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EVALUATION OF HYPERBARIC FILTRATION

FOR FINE COAL DEWATERING

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OBJECTIVES AND SCOPE OF WORK

The main objectives of the project are to investigate the fundamental aspects of particle-liquid interaction in fine coal dewatering, to conduct laboratory and pilot plant studies on the applicability of hyperbaric filter systems and to develop process conditions for dewatering of fine clean coal to less than 20 percent moisture.

The program consist of three phases, namely

Phase I - Model Development

Phase II - Laboratory Studies

Phase III - Field Testing

The Pennsylvania State University will lead the effort in Phase I, the University of Kentucky in Phase II, and Consol Inc. in Phase III of the program. All three organizations will be involved in all the three phases of the program. The Pennsylvania State University will develop a theoretical model for hyperbaric filtration systems, whereas the University of Kentucky will conduct experimental studies to investigate fundamental aspects of particle-liquid interaction in fine coal dewatering. Finally, the optimum filtration conditions identified through both phases will be tested in a Consol Inc. coal preparation plant using an Andritz Ruthner portable hyperbaric filtration unit.

INTRODUCTION

The development and improvement of mechanical methods for filtration of coal fines are very important objectives in coal preparation technology for economic, conservation, caloric recovery and pollution abatement reasons. In recent years greater quantities of wet pulverized fine coal have been produced in coal preparation processes. Almost all coal pretreatment and cleaning processes are water based and beside this Run-Of-Mine coal contains a lot of surface moisture because in modern mechanized mining operations water is sprayed in the mine to suppress dust. Thus mining operations as well as cleaning precesses result in a lot of wet fine coal.

The normal practice in the coal preparation plant is to remove the water from the fine coal slurry by vacuum filtration and drying. Conventional vacuum filtration typically produces filter cake moisture containing in the range of 25 to 30 weight percent from minus 28 mesh coal slurries. Although the desired product quality can be obtained by using thermal dryers, there are problems associated with these equipment such as high capital costs and the greatest potential source of air pollution in a coal cleaning plant.

In the present research project, an alternative to thermal drying, hyperbaric filtration which has shown potential in lowering moisture content in fine coal to about 20 percent level, is being investigated in detail. This project will essentially focus on developing fundamental information on particle-liquid interaction during hyperbaric filtration and applying the knowledge in developing optimum conditions for the pilot plant testing of the hyperbaric filter system.

APPROACHES AND PROGRESS

PHASE I Model Development

The literature review has been extended to include a detailed survey of porosity and capillarity in packed beds. A preliminary model for dewatering by gas displacement is being developed on the following assumptions:

- the cake contains a system of interconnected pores with a distribution of effective radii.
- at any stage in the process the liquid flow rate through a given pore is determined by the pressure drop across the liquid remaining in the pore minus the capillary pressure in the pore.
- prior to gas breakthrough, the entire pressure drop across the cake acts over the liquid remaining in the pore.
- following initial gas breakthrough, the pressure gradient becomes linear over the entire cake thickness which reduces the driving force for dewatering in any given pore.
- dewatering continues until gas flow becomes limited by pumping capacity.

Based on these assumptions the velocity of liquid flow in a pore of given radius at any stage in the process can be calculated. The overall rate of liquid removal and, hence, the residual moisture content can then be determined by integration over all pore sizes. The specific rate expressions for the various stages in the process are currently being formulated.

The immediate objective of the modeling effort is to provide a realistic scheme for mathematical simulation of the process in order to evaluate the general role of chemical, physical and structural variables.

PHASE II Laboratory Studies

Laboratory studies for the dewatering of fine clean coal were carried out using a Mott Porous Disk Test apparatus as shown in Figure 1. The coal used during this period was froth flotation product sample of Illinois No. 6 supplied by Consolidation Coal Inc. The filtration variables studied included the solids concentration, cake thickness, slurry pH, filtration time, applied pressure, particle size and filtrate viscosity. The results from the experiments are presented and discussed below.

