Concentration by Flotation of a Complex Galena - Sphalerite - Chalcopyrite Ore from the Nine Mile District Near Missoula, Montana

Truxton J. Fisher

John L. Tokich

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CONCENTRATION BY FLOTATION OF A COMPLEX
GALENA - SPHALERITE - CHALCOPYRITE ORE FROM
THE NINE MILE DISTRICT NEAR MISSOULA, MONTANA

By
Truxton J. Fisher
and
John L. Tokich

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
April 30, 1943
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ACKNOWLEDGEMENT

The writers desire to take this opportunity to express their gratitude to Dr. S. R. E. Cooke for his able guidance and sincere cooperation.
INTRODUCTION

At the present time ore bodies being mined are becoming more and more complex in mineral association, thus presenting a more difficult problem in their concentration. Lead-zinc sulphide ores are among the more common ores which present such difficulties. An efficient separation of the minerals present in these ores is desirable because in lead concentrates zinc is a diluent for which the producer is penalized by the smelter, and likewise too much lead in zinc concentrates is undesirable both to the shippers and the buyers. Since in many cases, galena and sphalerite are so intimately locked as to prevent separation by selective mining, a process of preferential flotation must be used to separate these two minerals.

Concentration of a lead-zinc ore should present very few difficulties according to the prevailing theory of the separation of the minerals present. However, ores of this type frequently contain sufficient quantities of other minerals to such an extent that serious problems arise in obtaining satisfactory concentration.

The present report is based upon an investigation of the concentratability of a complex lead-zinc-copper ore from the "Lost Cabin" group of mining claims in the Nine Mile district near Missoula, Montana. The ore contains galena (PbS), iron bearing sphalerite, and chalcopyrite (CuFeS₂) as the economic minerals in a gangue composed chiefly of quartz (SiO₂), chlorite, and some pyrite (FeS₂). Silver is present to the extent of 4.1 oz.
per ton of ore and is associated with the galena.

Normally there should be no essential difficulty in separating galena from sphalerite by flotation. However, when a copper mineral is present, it frequently happens that copper ion is liberated on grinding, and in sufficient quantities to cause activation of the sphalerite. This "natural" activation necessitates the use of cyanide to depress the sphalerite, and, especially if much copper is in solution, a considerable cyanide consumption may be expected. Furthermore, an incipient state of oxidation of the galena will liberate lead ions which will permanently activate sphalerite and lower the efficacy of separation.

Earlier tests using standard procedures showed that the separation of galena from sphalerite and of chalcopyrite from these two minerals was not good, and the purpose of this investigation was to produce, if possible, high grade concentrates with correspondingly high recoveries, and to attempt to elucidate those factors causing poor separation.
FLOTATION

For flotation the surface properties of a mineral are changed in such a way as to render that surface more readily wetted by air than by water. This alteration is accomplished by reagents known as collectors. Collectors react with the surface of the mineral to give a compound which has this desired property. The mineral will then attach itself to an air bubble if given opportunity and will be carried to the surface of the flotation cell providing its mass is sufficiently small. At the present time the largest floatable particle is one not exceeding a size of approximately thirty-five mesh. The next step in flotation is to have a froth strong enough to hold ore particles which have been brought to the surface.

Differential flotation of an ore containing sphalerite, galena, and a copper sulphide presents a problem that cannot be solved by simple means. The first step in flotation is to grind the ore to a size where all the minerals are unlocked. The next stage is the addition of chemical reagents, each of which plays a specific role in changing the surface properties of the minerals present.

Using a xanthate as a collector, the slightly oxidized coating on the galena particles reacts to form a surface of lead xanthate.* This compound is very insoluble and is wetted by air rather than by water. Due to the ease with which this compound forms and its insolubility, galena is one of the easiest minerals to float.

Pure, unactivated sphalerite is one of the most difficult

* Ref. 5, P. 29
minerals to float. This may be attributed to the fact that the reaction product between the collector and the sphalerite surface is a highly soluble compound which readily dissolves, leaving the mineral in its original state of inactivation. However, sphalerite readily acquires from copper-bearing solutions a coating of coval-lite having a thickness of one or more atomic diameters, which renders it amenable to the action of common collectors. Highly oxidized lead sulphide will also activate sphalerite by furnishing lead ions. The properties of copper or lead-activated sphalerite are much the same as those of the sulphides of the activating ion in relation to its response to flotation collectors. The difficulties encountered in making a separation between galena, sphalerite, and a copper sulphide are therefore evident.

