RESPONSE OF AN INDUSTRIAL COAL FLOTATION CIRCUIT TO 
CHANGING REAGENT DOSAGES

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ABSTRACT

A number of on-stream coal slurry analyzers are presently being developed and commercialized for measuring ash and solids in coal process streams, particularly around flotation circuits. The eventual goal of these efforts is to develop on-line quality control systems for flotation circuits and other fine-coal cleaning operations. As part of this on-line monitoring and control effort, it is important to gain a better understanding of the response of industrial flotation circuits to changing operating conditions.

This paper summarizes the results from a detailed sampling program performed at an industrial coal flotation circuit in western Pennsylvania. The testing focused on evaluating the response of the circuit to changes in reagent dosages, operating conditions and feed compositions. The testing indicated that it is desirable to maintain high collector-to-frother ratios to enhance coarse particle flotation. The recovery of fine impurity particles was also proportional to water recovery, due to hydraulic entrainment.

\textit{Key words:} Industrial, Coal, Flotation, Circuit, Reagent, Response.

INTRODUCTION

Froth flotation is the principal method of cleaning fine (minus 150 \( \mu \text{m} \)) coal particles in industrial coal preparation plants. In recent years, a number of advanced flotation machines (i.e., flotation columns, air-sparged hydrocyclones, and the Jameson Cell) have been commercialized and are being implemented at a number of industrial preparation plants, particularly in Australia and the eastern United States. (Manlapig et al., 1993; Drummond et al, 1994; Davis, 1993; Kawatra and Eisele, 1993; Eisele and Kawatra, 1994a,b)) However, banks of conventional, mechanically-agitated cells continue to be the most common industrial flotation circuit equipment.

The emphasis on more fine-coal cleaning applications, coupled with the development of on-stream coal slurry analyzers (Kawatra, 1993), has increased efforts to better understand the behavior of industrial coal flotation circuits; both to optimize their performance and develop systems for on-line process control. This paper summarizes the primary results from a detailed sampling program conducted on an industrial coal flotation circuit to assess the impacts of key operating variables on circuit performance. The study was unique in that it:
was performed over a two-month period under eleven different daily test conditions (i.e., reagent dosages and feed compositions);

assessed the flotation performance of the circuit, by size, for the various size fractions being upgraded (500 µm x 150 µm, 150 µm x 45 µm, and 45 µm x 0); and

determined the performance around the individual cells within the four cell circuit through extensive froth and pulp sampling, coupled with the use of a material balance computer program.

The results from studies, such as this one, can form the basis for flotation optimization and control strategies.

**TABLE 1: Run-of-Mine Coal Compositions for Mines 1 and 2.**

<table>
<thead>
<tr>
<th>Size Fraction</th>
<th>Weight (wt%)</th>
<th>Ash (wt%)</th>
<th>Sulfur (wt%)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Mine #1: Upper Freeport Seam</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Top x 76 mm</td>
<td>2.9</td>
<td>65.5</td>
<td>0.81</td>
</tr>
<tr>
<td>76 mm x 32 mm</td>
<td>15.6</td>
<td>52.1</td>
<td>1.00</td>
</tr>
<tr>
<td>32 mm x 19 mm</td>
<td>14.3</td>
<td>39.8</td>
<td>1.30</td>
</tr>
<tr>
<td>19 mm x 9.5 mm</td>
<td>35.5</td>
<td>30.5</td>
<td>1.50</td>
</tr>
<tr>
<td>9.5 mm x 500 µm</td>
<td>24.2</td>
<td>28.9</td>
<td>1.77</td>
</tr>
<tr>
<td>500 µm x 100 µm</td>
<td>5.8</td>
<td>27.1</td>
<td>1.91</td>
</tr>
<tr>
<td>100 µm x 0</td>
<td>1.7</td>
<td>27.2</td>
<td>1.83</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td>100.0</td>
<td>35.6</td>
<td>1.47</td>
</tr>
<tr>
<td><strong>Mine #2: Lower Kittanning Seam</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Top x 100 mm</td>
<td>0.8</td>
<td>52.7</td>
<td>2.25</td>
</tr>
<tr>
<td>102 mm 25 mm</td>
<td>15.5</td>
<td>43.1</td>
<td>5.47</td>
</tr>
<tr>
<td>25 mm x 19 mm</td>
<td>6.7</td>
<td>34.3</td>
<td>4.84</td>
</tr>
<tr>
<td>19 mm x 9.5 mm</td>
<td>37.2</td>
<td>25.2</td>
<td>4.25</td>
</tr>
<tr>
<td>9.5 mm x 500 µm</td>
<td>28.0</td>
<td>18.8</td>
<td>3.71</td>
</tr>
<tr>
<td>500 µm x 100 µm</td>
<td>8.3</td>
<td>15.7</td>
<td>3.32</td>
</tr>
<tr>
<td>100 µm x 0</td>
<td>3.5</td>
<td>22.8</td>
<td>4.95</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td>100.00</td>
<td>26.1</td>
<td>4.26</td>
</tr>
</tbody>
</table>

