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**POC-SCALE TESTING  
OF AN ADVANCED FINE COAL DEWATERING EQUIPMENT/TECHNIQUE**

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**U.S. Department of Energy  
Pittsburgh Energy Technology Center  
Pittsburgh, PA 15236**

**By**

**D. Tao  
J.G. Groppo  
B.K. Parekh  
Center for Applied Energy Research  
University of Kentucky  
Lexington, KY 40511**

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## **EXECUTIVE SUMMARY**

Froth flotation technique is an effective and efficient process for recovering of ultra-fine (minus 74  $\mu\text{m}$ ) clean coal. Economical dewatering of an ultra-fine clean coal product to a 20% level moisture will be an important step in successful implementation of the advanced cleaning processes. This project is a step in the Department of Energy's program to show that ultra-clean coal could be effectively dewatered to 20% or lower moisture using either conventional or advanced dewatering techniques.

The cost-sharing contract effort is for 45 months beginning September 30, 1994. This report discusses technical progress made during the quarter from April 1 – June 30, 1998.

### **OBJECTIVES AND SCOPE OF THE PROJECT**

The main objective of the proposed program is to evaluate a novel surface modification technique, which utilizes the synergistic effect of metal ions-surfactant combination, for dewatering of ultra-fine clean coal on a proof-of-concept scale of 1 to 2 tph. The novel surface modification technique developed at the UKCAER along with the use of conventional reagents was evaluated using vacuum, centrifuge, and hyperbaric filtration equipment. Dewatering tests were conducted using the fine clean coal froth produced by the column flotation units at the Powell Mountain Coal Company, Mayflower Preparation Plant in St. Charles, Virginia. The POC-scale studies were conducted on two different types of clean coal, namely, high-sulfur and low-sulfur clean coal produced at the

plant. The Mayflower Plant processes coals from five different seams, thus the dewatering results could be generalized for most of the bituminous coals.

## **APPROACH**

The project team consisted of the University of Kentucky Center for Applied Energy Research (UKCAER), Powell Mountain Coal Company (PMCC), Andritz Ruthner Inc., WesTech Engineering Inc., and Decanter Machine, Inc.

The UKCAER is the prime contractor of the project which has been divided into nine (9) tasks. The clean coal froth generated by the 'Ken-Flote' columns at the PMCC Mayflower Preparation Plant was utilized for dewatering studies using hyperbaric, centrifuge, vacuum and ceramic die filter dewatering techniques.

## **ACCOMPLISHMENTS DURING THE QUARTER**

In the last quarterly report, it was noticed that the baseline dewatering data varied significantly. This abnormality was attributed to the use of house vacuum which varied significantly during the testing. This quarter tests were repeated using a portable vacuum pump which provided a constant vacuum of 25 inches of mercury.

Using 30 secs cake drying time and 30 secs cake formation time, the high- and low-porosity ceramic leaf filters provided 21.5% and 18.0% filter cake moistures, respectively. The solids loading on the high- and low-porosity filters were 0.8 Kg/m<sup>2</sup> and 0.44 Kg/m<sup>2</sup>, respectively.

Addition of 10 g/t of an anionic flocculant lowered the filter cake moisture from 22.0% to 14.0% using the high-porosity filter, and 18.0% to 13.5% using the low-porosity filter. Addition of 15 g/t of a cationic flocculant lowered filter cake moisture from 18.0% to 16.0% using the low-porosity filter. High-porosity filter did not provide any lowering of filter cake moisture, however, the solids loading increased from 1.5 kg/m<sup>2</sup> to 5.8 kg/m<sup>2</sup> at a flocculant dosage of 25 g/t. This high solids loading indicated thicker filter cake which would retain a high moisture.

Among the three surfactants studied, only the non-ionic and the cationic were effective in lowering the filter cake moisture. 0.4 kg/t of a non-ionic surfactant (octyl phenoxy polyethoxy ethanol) lowered filter cake moisture from 19.5% to 16.8%; and 1 kg/t of the cationic surfactant CPCL, lowered the filter cake moisture from 19.0% to 15.8%.

Addition of 0.4 kg/t of copper ions or 0.3 kg/t of aluminum ions lowered the filter cake moisture from 20.5% to 17.0%, using the low-porosity filter. The high-porosity filter which showed increase solids loading (thicker filter cakes) did not provide any lowering of the filter cake moisture.

Low-porosity filter was found to be more effective in lowering the filter cake moisture than high-porosity ceramic filter. However, high-porosity was more effective in providing higher solids loading than low-porosity filter.

## INTRODUCTION

For cleaning of coal finer than 0.5 mm (28 mesh) processes based on surface chemical technique such as froth flotation and oil agglomeration are the most effective. However, the froth flotation process, which is commercially used, produces a product containing about 80% moisture. The recently developed column flotation technique provides higher recovery of low ash product, but also suffers from the same problem of high moisture product. Dewatering of the fine coal to a low (~20%) moisture level using the conventional filtration equipment has not been possible. This project offers a novel surface-modification approach to modify coal surface so it could dewater to a low moisture level using conventional and advanced dewatering equipment.

The aim of this program is to test the UKCAER-developed novel coal surface modification approach on a pilot scale at the rate of 1-2 tph of solids using vacuum, centrifuge and hyperbaric filtration technique. This proof-of-concept testing was performed at the Powell Mountain Coal Company Mayflower Plant located in St. Charles, Virginia.

The project involved a teaming arrangement between the University of Kentucky for Applied Energy Research (CAER), the Powell Mountain Coal Company (PMCC), the Andritz Ruthner Inc. (ARI), WesTech Engineering Inc., and Decanter Machine, Inc.

