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Technical Progress Report

Second Quarter

(January 1, 1995 - March 31, 1995)

DEVELOPMENT OF A VIDEO-BASED SLURRY SENSOR FOR ON-LINE ASH ANALYSIS

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ABSTRACT

Automatic control of fine coal cleaning circuits has traditionally been limited by the lack of sensors for on-line ash analysis. Although several nuclear-based analyzers are available, none have seen widespread acceptance. This is largely due to the fact that nuclear sensors are expensive and tend to be influenced by changes in seam type and pyrite content. Recently, researchers at VPI&SU have developed an optical sensor for phosphate analysis. The sensor uses image processing technology to analyze video images of phosphate ore. It is currently being used by Texasgulf for off-line analysis of dry flotation concentrates. The primary advantages of optical sensors over nuclear sensors are that they are significantly cheaper, are not subject to measurement variations due to changes in high atomic number minerals, are inherently safer and require no special radiation permitting. The purpose of this work is to apply the knowledge gained in the development of an optical phosphate analyzer to the development of an on-line ash analyzer for fine coal slurries.

During the past quarter, tests were performed on two prototype sample presentation systems for the optical analyzer. Preliminary results indicate that the flow of slurry past the camera lens is too inconsistent to provide reliable results. A third option for sample presentation is being explored.

INTRODUCTION

Automatic control of fine coal cleaning circuits has traditionally been limited by the lack of sensors available for on-line ash analysis. Although a number of nuclear-based slurry analyzers have been tested, none have received widespread acceptance. This is largely due to the fact that nuclear sensors are very expensive for the limited accuracy available. They also tend to be influenced by changes in seam type and pyrite content.

Over the past three years, the principle investigators of this work have developed and installed two optical phosphate analyzers at the Texasgulf phosphate operation near Aurora, North Carolina. These devices use image processing technology to analyze video images of phosphate flotation concentrates and determine the P_2O_5 content and CaO/P_2O_5 ratio. They are currently being used in an off-line configuration on dry samples.

The primary advantages of optical sensors over nuclear sensors are that they are significantly cheaper (i.e., approximately 10% of the cost), are not subject to measurement variations due to changes in high atomic number minerals, are inherently safer and require no special radiation permitting. Previous experience has also shown that they are more easily understood and accepted by plant operators.

The purpose of this project is to apply the knowledge gained in the development of the optical phosphate analyzer to the development of an on-line sensor for measuring ash content in fine coal slurries. Included in this effort is fundamental research to determine the appropriate light source, image processing algorithms and sample presentation scheme necessary for coal slurry analysis. The following is a summary of work completed during the second quarter of this project.

PROJECT TASKS

Task 1 - Project Planning

All project planning activities under Task 1 are now completed. Periodic meetings with personnel at Pittston Coal Company are being held to keep them apprised of progress on the development of the optical ash analyzer.

Task 2 - Laboratory Testing

The purpose of this task is to establish the appropriate software configuration and mathematical correlations necessary to determine ash content from image analysis of a coal slurry. Included in this effort is the study of the gray-level spectra obtained from images of coal slurries containing various ash and solids contents. In addition, a variety of methods for illuminating the slurry are being investigated.

During the first quarter of this project, all equipment and commercial software for the PC-based image processing system were purchased. Thus, work during the second quarter has primarily focused on the development of specific software programs for on-line coal analysis and neural network pattern recognition. In addition, plans have been made to conduct studies on the use of monochromatic light as a means of illuminating the coal slurry. A monochromator has been identified for use in this work, and a UCR intern will be conducting these tests over the summer.

Task 3 - Bench-Scale Testing

The purpose of this task is to develop a sample presentation system and to test the system in conjunction with the image analyzer and software developed under Task 2. A major part of this effort is involved with finding a means of presenting a flowing coal slurry in a smooth and consistent manner so that the camera can obtain a clear image for analysis. During the past quarter, two sample presentation systems were evaluated. These systems, which were discussed in detail in the first quarterly report, are shown in Figures 1 and 2.

