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AN ADVANCED CONTROL SYSTEM FOR FINE COAL FLOTATION

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ABSTRACT

A model-based flotation control scheme is being implemented to achieve optimal performance in the handling and treatment of fine coal. The control scheme monitors flotation performance through on-line analysis of ash content. Then, based on the economic and metallurgical performance of the circuit, variables such as collector dosage, frother dosage, and pulp level are adjusted using model-based control algorithms to compensate for feed variations and other process disturbances. Recent developments in sensor technology are being applied for on-line determination of slurry ash content.

During the sixth quarter of this project, following a lengthy period of negotiation, the contract was officially novated to Virginia Polytechnic Institute and State University as prime contractor, a new contract was awarded, and work was resumed. A kick-off meeting was held at VPI&SU in late August with John Herbst and Bill Pate from J.A. Herbst and Associates in attendance. The purpose of this meeting was to discuss the new project timetable and reorganize several of the project tasks. In addition, documentation was submitted to DOE requesting a change in the in-plant test site and the subcontracting coal company from Cyprus-Amax to Pittston. This change was necessitated by the fact that during the novation process, Cyprus-Amax had closed its Maple Meadow mine which was supplying coal to the Maple Meadow plant. Thus, all previous sampling and testing was irrelevant and a new test site was needed. In the meantime, while DOE approval was pending on the change in subcontractor, work was resumed on some of the generic aspects of Tasks 3 and 4 that could be carried out without the need for plant samples. This work included some software development, under Task 3, and some modifications to the video-based slurry analyzer under Task 4.

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EXECUTIVE SUMMARY

Over the past thirty years, process control has spread from the chemical industry into the fields of mineral and coal processing. Today, process control computers, combined with improved instrumentation, are capable of effective control in many modern flotation circuits. Unfortunately, the classical methods used in most control strategies have severe limitations when used in froth flotation. For example, the nonlinear nature of the flotation process can cause single-input, single-output lines to battle each other in attempts to achieve a given objective. Other problems experienced in classical control schemes include noisy signals from sensors and the inability to measure certain process variables. For example, factors related to ore type or water chemistry, such as liberation, froth stability, and floatability, cannot be measured by conventional means.

The purpose of this project is to demonstrate an advanced control system for fine coal flotation. The demonstration is being carried out at an existing coal preparation plant by a team consisting of Virginia Polytechnic Institute and State University (VPI&SU) as the prime contractor and J.A. Herbst and Associates as a subcontractor. The objectives of this work are: 1) to identify through sampling, analysis, and simulation those variables which can be manipulated to maintain grades, recoveries, and throughput rates at levels set by management; 2) to develop and implement a model-based computer control strategy that continuously adjusts those variables to maximize revenue subject to various metallurgical, economic, and environmental constraints; and 3) to employ a video-based optical analyzer for on-line analysis of ash content in fine coal slurries.

The project, which originally started in August of 1995, has been on hold for the past year due to a change in the prime contractor. The process of novating the contract to VPI&SU began in July of 1996, and a new contract has been in place since August of 1997. A subcontract with John Herbst and Associates with primary responsibility for the advanced control system was also put in place in August of 1997. In the mean time, it was learned that the mine supplying coal to the original test site (Cyprus-Amax Maple Meadow preparation plant) had closed. The plant was to remain open, but the coal feeding the plant was scheduled to change sometime in early 1998. This meant that either the project would have to be delayed and a new sampling campaign conducted, or a new test site would be needed. After discussions with the DOE COR, it was agreed that testing of the advanced control system would be carried out on the flotation bank at Pittston's Moss No. 3 preparation plant. Approval for this change is still pending with DOE, but it is expected in the near future. Finally, work of a generic nature has continued on Tasks 3 and 4. Specifically, this work has involved software development in Task 3, and some modifications to the design of the video-based slurry analyzers to improve its long-term performance in an industrial environment as part of Task 4.

At present, this project is only slightly behind schedule, but it is expected that it can be brought back on schedule quickly once the subcontract with Pittston is approved.

INTRODUCTION

Over the past thirty years, process control has spread from the chemical industry into the fields of mineral and coal processing. Today, process control computers, combined with improved instrumentation for monitoring process parameters and performance, have demonstrated improved control in many modern flotation plants. Unfortunately, the classical methods used in most control strategies have severe limitations when it comes to control of froth flotation. The nonlinear nature of the flotation process, for example, can cause single-input, single-output control lines to battle each other in attempts to achieve a specific control objective. Other problems experienced in classical control schemes include noisy signals from measuring devices and the inability to measure certain process variables. Furthermore, factors related to ore type or process water chemistry, such as liberation characteristics, froth stability, and floatability, cannot be measured by conventional means.