**PLANT DESCRIPTION**

The industrial coal preparation plant which was sampled is located in western Pennsylvania. The preparation plant upgrades run-of-mine coal from two underground mines, which mine the Upper Freeport and Lower Kittanning Seams, respectively. Table 1 contains typical run-of-mine coal analyses
RESPONSE OF FLOTATION CIRCUIT TO CHANGING REAGENT DOSAGES

from the two mines during the time period when the sampling program was conducted. The Upper Freeport Seam had much lower sulfur content and somewhat higher ash content than the Lower Kittanning Seam.

Figure 1 contains a schematic of the preparation plant flowsheet. During the period of the sampling program, the plant was processing 550 metric tons/hour (mt/hr), with about a 50/50 mixture from the two mines. The primary cleaning unit operations were a Jeffrey Baum Jig for the 150 mm x 1.0 mm size fraction, Krebs water-only cyclones for the 1.0 mm x 250 μm size fraction and a Wemco flotation bank for the 250 μm x 0. In actuality, the flotation circuit contained particles as coarse as 500 μm, due to misplacement and screen wear.

NORMAL FLOTATION CIRCUIT OPERATING CONDITIONS

The preparation plant flotation circuit normally operates with a total feed rate of approximately 12,000 liters/min at 6.0 to 8.0 wt% solids (13 to 16 kg/s solids feed rate). The reagent dosages are kept at 100 cc/min (approximately 0.092 g/kg) for the No. 2 fuel oil collector and 38 cc/min (approximately 0.034 g/kg) for the MIBC frother.

Prior to conducting the test matrix of various reagent dosages, the flotation circuit was first sampled at the normal operating conditions. The goal of this test was to establish the baseline circuit performance and work out any logistical problems with sampling and analytical procedures.

Table 2 contains the size and ash analyses for the feed, concentrate and tailings samples collected during the flotation circuit sampling program, at normal operating conditions. The overall weight recovery as 68.4 wt% and the individual size fraction weight recoveries are also listed. Weight recoveries were lowest in the coarsest size fraction, where floatability is marginal, and the finest size fraction, where the feed has the highest ash content due to clays present. The results in Table 2 support findings by other researchers that the intermediate 150 μm x 75 μm particles are normally the most readily floatable size fraction (Sun and Zimmerman, 1950).

