INVESTIGATION TO CONTROL MINE DUST USING SURFACTANTS AND A NEW APPROACH FOR ELIMINATING THEIR NEGATIVE EFFECT ON FLOTATION

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ABSTRACT

The possibility of using surfactants as wetting agents for the suppression of sulphide ore dust has been investigated. Numerous surfactants were examined to determine their characteristics and to investigate their ability to improve the wetting of the sulphide ore dust.

However, the surfactants selected as potential dust suppressors proved to have a negative effect on the flotation results of the ore contaminated with such reagents.

An investigation carried out to eliminate this drawback succeeded in developing a technique by which the detrimental influence of the surfactants was eliminated. The method consisted of adsorbing the surfactants on activated carbon and separating the carbon from the ore prior to flotation.

The technique which has been proved to work even under excessive addition of surfactants is simple and requires minimal changes in the plant flowsheet.

A full scale investigation is under way.

1 Canada Energy, Mines and Resources - CANADA
I INTRODUCTION

Dust measurements in mines clearly indicated (1,2) that the major mineral dust exposure is due to loading and transport of the ore from the mining areas. One approach to the solution of this dust problem is the application of water sprays to reduce dust dispersion. Wetting of broken rock is very effective in preventing fine dust from becoming airborne by binding it to the larger lumps. Experiments have shown that most common rocks are readily wetted by water. However, the dust originating from sulphide minerals exhibits an inherent hydrophobicity that makes water spreading on the surface of the particles more difficult, creating problems in dust suppression.

The surfactants are known to be able to reduce the surface tension of the water, facilitating the wetting and the suppression of the sulphide ore dust, but on the other hand the flotation of the sulphide ore is susceptible to interference by surfactants.

A laboratory study was initiated to examine the effects of surfactants on the wetting of sulphide ore dust.

Numerous surfactants were investigated for their properties and ability to suppress dust and some of them were selected as suitable sulphide dust suppressors.
However, further testwork indicated that the presence of the wetting agents in the ore, adversely affected the efficiency of minerals separation in the flotation process.

Then a research program began to study the possibility of eliminating the detrimental effect of the surfactants on flotation results.

Several possibilities were explored and finally a technique was developed by which the surfactants used as dust suppressors were adsorbed on activated carbon and removed from the slurry prior to the flotation process.

This presentation covers the results of the investigation carried out to select suitable surfactants as potential dust suppressors and to annihilate their negative effect on flotation.

II EXPERIMENTAL MATERIALS

I. Ore sample

A sample of copper sulphide ore from Opemiska Division of Falconbridge Company was used for selecting suitable wetting agents as potential sulphide dust suppressors. The sample also served to investigate the surfactants influence on copper flotation and to develop the technique for surfactants removal prior to the mineral extraction process.
The head assay of the sample is given in Table I.

Table I. Head assay

<table>
<thead>
<tr>
<th>Element</th>
<th>Pb</th>
<th>Cu</th>
<th>Zn</th>
<th>S</th>
<th>Fe</th>
<th>SiO₂</th>
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<td>0.08</td>
<td>5.27</td>
<td>15.98</td>
<td>41.83</td>
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</tbody>
</table>

The sample was crushed to -12 mm and part of it was screened on 37 micrometer sieve. The -37 μm fraction represented the dust product which was used in the testwork. The other part of the sample was employed for flotation experiments.

2. Wetting agents

A large number of surfactants were received for this investigation.

G.A.F. supplied modified linear aliphatic polymers of non-ionic type under the commercial name of Antarox.

Cyanamid offered sodium dioctyl sulphosuccinate surfactants of anionic type from the Aerosol series.

Canada Packers gave the Sterling surfactants: a phenol polyglycol ether of non-ionic type, a sodium sulphonate of anionic type and a cationic surfactant in an emulsion form.
Armak supplied some polyethylene glycol esters of non-ionic type. Bate chemical offered an anionic surfactant and C.I.L. of WITCO Corporation gave the Coherex a dust retardant.