The purpose of this project is to demonstrate an advanced control system for fine coal flotation at an operating coal preparation plant. The objectives of this work are: 1) to identify through sampling, analysis, and simulation those variables which can be manipulated in the plant to maintain grades, recoveries, and throughput rates at levels set by management; 2) to develop and implement a model-based computer control strategy that continuously adjusts those variables to maximize revenue subject to various metallurgical, economic, and environmental constraints; and 3) to employ a video-based optical analyzer for on-line analysis of ash content in fine coal slurries. The following is a summary of work completed during the sixth quarter of this project.

TECHNICAL DISCUSSION

Task 1 - Project Planning

During the month of August, a contract was officially awarded to VPI&SU to assume control of contract no. DE-AC22-95PC95150 entitled "An Advanced Control System for Fine Coal Flotation". This project, which originally started in August of 1995, had been on hold for the past year due to a change in the prime contractor. A subcontract was subsequently awarded to J.A. Herbst and Associates, giving them primary responsibility for development of the model-based control system. Two representatives of J.A. Herbst and Associates, John Herbst and Bill Pate, traveled to Blacksburg, Virginia, for a project kick-off meeting during the week of August 18. The purpose of this meeting was to discuss work that had been previously completed, assess the present status of the contract, and plan for future activities. At the same time, VPI&SU personnel detailed the reporting requirements that were expected of J.A. Herbst and Associates. Work was also conducted on the preparation of a paper for the DOE Contractor's Review Meeting which was presented in Pittsburgh on September 4, 1997.

Finally, VPI&SU was informed by Les Fish of Cyprus-Amax Maple Meadow Mining that the Maple Meadow Mine would be closing and the coal at the Maple Meadow Preparation Plant would be changing shortly after January 1, 1998. This unexpected change in the plant test site meant that either the project would have to be delayed and essentially restarted after January 1, 1998, or a new test site would be needed to keep the project on track. After discussions with the DOE COR it was decided that the best approach would be to shift test sites to the Moss No. 3 Preparation Plant which had been offered by the Pittston Coal Company.

A schematic diagram of the flotation bank at the Moss No. 3 plant is shown in Figure 1. As shown, this bank consists of four 1000-cubic-foot Wemco cells and handles nearly 3 times the flow of the bank at the Maple Meadow plant. It also processes finer coal which is more amenable for analysis by the optical sensor. Since the optical sensor was developed using the coal that feeds this plant, there is reasonable certainty that the sensor will be successful in this application.

At this point, Pittston Coal Company has agreed to assume a similar cost-sharing commitment as had been previously provided by Cyprus-Amax. In order to make this subcontract change official, a "Consent to Subcontract" document was submitted to DOE on September 10, and all additional documentation was subsequently provided, as requested. It now appears that a subcontract with Pittston should be in place in the very near future.

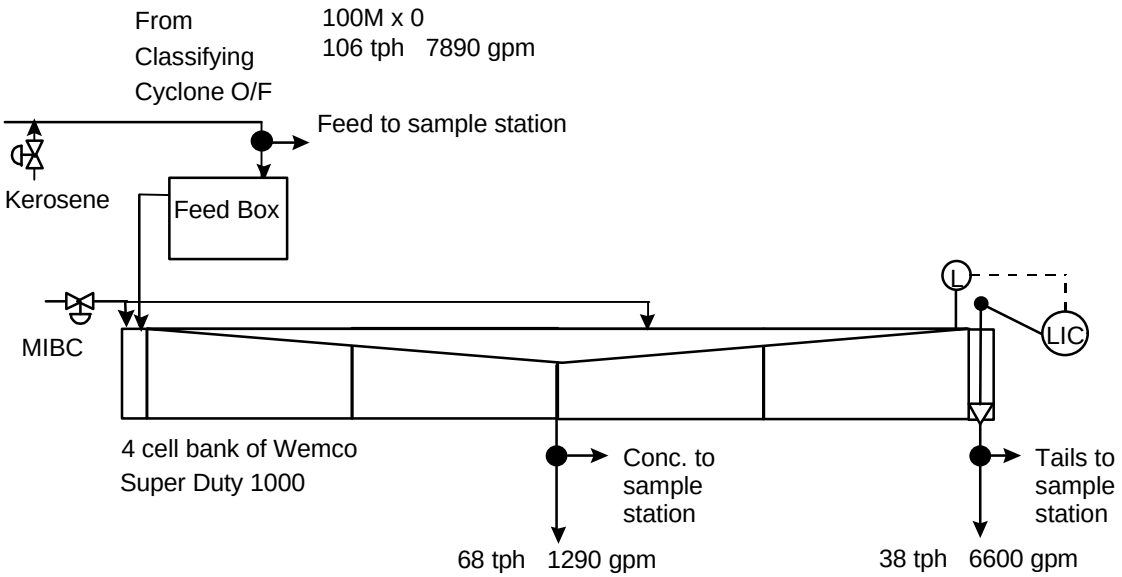


Figure 1. Schematic diagram of Pittston's Moss No. 3 flotation circuit.