## **APPROACH**

A team of scientists and engineers from the Center for Applied Energy Research, Powell Mountain Coal Company, and equipment manufacturers was formed to accomplish the objectives of the program. Each team member brought fine particle dewatering knowledge and experience to the project. The UKCAER, who is the prime contractor, manages the project and conducts the major part of the study. The PMCC provided assistance and facility in conducting the pilot scale tests, and ARI conducted laboratory dewatering tests and also pilot scale tests using the hyperbaric pressure filtration unit at the PMCC. Figure 1 shows the project organization chart. The project schedule for the program is shown in Figure 2.

The CAER collected clean coal froth samples from the Mayflower plant for the laboratory studies. Samples of clean coal slurries were also sent to other project participant teams for studies using their laboratory-scale units. It was emphasized to identify optimum process and operating conditions to dewater the clean coal slurry to about the 20% level moisture. It is believed that the proposed research can produce low moisture products on a pilot scale to the same extent which has already been achieved in laboratory studies.

The basic components of the process has been tested in laboratory. The purpose of the proposed work here is to evaluate all of the component steps on a consistent basis, and, to the extent possible in laboratory studies, demonstrate

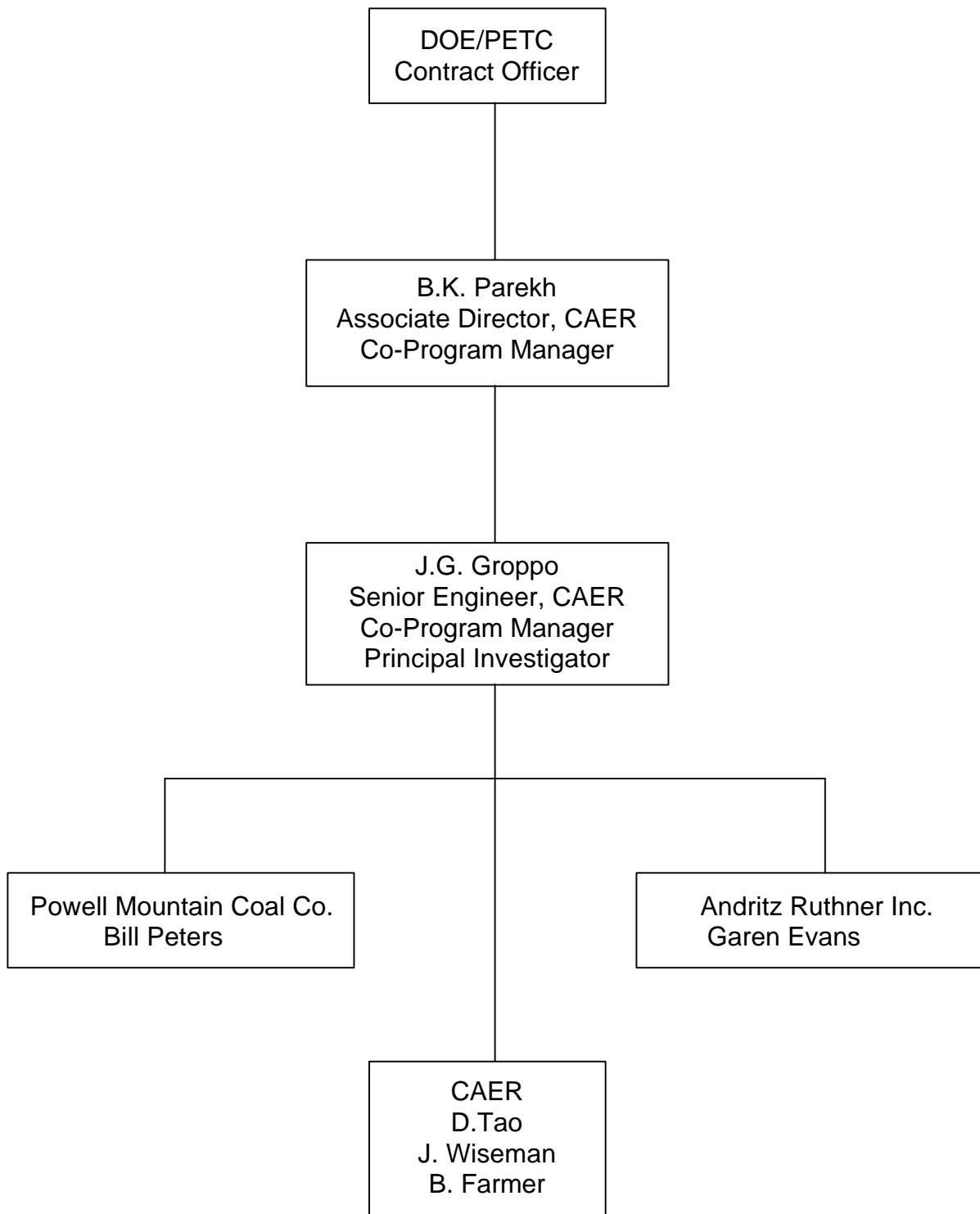


Figure 1. Project management organization chart



the feasibility of their integration. The outcome of this program will be to identify a process/technique combination which is able to achieve a 20% or lower moisture in the fine clean coal product and to provide a technical and economic evaluation of the integrated concept in sufficient detail for a coal company to assess the potential for installation of the dewatering process in their plant.

## **RESULTS AND DISCUSSION**

The project tasks and subtasks are listed in table 1. During this quarter (April 1 to June 30, 1998) work was conducted using the ceramic disc leaf filter apparatus.