Effect of Filtration Time

The effect of filtration time on moisture content of the filter cake versus time is shown in Figure 2 using two different pressures and cake thicknesses. It was observed that moisture content of the filter cake decreases with increasing filtration time. For any given pressure and cake thickness the residual moisture content of the coal filter cake decreases continuously over range of filtration period from 0.5 to 3 minutes. Beyond 3 minutes, it remains approximately constant. Based on these results, it was decided to use a filtration time of 3 minutes in all subsequent experiments.

Effect of Driving Force

Figure 3 depicts the effect of applied pressure on residual moisture content of the filter cake. It was observed that the final moisture content of the fine coal filter cake decreased with increasing driving force. With an applied pressure of 10 psig, the moisture content decreases from 41.4 to 34.5 percent at the end of 1 minute of dewatering. But it drops from 41.4 to 22.1 percent at a pressure of 100 psig. These results clearly imply that the rate of dewatering increases with increasing driving force.

Effect of Cake Thickness

The effect of cake thickness on moisture of the filter cake is depicted in Figure 4 using various applied pressures. For a lower given driving force, i.e., below 40 psig, the dependence between moisture content of the filter cake and cake thickness is approximately linear. The final moisture content of the filter cake was not improved over the range of 0.8 to 2.0 cm of cake thickness. It was found that cake thickness of 1.4 to 2.0 cm were the optimum condition for our filtration unit.

Effect of Solid Concentration

The solid concentration in the slurry was varied from 5.6 to 46.6 percent by weight in order to study its effect on filtration and dewatering properties. The experimental results are plotted in Figure 5. It is clear that increasing the solid concentration of the slurry leads to decrease of residual cake moisture content. These may be explained as follows. When solid concentration is increased particle segregation is reduced during the cake formation period. This results in a more uniform filter cake due to the more uniform distribution of particles. Direct observation for the uniformity or non-uniformity of the filter cake was obtained by the image analysis of the consolidated filter cakes with two different solid concentrations in the slurry. The detailed description of cake consolidation technique will be discussed on the next quarterly report.

Effect of Filtrate Viscosity

The viscosity of the filtrate is one of the principal variables in filtration. Holding other variables fixed, the rate of filtration should be inversely proportional to the viscosity of the filtrate. The effect of altering filtrate viscosity over a range of 0.28 to 1.00 cP on moisture content of the filter cake was investigated by heating the test slurry. Residual moisture content within the cake is given as function of filtrate viscosity in Figure 6. It was observed that final moisture content of the filter cake increased with increasing viscosity of filtrate.

Effect of Slurry pH

The natural pH of the clean coal froth was observed to be in the range or 7.2 to 7.6. Filtration and dewatering of fine coal in the slurry pH range from 1.5 to 12.7 was studied to determine the effect of slurry pH on moisture content of the filter cake. The electrophoretic mobility as well as filter cake moisture data with respect to pH are plotted in Figure 7. The figure shows that coal particle reverses charge as pH is increased, showing two points of zero charge (PZC) at pH of about 2.8 and 12.5. At PZC, the final filter cake moisture contents were reduced by 4.0 percent at 30 psig, and by 2.00 percent at 70 psig.

Effect of Particle Size

The experiments on the effect of particle size on filtration were conducted using four different size fractions of coal particles. The effect of particle size on moisture content in the filter cake is depicted in Figure 8, which shows that the final moisture content for the filter cake with the smallest particles (-200 mesh coal) is much higher than for the largest size particle (+60 mesh coal). This is due to the fact that the -200 mesh coal contains a larger proportion of small particles than others resulted in a larger specific surface area, and thus it retains more moisture.

Effect of various size coal particles on the filtration rate is shown in Figure 9. Note, that for +60, 60 x 100 and 100 x 200 mesh size particles (Fig. 9[a]) the filtration rate is similar, however, as expected for -200 mesh (Fig. 9[b]) it is significantly slower than coarse size particles. For all the particles, the filtration rate is directly proportional to the pressure regardless of the particle size.

PHASE III Field Testing

No activities were conducted.

FUTURE WORK

- The filtration and dewatering experiments will be performed using pressure/vacuum filtration cell as shown in Figure 10. The rate of filtration will be monitored by a load cell system connected to a mini computer.
- Three different types of flocculants having same molecular weight and ionic charge density obtained from American Cyanamide will be used in flocculant-assisted filtration studies.
- For additive-assisted filtration and dewatering investigations the following variables will be involved; mixing condition, surface tension, contact angle, cake moisture content and additive dosage.