| TABLE 2: Normal Flotation Circuit Performance (dry basis). Collector: #2 fuel oil, 0.10 kg/mt. Frother: MIBC, 0.04 kg/mt |
| Size Fraction | Feed | Concentrate | Tailings | |
| 500 μm x 300 μm | 3.8 | 12.4 | 3.7 | 5.4 | 65.5 | 4.2 | 25.4 |
| 300 μm x 150 μm | 13.8 | 15.2 | 14.5 | 5.8 | 72.3 | 12.1 | 39.4 |
| 150 μm x 75 μm | 18.9 | 15.9 | 21.3 | 7.8 | 77.2 | 13.6 | 43.2 |
| 75 μm x 45 μm | 12.4 | 17.1 | 13.7 | 9.0 | 75.1 | 9.8 | 41.8 |
| 45 μm x 0 | 51.1 | 28.8 | 46.8 | 14.0 | 62.7 | 60.3 | 53.7 |
| TOTAL | 100.0 | 22.4 | 100.0 | 10.5 | 68.4 | 100.0 | 48.2 |

TEST CONDITIONS

The primary testing program involved sampling the flotation circuit at various reagent addition levels. Eleven tests were conducted at various frother and collector addition levels. Table 3 contains the test...
Figure 1: Preparation Plant Flowsheet
conditions which involved various No. 2 fuel oil collector addition levels for three frother dosages (15, 38 and 57 cc/min).

The fuel oil was added to the circuit feed box; whereas, the MIBC was added at approximately equal rates to the air inlet of both the first and second cells of the four-cell flotation bank. The reagent rates (g/kg) were calculated based on the average solids feedrates for all eleven tests, and were not adjusted for any test-to-test feedrate variations.

Initially, a complete 3 x 5 test matrix of frother and collector addition levels was planned. However, the preparation plant flow scheme had to be altered to produce metallurgical grade coal after the eleventh test, making any further comparative tests impossible. Fortunately, the testing pattern shown in Table 3 still provided a substantial basis for analysis of the coal flotation circuit's response.

**TABLE 3: Flotation Circuit Test Matrix**

<table>
<thead>
<tr>
<th>Test Number</th>
<th>Run Order</th>
<th>MIBC Frother Addition Levels</th>
<th>Fuel Oil Collector Addition Levels</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>cc/min</td>
<td>g/kg</td>
</tr>
<tr>
<td>1</td>
<td>9</td>
<td>15</td>
<td>0.013</td>
</tr>
<tr>
<td>2</td>
<td>4</td>
<td>15</td>
<td>0.013</td>
</tr>
<tr>
<td>3</td>
<td>5</td>
<td>15</td>
<td>0.013</td>
</tr>
<tr>
<td>4</td>
<td>6</td>
<td>15</td>
<td>0.013</td>
</tr>
<tr>
<td>5</td>
<td>7</td>
<td>38</td>
<td>0.034</td>
</tr>
<tr>
<td>6</td>
<td>2</td>
<td>38</td>
<td>0.034</td>
</tr>
<tr>
<td>7</td>
<td>1</td>
<td>38</td>
<td>0.034</td>
</tr>
<tr>
<td>8</td>
<td>3</td>
<td>38</td>
<td>0.034</td>
</tr>
<tr>
<td>9</td>
<td>8</td>
<td>38</td>
<td>0.034</td>
</tr>
<tr>
<td>10</td>
<td>10</td>
<td>57</td>
<td>0.051</td>
</tr>
<tr>
<td>11</td>
<td>11</td>
<td>57</td>
<td>0.051</td>
</tr>
</tbody>
</table>

**SAMPLING, ANALYTICAL AND DATA EVALUATION**

One priority of the project was to conduct the sampling program for each test at near steady-state conditions for an extended period. An equilibration time of 45 minutes was allowed for the plant to achieve steady-state conditions after any feed disruptions or reagent changes. Once the circuit had been equilibrated, the sampling program for each test was conducted over a two-hour period. The sampling program involved taking 6 to 8 cuts of each of the following ten samples over the two-hour period:

- flotation feed;
- concentrate (froth product) from each of the four cells;
- tailings (pulp) in the discharge area of the first three cells;
- final tailings from tailing discharge port; and
- combined concentrate from product launder.
A total volume of 2 to 3 gallons was collected for all samples.

Timed samples of the concentrate flowrates from the four cells were also taken twice during the sampling program, and averaged, to determine a flow balance of the flotation circuit. The froth depth in the cells was also monitored and recorded, and reagent dosages were checked prior to, and after, the sampling program was completed.

All ten samples were analyzed for moisture, ash and sulfur content in accordance with ASTM Standards. The samples were also wet-vacuum screened into three size fractions (plus 150 microns, 150 x 45 microns and minus 45 microns), then dried, weighed and analyzed for ash content.

Lastly, the sampling results were balanced using a mass balance computer program. The computer program allowed for confidence weight factors to be put on all flowrates, weight percentages and assay measurements. The program then adjusted the data so that all constituents (water, solids and ash) were balanced by size for each cell within the circuit, while minimizing an error function shown below (Suardini, 1994)

\[ F_n = \sum WF_i (CF_i - MF_i)^2 \]

where \( F_n \) = Total error function
\( WF_i \) = Confidence weight factor for each component, by size
\( CF_i \) = Corrected flowrate for each component, by size
\( MF_i \) = Measured flowrate for each component, by size

Generally, the concentrate screen analyses and ash contents from the various cells varied only +/-0.50 wt% and +/-0.10 wt%, respectively, between the measured and balanced results. The final tailings and feed screen analyses and ash contents varied only +/-0.50 wt% and +/-0.50 wt%, respectively. The vast majority of the data adjustments occurred for the pulp samples from the first three cells, where reliable discharge samples were difficult to obtain. The remaining results and discussion relate to the “balanced” sampling data.

UNCONTROLLED FEED VARIATIONS

A number of flotation circuit feed variables, which are known to affect the performance of the circuit, could not be controlled during the sampling program. Table 4 contains a listing of the ranges in feed slurry composition, flowrates and pH that were experienced. For Test #1 through Test #9 (middle column in Table 4), the ranges were approximately what could be expected on a day-to-day basis for the plant circuit. However, during Tests #10 and #11, one of the four water-only cyclones preceding the flotation circuit plugged and the problem went unnoticed for the two tests. This problem caused extremely low total feed flowrates and extremely high feed solids contents as shown in the final column in Table 4. The feed ash contents were also lower than expected due to this flow deviation. The data evaluation for Tests #10 and #11, conducted at high MIBC frother dosages (see Table 3), are, therefore, somewhat suspect.
TABLE 4: Uncontrolled Flotation Feed Variations

<table>
<thead>
<tr>
<th>Uncontrolled Feed Variables</th>
<th>Test #1 - #9 Range</th>
<th>Test #1 - #11 Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>pH</td>
<td>6.35 - 7.35</td>
<td>6.35 - 7.35</td>
</tr>
<tr>
<td>Solids Flowrate (kg/s)</td>
<td>11.1 - 17.2</td>
<td>11.1 - 17.2</td>
</tr>
<tr>
<td>Total Flowrate (liters/min)</td>
<td>10,000 - 13,200</td>
<td>7,200* - 13,200</td>
</tr>
<tr>
<td>Solid Content (wt%)</td>
<td>6.3 - 8.3</td>
<td>6.3 - 13.3*</td>
</tr>
<tr>
<td>Ash Content (wt%)</td>
<td>21.8 - 24.3</td>
<td>18.4* - 24.3</td>
</tr>
</tbody>
</table>

* Extremely low feed total flowrates (7,200 liters/min), extremely high feed solids content (13.3 wt%), and lower than normal ash content (18.4 wt%) experienced in Tests #10 and #11, due to plugging of the feed to one of the water-only cyclones (see Figure 1).

OVERALL TEST RESULTS

This section describes the relationships between flotation weight recoveries, ash contents and solids contents for the combined size fractions. The subsequent section considers the flotation results by size.

Overall Concentrate Weight Recovery and Ash Content Relationships

The concentrate weight recovery versus fuel oil collector addition dosages are plotted in Figure 2. Each line represents a different MIBC frother dosages. For information purposes, the concentrate ash contents are listed in parentheses above each data point.

Figure 2: Overall concentrate weight recoveries at various reagent dosages. Concentrate ash contents are in parentheses (all results are dry basis)
As the reagent dosages were increased, the concentrate weight recovery increased gradually, from 15.7 wt% at low reagent additions up to 86.4 wt% at high reagent additions. Concentrate weight recoveries were much more sensitive to increased MIBC additions than increased fuel oil additions. The inconsistent increases in weight recovery with increasing fuel oil additions (at 0.034 g/kg of MIBC), indicate the substantial deviations from ideal behavior, mostly caused by uncontrolled variations in feed conditions (composition and flowrate).

Past researchers have often stated that, at excessive collector dosages, concentrate yield decreases due to a reduction in mobility of the froth. This behavior was not observed in this coal flotation circuit. However, the maximum collector dosage of only 0.16 g/kg may not have been excessive enough to cause the concentrate yields to begin to decrease.

The numbers in parentheses above the data points in Figure 2 correspond to the ash content in the concentrate product for each test. Ash contents in the concentrate increased gradually with increased weight recovery due to the recovery of marginally floatable, higher ash content particles at higher reagent levels.

Figure 3 contains the relationship between concentrate ash content and weight recovery for each of the tests. From close observation of the data, it becomes apparent that the deviation from the ideal curve was at least somewhat due to variations in feed ash content. In general, the points above the curve had higher than average feed ash contents and the points below the curve had lower than average feed ash contents. Conversely, variations in the fuel oil-to-MIBC ratios appeared to have no significant affect on the concentrate ash content versus concentrate weight recovery relationship.

![Figure 3: Concentrate ash content versus weight recovery. Feed ash contents are in parentheses (all results are dry basis)](image)

Overall Concentrate Weight Recovery and Solids Content Relationships

Figure 4 contains the sample plots of concentrate weight recovery versus reagent dosage shown in Figure 2 except that the concentrate solids are listed above each data point. The solids content in the concentrate did not follow any pattern with increased weight recovery or changing fuel oil-to-MIBC
Figure 5: Concentrate solids content versus weight recovery. Feed solids contents are in parentheses (weight recoveries are dry basis).

Ratios. These results were contrary to the laboratory findings of Zimmermann, who demonstrated that solids contents in the froth product increase at higher reagent addition levels, especially increased fuel oil addition levels (Zimmerman, 1948).

Figure 4: Overall concentrate weight recovery at various reagent dosages. Concentrate solids contents are in parentheses (weight recoveries are dry basis).

The concentrate solids content for each test are plotted versus the concentrate weight recovery in Figure 5, with feed solids content listed above each data point. There are also no correlation between concentrate solids contents and feed solids contents.
The lack of any clear dependency between concentrate solids content and weight recovery can best be explained by the phenomena occurring in the froth layer. Cutting et al. (1981) demonstrated that water and marginally floatable species selectively drain from the lower levels of the thick froth layers in industrial flotation circuits. He described this behavior as a froth washing phenomenon, and stated that it is most prevalent in the thick froth of flotation columns. However, since froth layers in excess of 15 cm were also measured in the cells of the industrial flotation circuit, the froth washing phenomenon was probably also occurring in this conventional flotation circuit.

Conversely, the thick froth layer required for froth washing to become significant is rarely present in laboratory batch flotation cells. This may explain why Zimmermann (1948) observed deviations in concentrate solids content at various reagent levels in his laboratory batch testing which did not occur during this plant study.

**GRADES AND RECOVERIES BY SIZE**

A number of interesting trends and relationships were drawn during the overall circuit evaluation in the previous section. However, there were a number of discrepancies in weight recovery versus ash content relationships, and more specifically, weight recovery versus solids content relationships, which could not be readily explained. To better understand the circuit behavior, it is beneficial to further break down and evaluate the results by:

- coal size fraction, and
- individual cell within the flotation bank

The remainder of the discussion focuses on the test results for three discrete size fractions (500 μm x 150 μm, 150 μm x 45 μm and 45 μm x 0), with specific emphasis on better understanding the relationships which affect the overall flotation performance, as well as determining the strategies for optimizing and controlling industrial coal flotation circuits.

A cell-by-cell analyses of the circuit is not contained in this discussion due to limitations of the scope of this paper. However, the cell-by-cell data does explain some additional discrepancies in the results, such as the apparent randomness of the concentrate solids versus weight recovery relationship (see Figure 5). A complete evaluation of those results are included in another publication (Suardini, 1994).

**Sized Concentrate Weight Recovery and Ash Content Relationship**

As was done earlier for the combined size fractions, Figures 6, 7 and 8 contain the plots of concentrate weight recovery versus fuel oil collector addition for the three size fractions (i.e., 500 μm x 150 μm, 150 μm x 45 μm x 0), respectively. Each line represents a different MIBC frother dosage. For information purposes, the concentrate ash contents are again listed in parentheses above each data point.

In addition to those plots, Figure 9 contains the concentrate ash content versus weight recovery plots for all three size fractions. The main observations in Figures 6 through 9 include:

- weight recoveries varied most dramatically over the reagent dosage range for coarsest, 500 μm x 150 μm, size fraction (4.3 wt% to 92.2 wt%). For progressively finer size fractions, the weight recovery variation was less dramatic (i.e., from only 20.9 wt% to 79.0 wt% for 45 μm x 0). This behavior was caused by the higher proportion of clean coal particles in the coarse size fraction, coupled with their lower floatability at low reagent dosages.
Figure 6: Concentrate weight recoveries of 150 μm x 45 μm particles at various reagent dosages. 150 μm x 45 μm concentrate ash contents are in parentheses (all results are dry basis)

Figure 7: Concentrate weight recoveries of 500 μm x 150 μm particles at various reagent dosages. 500 μm x 150 μm concentrate ash contents are in parentheses (all results are dry basis)

- from the equal overall weight recovery/ash tests in Figure 6, it can be observed that higher fuel oil-to-MIBC ratios promote coarse particle flotation, while lower fuel oil-to-MIBC ratios promote fine particle flotation. The former is desirable to ensure acceptable coarse particle recovery and to assist in downstream product dewatering efficiency. The improvement in coarse-particle recovery at high collector dosage is due both to the coarse particles requiring a higher level of hydrophobicity in order to float because of their greater mass, and to preferential absorption of collector on fine particles. In order to efficiently recover both the coarse and fine coal, it is often useful to separate the coal into a
Figure 8: Concentrate weight recoveries of 45 \( \mu m \times 0 \) particles at various reagent dosages. 45 \( \mu m \times 0 \) concentrate ash contents are in parentheses (all results are dry basis).

Figure 9: Concentrate ash content versus weight recovery, by size (all results are dry basis).

coarse coal fraction and fine coal fraction, so that the collector dosage can be optimized separately for each particle size. This allows the flotation circuit to use the high collector dosage needed for coarse particle flotation, while still maintaining a low collector dosage for fine particles so that their flotation will be reasonably selective.

from Figure 9, it can be observed that concentrate ash contents tracked very closely to concentrate weight recovery for the coarse, 500 \( \mu m \times 150 \mu m \), and intermediate, 150 \( \mu m \times 45 \mu m \), size fractions
and are only slightly dependent on other conditions (such as feed ash content). By contrast, the correlation between concentrate ash content and weight recovery for the finest, 45 μm x 0, size fraction is much poorer and must be controlled by other factors (i.e., feed ash content and water recovery).

The second observation supports findings by Sun and Zimmermann (1950) that higher reagent levels, particularly collector additions, promote coarse coal particle flotation. The factors which impact the fine, 45 μm x 0, flotation efficiency (i.e., the ash versus weight recovery relationship mentioned in the third observation) are assessed in more detail in the following subsection.

Size, Concentrate Ash, Combustibles, and Water Recovery Relationships

Figures 10 through 12 contain the individual size fraction, concentrate ash recovery, combustibles recovery versus water recovery relationships. There was essentially a linear relationship between ash recovery and water recovery for all of the size fractions, and particularly for the finest, 45 μm x 0, size fraction. Such a linear relationship between ash recovery and water recovery is characteristic of hydraulic entrainment (Lynch et al., 1981; Luttrell and Yoon, 1992; Aplan, 1976). However, in these tests, the relationship of the combustibles recovery to the water recovery is also basically linear, which indicates that the froth is overloaded, and that the proportion of water, and therefore of entrained solids, in the froth is a constant.

![Figure 10: 500 μm x 150 μm concentrate ash recovery and combustibles recovery versus water recovery relationships.](image)

The overloaded condition of the froth means that it is not practical to reduce entrainment by reducing the water recovery, as any reduction in water recovery will markedly reduce the coal weight recovery, as shown in Figure 13. In order to reduce entrainment of ash in this case, other methods would be needed, such as:

- diluting the feed to lower solids content. However, this change will reduce flotation circuit retention time and probably circuit weight recovery. It should be compensated for by other adjustments, such as increasing reagent dosages.
Concentrate Water Recovery (Wt. %)

Figure 11: 150 μm x 45 μm concentrate ash recovery and combustibles recovery versus water recovery relationships.

Figure 12: 45 μm x 0 concentrate ash recovery and combustibles recovery versus water recovery relationships.

- increasing froth depth in the flotation bank. However, this normally has only a marginal impact on reducing water recovery."
When a flotation cell is not overloaded, it is possible to reduce the water recovery to the froth without greatly reducing the combustibles recovery, and so to reduce the content of entrained ash in the froth. However, when the froth has become overloaded, any further reductions in the water recovery result in the froth becoming less fluid, and so reductions in entrained ash are accompanied by corresponding reductions in the combustibles recovery.

Implementing a staged flotation circuit (i.e., rougher and cleaner banks), where the rougher concentrate is diluted and refloated in the cleaner bank. This reduces overall water recovery and subsequent fine ash particle recovery.

In recent years, a number of coal cleaning plants have also installed column flotation cells, at least partially to reduce the hydraulic entrainment. The columns are advantageous in that they have thicker froth layers which enhance froth water drainage (Luttrell and Yoon, 1992). They also can be readily adapted with froth spray bars to increase the proportion of the water reporting to the tailing system (i.e., positive bias).

CONCLUSIONS

From the results of this study, a number of conclusions can be drawn.

1. The solids content of the froth product was essentially constant, with random variations between 21 and 23 % wt. solids, despite changes in reagent dosages, concentrate weight recoveries, and feed solids contents. This indicates that the cells were operating in an overloaded condition, with the froth carrying as much coal as it was capable of while still flowing from the cells.

2. It is commonly assumed, based on Zimmerman's coal flotation work, that the addition of extra collector causes the froth to have a higher percent solids, and that it will therefore be easier to filter. However, the data presented in this paper shows that in a plant operating with an overloaded froth, adding collector does not systematically change the froth solids content. Increased fuel oil dosage can still improve filtration of the clean coal, but this will be because of increased coarse-particle recovery and increased particle hydrophobicity, and not because of decreased froth water content.
3. The concentrate weight recoveries were much more sensitive to frother additions than to collector additions. This was a result of the overloaded froth. As the frother dosage was increased, the froth volume was also increased, which in turn allowed more coal to be removed from the cell. Since the froth remained overloaded, the quantity of entrained ash per unit mass of coal remained nearly constant, and so increasing the frother dosage did not greatly affect the ash content of the concentrate.

4. Overall concentrate ash contents tracked very closely with the concentrate weight recoveries. The level of entrainment was not varying significantly, and so the major factor affecting the concentrate ash content was the increase in flotation of locked particles at higher concentrate weight recoveries.

REFERENCES