In the last quarterly report, it was mentioned that the use of house vacuum provided wide variations in the dewatering results. The variations in results were attributed to fluctuating vacuum force observed during the testing. This quarter, all the ceramic leaf filter tests were repeated using a portable vacuum pump which provided a constant 25 inches Hg of vacuum. Figures 3, 4, and 5 demonstrate the experimental steps for the ceramic leaf filter tests. All the dewatering tests reported were conducted using the 'as received' clean coal slurry containing 12.8% solids.

Figures 6 and 7 show the effect of cake drying time (CDT) on cake moisture and solids loading for the 'as received' clean coal slurry from the Powell Mountain Coal Company using high- and low-porosity ceramic filter, respectively. As expected, the filter cake moisture decreases from 23.6% to



Figure 3. Ceramic disc leaf filtration set-up



Figure 4. Dewatering/drying stage of the filter cake

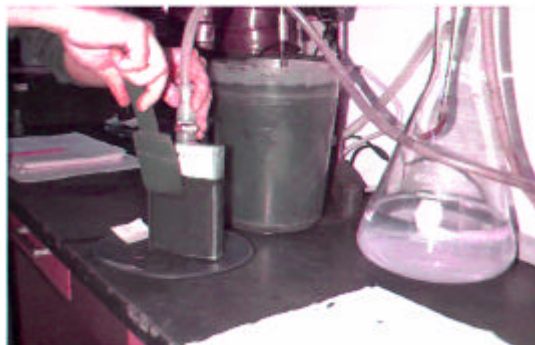


Figure 5. Removing of the filter cake

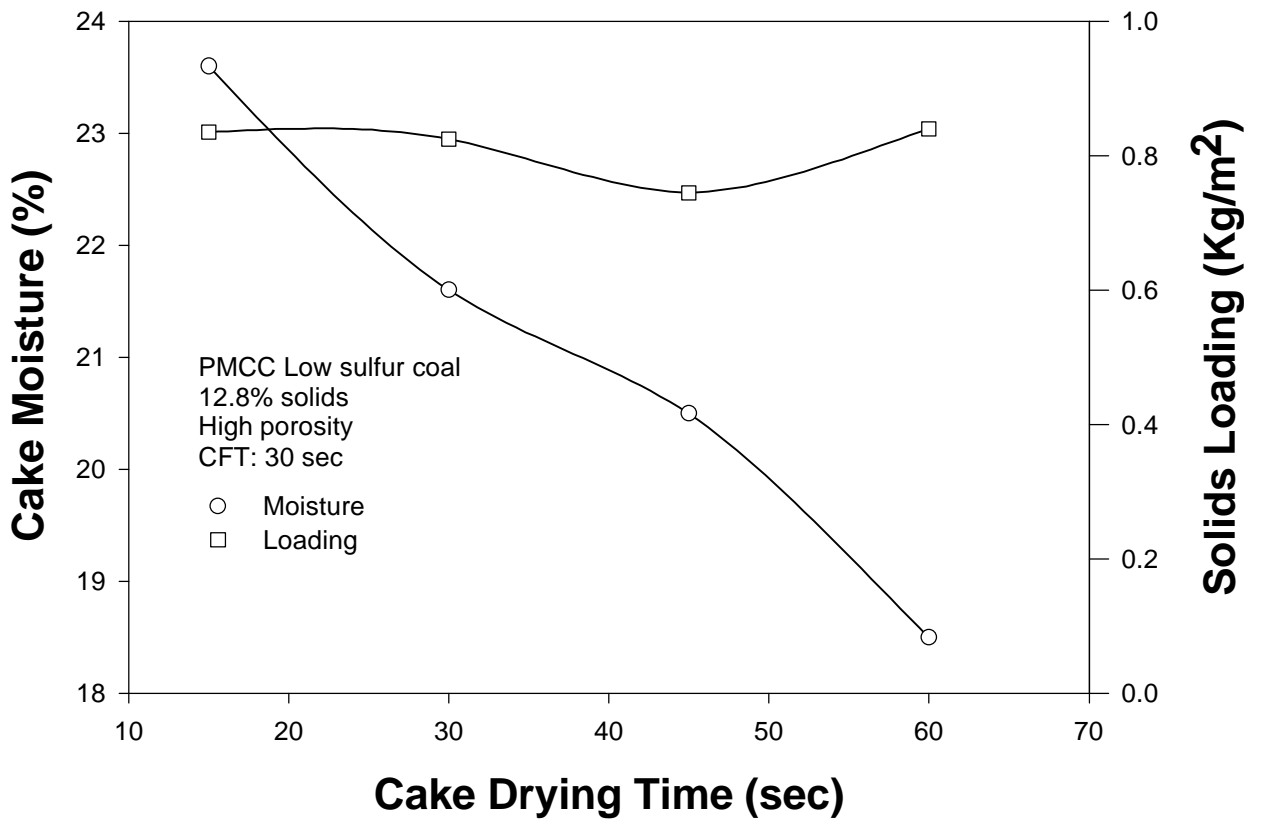


Figure 6. Effect of cake drying time on filter cake moisture and solids loading using the high porosity filter