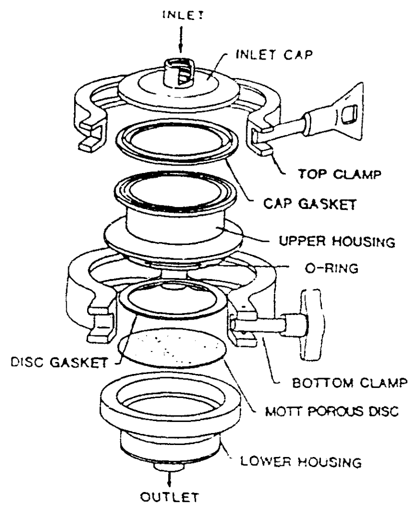

Figure 1. Mott Porous Disk Test apparatus

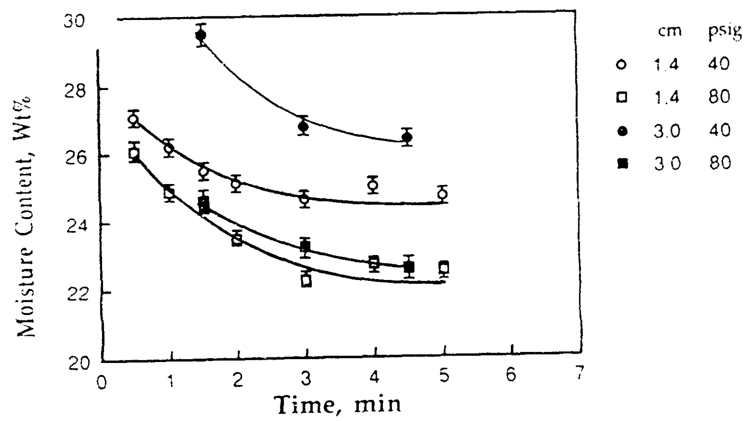

Figure 2. Effect of filtration time on cake moisture content

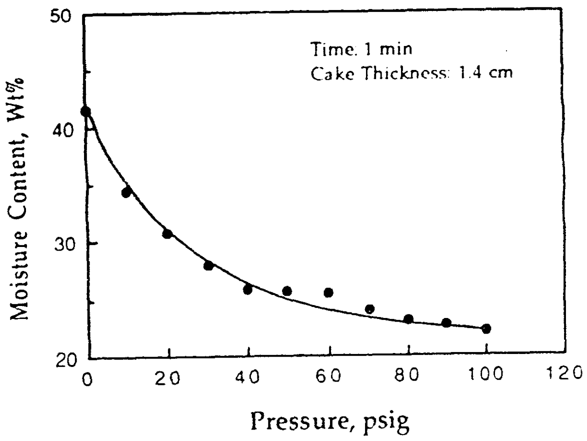

Figure 3. Effect of pressure on cake moisture content

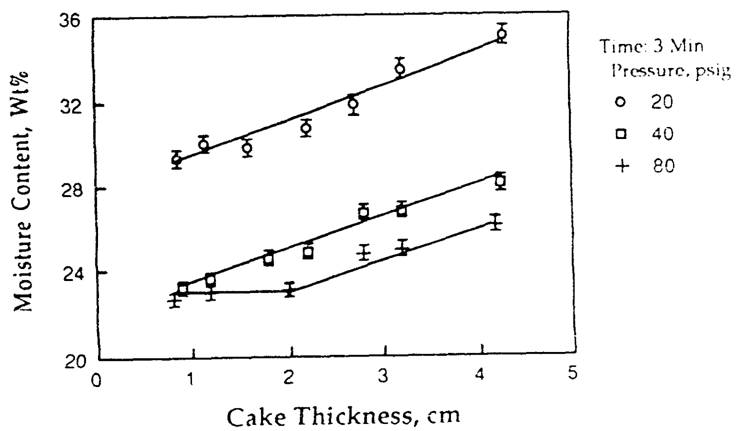