Task 2 - Sampling and Data Analysis

Subtask 2.1 - Plant Sampling: Assuming the change in subcontractor and test site is approved, this subtask will be repeated at the Moss No. 3 preparation plant. It is expected that this work will be completed by the end of October, 1997.

Subtask 2.2 - Data Analysis: This subtask is scheduled to begin in October, 1997.

Task 3 - Model Building and Computer Simulation

While VPI&SU awaits official approval of the change in test site, J.A. Herbst and Associates has begun to work on the parts of this task that are generic to any test site. Specifically, this work has involved development of some of the models and computer code.

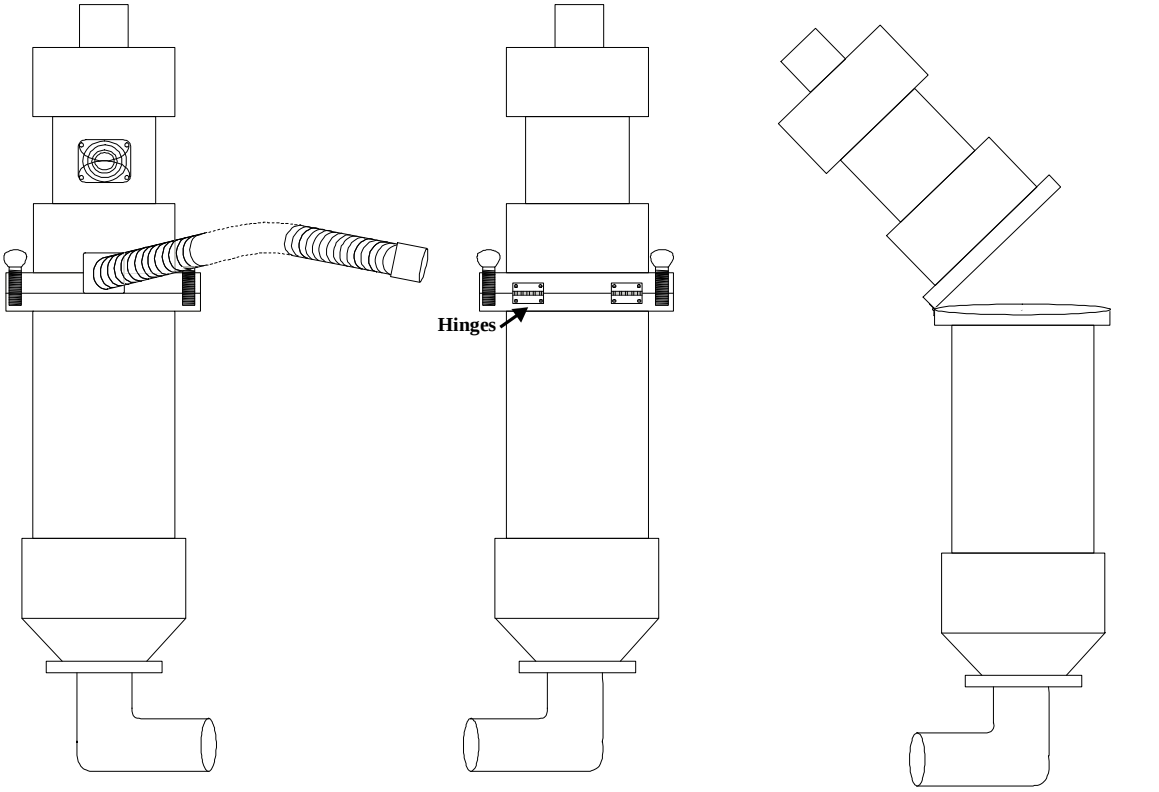
Task 4 - Sensor Testing

Subtask 4.1 - Calibration Testing: Assuming the change in subcontractor and test site is approved, this subtask will be repeated at the Moss No. 3 preparation plant. It is expected that this work will begin in October, 1997.

Subtask 4.2 - Design and Fabrication: Although this subtask is scheduled to resume in December, 1997, some design modifications are being carried out while VPI&SU awaits approval on the change in subcontractor and test site.

Two main changes in the sampling system design were carried out in response to problems observed during plant testing. First, it was noticed that the glass disk which separates the camera chamber from the slurry chamber was being splashed with slurry drops. In order to prevent such occurrence, the tube was sealed more tightly, and the design was altered so that the glass could be

accessed easily for cleaning. Originally, the sampling tube consisted of two main pieces which were joined permanently by a large number of screws and nuts. Most of these screws were eliminated, and hinges were placed as shown in Figure 2 so that the glass disk can be exposed when the top portion of the tube is lifted.



Modifications to Sampling Tube

Figure 2. Modified sample presentation tube allowing easy access to glass partition.

