TECHNICAL PROGRESS REPORT

APPALACHIAN CLEAN COAL TECHNOLOGY CONSORTIUM

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by

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Project Report for the period

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Performing Organizations:

Virginia Polytechnic Institute & State University
Blacksburg, VA

University of Kentucky
Lexington, KY

West Virginia University
Morgantown, WV

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Introduction

The Appalachian Clean Coal Technology Consortium (ACCTC) has been established to help U.S. Coal producers, particularly those in the Appalachian region, increase the production of lower-sulfur coal. The cooperative research conducted as part of the consortium activities will help utilities meet the emissions standards established by the 1990 Clean Air Act Amendments, enhance the competitiveness of U.S. coals in the world market, create jobs in economically-depressed coal producing regions, and reduce U.S. dependence on foreign energy supplies.

The consortium has three charter members, including Virginia Polytechnic Institute and State University, West Virginia University, and the University of Kentucky. The Consortium also includes industry affiliate members that form an Advisory Committee. Affiliate members currently include AMVEST Minerals; Arch Minerals Corp.; A.T. Massey Coal Co.; Carpco, Inc.; CONSOL Inc.; Cyprus Amax Coal Co.; Pittston Coal Management Co.; and Roberts & Schaefer Company.

Objectives

In keeping with the recommendations of the Advisory Committee, first-year R&D activities are focused on two areas of research: fine coal dewatering and modeling of spirals. The industry representatives to the Consortium identified fine coal dewatering as the most needed area of technology development. Dewatering studies will be conducted by Virginia Tech's Center for Coal and Minerals Processing. A spiral model is developed by West Virginia University. The research to be performed by the

University of Kentucky has recently been determined to be: "A Study of Novel Approaches for Destabilization of Flotation Froth". Project management and administration will be provided by Virginia Tech, for the first year.

Virginia Tech: Innovative Approaches to Fine Coal Dewatering

Introduction

There are no practical solutions to the problems associated with the dewatering of fine coals at the moment. The mechanical dewatering technologies used today are inefficient while thermal drying is capital-intensive and costly to operate. Therefore, there is an impending need for innovative approaches to solving problems in fine coal dewatering.

In this project, two different approaches are taken. One approach involves displacing the water on the surface of coal by liquid butane that can be readily recovered and recycled. The other approach is to use disposable dewatering chemicals (aids) in mechanical dewatering.

The objectives of the proposed work are i) to test the liquid butane process on a variety of coals from the Appalachian coal fields, and ii) to identify suitable dewatering aids that would enable mechanical dewatering to reduce the moisture to the levels satisfactory to electrical utilities and other coal users.

Dewatering Using Liquid Butane Figure 1 describes the process of dewatering fine coal using liquid butane as described in the U.S. patent No. 5,458,786 (Yoon and Luttrell, 1995). In this process, a wet coal (1) is fed to a reactor (3), in which appropriate amount of recycled butane is added. The mixture is agitated to provide a contact between butane droplets (6) and coal particles (7) suspended in water (8). Upon contact, the liquid butane displaces water from the coal surface and forms a separate phase in which coal particles are dispersed. The mixture is transported to another reactor (9), where butane and displaced water are phase-separated. The phase-separated water is removed through a valve (10), while the butane is transported to another reactor (12) and allowed to evaporate by releasing the pressure. The butane vapor is liquefied by means of a condenser (5) and recycled. What is left in the reactor (12) is a "dry" coal.

The process described above has been tested on several bituminous coal samples in batch experiments. The most extensive series of tests were conducted on the clean coal product obtained using the Microcel™ flotation column at the Middle Fork preparation plant near Lebanon, Virginia. The coals sample assayed 7% ash, and its median particle size was 21 μm. Parametric testing was conducted using different amounts of liquid butane at different pulp densities. The results showed that product moisture decreases with increasing butane-to-coal ratio. At a butane-to-dry coal ratio of 1.0, the product moisture of the Middle Fork coal was reduced to 0.9-1.6% by weight. It was found that the stirring time and stirring rate (rpm) has little effect on the product moisture. Similar results were obtained with a Pittsburgh No. 8 coal and a Canadian coal from British Columbia.

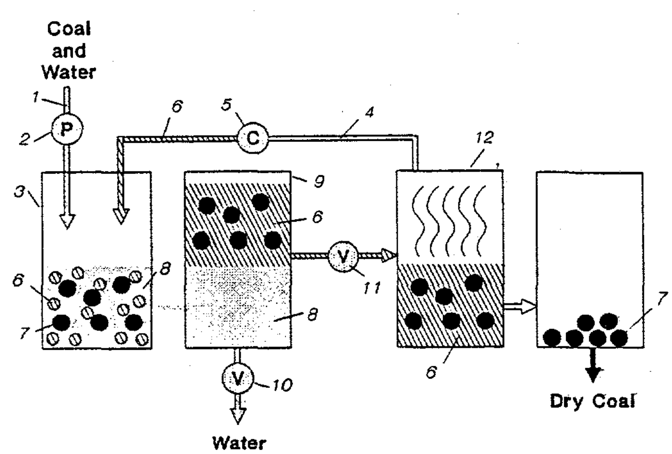

Figure 1. Schematic representation of the fine coal dewatering process using butane.