The initial prototype sample presentation system (Figure 1) was originally thought to have several advantages including the fact that the camera could be mounted over the ramp, behind the ramp, over the slurry film as it falls off the ramp or behind the slurry film. Furthermore, the slurry could be illuminated using reflected light, transmitted light or any combination of the two. Unfortunately, preliminary testing also revealed several disadvantages. For example, in order to produce a smooth film of slurry across the overflow ramp, the flow rate through the sample box had to be relatively low. This allowed suspended particles to settle out and segregate in the box. An increase in the flow through the box reduced the settling problem at the expense of even laminar flow across the ramp. In addition, the Plexiglas ramp showed an affinity for attracting particles in the slurry. Even at high flow rates the ramp became dirty and caused the images to degrade over time.

From this initial test work, it became apparent that an interface between the slurry and the camera lens should be avoided. This led to the development of a second prototype (Figure 2). The second prototype was designed to take advantage of the smooth film that was observed falling off the overflow weir of the first prototype, while eliminating the problems associated with particle segregation and sanding in the sample box. As discussed in the first quarterly report, the second prototype discharges a thin film of slurry through a 150 mm by 1.8 mm slot in the bottom of a sample container. This film passes in front of a television camera and can be illuminated from either side to provide reflected light or transmitted light images to the image analysis system. Since there is no interface between the camera lens and the slurry film the image does not degrade with time.

Initial shakedown tests of the second prototype were carried out using water. From a qualitative point-of-view, the film appeared to be very smooth as it passed in front of the television camera. However, when coal slurry was added to the system and images were captured by the computer, it was clear that the slurry film contained too many ripples. These images can be seen in Figures 3 and 4. As shown, the ripples create a form of "noise" in the image which tends to mask the change in slurry color as a function of ash content; thus, reducing the resolution of the video sensor. The ripples in the film can be reduced by decreasing the width of the opening in the bottom of the sample container; however, this increases the chance of plugging. Typically, an opening of this type must be at least three particle diameters greater than the maximum particle size in the slurry. Since this device is designed to handle -28 mesh material, the minimum opening width must be approximately 1.8 mm.

In summary, both sample presentation schemes have advantages and disadvantages. It appears that both could be used in this application; however, other alternatives should be explored before deciding on a particular scheme. Image presentation is typically the key to any video-based analysis system. Thus, a third alternative is currently being explored before the sample presentation system is finalized.

Task 6 - Sample Analysis and Characterization

The purpose of this task is to collect industrial samples for use in designing and calibrating the optical sensor. During the past quarter, several additional 19-liter (5-gallon) buckets of flotation column tailings were collected from the Middle Fork preparation plant for use in designing the slurry presentation system. These samples have not been analyzed since they are primarily being used to evaluate the slurry flow characteristics through the sample presentation system.

SUMMARY STATUS AND FUTURE WORK

Major accomplishments during the past quarter are listed as follows:

1. Software development has begun and plans have been made for conducting studies using a monochromatic light source to illuminate the coal slurry. These studies will be carried out by a UCR summer intern.
2. Two prototype sample presentation systems have been tested. Both appear to have potential; however, they also have several disadvantages. It was concluded that any sample presentation system must be free of any kind of interface between the slurry and the camera lens. It was also concluded that the sample presentation system must provide a smooth, uniform flow of slurry in front of the camera lens. A third prototype sample presentation system is currently being investigated which may satisfy these requirements.

As shown in Table 1, the project appears to be on schedule at this point. During the coming quarter, it is expected that the design specifications for the sample presentation system will be finalized and work will continue on software development and sample illumination studies.

