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TECHNICAL REPORT  
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Project Title: **IN-PLANT TESTING OF A NOVEL COAL CLEANING CIRCUIT  
USING ADVANCED TECHNOLOGIES**

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Principal Investigator: R. Q. Honaker  
Department of Mining Engineering  
Southern Illinois University at Carbondale  
Other Investigators: S. Reed and M.K. Mohanty  
Kerr-McGee Coal Corporation  
Project Manager: K. Ho, ICCI

**ABSTRACT**

Research conducted at SIUC over the past two years has identified highly efficient methods for treating fine coal (i.e., -28 mesh). In this study, a circuit comprised of the three advanced fine coal cleaning technologies is being tested in an operating preparation plant to evaluate circuit performance and to compare the performance with the current technologies used to treat -16 mesh fine coal. The circuit integrates a Floatex hydrosizer, a Falcon concentrator and a Jameson froth flotation cell. The Floatex hydrosizer is being used as a primary cleaner for the nominally -16 mesh Illinois No. 5 fine coal circuit feed. The overflow of the Floatex is screened at 48 mesh using a Sizetec vibratory screen to produce a clean coal product from the screen overflow. The screen underflow is further treated by the Falcon and Jameson Cell.

During this reporting period, tests were initiated on the fine coal circuit installed at the Kerr-McGee Galatia preparation plant. The circuit was found to reduce the ash content of the nominally -16 mesh fine coal circuit feed from 23.7% to 5.2% while recovering greater than 85% of the combustible material. This metallurgical performance equates to a relatively high separation efficiency of 72%. In addition, the pyritic sulfur content was reduced from 0.73% to 0.20% at the same recovery value, which corresponds to a pyritic sulfur rejection of 84%. The high separation efficiency achieved by the circuit is largely due to the highly effective treatment of the +48 mesh fraction provided by the Floatex hydrosizer. The ash content in this size fraction was reduced from about 18.1% to a remarkably low value of 4.68% while achieving a 93% combustible recovery. In addition, the pyritic sulfur content was reduced from 0.56% to 0.18%. The product quality achieved on the 48 mesh screen underflow by the Falcon and Jameson Cell was slightly inferior to that achieved on the +48 mesh size fraction. The ash content in the -48 mesh fraction was reduced from 24% to about 6% while recovering 85% of the combustibles. Additional in-plant circuitry tests are on-going.

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## EXECUTIVE SUMMARY

The goal of this project is to demonstrate through in-plant testing the improved separation performance and enhanced economics that may be provided by a fine coal cleaning circuit utilizing advanced coal cleaning devices. In addition, it is also a goal to develop a pre-combustion coal cleaning strategy for the production of Phase I and II compliance coal from medium-to-high sulfur Illinois Basin coals.

The fine size fraction (i.e., -28 mesh) in U. S. coal preparation plants has been given very little attention until recently. However, the production of larger amounts of fines by the increase in mine mechanization and the fact that the fine coal fraction contains the most pure coal particles in the preparation plant has created a great deal of interest in the efficient cleaning and recovery of fine coal. Several technologies have been developed and introduced to the coal industry which assist the plant operators in achieving this task. The modifications to the original spiral concentrators to treat fine coal have resulted in their recent popularity among coal producers. However, despite the units simplicity of operation, several problems exist related to their separation performance capabilities and operational/maintenance characteristics. For example, their relatively small throughput per unit (i.e., 3 tph) requires the need for a large number of units to treat a moderate size stream and, thus, a complex distribution system that often gets plugged during operation. In addition, the specific gravity cut point provided by the spiral is a relatively high 1.8 and, despite extensive efforts, has yet to be decreased. Conventional flotation is another technology commonly used to treat fine coal but also has problems with the entrainment of clay particles in the clean coal concentrate and its ineffectiveness at cleaning coals containing a significant amount of middling particles.