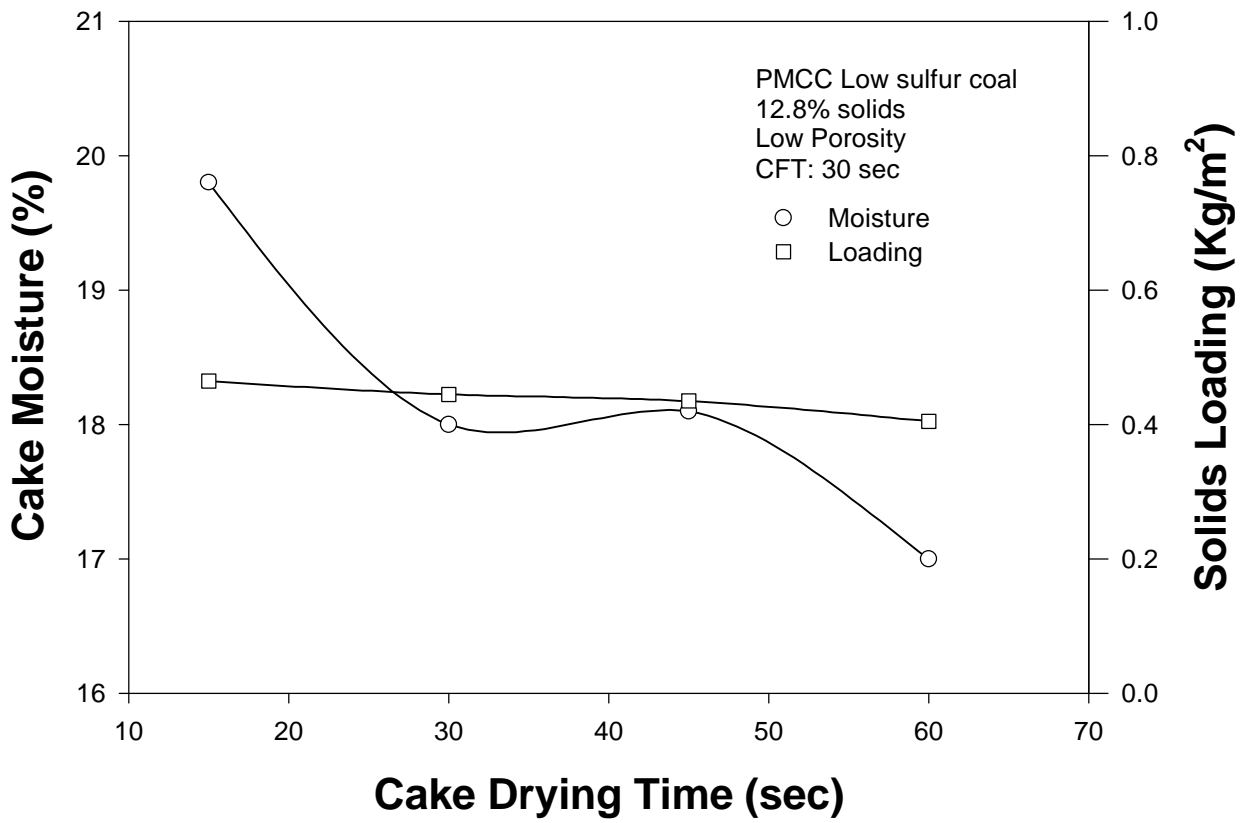


Figure 7. Effect of cake drying time on filter cake moisture and solids loading using the low porosity filter

18.5% for the high-porosity filter and from 19.8% to 17.2% for the low-porosity filter, as the cake drying time increases from 15 to 60 secs. However, the solids loading remains constant ( $\sim 0.8 \text{ kg/m}^2$  for the high-porosity and  $\sim 0.4 \text{ kg/m}^2$  for the low-porosity filter) over the entire cake drying time.

Figure 8 shows the effect of anionic flocculant dosage on cake moisture and solids loading. Note, that the addition of 10 g/t of the flocculant was effective in lowering the filter cake moisture from 22% to 14% for the high-porosity filter and from 18% to 13.5% for the low-porosity ceramic filter. Increasing flocculant dosage did not provide further lowering of the cake moisture, however, the solids loading on both the filters increases with the increase in flocculant dosage.

The effect of a cationic flocculant dosage on the filter cake moisture and solids loading is shown in Figure 9. Addition of cationic flocculant results in a slight decrease in filter cake moisture from 18% to 16% at a dosage of 15 g/t using the low-porosity filter. For the high-porosity filter, the filter cake moisture remains constant, however, the solids loading increases from  $1.8 \text{ kg/m}^2$  to  $5.8 \text{ kg/m}^2$  when flocculant dosage increases to 25 g/t.

Of the three surfactants (i.e. cationic, anionic, and non-ionic), only the non-ionic (octyl phenoxy polyethoxy ethanol) and the cationic surfactants (cetyl pyridinium chloride) showed any significant effect in lowering of the filter cake moisture. Figure 10 shows the effect of the non-ionic surfactant dosage on the porosity filter shows lowering of filter cake moisture from 19.5% to 16.8% at a