Dow Corning offered a large number of silicone glycol type surfactants in the experimental stage.

Finally Alchem Inc., supplied some non-ionic and anionic polyelectrolyte surfactants.

3. Activated carbon

The carbon used to adsorb and eliminate the surfactants from the ore prior to flotation was procured from Calgon Canada. The product used in this investigation was an activated carbon known as SGL 8 x 30 obtained from bituminous coal.

III RESEARCH WORK

The research work initiated to improve the dust control in sulphide ore mines by the use of surfactants was carried out in three successive phases:

1. Selection of suitable wetting agents;
2. Determining the effect of surfactants on flotation;
3. Investigation to eliminate the surfactants negative effect.
1. Experiments to evaluate the surfactants properties

The wetting agents were examined for their ability to act as sulphide ore dust suppressors. The most suitable surfactants were selected on the basis of the following tests and determinations:

a. Wetting ability

The most important criterion in selecting suitable surfactants was based on their wetting properties which reflected the ability of these agents to act as dust suppressors.

The laboratory method used to determine the surfactants wetting ability consisted in allowing a measured quantity of sulphide ore dust, spread at the surface of the reagent solution contained in a 500 mL beaker, to get wet and descend to the bottom of the vessel. The efficiency of the wetting action was evaluated on the basis of the ore sinkage rate, expressed in mg/s and determined as the required time in seconds, for wetting and sinking a quantity of 1000 mg sulphide ore dust spread on the surface of the reagent solution (Fig. 1). The sinkage rate for fast wetting agents reached 1000 mg/s while sinkage rate of the same dust in ordinary water was less than 1 mg/s.
b. Foaming

Excessive and/or persistent foam produced by the surfactants when mixed with water is an undesirable condition for dust suppression and further processing of the ore in the mill. The presence of excessive foam impedes a good spreading of the wetting agents on the surface of the fine particles reducing thus the efficiency of dust suppression. Also the frothy wetting agents could adversely affect the selectivity in the mineral separation process.

The surfactants foaming power was evaluated on the basis of foam maximum volume and foam persistency. These indices of selection were determined by measuring at various time intervals the volume of the foam produced by shaking a surfactant solution in a graduated test tube. (Fig. 2).

c. Other criteria of selection

Solubility of the surfactants at ambient temperature and the requirement of special precautions in handling, storage or operating with these reagents were other factors taken into account in selecting suitable dust-suppressors.
2. Selection of potential dust-suppressing agents

The most significative results of the experiments carried out to evaluate the surfactants as potential dust suppressors are given in Table 2.

A final selection of the most suitable wetting agents was made on the basis of surfactants response to various testing conditions. The required mark to pass a test was in most of the cases arbitrarily chosen, dictated by the performances of the majority of the reagents with the intention to eliminate those that gave the most inferior results.

For instance, the acceptability limit for sinkage rate was set at 500 mg/s and maximum foaming conditions were accepted when initial foam: solution volume ratio was 3:1 or lower. Also, poor solubility or toxic characteristics of the surfactants were other reasons for eliminating some of the reagents from further testing.

The following surfactants were selected to be further examined: Sterling NP-10, Aerosol OTS, DOW E5753-11-1, BL-214 and 8A04.

3. Effect of wetting agents on flotation results

A sample of Opemiska copper ore was used to examine, in laboratory scale, the influence of the dust-suppressing surfactants on the flotation results.
To simulate the exposure of the ore to the wetting agents used as dust suppressors, the surfactants were added to the dry sample prior to the grinding stage. Solution of 2% wetting agents was used in the amount varying from 2.5 to 50 L solution per tonne of ore. About 10 L/t is considered an adequate spray to suppress the dust in an underground mine.

After grinding, the slurry containing the surfactants was transferred to a flotation cell and the copper flotation was performed under the conditions similar to those employed in the industrial plant. The flotation results with and without surfactants addition were then compared.

To simplify the testwork the copper flotation was limited to an open rougher-scavenger circuit, the rougher concentrate representing the final copper product.