Table 1. Project Schedule

Task	Month 2 4 6 8 10 12 14 16 18 20 22 24
Task 1 - Project Planning	
Task 2 - Laboratory Testing	
Task 3 - Bench-Scale Testing	
Task 4 - Pilot-Scale Testing	
Task 5 - In-Plant Testing	
Task 5.1 - Procurement and Fabrication	
Task 5.2 - Installation and Calibration	
Task 5.3 - Operation/Testing/Refinement	
Task 6 - Sample Analysis & Characterization	

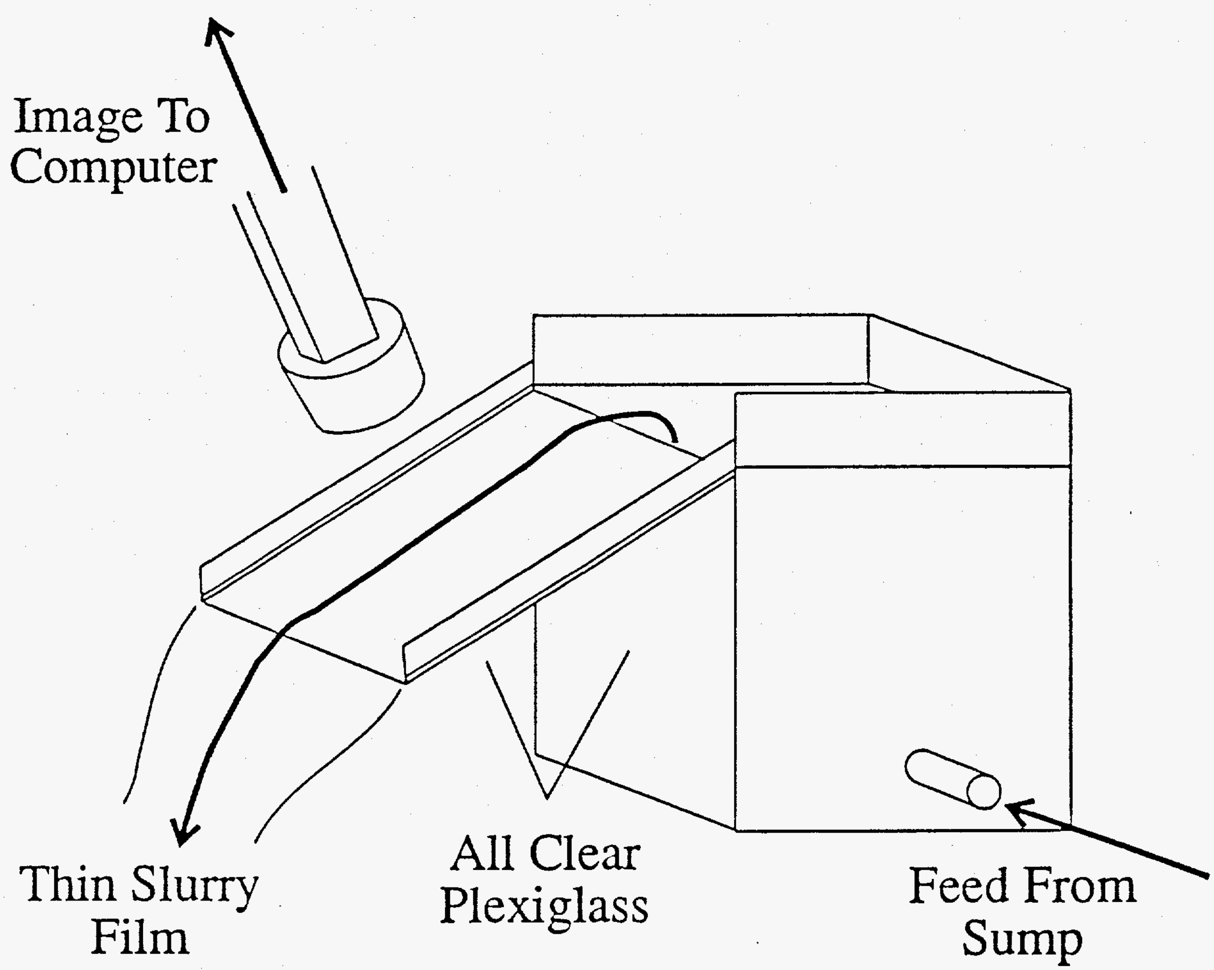

Figure 1. Schematic diagram of prototype one sample presentation system.