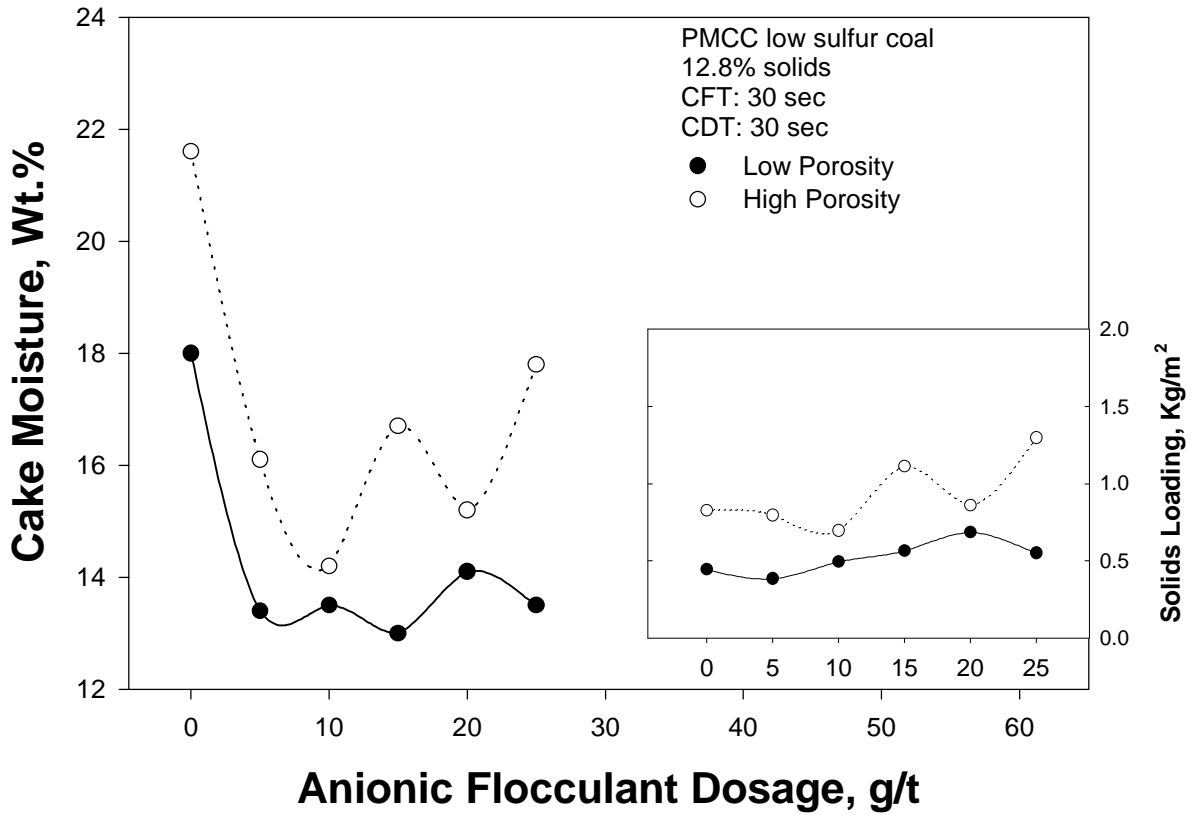


Figure 8. Effect of anionic flocculant dosage on filter cake moisture and solids loading

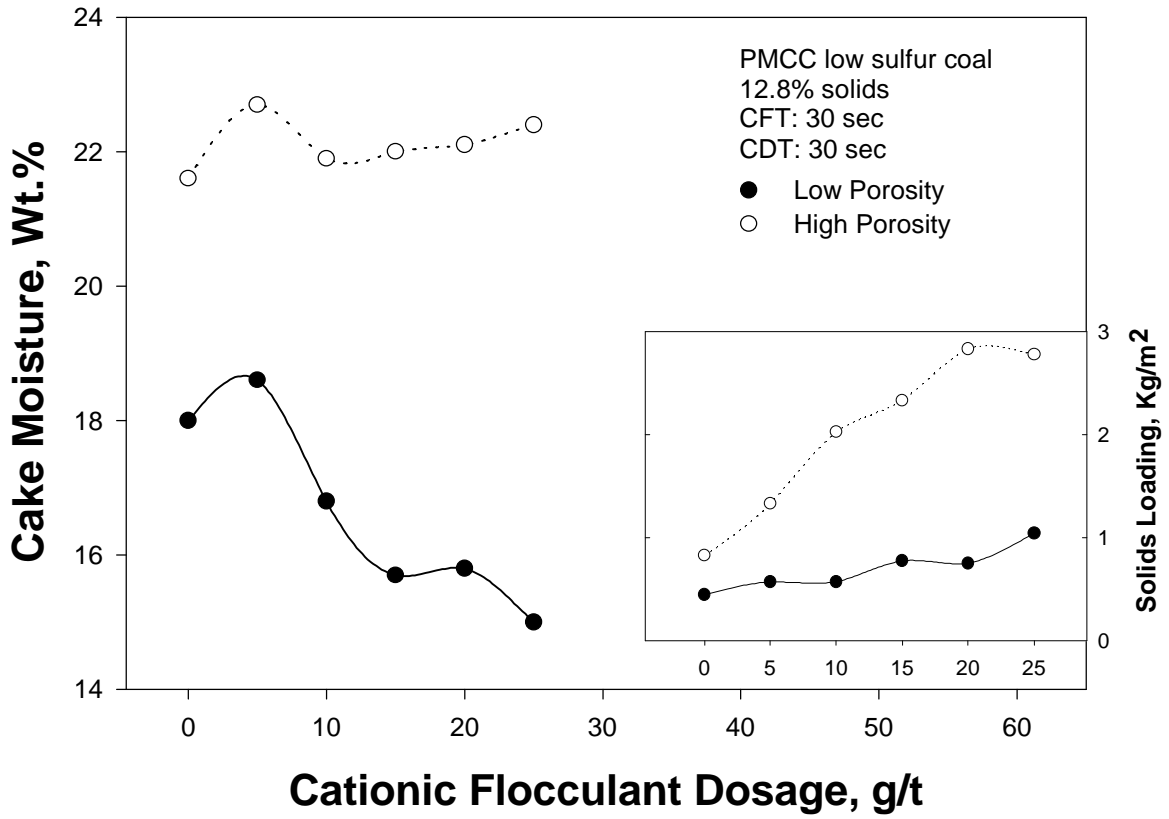


Figure 9. Effect of cationic flocculant dosage on filter cake moisture and solids loading