The grinding and the type of flotation reagents used in this testwork were similar to those employed in Opemiska concentrator.

A summary of the most significative flotation results (Cu grade and recovery in the rougher concentrate) obtained in the presence of surfactants are presented in Table 3.

When no surfactants were used the results of the flotation for the rougher concentrate were:

- Assay: 24.73% Cu
- Recovery of copper: 95.3%
All the surfactants tested on Opemiska ore had a detrimental effect on copper flotation, by drastically reducing the grade of the concentrate. The negative effect on flotation results increased with the amount of surfactant solution sprayed on the ore sample.

The deterioration of the concentrate grade was attributed to the excessive amount of froth produced by the surfactants. This has made the slimes and some gangue minerals to become entrained in the froth and float along with the copper minerals, reducing the Cu content of the concentrate. It may also be possible that during the grinding and conditioning the surfactants have been indiscriminately adsorbed at the surface of the minerals (copper carriers and gangue) interfering with the selective adsorption of the collectors.

Since the surfactant 8M04 manufactured by Alchem Inc. affected the flotation results to a lesser extent than the others it was decided to use this reagent for the research work aimed to eliminate the detrimental influence of the surfactants-dust-suppressors on flotation.

4. Investigation to annihilate the negative effect of the wetting agents on flotation

Research work to eliminate the adverse effect of the surfactants on Opemiska ore flotation was initiated pursuing various lines of investigation.
The adjustment of the flotation reagents, particularly the frother, was tried to compensate for the foaming effect of the surfactants. Although the amount of froth was reduced to certain extent, no improvement of the copper concentrate was obtained. Therefore, this line of investigation was abandoned.

The manufacturers of the selected surfactants were contacted to investigate possible conditions for surfactants destruction after their use as dust suppressors. No positive response has been received yet on this route of investigation.

Since these two routes of investigation could not provide a method to restore the grade of the flotation concentrate in the presence of the surfactants, the research work was directed toward finding means to remove the wetting agents from the slurry, before the addition of the flotation reagents.

The investigation conducted in this direction succeeded in developing a technique by which the wetting agents could be removed from the slurry by adsorption on activated carbon. By applying this procedure the detrimental effect of the wetting agents was annihilated.

The conditions and results of this testwork are further described.

A. Carbon adsorption procedure

The concept of removing the surfactants sprayed on the ore by using the carbon adsorption technique was based on the
idea that organic matters can be adsorbed on certain types of activated carbon. If the surfactants-contaminated ore is put in contact with activated carbon, the wetting agents which are organic chemicals can be adsorbed on carbon. Then, the carbon loaded with surfactants can be removed and the decontaminated ore will be further processed without difficulty.

The developing of carbon adsorption technique for surfactants removal required detailed study of several conditions; e.g. type of activated carbon, addition point, amount of carbon and contact time, method of carbon removal, etc.

To find a proper brand of carbon for this application a search of the various types of activated carbon available on the market was conducted. Several carbon manufacturers were contacted and the final choice was based on products specifications and recommended usages.

The place of carbon addition and removal was carefully examined to avoid possible adsorption of the flotation reagents of organic composition. For this reason, in most of the tests the carbon was kept in contact with the ore and removed from the slurry prior to the addition of flotation organic reagents (collector and frother).

The surfactants adsorption was examined under two conditions: carbon addition in the grinding stage and after grinding.
When carbon was added in the grinding mill it was ground with the ore, the surfactants adsorption took place during grinding and the carbon was recovered by flotation in the copper concentrate. It was not possible to selectively float the carbon from the copper.

In another series of tests the carbon was added after grinding and was kept in contact with the ore in a conditioning stage for certain amounts of time. The surfactants adsorption took place in the conditioning stage. After that the carbon which was much coarser than the ground ore was separated from the slurry by screening. The surfactants-decontaminated slurry was then conditioned with flotation reagents and the copper concentrate was collected.

The addition of carbon after grinding was the preferred route to obtain the adsorption of surfactants since in this way the carbon can be recuperated and reused.