Tests conducted over the past two years as part of ICCI projects have identified fine coal cleaning technologies that appear to provide an improved separation performance when compared to technologies currently being used in the coal industry. The research projects evaluated three distinctly different solid-solid separation technologies, namely, hindered-bed classification, enhanced gravity concentration, and column flotation, which were found to be highly efficient for treating ranges of particle sizes that are compatible when placed in a circuit arrangement. The hindered-bed classifier, commercially known as the Floatex, was found to be the most effective on the 16 x 48 mesh size fraction. The specific gravity-cut point provided by the unit is about 1.8 while achieving a probable error value ( $E_p$ ) of 0.12, which is an improvement in efficiency over spiral concentrators which yield a  $E_p$  of 0.12 to 0.20. In addition, the unit is able to treat much larger throughputs, thereby, eliminating the need for a complex feed distribution system. The operating parameters of the Floatex can be easily adjusted by a controller, which is not currently possible for spiral concentrators.

The Falcon Concentrator, an enhanced gravity concentrator, was found to be the most efficient at treating the 48 x 400 mesh coal size fraction. The specific gravity cut point was found to be easily varied by the adjustment of operating variables to achieve values between 1.5 and 1.7, which are less than those achievable by spiral concentrators. The  $E_p$

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value obtained from the Falcon unit was approximately 0.12. Pyritic sulfur rejections greater than 75% were achieved while maintaining recovery values at near or greater than 90%.

A number of studies comparing the performance of column flotation with conventional flotation, which is presently the most common process used for treating the -100 mesh size fraction, has found that column flotation is more efficient in the recovery of ultrafine particles and produces much lower product ash contents. In an ICCI study, recovery values greater than 90% were achieved by number of different flotation column units while reducing the ash contents of Illinois Basin coal containing 60% -325 mesh material from as high as 50% to below 5%. These results demonstrate the excellent desliming efficiency of flotation columns. The Jameson Cell was found to be very attractive due to its high throughput and operational simplicity. The cell is self-aspirating, using a venturi-based system to draw air into a long tube where the bubbles are intimately mixed with the coal particles. The only requirement for the system is a feed pressure of approximately 20 psi.

In this project, a fine coal circuit comprised of the three aforementioned advanced coal cleaning technologies is being tested in an operating coal preparation plant for the purposes of improving the efficiency of current preparation plant operations and developing a Phase II compliance strategy for medium-to-high sulfur coal. To meet this goal, the specific project objectives must be realized, which are: 1) To install a fine coal cleaning circuit having a mass flow capacity of approximately 5 tph at Kerr-McGee's Galatia preparation plant; 2) To test the circuit in a "real-life" environment while varying the operating conditions of the various units; 3) To compare the separation performance achieved by the circuit with the performance obtained by the circuit presently used for the treatment of the same size fraction; 4) To determine the economic benefits of the proposed circuit when compared to current circuits used to treat the same size fraction and 5) To produce Phase II compliance coal through the micronization and retreatment of the clean coal product from the proposed circuit. In addition to the above objectives, an on-line coal analyzer, commercially known as the AMDEL system, will be evaluated in an effort to study the effects of the operating parameters and to demonstrate its use as an effective control device.

During this reporting period, the circuit, which is comprised of an 18 x 18 in<sup>2</sup> Floatex, a 10-inch diameter Falcon Concentrator, and a Jameson Cell, was installed at Kerr-McGee's Galatia preparation plant. The Galatia coal preparation plant treats coal from two sections of the Illinois No. 5 coal seam which have distinctly different characteristics, especially in terms of total and pyritic sulfur contents. The 16 mesh x 0 size fraction is currently cleaned by a combination of spiral concentrators (16 x 100 mesh size fraction) and conventional flotation (-100 mesh size fraction). For the fine circuit feed, the total sulfur content in the high sulfur coal is 2.4% whereas the low sulfur coal has a sulfur content of 1.4%. The corresponding pyritic sulfur contents are 1.6% and 0.7%, respectively. The ash content in the -16 mesh fine circuit feed was approximately 24% for both coals. However, these values tend to fluctuate due to in-seam variations, the mining

practice and the bulk material handling system. Typically, the size distribution of the feed consists of 10% +16 mesh, 50% 16 x 100 mesh and 40% -100 mesh. The solids content in the fine circuit feed is about 13% by weight.

