FINAL TECHNICAL REPORT
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Project Title: **SCALE UP OF THE ISGS FROTH WASHER FOR TESTING IN A COMMERCIAL PLANT**

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ABSTRACT

The purpose of this project was to scale up the ISGS froth washer for testing at a commercial plant. Specifically, the approach taken was to scale up the ISGS washer by more than a factor of ten from a 0.11-ft^3 miniature cell to a 1.3-ft^3 cell. The washer has been developed at the ISGS to increase the throughput and cleaning efficiency of a froth flotation circuit.

Our goal for this phase has been to determine the shape and dimensions of the ISGS washer, which from its proof-of- concept to pilot-plant scale has been developed in two years, and is capable of processing effectively the concentrate generated in a plant. The work started by designing and constructing, a washer suitable for use in a plant. A rectangular-shaped washer that increases the cross-sectional area, but maintains a shallow froth to maintain a high rate of rejection of fine pyrite and clay particles was selected. Also grooves were added to the bottom of the washer to enhance the flow of the streams of contaminants thereby minimizing the contact of the froth with the streams of contaminants.

To prove the versatility of the design, the washer had to be tested under maximum load conditions and scaled up by testing it both on a 0.11-ft^3 miniature as well as a 1.3-ft^3 cell. To find the maximum load conditions and to compare the performance of the scaled-up version of the washer with prototype, the optimum operating conditions had to be determined first. To achieve this goal, tests were conducted first to determine important operating parameters and their effective sphere of influence. Using a statistically designed matrix of experiments the impact of the simultaneous change, within certain limits, of these important parameters on the performance of the washer and hence, the optimum operating conditions were determined. It was able to produce under certain conditions a cleaner product with less sulfur than that predicted by the Advanced Flotation Release Analysis (AFR) also known as Advanced Flotation Washability Analysis Curve (AFWAC).

Based on the encouraging performance of the washer with the miniature cell, tests on the 1.3-ft^3 subaeration cell equipped with the washer were performed. Theses tests showed that even at one third of its capacity the larger washer handled, all the froth that was generated in the cell and produced a product that was often better than that predicted by the AFWAC. An increase in its size improved the stability of the cell. Scale-up was successful and a 90% reduction in pyritic sulfur content was achieved.

EXECUTIVE SUMMARY

The circular washer developed at ISGS when attached to a subaeration cell, had produced consistently a product that was cleaner than that produced with a packed column using the same feed material. Also, the rate of production of concentrate of the cell with the washer was greater than that of ordinary flotation columns. The goal of this project was to design a washer that could be used in an industrial environment and help a subaeration flotation cell produce clean coal in single-stage flotation tests. Commercial development and installation of such a device will have a significant impact on the future of the coal industry in Illinois by increasing recovery of fine coal and decreasing coal washing costs.

During the intensive washing and enhanced drainage that occur in the inclined washer, both the particles that are mechanically carried over, unselectively attached to the froth and those that are trapped between the air bubbles are flushed out. To make sure that flushed particles do not become re-entrained in the lower layers of the froth, it is better to limit the vertical height of the froth that is being washed. In the ISGS washer, the washed-out minerals are carried a short vertical distance to a separate stream along the lower part of the washer, and not allowed to become entrapped again.

Without the usual multiple stages of cleaning and re-cleaning, the ISGS washer allows a single flotation cell to produce a product cleaner than that produced by a flotation column at the throughput rate of a common subaeration cell. In other words, this device is an improvement on the old system of subaeration cell batteries in which the froth or tails were recleaned to generate a product of desired quality. Equipped with this device, each cell can produce the final product in a single run leading to greatly increased capacity of the plant or a decrease in the number of the cells required to process a given quantity of material. The result may be considerable savings in installation and/or operational cost. Costs also will be saved because of the better cleaning efficiency of fines and because of the associated saving on disposal of fines.

The ISGS washer has been tested on both a subaeration cell and a column. A froth flotation system retrofitted with the inclined washer produces better grades and recoveries than the most advanced systems being developed - sometimes even better grades and recoveries than those predicted by the Advanced Flotation Washability Analysis Curve (AFWAC). There are several reasons why the ISGS washer can operate so effectively:

- the ISGS washer provides multi-stage washing along the length of the washer, with clean wash water at each stage;
- because of the small froth depth, lower levels of the froth do not tend to become crushed and contaminants need only travel a short distance to a stream at the bottom of the tube to return to the pulp which is especially effective for rejecting fine clay and pyrite particles that have a very slow settling velocities;
- to produce cleaner coal at higher recovery rate, the amount of wash water and pulp level can be increased to levels that would flood a normal column without causing any difficulty in the operation of the inclined column;

- to provide a cleaner coal product, the turbulence of washing can be increased by spraying the water onto the froth to the point that would destroy the froth in a vertical washer on a column, but because of the wet, flowing conditions, the froth in the ISGS washer just becomes more fluid and cleaner under these conditions.