The other significant modification in the ash analyzer was the implementation of an automatic control loop intended to maintain the amount of incident light at a constant level. Previously, the system was set up so that a portion of the image was used as a reference to determine if the light intensity had changed. If so, the operator was instructed to increase or decrease the output of the light source to correct the difference. Unfortunately, the frequency of the variations in illumination were much higher than expected, and operator intervention was required more often than was considered practical. As a result, the light source was replaced with a unit that could be remotely controlled with a voltage signal. As illustrated in Figure 3, a voltage is sent from the computer to the illuminator, and the voltage value is modified when the gray value of the reference image drifts outside a predetermined operating range.

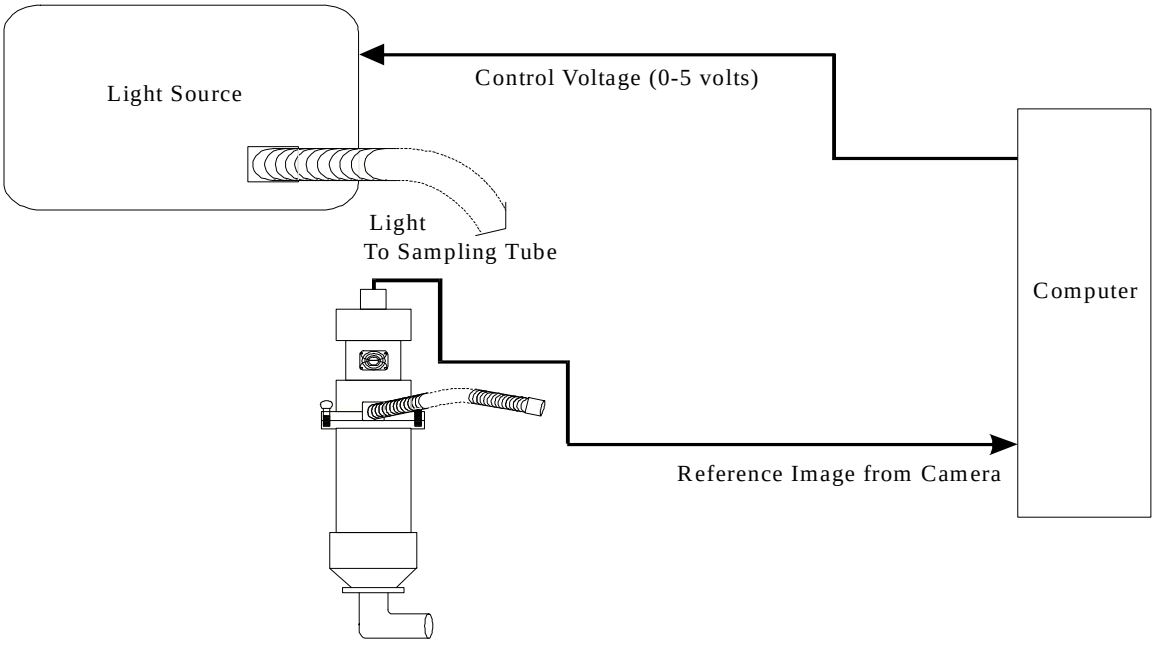


Figure 3. Schematic diagram of feed-back loop for sample illumination system.

Task 5 - Sample Analysis and Characterization

This task has been delayed until October, 1997, pending approval of the change in subcontractor and test site.

Task 6 - Equipment Procurement and Installation

This task is scheduled to begin in November, 1997.

Task 7 - Operation and Testing

This task is scheduled to begin in April, 1998.

Task 8 - System Evaluation

This task is scheduled to begin in May, 1998.

Task 9 - Decommissioning

This task is scheduled to begin in January, 1999.

Task 10 - Final Report

This task is scheduled to begin in February, 1999.

SUMMARY STATUS AND FUTURE WORK

Following a lengthy process of contract novation and negotiation, a contract has now been awarded to VPI&SU, and a subcontract is now in place with J.A. Herbst and Associates. A kick-off meeting was held with representatives of J.A. Herbst and Associates to get the project back on line. In the mean time, it was learned that the mine supplying coal to the preparation plant being used as the test site had closed. This meant that either the project would have to be delayed further or a new test site would be required. After discussions with the DOE COR, it was agreed that the test site would be moved to Pittston's Moss No. 3 plant near Carbo, Virginia. A new subcontract with Pittston Coal Company is expected to be in place in the very near future pending DOE approval. Finally, work of a generic nature has continued on Tasks 3 and 4. Specifically, this work has involved software development and some modifications to the design of the video-based slurry analyzers.

Based on the new timetable for this novated project, the contract is only slightly behind schedule due to the problems associated with the test site. It is expected that the project can be quickly brought back on schedule once official approval is received on the Pittston subcontract.