As previously described, the novel fine coal circuit integrates a Floatex hydrosizer, a Falcon concentrator and a Jameson froth flotation cell. The Floatex hydrosizer is being used as a primary cleaner for the nominally -16 mesh fine coal circuit feed. The overflow of the Floatex is screened at 48 mesh using a Sizetec vibratory screen to obtain a relatively coarse clean coal product from the screen overflow. The -48 mesh screen underflow is subsequently treated by the Falcon Concentrator and/or the Jameson Cell. Two circuit arrangements were evaluated during this reporting period for treating the -48 mesh size fraction: 1) Falcon Concentrator followed by the Jameson Cell in a rougher-cleaner arrangement and 2) Jameson Cell in a rougher-only and rougher-scavenger arrangements. The circuit was fed from a representative fraction of the plant fine circuit feed at a volumetric feed rate of 60 gallons/min which equates to a mass flow rate 2 tph.

Due to preparation plant scheduling, the majority of the tests during this reporting period was conducted on the low sulfur coal from the Illinois No. 5 coal seam. However, efforts will be provided to conduct tests during the next reporting period on specifically the high sulfur coal. Operating parameter values of the different process units were varied and samples collected from the product streams of the individual units and the overall circuit. Ash content, pyritic and total sulfur contents were performed on the samples, although some sulfur analyses were not completed due to time constraints. During the next reporting period, the sulfur analyses will be completed and the samples analyzed for BTU contents. Washability analyses will be performed on selected samples obtained from the advanced and conventional circuits. The separation performance and economic viability of the proposed circuit will be compared with the existing conventional circuit. Furthermore, the clean coal concentrate produced from the advanced fine coal circuit will be collected, micronized, and retreated in a Packed-flotation column and a Falcon concentrator in an effort to produce Phase II compliance coal. The clean coal product from this treatment will be given to ICCI as a potential feed stock for chemical/microbial processes.

The novel fine coal cleaning circuit consisting of a Floatex hydrosizer, Falcon Concentrator, and a Jameson Cell provided highly efficient cleaning of -16 mesh fine coal. Results obtained from in-plant testing found that the circuit was able to reduce the ash content of a nominally -16 mesh fine coal circuit feed from 23.7% to 5.2% while recovering greater than 85% of the combustible material. This metallurgical performance equates to a relatively high separation efficiency of 72%. In addition, the pyritic sulfur content was reduced from 0.73% to 0.20% at the same recovery value, which corresponds to a pyritic sulfur rejection of 84%.

The Floatex hydrosizer was found to provide an excellent metallurgical performance over a relatively narrow size fraction of 16 x 48 mesh. The ash content in this size fraction was reduced from about 18.1% to a remarkably low value of 4.68% while achieving a

93% combustible recovery. In addition, the pyritic sulfur content was reduced in this size fraction from 0.56% to 0.18%. Due to the significant amount (i.e., 44%) of +48 mesh material in the fine circuit feed, the excellent separation performance had a substantial and positive impact on the overall circuit performance.

The circuit utilizing the Falcon concentrator was found to provide a superior separation performance when compared to the circuit using only the Jameson Cell to treat the -48 mesh size fraction. For a given product quality, the Falcon-based circuit provided 5 percentage points improvement in the circuit combustible recovery values. The ash reduction achieved from the treatment of the 48 mesh screen underflow was slightly less than that obtained on the +48 mesh material. The Falcon-Jameson circuit reduced the ash content from 24.0% to about 6.0% while recovering 85% of the combustible material. The pyritic sulfur content was reduced to 0.2% which yielded a total sulfur content of nearly 0.9%.