Figure 4. Effect of cake thickness on cake moisture content

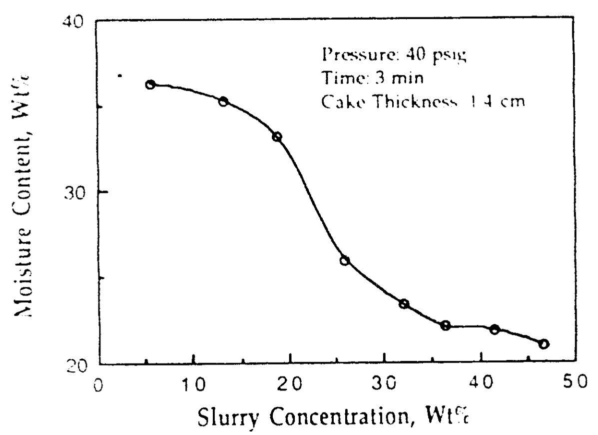

Figure 5. Effect of slurry concentration on cake moisture content

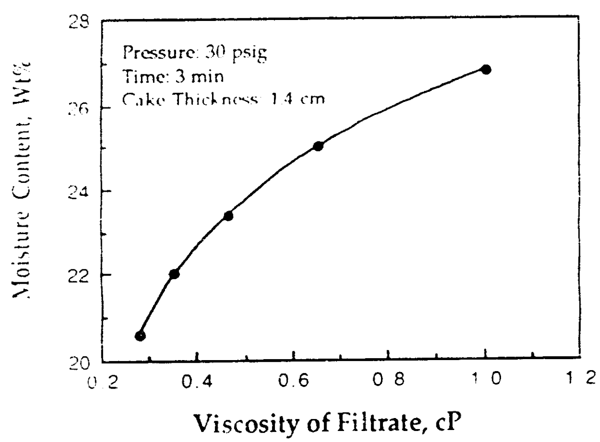

Figure 6. Effect of filtrate viscosity on cake moisture content

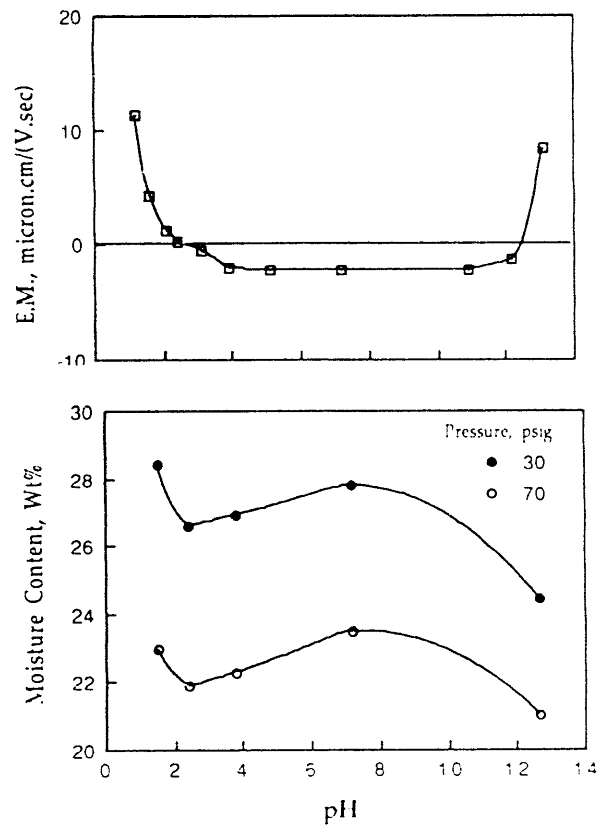