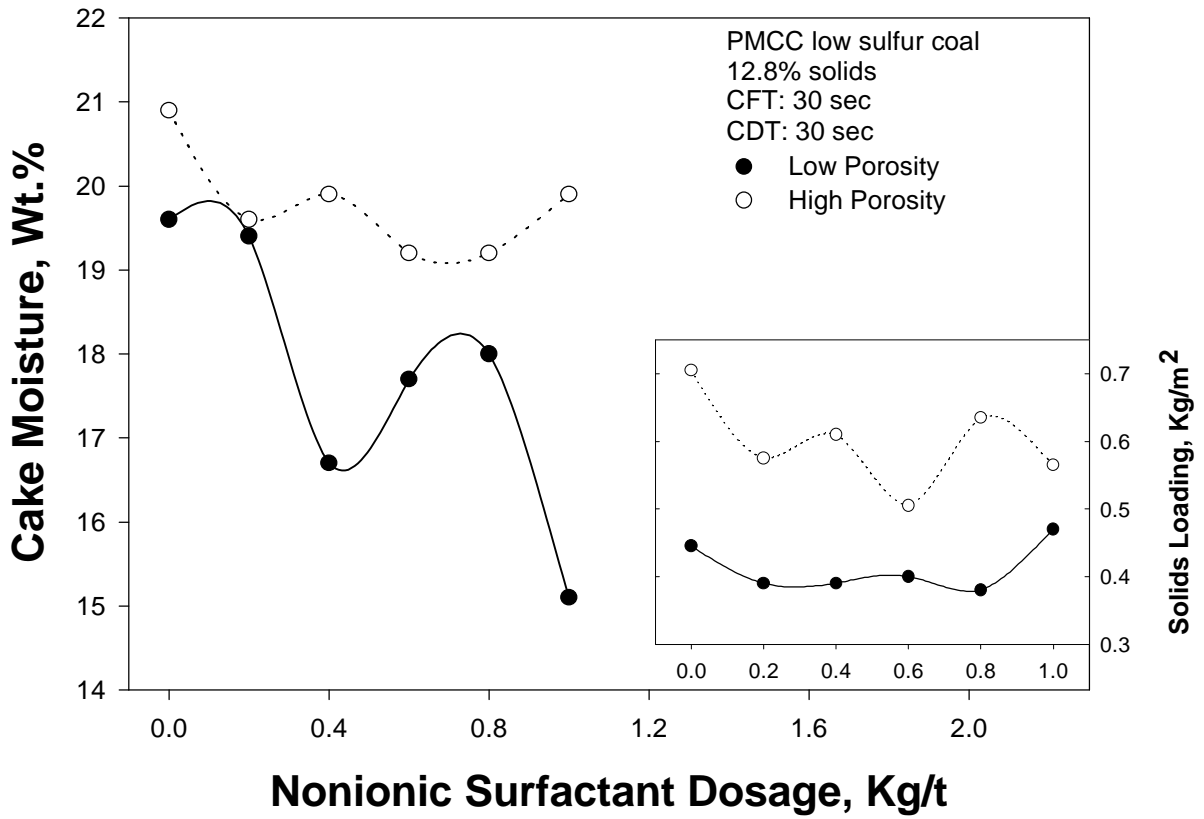


Figure 10. Effect of nonionic surfactant dosage on filter cake moisture and solids loading using high and low porosity ceramic filters

filter cake moisture and solids loading. Again, in this case also, only the low-surfactant dosage of 0.4 Kg/t. The solids loading for both filters declined with increasing surfactant dosage.

Figure 11 shows the effect of the cationic surfactant CPCL dosage on the filter cake moisture and solids loading. Again, the filter cake moisture declines significantly from 19% to 15.8% for the low-porosity filter at a surfactant dosage of 1 kg/t. For the high-porosity filter, the filter cake moisture lowers from 22% to 20.5% at a dosage of 0.6 kg/t. For both the filters solids loading increases with the increase in the surfactant dosage; the solids loading increases significantly for the high-porosity compared to low-porosity filter.

The data on effects of copper metal ion addition on the filter cake moisture and solids loading are shown in Figure 12. It shows that with the low-porosity filter, addition of 0.4 Kg/t of copper ions lowered the filter cake moisture from 20.5% to 17%, however, for the high-porosity filter an increase in filter cake moisture occurs. Both the filters show increase in solids loading with increasing copper ion dosages.

Addition of 0.3 Kg/t of aluminum ions was also effective in lowering the filter cake moisture from 20.5% to 17% using the low-porosity filter, however, for the high-porosity filter moisture increases with increasing aluminum ion dosages (Figure 13). Both the filters provide increase in solids loading with increasing aluminum ion dosages.