Chalcopyrite is readily floated with short chain xanthates such as ethyl xanthate. It is depressed by cyanide ion, but not as readily as copper activated sphalerite, and separation of these two minerals is normally based on this difference in behavior.
TECHNIQUE OF FLOTATION TESTING

A large sample of the ore was ground dry to minus ten mesh. Smaller samples, weighing 500 or 600 grams as the case might be and suitable for laboratory flotation tests, were then carefully cut from the original sample. These were then ground by stages to minus sixty-five mesh in an Abbe' pebble mill that was half filled with flint pebbles. This was done by grinding the entire sample for three minutes. The mill was then emptied and the ore wet screened on a sixty-five mesh screen. This preliminary grind formed new surfaces on all fine material in the original sample, thus making it more amenable to the action of the collector. The oversize was returned to the mill and ground for an additional twelve minutes, so that the grind was essentially through sixty-five mesh and ready for the flotation cell.

Flotation was effected in a Fagergren laboratory cell. Distilled water was used in both grinding and flotation. Regulation of the pH was done by the use of lime (Ca(OH)$_2$).

A visual examination of the flotation products showed whether separation of the galena and sphalerite was effective enough to warrant assays. Separation of the galena and sphalerite and finally of the chalcopyrite was not effected until the final test.

Lime was added as a five percent slurry. All other reagents except collectors and frothers were measured out by a pipette from five percent aqueous solutions. Collectors were pipetted from one percent solutions and frothers were added from dropping pipettes. The pH was measured on filtered pulp samples in a La Motte pH roulette.
All assays were made by the writers in partial fulfillment of the course. Assaying methods were conducted according to procedures outlined by L. W. Hartkemeier of the Colorado School of Mines.
Test 1.

Object: To determine the effect of 1.6 pounds of potassium cyanide per ton of ore in depressing the sphalerite and allowing the galena and chalcopyrite to float.

Sample: 600 grams ore.

Reagents:

<table>
<thead>
<tr>
<th>Lead Rougher Concentrates</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Potassium cyanide (KCN)</td>
<td>1.6 lb per ton</td>
</tr>
<tr>
<td>Potassium ethyl xanthate</td>
<td>0.1 lb per ton</td>
</tr>
<tr>
<td>Terpineol</td>
<td>0.05 lb per ton</td>
</tr>
<tr>
<td>Lime (Ca(OH)₂)</td>
<td>1.0 lb per ton</td>
</tr>
<tr>
<td>pH 8.4</td>
<td></td>
</tr>
</tbody>
</table>

Remarks:

The pulp was conditioned in the cell with potassium cyanide for ten minutes and then the material was floated. Nearly all sulphides except some of the pyrite floated, showing that the amount of potassium cyanide used had no effect upon depressing the sphalerite.
Test 2.

**Object:** To determine the effect of 3 pounds of potassium cyanide per ton of ore in depressing the sphalerite.

**Sample:** 600 grams ore.

**Reagents:**

<table>
<thead>
<tr>
<th>Ball Mill</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nothing</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Lead Rougher Concentrates</th>
</tr>
</thead>
<tbody>
<tr>
<td>Potassium Cyanide---------3.0 lb per ton</td>
</tr>
<tr>
<td>Potassium ethyl xanthate Z-3--0.1 lb per ton</td>
</tr>
<tr>
<td>Terpineol-----------------0.05 lb per ton</td>
</tr>
<tr>
<td>Lime----------------------1.0 lb per ton</td>
</tr>
<tr>
<td>pH 8.4</td>
</tr>
</tbody>
</table>

**Remarks:**

The ore from the mill was filtered, washed and floated. Conditioning time with the potassium cyanide was ten minutes. All sulphide material appeared in the lead rougher concentrates, showing that the potassium cyanide did not depress the sphalerite.
Test 3.

**Object:** To depress the sphalerite by using 6 pounds of potassium cyanide per ton of ore and float the lead and copper sulphides as a separate concentrate.