Use of Dewatering Aids A series of vacuum filtration tests were conducted on a variety of bituminous coals using various dewatering aids developed at Virginia Tech. The nature of the reagents are not disclosed here due to the proprietary nature. Table I shows the results obtained with the Microcel™ flotation product from the Middle Fork plant. The tests were conducted using a 3-inch diameter Buchner funnel with a medium porosity. In each test, a 100 ml of coal slurry was poured into the funnel before a vacuum pressure was applied. After most of the water was removed, the vacuum pressure was kept on for five minutes to remove the residual moisture. The cake thickness was approximately 0.5 inches.

Table I. Results of the Filtration Tests Conducted on a -100 Mesh Microcel™ Flotation Product*

Vacuum Pressure (inches Hg)	Reagent Dosage (lb/ton)	Product Moisture (% wt.)	
		W/O	With
24.5	2.5	22.9	11.9
28.5	2.0	17.8	5.4

*20 μm median size

Similar tests were conducted with a Pittsburgh No. 8 coal sample (-28 mesh). At a pressure of 24.5 inches Hg, the moisture content was reduced to 14.1% with 2 lb/ton of reagent A at 0.5 inches of cake thickness and 5 minutes of drying time. This result is far superior to that (20.7%) obtained without a dewatering aid. At a pressure of 28.5 inches of Hg, the moisture content was reduced to 11.9%. The results obtained with the Middle Fork and Pittsburgh coal samples suggest that the dewatering aids used in the present work are useful for increasing the efficiency of vacuum filtration. Although the 5 minutes of drying cycle time may be excessive, the beneficial effect of using the reagent can also be seen at shorter cycle times.

Dewatering tests were also conducted on a 28 mesh x 0 mesh Elkview coal sample from British Columbia. Two sets of tests were conducted using different amounts of coal slurry. The tests conducted with 100 ml of slurry gave approximately 0.2-inches of cake thickness, while the tests conducted with 200 ml slurry gave 0.4-inches of cake thickness. A 5-minute drying cycle time was employed in each test. The results are shown in Table II. It shows that moisture content decreases with increasing reagent dosage, decreasing cake thickness, and with increasing temperature.

Table II. Results Obtained Using Reagent A on the Elkview Coal Sample (-28 mesh x 0)

	100 ml slurry [1]		200 ml slurry [2]	
Temperature °C	Reagent Dosage (lbs/ton)	Moisture (% Wt)	Reagent Dosage (lbs/ton)	Moisture (% Wt)
	0	22.5	0	27.8
~ 23	0.5	16.5	0.5	21.3
(ambient)	1.0	13.8	1.0	16.8
	2.0	10.3	2.0	13.6
	5.0	9.4	5.0	11.1
	0	19.4	0	22.1
60	0.5	15.7	0.5	18.4
	5.0	8.0	5.0	10.4

[1] 0.20 inches cake thickness
[2] 0.40 inches cake thickness

West Virginia University: Spiral Modeling

This spiral project developed a fundamental model of what physically happens to fluids and particles in the complex curvilinear flow fields of spirals. We are satisfied that we have developed the basic understanding of how a spiral behaves, are able to design spirals for specific feeds, and predict spiral design behavior for different types of particles. We feel our work to date is an excellent beginning.

To date we have completed the following tasks. We have: 1) developed the physical model, 2) developed the mathematical model, and 3) developed the numerical model. Using the numerical model, we have simulated: 3a) pure water flow, 3b) curvilinear flow, and 3c) slurry flow. For simulation, we are developing a software program that will accurately portrays a spirals behavior for a wide variety of spiral designs and particle designs. In this program, all spiral profiles be assumed to be elliptical.

As particles move down the helix path, they are subjected to five forces. These are 1) hydrodynamic drag, 2) hydrodynamic lift, 3) friction, 4) gravity and 5) centrifugal forces. Paradoxically, for a given particle, these forces are balanced in the radial direction. Thus particles, based on their size, shape and density, have a radial equilibrium position in the spiral radial position.

The simplest model is by Allen (1982). Allen considers particle stability in the transverse direction of a sloping surface in a meandering open channel. Ignoring super elevation, longitudinal slope and lift and centrifugal forces, the criterion for static equilibrium is given by simply equating the gravity force and drag force components in the transverse direction.