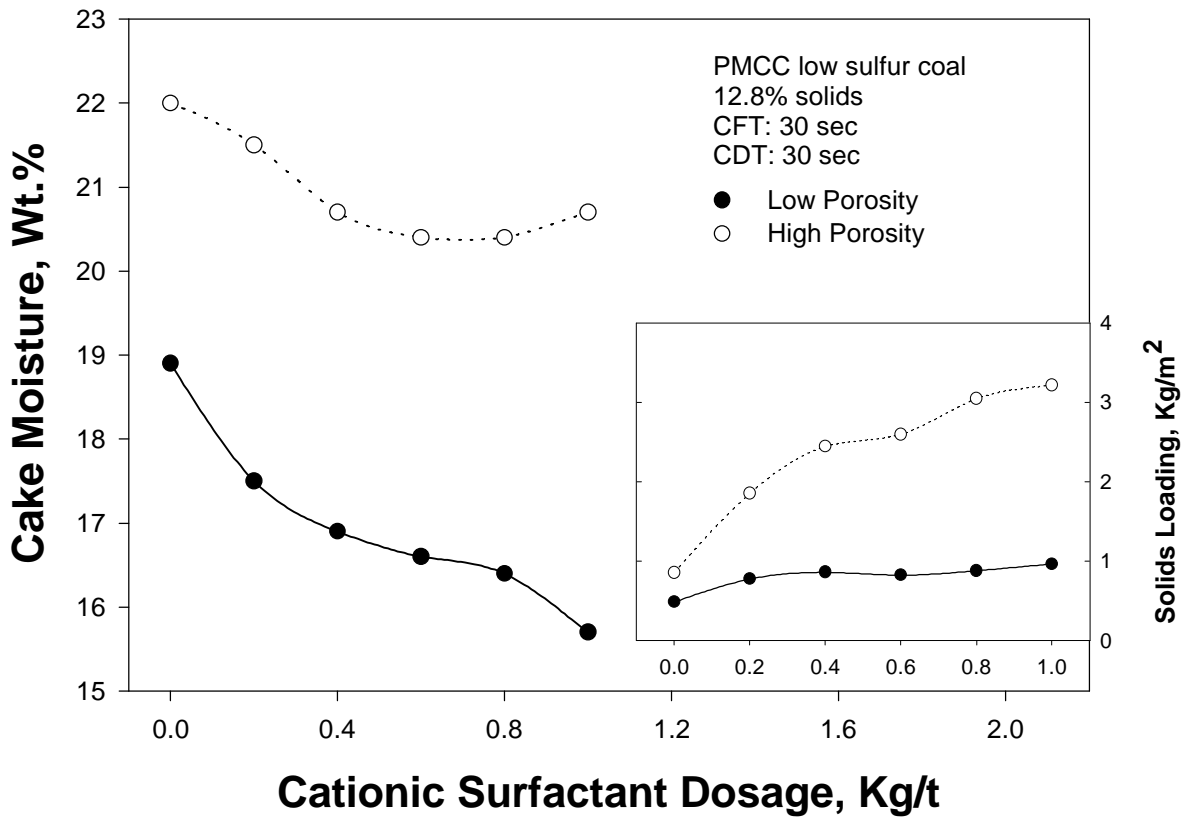


Figure 11. Effect of cationic surfactant dosage on filter cake moisture and solids loading using high and low porosity ceramic filters

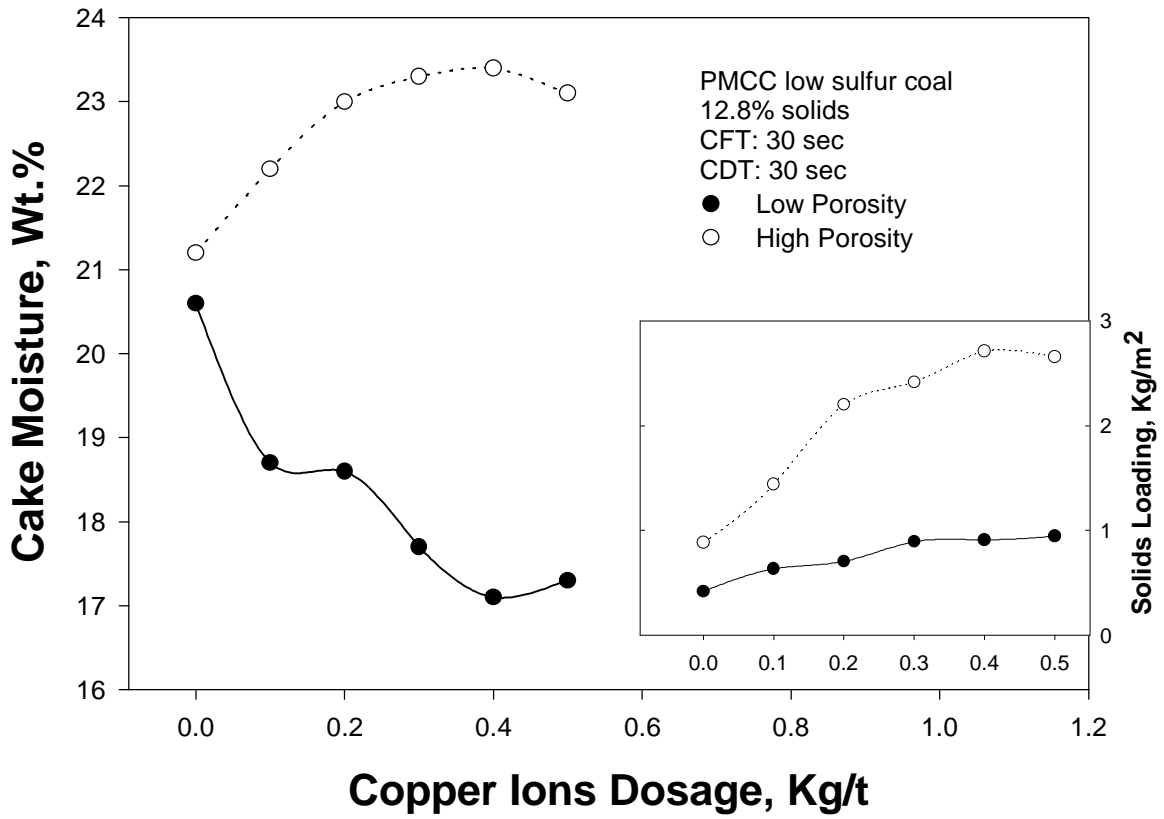


Figure 12. Effect of copper ion dosage on filter cake moisture and solids loading