During the previous reporting period, relatively low combustible recovery values were obtained from the single-stage treatment of a nominally -100 mesh flotation feed sample using the Jameson Cell. However, the combustible recovery values obtained from the Jameson Cell were substantially increased by the use of a two stage operation in a rougher-scavenger circuit arrangement. In fact, high combustible recovery values of about 90% and greater were achieved on particle size fractions up to 48 mesh. Ash contents were significantly reduced from about 40% in the -400 mesh size fraction to about 7.0% while overall ash contents of 6.0% and lower were achieved for the -48 mesh size fraction. The low recovery values obtained from single-stage Jameson Cell treatment is likely due to the co-current bubble-particle collision environment and the scale-up effects in the downcomer. Since the downcomer length is maintained at a constant value during scale-up, the length-to-diameter ratio increases as the Jameson Cell is transferred from lab-scale to an industrial-scale unit. As a result, the increased axial mixing provides a mechanism by which particles can be by-passed through the downcomer without colliding with an air bubble. This indicates a need for two-stage operations for industrial Jameson Cell installations.

## OBJECTIVES

The goal of this project is to demonstrate through in-plant testing the improved separation performance and enhanced economics that may be provided by a fine coal cleaning circuit utilizing advanced coal cleaning devices. To meet this goal, the specific project objectives must be realized, which are:

1. To install a fine coal cleaning circuit having a mass flow capacity of approximately 5 tph at Kerr-McGee's Galatia preparation plant,
2. To test the circuit in a "real-life" environment while varying the operating conditions of the various units,
3. To compare the separation performance achieved by the circuit with the performance obtained by the circuit presently used for the treatment of the same size fraction,
4. To determine the economic benefits of the proposed circuit when compared to current circuits used to treat the same size fraction.
5. To produce Phase II compliance coal through the micronization and retreatment of the clean coal product from the proposed circuit.

In addition to the above objectives, an on-line coal analyzer, commercially known as the AMDEL system, will be used in an effort to study the effects of the operating parameters and to demonstrate its use as an effective control device. The on-line analyzer has the ability to analyze the ash content, air content, and solids content of a coal slurry with a total analysis time of 1 minute. This response time is a large improvement over existing systems which require 15 to 20 minutes for de-aeration.

## INTRODUCTION AND BACKGROUND

In this study, in-plant circuitry testing will be conducted which will incorporate advanced coal cleaning technologies that have been successfully evaluated over the past two years at SIUC. It is believed that the implementation of these technologies will result in a more efficient fine coal cleaning circuit, a reduction in floor space requirements, and an overall simplified operation that is easily adaptable to automation. A description of each technology and a summary of pertinent separation performance data produced from each unit is provided in the following sections.

### Floatex Hydrosizer

The Floatex hydrosizer is a hindered-bed classifier which utilizes elutriation water added in the bottom of the cell to suspend the particles entering in the feed, thereby, creating a fluidized bed. Heavy particles pass through the fluidized bed toward an underflow discharge while the light particles are pushed out the top by the velocity of the upward

flow of water. A pressure transducer is used to monitor and control the bed density by manipulation of an underflow control valve.

Tests results from a 9 x 9 in<sup>2</sup> Floatex revealed that the unit could effectively treat the 16 x 65 mesh size fraction of an Illinois No. 5 coal sample. The product ash and total sulfur contents were reduced from 20% to 8% and 2.23% to 1.49%, respectively, while recovering 95% of the combustibles at a mass throughput of 1.2 tph/ft<sup>2</sup>. The tailings ash and total sulfur content was 79.8% and 6.28%, respectively. A summary of these results are provided in Table 1.

Washability analyses of 16 x 100 mesh product and feed samples from the test providing the results in Table 1 resulted in the partition curve shown in Figure 1. The partition curve indicates that the Floatex provides a sharp separation at a specific gravity of approximately 1.8 for the treatment of 16 x 100 mesh coal. The probable error value ( $E_p$ ) determined from the partition curve is 0.12, indicating a more efficient process than spiral concentrators which have  $E_p$  values between 0.12 and 0.20.

Table 1. Results obtained from the treatment of 16 x 100 mesh Illinois No. 5 coal collected from the Galatia Preparation Plant using a 9 x 9 in<sup>2</sup> Floatex hydrosizer. The mass feed rate was 1.2 tph/ft<sup>2</sup>.