Therefore, more detailed investigation to determine the optimum carbon addition and contact time was carried out with carbon added after the grinding stage. Various additions of carbon from 1 to 20 kg carbon/tonne of ore was tried, under conditioning time of 15 min to 2 h. The conditioning stage was performed at low rpm to avoid carbon destruction by attrition and abrasion.

The technique of surfactants adsorption using two variants of carbon addition is briefly described below. (Fig. 3).
- The ore was sprayed with a 2% solution of surfactant, in the amount of 10±50 L/t, to simulate the exposure of the mined ore to dust suppressors.
- The contaminated ore was placed in the grinding mill and the grinding was performed under usual conditions.
- The ground ore was transferred to a conditioner and the carbon was added in the amount of 1 to 20 kg/t. The contact time between carbon and slurry was maintained for 15 min to 2 h under low rpm to reduce carbon degradation.

After conditioning, the carbon loaded with surfactant was removed by screening on a 425 μm screen. As a precaution, to avoid the possible presence of few coarse ore particles in the carbon, the ground ore was screened on 425 μm before conditioning with activated carbon. The surfactant-decontaminated slurry was transferred to a flotation cell, the flotation reagents were added and copper flotation was performed as usual.

### B. Results

Detailed testwork carried out in the recoverable carbon variant focused on investigating the influence of two parameters: amount of carbon addition and contact time.

Summary of the work conditions and results are given in Table 4.
The results of these tests indicated that a certain relationship between carbon addition and contact time must exist in order to annihilate the surfactants negative effect and to restore the copper grade and recovery in the flotation concentrate.

For each carbon addition an optimum conditioning time was determined, conditions under which the copper grade and recovery in the flotation concentrate were similar to those obtained when no surfactant was sprayed on the ore. To annihilate the negative effect of surfactants the following relationship between carbon addition and contact time was established.

Carbon addition of 5 g requires 90 min contact time
Carbon addition of 7 g requires 60 min contact time
Carbon addition of 10 g requires 45 min contact time
Carbon addition of 20 g requires 15 min contact time

The relationships between carbon addition and losses versus contact time were plotted in Fig. 4. The carbon loss by abrasion, during various conditioning times was very low (1.2% or less).
The carbon addition and contact time were inversely related. The same efficiency in surfactant adsorption could be obtained by using a small amount of carbon for a long conditioning time or a large carbon addition for a short contact time.

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However, the carbon loss was in direct relation with the duration of contact time. Since carbon can be recovered and reused it was considered more important to minimize the carbon loss rather than the carbon addition. Therefore the selected conditions were: 20 kg/t carbon addition for 15 minutes contact time. Under these conditions carbon loss was insignificant.

Also, it should be noted that the required amount of carbon and contact time to annihilate the negative effect of surfactants was determined under excessive addition of wetting agents, i.e., 50 L, solution 2%, per tonne or ore. However, a more realistic spray of wetting agents to suppress dust would be only 10 L/t.

Several tests were carried out to determine the required carbon addition to annihilate a surfactant spray of 10 L/t. The contact time for all these tests were kept to a minimum.

A summary of the results is presented in Table 5.
Table 5 - Results using 10 L/t surfactant spray

<table>
<thead>
<tr>
<th>Contact Time</th>
<th>Carbon Added, kg/t</th>
<th>Flot. rougher conc.</th>
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</thead>
<tbody>
<tr>
<td>minutes</td>
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<td>Weight % Cu</td>
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<tr>
<td>15</td>
<td>20</td>
<td>17.4</td>
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<tr>
<td>15</td>
<td>10</td>
<td>19.9</td>
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<tr>
<td>15</td>
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<td>15</td>
<td>1</td>
<td>21.8</td>
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</table>

The data of this series of tests showed that under 10 L/t surfactant spray even 1 kg/t carbon addition was enough to decontaminate the ore and to restore the copper grade in the flotation concentrate. The carbon loss for 1 kg/t addition and 15 minutes contact was undetectable.