Our force balance models, even though developed in the context of hydrological phenomena taking place on vastly larger scales of channel dimensions and flows, are capable of exhibiting at least the broad performance characteristics of the spiral. The slimes and low density solids are driven to the outer rim of the trough and the heavy and coarse particles segregate on the inner side. There is a continuous classification of the middlings along the width of the trough. However, the spread of particle size in these mathematical simulations is significantly broader, that is, the rate of change of size with radial distance is greater, especially in the Allen model, than what is encountered in a spiral. This is due to the omission of centrifugal force and the steep tangential slope of the spiral in the models, apart from the fact that all three models are based on horizontal water surface in the transverse direction. In this first research effort in hopefully a series on spirals we have forecast further planned research. In future research, we plan to fill these lacunae by formulating a general force balance spiral model, more in tune with the spiral characteristics. While there remains much work to be done, we believe that we have or will satisfactorily fulfilled all objectives promised in the grant. We remain on time or ahead of schedules. While the problem was more difficult than we thought, we have made more progress that thought possible.

University of Kentucky: Study of Novel Approaches for Destabilization of Flotation Froth

In froth flotation process, frothers are utilized to provide smaller size stable bubbles which would carry the floatable particle. Ideally, the froth should have good fluidity and optimal rigidity. The froth should be stable enough to carry the particles out of the flotation cell. Once the froth is scraped out of the cell, however, it should collapse to free floated particles. Overly stable froths can cause serious problems for downstream processes, like dewatering of flotation concentrate, handling tailings, and re-use of processing waters. Generally, alcohol based frothers provide froth which collapses as soon as froth is removed from the flotation cell and sprayed with water. Glycol based frothers, on the other hand, provides a much more stronger froth which is difficult to break by simple physical techniques and requires large amount of chemicals to break the froth, which adds to the processing cost.

The main objective of the project is to develop new defoaming techniques for destruction of overly stable froths produced in fine coal froth flotation. It is also the objective of the project to study chemical dynamics of the three phase froth.

The research program, which began January 1, 1996, consist of four (4) tasks. The progress accomplished in each task is given below.

Task 1. *Sample Acquisition and Characterization*

Samples of column flotation feed containing 32.9% ash, and the froth product containing 8.5% ash, were obtained from the Pittston Coal Company's Holston plant located in Hatfield, Kentucky. The average particle size for the feed and froth product was 40 μm and 80 μm, respectively. The froth product contains significantly low amount of fine size particles (<75 μm) than the feed (48% vs. 63%), possibly due to the removal of fine particles such as clays.

Task 2. *Dynamic Stability Studies of Froth*

Dynamic froth stability study is being conducted using a "Foam Stabo System" (Figure 2) developed at the UKCAER. Froth destabilization study involves various steps including bubble contact, coalescence, film thinning, rupture, etc. These steps occur in a very short span of time. Thus, a pressure transducer is connected to a computer for accurate data acquisition.

The decay of froth stability with time can be fundamentally described by the rate of decrease of the total area of extended liquid surface. The area of liquid surface in a froth can be determined by the following equation:

$$A(t) = \frac{3V}{2\sigma}\left(\Delta P_{\infty} - \Delta P(t)\right)$$

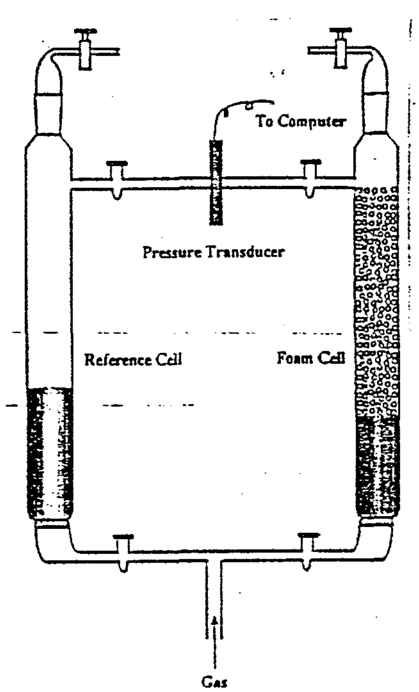

Figure 2. Apparatus for measuring the total surface area and the drainage rate of foam.

in which $A(t)$ is the area of liquid surface in the foam at time t, V the volume of gas in the foam, σ the surface tension, ΔP_{∞} the change in pressure at infinite time, and $\Delta P(t)$ is the pressure at time t (Ross, 1969; Nishioka, 981). In the present work, the pressure changes are monitored by means of a pressure transducer, which has been calibrated.

Task 3. *Fine Coal Froth Destabilization Studies*

This task will consist of studies on chemical and mechanical defoaming techniques for fine coal flotation froth. The chemical process involves use of coal, magnetite, or limestone particles coated with surfactant for froth spraying. The mechanical process utilizes cyclone, ultrasonic energy, or vacuum to destabilize froth. Work in this area will be initiated in later stage of the project. The results will give information on dynamic froth stability such as half-life time, drainage time constant, diffusion time constant.

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