Size Fraction	Weight (%)		Ash (%)		Total Sulfur (%)	
	Feed	Product	Feed	Product	Feed	Product
+16	18.6	10.9	18.0	4.50	1.67	1.34
16 x 28	21.8	22.0	21.1	5.44	2.02	1.42
28 x 48	23.7	25.7	20.7	6.84	2.65	1.48
48 x 65	8.5	9.8	16.8	10.4	2.41	1.61
65 x 100	6.6	7.6	23.0	18.5	2.80	1.78
-100	20.9	24.0	41.6	38.9	3.19	2.73

As part of a previous ICCI project, in-plant testing of an 18 x 18 in<sup>2</sup> Floatex unit was performed at the Galatia Preparation plant on spiral concentrator feed which is nominally 16 x 100 mesh. The results obtained from these tests agree with those from the smaller unit in that the Floatex provides an efficient separation performance for the 16 x 100 mesh size fraction. In fact, the Floatex results were found to be superior to those achieved by the spiral concentrators as shown in Table 2.

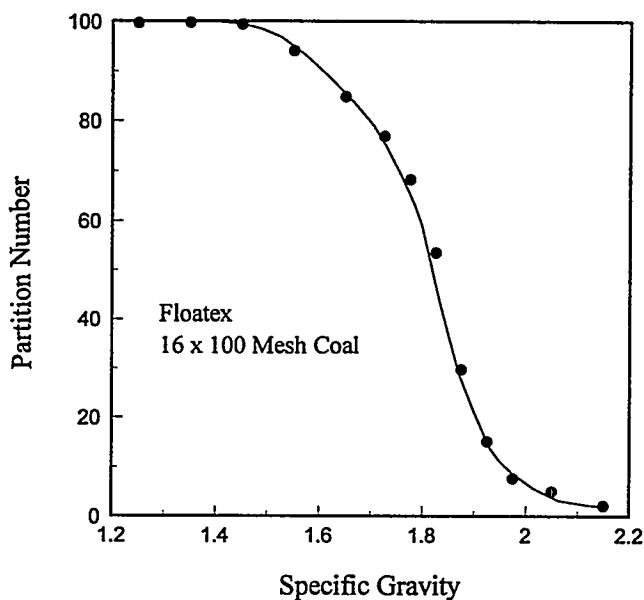


Figure 1. The partition curve produced by the Floatex hydrosizer from the treatment of nominally 16 x 100 mesh Illinois No. 5 coal. Mass throughput was 1.2 tph/ft<sup>2</sup> at a feed solids concentration of 35% by weight.

Table 2. Results obtained from the in-plant testing of an 18 x 18 in<sup>2</sup> Floatex at the Galatia Preparation Plant.

Test Number	Ash (%)			Total Sulfur (%)			Yield (%)
	Feed	Product	Tailings	Feed	Product	Tailings	
Floatex							
1	23.2	8.46	79.3	2.43	1.70	4.48	79.2
2	20.6	9.59	66.4	2.29	1.66	4.70	80.6
3	19.4	8.70	72.7	----	----	----	83.3
4*	20.8	7.32	82.4	1.35	1.04	3.07	82.0
Spiral							
1	20.3	10.0	57.9	2.27	1.73	4.26	78.5
2	20.7	10.6	58.8	----	1.84	4.23	79.1
3	21.8	10.8	53.3	----	1.90	4.75	74.1

\*low sulfur feed

#### Falcon Concentrator

The Falcon Concentrator is a spinning flowing film separator. The concentrator uses up to 300 g's of centrifugal force to cause deposition and stratification of fine particles against the inside of the smooth centrifugal bowl wall. The feed enters in the bottom of

the bowl where a rotor enhances the acceleration of the particles to the bowl wall. Due to the sloped wall (approx.  $10^{\circ}$  from vertical), a force parallel to the wall pushes the bed of solids up the bowl. As the bed moves, the heavy particles migrate toward the bowl wall while the light particles move inward toward the center of the bowl. The bed of particles move along the bowl wall and across a 1/2- inch slot that exists around the circumference of the bowl. The heavies flow into the slot and are discharged through orifices. The light particles flow over top the slot and report to the overflow as the final product with the particles that remained dispersed in the feed water.