**Sample:** 600 grams ore.

**Reagents:**

- **Ball Mill**
  - Nothing

Lead Rougher Concentrates
- Potassium cyanide-----------------6.0 lb per ton
- Potassium ethyl xanthate Z-3-----0.1 lb per ton
- Terpineol------------------------0.05 lb per ton
- Lime-----------------------------0.5 lb per ton
- pH 8.6

**Remarks:**

The ground ore was filtered, washed and floated. Conditioning time with the potassium cyanide was ten minutes. The sphalerite reported in the lead roughers showing that it would not be depressed by the given quantity of potassium cyanide.
Test 4.

Object: To float the chalcopyrite and galena and attempt to depress the sphalerite by using 12 pounds of potassium cyanide per ton of ore.

Sample: 600 grams of ore.

Reagents:

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Ball Mill</td>
<td>Nothing</td>
</tr>
<tr>
<td>Lead Rougher Concentrates</td>
<td></td>
</tr>
<tr>
<td>Potassium cyanide</td>
<td>12.0 lb per ton</td>
</tr>
<tr>
<td>Potassium ethyl xanthate Z-3</td>
<td>0.1 lb per ton</td>
</tr>
<tr>
<td>Terpineol</td>
<td>0.05 lb per ton</td>
</tr>
<tr>
<td>Lime</td>
<td>0.5 lb per ton</td>
</tr>
<tr>
<td>pH</td>
<td>8.6</td>
</tr>
</tbody>
</table>

Remarks:

Procedure was identical to that of the previous tests. The potassium cyanide used did not depress the sphalerite.
Test 5.

Object: To attempt depression of the sphalerite by using potassium cyanide and a cleaning agent, aerosol O.T., while allowing the chalcopyrite and galena to float.

Sample: 600 grams ore.

Reagents:

**Ball Mill**
- Potassium cyanide----------1.6 lb per ton
- Aerosol O.T.---------------0.05 lb per ton
- Lime------------------------1.0 lb per ton

**Lead Rougher Concentrates**
- Potassium ethyl xanthate------0.05 lb per ton
- Terpineol----------------------0.05 lb per ton
- pH 8.4

Remarks:

Reagents were added to the grinding circuit in stages. The addition of terpineol seemed cause activation of the zinc sulphide, and was therefore discarded as a frother. An attempt was made to clean the lead rougher concentrates which contained some fine sphalerite. The cleaning operation was not successful.
Test 6.

Object: To allow the galena and chalcopyrite to float while attempting to depress the sphalerite by the use of potassium cyanide and a cleaning agent, aerosol O.T.

Sample: 600 grams ore.

Reagents:

<table>
<thead>
<tr>
<th>Ball Mill</th>
<th>Potassium cyanide</th>
<th>3.2 lb per ton</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Aerosol O.T.</td>
<td>0.5 lb per ton</td>
</tr>
<tr>
<td></td>
<td>Lime</td>
<td>2.0 lb per ton</td>
</tr>
</tbody>
</table>

| Lead Rougher Concentrates | Potassium ethyl xanthate | 0.05 lb per ton |
|                          | pH 8.4                |

| Zinc Rougher Concentrates | N Amyl alcohol | 0.1 lb per ton |

Remarks:

The reagents were added in stages to the grinding circuit. The lead rougher concentrates contained fine sphalerite. In an attempt to clean the roughers sodium silicate was added to the cell which gave a fairly good galena concentrate. The test was fairly successful and products was saved for assaying.
Test 7.

Object: To depress the sphalerite with potassium cyanide and aerosol O.T., while allowing the galena and chalcopyrite to float.

Sample: 500 grams ore.

Reagents:

Ball Mill
- Potassium cyanide-----------------1.6 lb per ton
- Aerosol O.T.-----------------0.05 lb per ton
- Lime---------------------------2.0 lb per ton

Lead Rougher Concentrates
- Potassium ethyl xanthate Z-3-------0.05 lb per ton

Zinc Rougher Concentrates
- Copper sulphate (CuSO₄·5H₂O)-------1.5 lb per ton
- Sodium aerofloat-----------------0.01 lb per ton
- Sodium aerofloat B----------------0.01 lb per ton
- Pine oil--------------------------0.05 lb per ton
- pH 8.8

Remarks:

A smaller sample was taken to reduce the pulp density and therefore make a lighter froth. The lead rougher concentrates were cleaned and the product was quite free of sphalerite. Copper sulphate was added to activate the sphalerite and the product was floated. An examination of the tails showed coarse particles of galena. This indicated that insufficient collector was used. The results however were very encouraging.
Test 8.