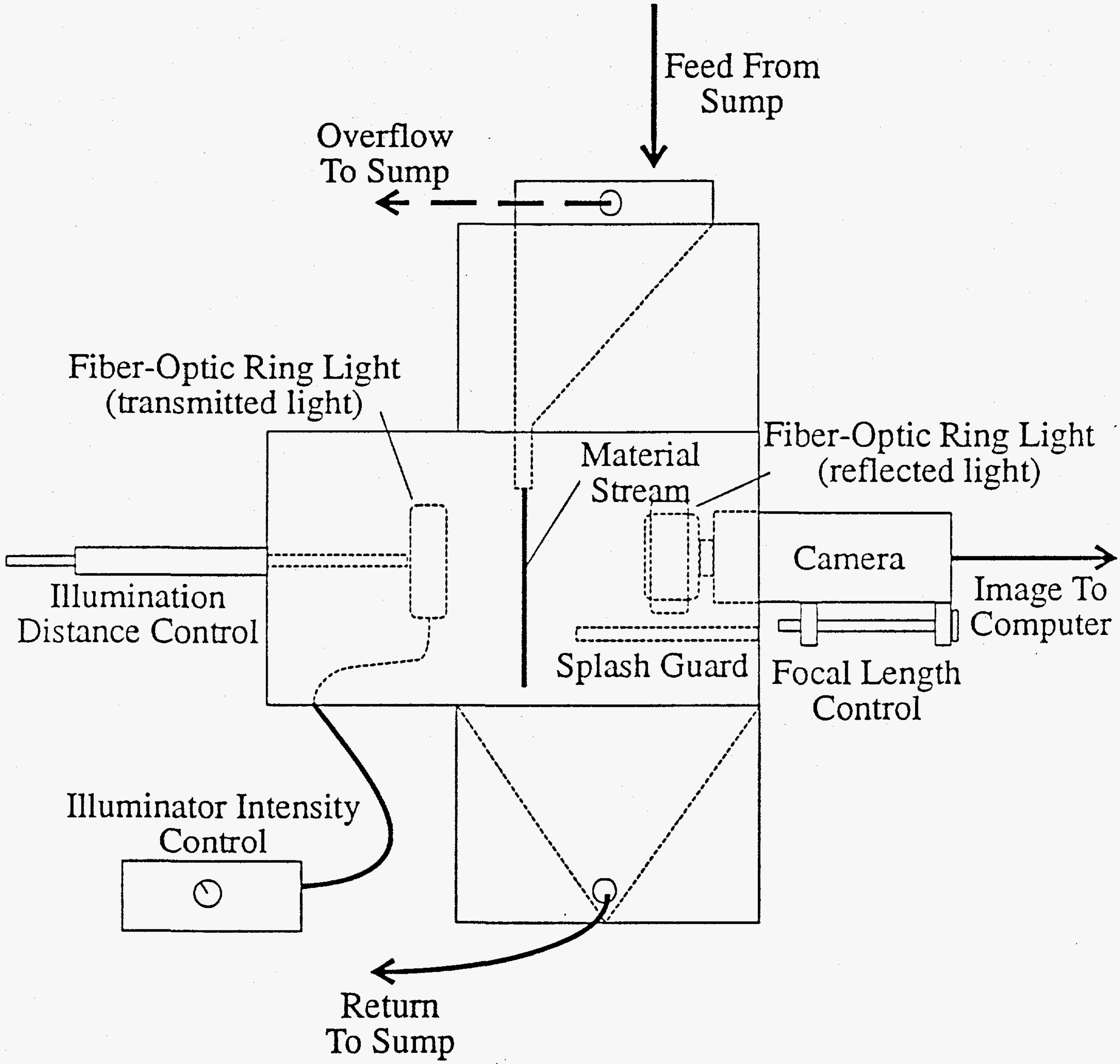

Figure 2. Schematic diagram of prototype two sample presentation system.