The ISGS washer can be operated successfully to produce a well-drained dry froth or a very wet, water-laden froth depending on the needs of the system and the capacity of the filtration system. In either case, the coal produced is cleaner than that produced by advanced columns.

In the subaeration flotation, aeration rate was used to increase the recovery. Unlike the results from the circular 4-inch inclined washer, it appears that the capacity of the 2-inch circular inclined washer was pushed to its limit as the throughput was increased to 200 lb/hr/ft^3. At a smaller throughput however, a much smaller ash content of 5.9% was produced. The most likely reason that the 2-inch ID washer could not be increased to the same throughput capacity as the 4-inch ID washer was because of the velocity of the froth. The faster the froth moves through the washer, the greater the tendency for it to push some of the stream of water trying to carry contaminants down to the bottom of the washer back up instead. However, it appears that increasing the diameter of the washer can have a negative effect on rejection of the fine pyrite particles. Our best pyritic sulfur rejection (0.5% PS) in the earlier version was attained in the 2-inch ID washer at low throughput. The ability to reject fine pyrite particles appears to decrease with increased diameter and increased throughput. One of the most important tasks for scaling up of the ISGS washer for use in a plant was to design its shape and size to overcome that problem. It was felt that a rectangular-shaped washer that increases the cross-sectional area, but maintains a shallow froth to maintain a high rate of rejection of fine pyrite and clay particles, would do the job. It was also felt that grooved-bottom washer would limit the contact of the froth with minimizing the contact of the froth with the streams of returning contaminants through the grooves.

Our goal for this phase has been to determine if the rectangular washer will work under maximum load, how the capacity of the washer could be increased if required without increasing its depth, and how to construct a similar washer for a pilot-plant cell. The performance of pilot-plant cell was also tested in the laboratory to ensure that its performance was similar to that of the table top cell and from that data to design, construct and test a modified plant-size unit if required.

To conserve feed it was felt that a miniature cell should be used during the tests required to find the maximum throughput load and optimum operating condition. A 0.11 ft^3 replica of an industrial subaeration cell was prepared. Then a rectangular shaped washer of appropriate size was designed, built and attached to this miniature cell. A rectangular-shaped washer increases the cross-sectional area, but maintains a shallow froth to maintain a high rate of rejection of fine pyrite and clay particles. Also, to limit the contact of the stream of contaminants with the stream of froth, grooves were added to the bottom of the washer for the streams of contaminants to flow along, minimizing the contact of the froth with the streams of contaminants.

Flotation tests were then conducted in the miniature cell attached to the miniature washer by varying one parameter at a time to determine the important parameters and their range of influence. Because the change in one variable at a time does not take into account the interaction of the variable among themselves and their combined effects on the process, a matrix of tests was designed statistically that will help determine the optimum operating conditions of the miniature cell and of the washer. Tests were then carried out according to this statically designed scheme and optimum operating conditions were determined. Tests on the miniature cell and washer were conducted when washer was used only at 1/3 of its capacity. The impact of variables such as the angle of inclination of the washer, the amount of wash water, stages of washing/length of washer, aeration rate and feed rate on the quality and quantity of material produced in flotation machines equipped with ISGS washer were determined. Under many of these conditions, the miniature cell and washer gave better results than predicted by the AFWAC.

The overall goal of our proposed work for 1998-1999 has been to scale-up the ISGS washer for use at a commercial plant. A 1.3-ft^3 Denver subaeration cell (more than a factor of ten larger than the miniature subaeration cell) was prepared for the pilot-plant tests. Three different washers were built to ensure that all the concentrate that is produced by the cell is handled efficiently. Tests were then conducted in the pilot-plant scale subaeration cell equipped with the ISGS washer of the smallest capacity. Fine coal, rejects, and a 1:1 mixture of the fine coal and reject from the same mine were used as a feed in these tests. The preparation plant rejects contained large amounts of clay-sized minerals, pyrite and a broad particle size distribution. As such, these fines required a carefully designed inclined washer. The fine coal on the other hand produced larger amount of concentrate which would tests the limits of the washer. The results of these tests were compared with the results of 1.3-ft^3 cell. The 1.3-ft^3 subaeration cell did not require more than 1/3 of its smallest washer to clean all of the froth generated. The operation of the larger cell were more stable than those of the miniature cell and hence it produced under certain conditions, a much cleaner product than predicted by the AFWAC. Its pyritic sulfur rejection was much better than that predicted by the AFWAC. A 90% reduction in pyritic sulfur was achieved.

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