Object: To improve the results obtained in test No. 7.

Sample: 500 grams ore.

Reagents:

Ball Mill
Potassium cyanide-------------------1.6 lb per ton
Lime-----------------------------2.0 lb per ton
Aerosol O.T.---------------------0.05 lb per ton

Lead Rougher Concentrates
Aerofloat 31---------------------0.05 lb per ton
pH 9.1 to 8.1

Remarks:
All sulphides floated so the products were discarded and the test was discontinued. The pH was reduced by the addition of sulphuric acid. The reason for all sulphides reporting in the first flotation was most likely that the collecting properties of the aerofloat 31 were too powerful.
Test 9.

Object: To duplicate results obtained in Test No. 7.

Sample: 500 grams ore.

Reagents:

**Ball Mill**
- Potassium cyanide
- Aerosol O.T.
- Lime

**Lead Rougher Concentrates**
- Potassium ethyl xanthate

pH 8.1

Remarks:

Both lead and zinc sulphides were floated so no further separation was attempted.
Test 10.

Object: To duplicate Test No. 7.

Sample: 500 grams ore.

Reagents:

Ball Mill
Potassium Cyanide-------------------1.6 lb per ton
Lime---------------------------------1.0 lb per ton
Aerosol O.T.------------------------0.05 lb per ton

Lead Rougher Concentrates
Potassium ethyl xanthate----------0.05 lb per ton
pH 8.2

Remarks:

It was believed that too much collector was being added to the cell thus causing the sphalerite to float with the galena, so the amount of potassium ethyl xanthate was decreased and added in stages. The sphalerite continued to report in the lead rougher concentrates so the test was discontinued.
Test 11.

Object: To note the effects of a smaller amount of collector on depressing the sphalerite.

Sample: 500 grams ore.

Reagents:

Ball Mill
- Potassium cyanide----------------2.0 lb per ton
- Aerosol 0.T.---------------------0.05 lb per ton
- Lime-----------------------------2.0 lb per ton

Lead Rougher Concentrates
- Potassium ethyl xanthate---------0.05 lb per ton
  pH 9.6

Lead Cleaner Concentrates
- Potassium cyanide-----------------2.0 lb per ton

Remarks:

The potassium ethyl xanthate was added to the cell in stages and allowed to condition for five minutes. Flotation was carried out after the 0.025 lb per ton of xanthate was conditioned. The product contained most of the galena and a considerable amount of fine sphalerite. After another addition of an equal amount of xanthate which was allowed to condition for the same period of time flotation was carried out which gave a product containing most of the sphalerite and some galena. An attempt to clean the lead rougher concentrates by the addition of 2 pounds of potassium cyanide per ton of ore was not very effective.
Test 12

Object: To observe the depressing properties of sodium silicate.

Sample: 500 grams ore.

Reagents:

Ball Mill
- Potassium cyanide----------------2.0 lb per ton
- Aerosol O.T.---------------------0.05 lb per ton
- Lime-------------------------------1.5 lb per ton
- Sodium silicate------------------0.1 lb per ton

Lead Rougher Concentrates
- Sodium silicate------------------0.4 lb per ton
- Potassium ethyl xanthate---------0.025 lb per ton
- Potassium cyanide----------------2.0 lb per ton
- Lime-------------------------------1.5 lb per ton
- pH 9.2 to 8.6

Remarks:

Reagents were added in stages, the pH was taken up to depression of both galena and sphalerite. There was no selectivity of either mineral however when the critical pH range was reached. PH was then lowered back to the collection of the mineral, but there was still no selectivity. The pH was brought down to a plus or minus 4 and everything floated. Test discontinued.
Test 13.

**Object:** To try a bulk float of all sulphides and get a depression of the galena with potassium dichromate.

**Sample:** 500 grams ore.

**Reagents:**

- **Ball Mill**
  - Lime-----------------------------1.5 lb per ton

- **Bulk Sulphides**
  - Aerofloat 31----------------------0.05 lb per ton
  - Potassium ethyl xanthate-----------0.05 lb per ton
  - Cresylic Acid----------------------0.05 lb per ton

- **Zinc Rougher Concentrates**
  - Lime-----------------------------small amounts periodically
  - Acid dichromate-------------------5.0 lb per ton

**Remarks:**

The sphalerite and chalcopyrite were floated together with a small quantity of five galena. The lime was added periodically to build up the pH to a range where sphalerite would be depressed. "Slop tests" were conducted in preparation for test No. 14.
Test 14.