Figure 7. Effect of slurry pH on cake moisture content

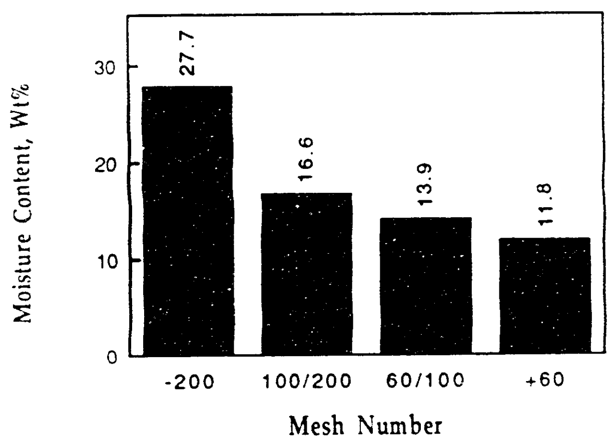

Figure 8. Efect of particle size on cake moisture content

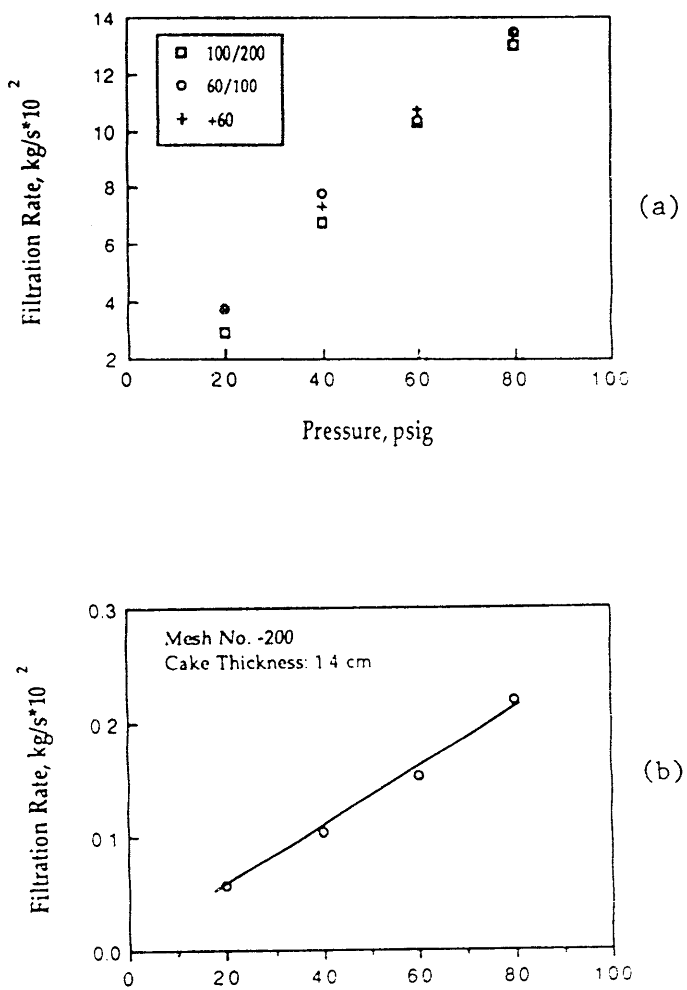

Figure 9. Effect of particle size on overall filtration rate

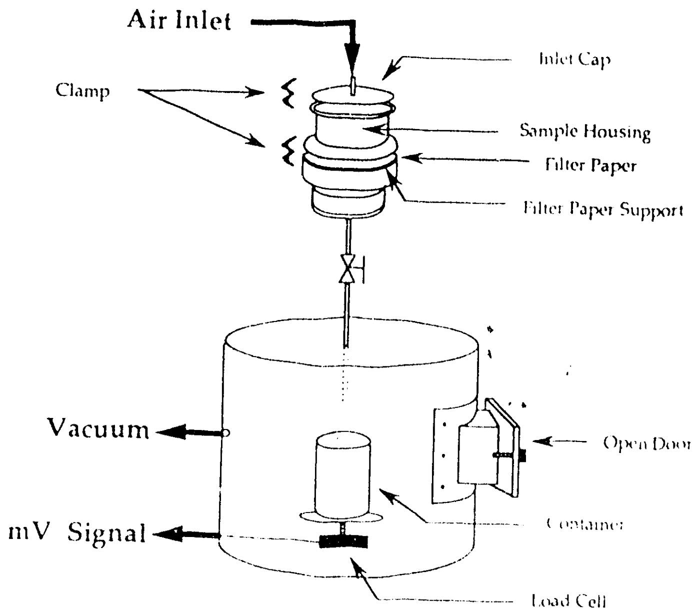

Figure 10. Pressure/vacuum filtration cell