. The bulk concentrate should be cleaned before conditioning.

This test showed fairly good results. The pyrite concentrates contained only minor amounts of the valuable minerals. The zinc and the lead-copper concentrates showed a fair recovery. Only traces of zinc, lead, and copper were found in the tails, which indicates a good recovery. The test could be improved with a few adjustments of reagents and more careful control of flotation.
TEST NO. 10

Object: To improve the separations obtained in Test No. 9 by changing the amount of reagents used, and by cleaning the products.

Sample: 600 grams ground through 100 mesh.

Reagents:

Ball mill—nothing.

Conditioner

Lime................................................. 3.0 lbs. / ton
Copper sulphate...................................... 0.5 lbs. / ton

(pH—8.4; conditioning time, 3 minutes)

Bulk rougher concentrate

Potassium ethyl xanthate......................... 0.1 lbs. / ton
Pine oil............................................. 0.10 lbs. / ton

Bulk cleaner—nothing.

Pyrite concentrates

Sulphuric acid................................. to pH of 6.0
Potassium amyl xanthate....................... 0.1 lbs. / ton

Bulk conditioner

Potassium cyanide............................... 1.0 lbs. / ton
Zinc sulphate...................................... 1.5 lbs. / ton
Sodium carbonate............................... 2.0 lbs. / ton
Lead-copper rougher concentrate

Potassium ethyl xanthate .......................... 0.1 lbs. / ton
Cresylic acid ......................................... 0.05 lbs. / ton

Zinc rougher concentrate

Lime .......................................................... 2.0 lbs. / ton
Copper sulphate ......................................... 3.0 lbs. / ton
Pine oil ...................................................... 0.10 lbs. / ton
Potassium amyl xanthate ............................... 0.05 lbs. / ton
Sodium Aerofloat ......................................... 0.05 lbs. / ton

(Condition 5 minutes before adding frother)

RESULTS OF ASSAY AND RECOVERIES

<table>
<thead>
<tr>
<th>Product</th>
<th>Wt. Gr.</th>
<th>Wt. %</th>
<th>Assay per cent (oz./ton)</th>
<th>Percent of total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Zn Pb Cu Ag Au</td>
<td>Zn Pb Cu</td>
</tr>
<tr>
<td>Cu-Pb R.</td>
<td>21.3</td>
<td>3.68</td>
<td>2.7 8.1 19.2</td>
<td>2.6 40.4 19.3</td>
</tr>
<tr>
<td>Fe Concs.</td>
<td>215.9</td>
<td>32.44</td>
<td>0.8 5.8 4.9</td>
<td>7.2 26.2 44.8</td>
</tr>
<tr>
<td>Zn Concs.</td>
<td>23.2</td>
<td>5.42</td>
<td>52.2 0.0 4.5</td>
<td>76.7 0.0 6.6</td>
</tr>
<tr>
<td>Zn Mids.</td>
<td>20.0</td>
<td>5.53</td>
<td>36.8 0.0 11.7</td>
<td>3.3 0.0 10.6</td>
</tr>
<tr>
<td>Bulk Mids.</td>
<td>26.7</td>
<td>4.34</td>
<td>8.7 5.7 18.4</td>
<td>10.2 55.4 15.9</td>
</tr>
<tr>
<td>Tails</td>
<td>313.5</td>
<td>49.74</td>
<td>0.0 0.0 0.2</td>
<td>0.0 0.0 2.8</td>
</tr>
<tr>
<td>Composite</td>
<td>630.6</td>
<td>100</td>
<td>6.8 3.4 2.3 8.1 0.1</td>
<td>100 100 100</td>
</tr>
</tbody>
</table>
Remarks:

The test was an improvement on the preceding test. The pyrite concentrate showed less copper, lead, and zinc. The zinc concentrates contained only minor amounts of lead and copper. There was a considerable amount of lead and copper and a small amount of zinc in the lead-copper rougher concentrate. The tails were quite clean and showed a good recovery. The zinc middlings contained large amounts of zinc but this could be overcome with finer adjustments of the reagents.
SUMMARY

It was found that the ore under investigation could be separated by three different methods.

The first method depressed the sphalerite and galena by the use of sodium sulfite and sulfur dioxide gas and allowed the flotation of a copper concentrate which appeared to be very pure. Also, the depression of the galena was so effective that prior activation and flotation of the sphalerite was possible. The time of conditioning with sulfur dioxide was twenty or thirty minutes. This procedure, although somewhat successful, is not very practical because of the excessive quantity of sulfur dioxide gas required.

Subsequent tests were carried on with the idea of eliminating the sulfur dioxide gas. Since sphalerite may be activated with either copper or lead ions, cyanide was added to destroy the copper ion and sodium bisulfite was added to counteract the lead ion activation. This was the plan of attack, and the separation appeared very good. It was found that the shorter the conditioning time, the purer the recovered concentrate. The only reagent which would destroy the sphalerite inhibitor after this depression was potassium permanganate and because of this added expense, such treatment might be impractical.
The best process of recovery is to follow the initial idea in floating a bulk concentrate after depressing the pyrite by raising the pH.

Time did not permit making tests to reduce the amount of lead, copper, and zinc in the iron concentrates, but it is quite possible that addition of more collector to the bulk concentrate would overcome this obstacle.

The final method of separation involves the use of potassium cyanide and sodium carbonate. The sphalerite was effectively depressed and the lead and copper minerals were floated by the use of normal reagents, as shown in the results of the tests.

In the first seven tests tap water was used for grinding and flotation. Other and later work showed that a dissolved salt in the tap water seemed to cause marked activation of the sphalerite. The effect of this additional variable on the results presented is not known. The last two tests which were made using distilled water only in grinding and flotation, indicate that the normal flotation sequence will effect satisfactory separation between the minerals in the ore.

Due to a lack of time, the gold and silver content in the different flotation products could not be ascertained. The iron concentrates carry the gold and it was found that the tetrahedrite, which carried the silver, floated with the lead-copper concentrates.
CONCLUSIONS

1. The best separation is obtained in Test No. 10, by using potassium cyanide and sodium carbonate for the depression of sphalerite.

2. Sodium bisulfite will depress sphalerite and galena and allow the recovery of copper.

3. The tetrahedrite will follow the copper-lead minerals. This is apparently proven by Test No. 3.

4. In a research on the flotation of a complex ore, it is a good idea to ascertain those soluble agents within the ore which interfere with flotation when the customary reagents fail to act in the proper manner.

5. Further work is necessary for proper selection of reagents and amounts to be used to effect better separations than those given in this report.
FLOW SHEET

Ore Sample

Abbe Ball Mill (Distilled H₂O)

Oversize

-100 mesh

Flotation cell

Bulk concentrate

Pb-Cu-Zn

Flotation

Pb-Cu Conc.

Flotation

Pb Conc.

Cu Conc.

Pb-Cu-Zn Flotation

Tails (Fe)

Flotation

Pyrite Conc. (Au bearing)

Tails

Waste

Tails (Zn)

Flotation

Zn Conc.

Zn Mids
BIBLIOGRAPHY

2. "Quantitative Analysis", S. W. Hackemeyer.