Object: To get a separation of chalcopyrite and galena by adjusting the pH.

Reagents:

**Ball Mill**
- **Lime**--------------------------1.5 lb per ton

**Bulk Concentrate**
- **Aerofloat 31**------------------0.05 lb per ton
- **Potassium Ethyl Xanthate**-----0.05 lb per ton
- **Cresylic Acid**-----------------0.05 lb per ton
- **pH 9.6**

**Bulk Cleaner Concentrates**
- **Lime**--------------------------1 lb per ton
- **pH 9.4**

**Zinc Rougher Concentrates**
- **Acid Dichromate**-----------------5 lb per ton
- **Potassium Ethyl Xanthate**-----0.05 lb per ton
- **Sulphuric Acid**-----------------5 drops

Remarks:

The chalcopyrite recovered at a pH of 9.6 contained fine sphalerite. The pH was then lowered to 7.05 and the sphalerite floated. Chalcopyrite in the cell was almost pure galena.

In the presence of dichromate the critical pH for sphalerite must be lower as it normally should be around 10.
Test 15.

Object: To obtain a separation of chalcopyrite and sphalerite.

Sample: 600 grams of ore.

Reagents:

- **Ball Mill**
  - Lime -------------------------- 1.5 lb per ton

- **Bulk Concentrates**
  - Aerofloat 31------------------ 0.05 lb per ton
  - Potassium Ethyl Xanthate------- 0.05 lb per ton
  - Cresylic Acid----------------- 0.05 lb per ton
  - pH 9.4

- **Bulk Cleaner Concentrates**
  - Lime-------------------------- 2.0 lb per ton
  - Amyl Xanthate----------------- 0.05 lb per ton
  - Potassium Ethyl Xanthate------- 0.05 lb per ton
  - Sodium Aerofloat B------------ 0.1 lb per ton
  - pH 5.15 to 11.15

- **Copper - Zinc Concentrate**
  - Potassium Cyanide------------- 1 lb per ton
  - Aerofloat 33------------------ 0.05 lb per ton
  - Sodium Aerofloat B------------ 0.1 lb per ton
  - Cresylic Acid----------------- 0.05 lb per ton
  - Acid Dichromate--------------- 5 lb per ton
  - pH 8 to 11.5

Remarks:

The pH in the copper-zinc concentrate was built up to 11.15 to depress the sphalerite, but this was not accomplished. Upon addition of the KCN everything was depressed. The attempt to separate the chalcopyrite and sphalerite was not very successful. The product from this test were assayed. (Table I)
<table>
<thead>
<tr>
<th>PRODUCT</th>
<th>WEIGHT, GRAMS</th>
<th>WEIGHT, PERCENT</th>
<th>ANALYSIS, PERCENT</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Zn</td>
<td>Cu</td>
<td>Pb</td>
</tr>
<tr>
<td>Tailings</td>
<td>296</td>
<td>50.5</td>
<td>1.71</td>
</tr>
<tr>
<td>Bulk Cleaner Middlings</td>
<td>74</td>
<td>12.7</td>
<td>3.07</td>
</tr>
<tr>
<td>Lead Conc.</td>
<td>143.5</td>
<td>24.5</td>
<td>13.72</td>
</tr>
<tr>
<td>Copper Zinc Bulk Middlings</td>
<td>21.0</td>
<td>3.6</td>
<td>3.99</td>
</tr>
<tr>
<td>Copper Zinc Conc.</td>
<td>51.2</td>
<td>8.7</td>
<td>36.97</td>
</tr>
<tr>
<td>Composite</td>
<td>583.7</td>
<td>100.0</td>
<td>7.94</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>PRODUCT</th>
<th>DISTRIBUTION, PERCENT</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Zn</td>
</tr>
<tr>
<td>Tailings</td>
<td>10.8</td>
</tr>
<tr>
<td>Bulk Cleaner Middlings</td>
<td>4.34</td>
</tr>
<tr>
<td>Lead Conc.</td>
<td>42.2</td>
</tr>
<tr>
<td>Copper Zinc Bulk Middlings</td>
<td>1.76</td>
</tr>
<tr>
<td>Copper Zinc Conc.</td>
<td>40.4</td>
</tr>
</tbody>
</table>
Test 16.