Another important element to be considered, in minimizing the cost of surfactant use for dust control and surfactant decontamination before flotation is the possibility of reducing the wetting agent concentration in the spray solution below 2%. For practical purpose the surfactant removal testwork was carried out using 2% solution of wetting agent. However, the tests performed to determine the ability of the surfactants to suppress dust indicated that for selected agents, the dust suppressing efficiency remained unchanged under various solution concentration down to 0.1%.

The optimum concentration of surfactants in the water spray for dust suppression will actually be determined during the experiments that will be carried out in underground mines.
It is obvious that a decrease in surfactant concentration or in the amount of solution spray will result in a corresponding reduction of the cost to annihilate the negative effect of the wetting agents.

**IV. CONCLUSIONS**

The research work dealing with the influence of dust-suppressing surfactants on flotation results of Opemiska copper ore led to the following conclusions:

1. Among the wetting agents examined several surfactants were selected as potential dust suppressors.
2. Surfactants used as wetting agents adversely affected the flotation results, particularly the concentrate grade.
3. A carbon adsorption technique could eliminate the detrimental effect of the surfactants and restore the concentrate grade, even when excessive amounts of wetting agents were used.
4. Under standard spraying conditions to suppress the dust (10 L solution/t of ore and 2% solution concentration) an addition of 1 kg activated carbon/tonne of ore for 15 min contact time was required to adsorb the surfactants and eliminate their detrimental effect on flotation results. The carbon loss was insignificant.
5. The process to eliminate the surfactants by adsorption on activated carbon is very simple and requires
minimal changes in the plant flowsheet. A carbon adsorption unit has to be inserted between grinding and flotation. Also, to regenerate the carbon a kiln must be installed in the plant.

The finding of surfactants that can be used as efficient dust suppressors in sulphide ore mines and the success of the carbon adsorption technique to eliminate the detrimental effect of the wetting agents on flotation, has opened wide the field of investigation to use wetting agents for better dust control in underground sulphide ore mines.

REFERENCES

1. G. Knight "Dust production and control in mines"; CANMET Report 80-23; Elliot Lake Laboratory, CANMET, Energy, Mines and Resources Canada; 1980.

2. R.J. Hamilton and G. Knight "Laboratory studies of the suppression of dust from broken coal and shale"; Int J - Rock Mechanics, Mining Science 1:105; 1963.


<table>
<thead>
<tr>
<th>Surfactant</th>
<th>Sinkage</th>
<th>Foaming</th>
<th>Solubility</th>
<th>Safety</th>
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<tr>
<td>Product Name</td>
<td>Surf. Conc. %</td>
<td>Rate mg/s</td>
<td>Surf. Conc. %</td>
<td>Foam:Sol'n mL Ratio Initial</td>
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<td>8</td>
<td>2.0</td>
<td>1:20</td>
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<td>Tergitol 08</td>
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<td>3</td>
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<td>2:20</td>
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<tr>
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Table 3 - Summary of flotation results in the presence of surfactants

<table>
<thead>
<tr>
<th>Surfactant</th>
<th>2.5 L/t Assay</th>
<th>2.5 L/t % Cu</th>
<th>2.5 L/t % Recovery</th>
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<th>5.0 L/t % Cu</th>
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Table 4 - Summary of conditions and results, carbon addition after grinding

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<tr>
<th>Carbon Amount</th>
<th>Contact min.</th>
<th>CU rougher concentrate</th>
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<th>Assay % Cu</th>
<th>% Dist. Cu</th>
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Fig. 1 Determining surfactants sinkage rate.

Fig. 2 Determining surfactants foaming power
Figure 3  SURFACTANT ADSORPTION AND REMOVAL

Ore sprayed with surfactant solution

GRINDING

Conditioning and surfactant adsorption on carbon

REMOVAL of CARBON

FLOTATION

Carbon loaded with surfactant

Concentrate

Tailings

Ground ore

Activated carbon

425 μm
Figure 4  CARBON ADDITION AND LOSS vs CONTACT TIME

Legend:
Carbon addition vs contact time:
Carbon loss vs contact time: