ABSTRACT

The purpose of this project was to test the pilot-scale version of the ISGS washer on a 1.3-ft³ subaeration cell in a plant to process 100 lb. tailings/hour and to determine what design and system upgrades may be required resulting from the scale-up of the cell.

The 1.3-ft³ cell was successfully tested online in a coal preparation plant in White County on a split stream during a debugging and testing operation in the presence of Dr. Ken Ho, project manager, ICCI. The modified subaeration cell was very effective in the removal of ash and sulfur. For 90% combustible recovery, the ash content of the product produced in the plant with the ISGS washer was about one third of the optimal performance of any flotation device predicted by Advanced Flotation Release Analysis (AFRA). For the same ash content, the recovery of the cleaner combustible with the ISGS washer was two times larger than that predicted by the AFRA. Irrespective of the combustible recovery, the ISGS washer produced a product with lower total and pyretic sulfur content than that predicted by the AFRA.

During the extension period, the 1.3-ft³ cell was tested on the hydro-cyclone overflow of a processing plant of a mine located in Saline County. At one third of its capacity, this cell handled all of the froth that was generated in this cell, and achieved similar outstanding results with respect to ash and sulfur rejection. Also, a 3-ft³ replica of the 1.3-ft³ cell was manufactured with some minor modifications to allow visual observation of the processes taking place within the unit, and to facilitate automation of the process. This 3-ft³ cell was tested in a coal processing plant in Logan County. These tests yielded valuable experiences for building a commercial-size unit. Based on the in-plant experiences, several changes in the design of the flotation cells that use the ISGS washer have been proposed.

In total 4 different effluents from three mines were successfully processed and feed rates of up to 200 lbs. of tailings/hour were achieved. Several automation strategies were also considered to avoid mechanical carry over of the impurities, and some simple techniques to control the flow rates and pulp levels in the cell were identified. Further research is required to test these automation techniques on a larger commercial size unit to further demonstrate the efficacy of the basic ISGS washer designs.

Pages 1-22 contain propriety information
EXECUTIVE SUMMARY

This project was designed to examine the performance of a pilot plant-scale version of a 1.3-ft³ subaeration cell equipped with the ISGS washer during online testing on a split stream in an industrial environment to process 100 lb. of tailing per hour, and to determine what design changes and system upgrades were required for its adoption by coal processing plants. After successful online testing in a coal preparation plant in White County on a split stream in the presence of Dr. Ken Ho, project manager, a project extension was requested so that the cell could be tested on refuse from another plant.

During the extension period the 1.3-ft³ cell was tested on hydro-cyclone overflow of a processing plant of a mine located in Saline County. Also a 3-ft³ replica of the 1.3-ft³ cell was manufactured with some minor modifications to allow visual observation of the processes taking place within the unit, and to facilitate automation of the process. This 3-ft³ cell was tested in a coal processing plant in Logan County. Thus, the system was tested on four refuse samples from three plants including two on-line testing in plants instead of one refuse sample in one plant and up to 200 lb of tailings/hour were successfully processed.

The ISGS washer, when attached to a subaeration cell in single-stage flotation tests, consistently produces a product that is cleaner than that produced with a packed column using the same feed material. ISGS washer improves also the throughput rates of the columns it is attached to. Under optimum conditions, the performance of flotation machines equipped with ISGS washer approaches closely and in some cases exceeds the optimal performance of any flotation device predicted by Advanced Flotation Release Analysis (AFRA).

The 1990 Clean Air Act Amendments (CAAA) are compelling energy producers to pursue more efficient and environmentally sustainable energy sources. Coal is the major natural energy resource of Illinois, but because of the CAAA and the inability of coal producers to compete for markets with out-of-state producers, the coal mines in Illinois have been steadily losing market share.

Illinois coal mines have been closing because they cannot produce coal that contains less sulfur and ash-forming minerals and is less expensive than their competitors. The coal produced is not of the desired quality because the processing methods used to upgrade coal have failed to generate a clean enough product at a reasonable cost. Both the inefficiency of the processing methods used and the capital and operating costs of the cleaning methods required to clean the coal thoroughly have been responsible for this dilemma. This predicament has encouraged the coal producers in Illinois to recover the easily cleanable coal from the mined-out material, and to discard the rest with the result that about 25% of the coal that is mined in Illinois is rejected. Discarded coal increases the cost of production instead of augmenting revenues in addition to posing environmental hazards.

The coal produced at coal cleaning plants contains more sulfur and ash-forming minerals than necessary because the processing methods currently used to upgrade Illinois coal cannot generate a cleaner product at a reasonable cost. As in any physical beneficiation method,
separation of particles by flotation is possible only if the various components are liberated. Nearly complete liberation of the pyrite in Illinois coal would require grinding to particle sizes not exceeding a few micrometers in size. In fine size ranges, the separation of fine particles in subaeration cells and flotation columns is adversely affected by 1) non-selective adhesion of particles to air bubbles, 2) entrapment of the mineral matter in the froth and 3) mechanical carryover of the particle suspended in slurry. Unlike coarser particles, the detaching forces working on the nonselectively attached fine non-combustible mineral particles are small and thus, they are not easily mechanically dislodged once they get "hooked" on the bubbles. One way to dislodge these nonselectively attached mineral particles and the entrapped mineral particles is to wash the froth with enough water such that these mineral particles are transferred back to the aqueous phase, and then to drain the froth adequately. This is accomplished in the ISGS froth washer.

During the intensive washing and enhanced drainage in the ISGS washer, both the mineral particles that are unselectively attached and those that are trapped between the air bubbles are flushed out. To ensure that the flushed mineral particles do not become trapped in the lower layers of the froth as they are transported, the wash water carries the particles down a short vertical distance (1 inch) to a separate stream flowing along the lower part of the washer, and not allowed to become entrapped in the counter current moving froth.

A device that can help existing processing equipment produce cleaner coal at a faster rate will reduce the number of flotation machines required to process a given amount of the material by about 65%. This will result in reductions of the capital and operating costs, and perhaps an increase in profits. Not only will the costs of disposing of rejected coal be reduced by recovering more fine coal, but revenues will be bolstered by the sale of a cleaner coal product generated from the material discarded earlier.

The flotation device used in this study has been successfully tested at the laboratory scale. The device, which consists of a 1.3-ft³ subaeration cell and the ISGS washer, was tested on-line in a plant to debug and troubleshoot it under continuous industrial conditions. The 1.3-ft³ subaeration cell with the ISGS washer was then used to process refuse from two other coal processing plants. Improvements to the system conceived during the on-line testing were incorporated in a 3-ft³ replica of the 1.3-ft³ cell that was manufactured with some minor modifications to allow visual observation of the processes taking place within the unit and to facilitate automation of the process. This 3-ft³ cell was tested during the contract extension period in a coal processing plant in Logan County on refuse from a coal processing plant. Through these tests, valuable experience was gained for building a commercial-size unit. The 3-ft³ cell provided an opportunity to visually observe the phenomena taking place inside the cell, and to plan effective automation of the system. The washer was tested on four different refuse samples from three different mines instead of one refuse as envisioned in the original proposal. In all of these tests, the results were better than those predicted by the AFRA.

Figures 1 and 2 compare the performance of the pilot-plant scale version of the subaeration cell equipped with the ISGS froth washer in cleaning a hydro-cyclone overflow with the results from AFRA. The AFRA was developed at Southern Illinois University (SIU) to
Figure 1. Comparison of combustible recovery versus ash content in the cleaned products produced from a slurry (5% solids) of coal refuse and fine coal mixture (24% ash) with the 1.3-ft³ subaeration cell equipped an ISGS washer in the laboratory, and in a plant on coal refuse (3% solids with 26% feed ash) conducted near optimum conditions. The AFRA for the slurry is shown as a standard.

Figure 2. Comparison of combustible recovery vs. sulfur in the cleaned products produced from a slurry (5% solids) of coal refuse and fine coal (3.44 % sulfur) with the 1.3-ft³ subaeration cell equipped with ISGS washer in the laboratory and in a plant on coal refuse (3% solids and 2.15% sulfur) conducted near optimum conditions. The AFRA for the slurry is shown for comparison.
determine the limits of commercially available flotation machines. The curve was used as a standard to evaluate the results achieved with the device in the laboratory and during online testing in a plant using a split stream. The online testing resulted in a cleaner product than that predicted by the AFRA for any flotation device.

For example, at a 90% recovery of combustibles, the AFR curve predicted that the product would have an ash content of about 11.5%, whereas the ash content of the products produced by the ISGS washer in the plant tests was about 4.5% under optimum conditions. Moreover, for the same ash content, the recovery of combustible material predicted by the AFR curve was about 42% whereas the ISGS washer produced about 90% recovery at the same ash content of 4%. The sulfur content of the combustible material was consistently about 0.5 to 1.0% less than that predicted by the AFRA (Figures 1 and 2) regardless of the amount recovered.

Similar ash and sulfur rejection performances were demonstrated while processing refuse from another mine (Figures 3 and 4). In these tests, a product containing only 3.7% ash was generated from a refuse sample containing 29.82% ash. The combustible recovery ranged from 82 to 94%. The predicted combustible recoveries for the same ash content of the product was about half of the recovery achieved with the ISGS washer. The sulfur rejection in these tests was also greater than that predicted by the AFRA (Figures 3 and 4).

Figure 3. Comparison between combustible recovery versus ash content of the products from a slurry of refuse containing 29.82% ash (solids feeding rate 82 lb/h to 200 lb/h) produced with subaeration cell equipped with ISGS washer and that predicted by the AFRA curve.
Figure 4. Comparison between combustible recovery versus the total sulfur content of the products produced from a refuse containing 1.36% sulfur (solids feeding rate 82 lb/h to 200lb/h) with subaeration cell equipped with the ISGS washer, and those predicted by AFRA.

The pyretic sulfur contents of the product is significantly lower than that predicted by the AFRA for comparable combustible recoveries for the same material (Figure 5). However, the pyretic sulfur content of the product depends on the nature of the material and its liberation and varies from plant to plant (Table 1).

Figure 5. Comparison between combustible recovery versus the pyretic sulfur content of the products produced from a refuse containing 1.36% sulfur (solids feeding rate 82 lb/h to 200lb/h) with subaeration cell equipped with the ISGS washer (triangles), and those predicted by the AFRA (solid line).
Table 1 shows a comparison of the pyritic sulfur rejection of selected samples of the three rejects that were analyzed.

<table>
<thead>
<tr>
<th>Type of Effluent</th>
<th>Feed</th>
<th>Product</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Ash %</td>
<td>Total sulfur %</td>
</tr>
<tr>
<td>Feed A</td>
<td>26</td>
<td>2.15</td>
</tr>
<tr>
<td>Feed B</td>
<td>29.82</td>
<td>1.36</td>
</tr>
<tr>
<td>Feed C</td>
<td>35.18</td>
<td>3.50</td>
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</tbody>
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These improvements in ash and sulfur reduction require that proper experimental conditions be maintained during the tests. At low retention times (less than 3 minutes) in the flotation cell / higher feed rates, the coal particles do not get enough time get conditioned with the collector and to collide with or attach to an air bubble resulting in decreased combustible recoveries. At unusually high solid:liquid ratios, the performance of the subaeration cell decreased. The ISGS washer helps a flotation unit produce a cleaner product but it cannot change the conditions in the cell itself. In an effort to improve the performance of the flotation device, the PI in cooperation with the Project Manager tried to design an improved flotation device.

Several automation strategies were also considered to maintain the feed, reject, and slurry rates at desired levels and to minimize the chances of mechanical carry-over of the impurities. The idea of minimizing the chances of mechanical carry-over of impurities and of maintaining an appropriate level of slurry within the unit by regulating the feed rate was rejected because a change in the feed rate would have required changes in several other parameters (reagent dosage, washing intensity, aeration), and would have complicated the process. Several simple automation techniques were identified to maintain the feed, reject, and slurry rates at desired levels.

The remainder of this report contains proprietary information and is not available for distribution except to the sponsor(s) of this project.