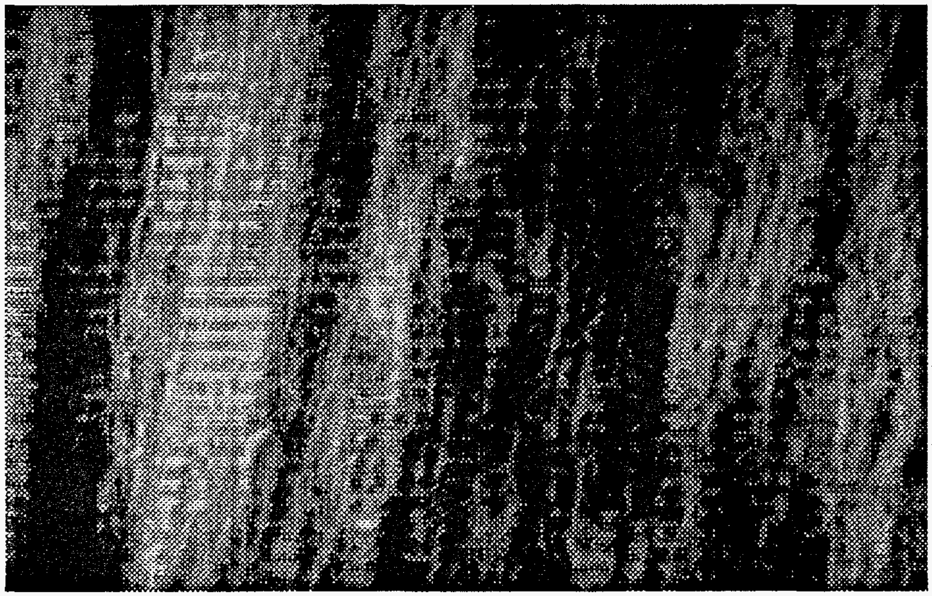

Figure 3. Digitized image from prototype two sample presentation system using reflected light.

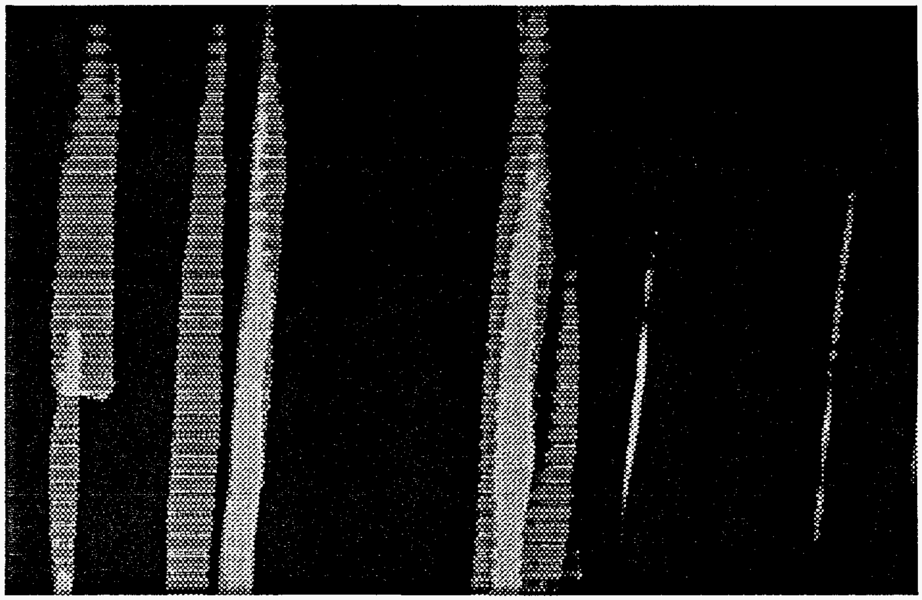

Figure 4. Digitized image from prototype two sample presentation system using transmitted light.