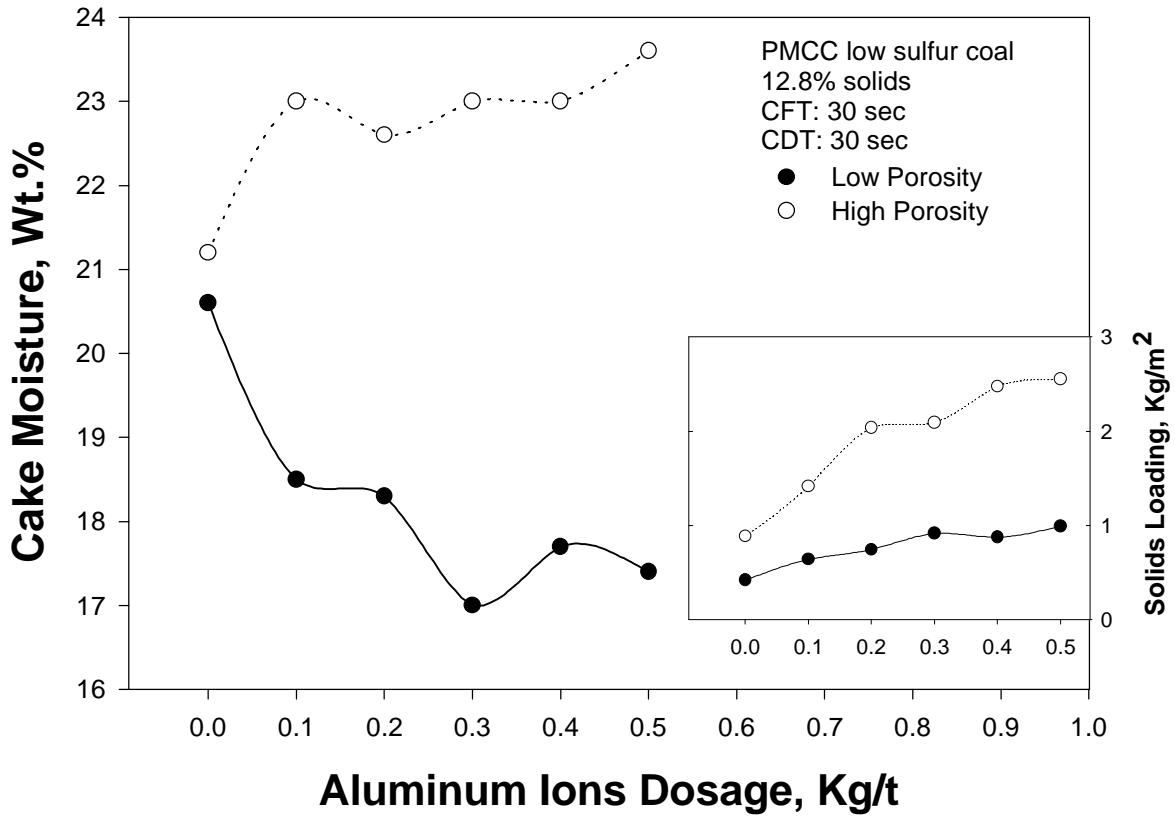


Figure 13. Effect of aluminum ion dosage on filter cake moisture and solids loading

## CONCLUSIONS

Based on the results presented above, the following conclusions are made.

- Utilization of a constant vacuum force obtained using a vacuum pump provided more consistent dewatering results. A slight variation in the baseline dewatering data observed could be due to some blockage of capillaries in the ceramic filters.
- A 30 sec cake drying time and 30 sec of cake formation time was found to be optimum for both the high- and low-porosity filters, providing 21.5% and 18.0% filter cake moistures, respectively. Solids loading under the above conditions for the high- and low-porosity filters was 0.8 Kg/m<sup>2</sup> and 0.44 Kg/m<sup>2</sup>, respectively. The high-porosity ceramic filter provided almost two times more solids loading than the low-porosity filter.
- Addition of 10 g/t of an anionic flocculant was effective in lowering filter cake moisture from 22% to 14% for the high-porosity filter and from 18% to 13.5% for the low-porosity filter. Both filters showed a slight increase in solids loading with increase in the flocculant dosage.
- Addition of 15 g/t of a cationic flocculant lowered filter cake moisture from 18% to 16% using the low-porosity filter. The high-porosity filter did not show any changes in the filter cake moisture with the addition of the cationic flocculant, however, the solids loading increased from 0.7 kg/m<sup>2</sup> to 2.4 kg/m<sup>2</sup> using 25 g/t of the flocculant.

- Among the three surfactants utilized, only the non-ionic and cationic surfactants were found to be effective in lowering the filter cake moisture. 0.4 kg/t of the non-ionic surfactant lowered filter cake moisture from 19.5% to 16.8%. For the cationic surfactant about 1 kg/t was required to lower the filter cake moisture from 19.0% to 15.8%.
- Addition of 0.4 kg/t of copper ions or 0.3 kg/t of aluminum ion lowers the filter cake moisture from 20.5% to 17%, using the low-porosity filter. The addition of copper or aluminum ions was not effective in lowering the moisture for the high-porosity filter.
- The low-porosity filter was more effective than the high-porosity filter in lowering the filter cake moisture. However, the high-porosity filter provided for a much higher solid loading than the low-porosity filter. A thicker cake will always have higher moisture than a thinner one, which explains why the high-porosity filter did not provide lowering of filter cake moisture.

### **ACTIVITIES FOR NEXT QUARTER**

All the tasks proposed for the project have been completed. Efforts are in progress in preparing the final report on the project.