Object: To make a separation of chalcopyrite and sphalerite by the use of potassium cyanide.

Sample: 600 grams ore.

Reagents:

<table>
<thead>
<tr>
<th>Conditioning</th>
<th>Lime</th>
<th>1.0 lb per ton</th>
</tr>
</thead>
<tbody>
<tr>
<td>Zinc sulphate</td>
<td></td>
<td>1.0 lb per ton</td>
</tr>
<tr>
<td>Potassium cyanide</td>
<td></td>
<td>1.0 lb per ton</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Lead Rougher Concentrates</th>
<th>Potassium Ethyl Xanthate</th>
<th>0.05 lb per ton</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Pine oil</td>
<td>0.05 lb per ton</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Zinc Conditioning</th>
<th>Copper sulphate</th>
<th>4.0 lb per ton</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Zinc Rougher Concentrates</th>
<th>Potassium Amyl Xanthate</th>
<th>0.05 lb per ton</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Sodium Aerofloat</td>
<td>0.05 lb per ton</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Zinc Cleaner Concentrate</th>
<th>No Reagents</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Lead Cleaner Concentrate</th>
<th>No Reagents</th>
</tr>
</thead>
</table>

Remarks:

Dr. S. R. B. Cooke ran this test. The sample was filtered after it was ground to -65 mesh and the residue placed in the flotation cell. This test was the basis for Test No. 17. The products were not assayed but the separation appeared complete.
Test 17.

Object: To make a separation of chalcopyrite and sphalerite by employing potassium cyanide.

Sample: 600 grams ore.

Reagents:

**Conditioning**
- Lime-----------------------------1 lb per ton
- Zinc nitrate---------------------1 lb per ton
- Potassium cyanide----------------1 lb per ton

**Lead Rougher Concentrates**
- Potassium Ethyl Xanthate---------0.05 lb per ton
- Pine oil--------------------------0.05 lb per ton

**Zinc Conditioning**
- Copper sulphate-----------------4.0 lb per ton

**Zinc Rougher Concentrates**
- Potassium Amyl Xanthate---------0.05 lb per ton
- Sodium Aerofloat-----------------0.05 lb per ton

**Lead Cleaner Concentrate**
- Pine oil-------------------------0.025 lb per ton

**Zinc Cleaner Concentrate**
- Pine oil-------------------------0.05 lb per ton

**Copper Rougher Concentrate**
- Potassium dichromate-------------5.0 lb per ton
- Potassium Ethyl Xanthate---------0.05 lb per ton
- Pine oil-------------------------0.05 lb per ton

Remarks:

This test was identical to Test No. 16. The separations appeared to be quite complete and satisfactory. Assays of the products were made. (See Table II)
## TABLE II

Results of Test 17

<table>
<thead>
<tr>
<th>PRODUCT</th>
<th>WEIGHT, GRAMS</th>
<th>WEIGHT, PERCENT</th>
<th>ANALYSIS, PERCENT</th>
<th>PERCENT</th>
<th>ASSAY, OZ/TON</th>
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</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Fe</td>
<td>Zn</td>
<td>Pb</td>
</tr>
<tr>
<td>Lead Cleaner</td>
<td>106.3</td>
<td>18.4</td>
<td>1.99</td>
<td>3.17</td>
<td>58</td>
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<tr>
<td>Conc.</td>
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<tr>
<td>Lead Middlings</td>
<td>35.6</td>
<td>6.16</td>
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<td>7.07</td>
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<tr>
<td>Lead Rougher</td>
<td>141.9</td>
<td>24.56</td>
<td>2.00</td>
<td>4.15</td>
<td>43.5</td>
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<tr>
<td>Zinc Cleaner</td>
<td>99.2</td>
<td>17.2</td>
<td>11.1</td>
<td>34.6</td>
<td>0.0</td>
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<td>Conc.</td>
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<td></td>
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<tr>
<td>Zinc Middlings</td>
<td>30.2</td>
<td>5.22</td>
<td>9.96</td>
<td>0.0</td>
<td>0.0</td>
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<td>Zinc Rougher</td>
<td>129.4</td>
<td>22.42</td>
<td>10.9</td>
<td>26.5</td>
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</tr>
<tr>
<td>Copper Rougher</td>
<td>20.3</td>
<td>3.52</td>
<td>10.7</td>
<td>20.22</td>
<td>10.05</td>
</tr>
<tr>
<td>Conc.</td>
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<td></td>
<td></td>
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</tr>
<tr>
<td>Tailings</td>
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<td>49.5</td>
<td>16.95</td>
<td>0.0</td>
<td>0.0</td>
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<tr>
<td>Composite</td>
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<td>100</td>
<td>11.7</td>
<td>7.92</td>
<td>11.09</td>
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<table>
<thead>
<tr>
<th>PRODUCT</th>
<th>DISTRIBUTION, PERCENT</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>Fe</td>
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<tr>
<td>Lead Rougher</td>
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<tr>
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<td>Zinc Rougher</td>
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<td>Copper Rougher</td>
<td>3.22</td>
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<tr>
<td>Conc.</td>
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<tr>
<td>Tailings</td>
<td>71.80</td>
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</table>
SUMMARY OF FLOTATION TESTS

The first four tests were performed by the standard procedure using potassium cyanide as a depressant for the sphalerite. Potassium ethyl xanthate (Z-3) was used as the collector and terpineol as the frother. Increasing amounts of cyanide were added in an attempt to depress the zinc sulphide but all amounts were ineffective in obtaining this depression. This tends to indicate either that the cyanide was not dissolving the activating copper or that the sphalerite was being activated through some other source which would not be affected by the cyanide.

The second set of tests (Nos. 5 to 12 inclusive) was based upon the assumption that the cyanide was not given opportunity to attack the copper coating and dissolve it. To counteract this difficulty aerosol O.T. was added to the grinding circuit as a cleansing agent to give the cyanide a clean surface to work on. In conducting these tests it was noted that the terpineol was causing collection of the zinc sulphide so its use as a frother was discontinued and the aerosol O.T. alone was employed as a frother. In one case, Test No. 7, results were obtained which were highly encouraging. Unfortunately this test was apparently not reproducible through some unknown factor. These last results led to tests made with stage additions of small quantities of collector during flotation (Tests 10 to 12 inclusive).

Since it was apparently impossible to obtain satisfactory depression of the sphalerite by the means employed another group of tests was conducted to produce a bulk product of the economic
sulphide minerals present (Test 13 to 15 inclusive). Potassium dichromate was employed to depress the galena from the cleaned bulk concentrates. This permitted the sphalerite and chalcopyrite to float together leaving a galena concentrate in the cell. Results were obtained which gave a fairly good galena concentrate, but since a separation between the sphalerite and chalcopyrite could not be made this method was abandoned.

In the last two tests (Nos. 16 and 17) a satisfactory separation was effected between the various minerals in the ore. Normal flotation sequence was employed, lime, cyanide and zinc sulphate being used to depress the sphalerite and the pyrite. On adding potassium ethyl xanthate and frother a bulk lead-copper concentrate readily floated. It contained a little zinc. The sphalerite was next floated by activating with copper sulphate and adding amyl xanthate and sodium aerofloat. The tailings from this procedure were clean containing no lead or zinc and only 0.05 percent copper. The bulk lead-copper concentrate was refloated, the lead being depressed with dichromate. A low grade copper concentrate floated, carrying 64.8 percent of the total copper in the ore and assaying 13.85 percent copper. This copper rougher concentrate could undoubtedly be cleaned, recleaned and graded up satisfactorily.

The lead concentrate was high grade, contains only 3.17 percent zinc and represents a 96.3 percent lead recovery. The zinc cleaner concentrate represents a 77.5 percent zinc recovery but contains only 34.6 percent zinc. Further cleaning, with addition of lime would undoubtedly reject pyrite and give a satisfactory zinc concentrate.
CONCLUSION

Results of this investigation indicate that zinc ion is apparently essential to the satisfactory depression of sphalerite in the presence of cyanide. Activation, according to some writers, can be prevented by adding a salt of the ion that becomes displaced from the solid surface during activation. However this matter has not been investigated. It is known that for each mineral there is a "critical cyanide ion concentration" above which flotation is impossible and below which flotation is possible. Since the function of alkalis is undoubtedly to fix the cyanide ion concentration, it seems possible therefore, that zinc sulphate may act similarly.
BIBLIOGRAPHY