Research conducted over the past year has found that the Falcon Concentrator achieves an efficient separation on the 65 x 400 mesh coal size fraction. As shown by the partition curves in Figure 2(a), the specific gravity cut point can be ranged from 1.5 to 1.7 while achieving a probable error value of approximately 0.12. However, the Falcon unit is less effective on the 28 x 65 mesh size fraction for which the cut point is 1.8 or greater and the probable error value varies from 0.2 - 0.3 (Figure 2b), resembling values achieved by single stage water-only cyclones. Thus, the Floatex hydrosizer would be the preferred method for the treatment of the 28 x 65 mesh size fraction.

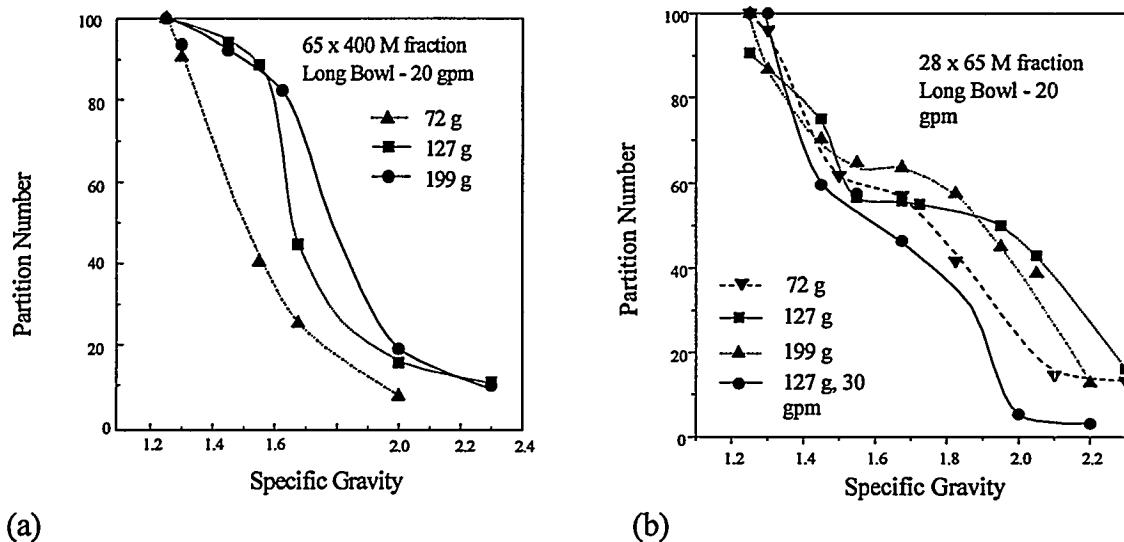


Figure 2. Partition curves produced from a continuous Falcon Concentrator from the treatment of nominally -28 mesh Illinois No. 5 seam coal. The products were screened to obtain the (a) 65 x 400 mesh and (b) 28 x 65 partition curves.

Mass feed rates and volumetric flows ranging from 1 to 4 tph and 10 to 40 gpm, respectively, were effectively treated by a 10-inch diameter continuous Falcon Concentrator. Typical size-by-size data provided in Table 3 illustrate the ability of the process to reject pyritic sulfur while maintaining high recovery values, even in the -325 mesh size fraction. It also indicates by the low calorific values the inability of the process

to effectively de-ash the -325 mesh material. Thus, it is required to deslime the Falcon overflow using a hydrocyclone or a flotation column..

As part of a current project, a 40-inch diameter Falcon Concentrator will be tested at the Coal Research Center of Southern Illinois University. The unit will be fed coal slurry at a rate up to 2000 gpm to establish maximum capacity. A projected mass flow rate for this unit is 100 to 150 tph.

Table 3. Results obtained from the treatment of Illinois No. 5 coal using a continuous 10-inch diameter Falcon Concentrator. Volumetric feed rate was 20 gpm at a solids content of 16% by weight.

Test Number	Total Sulfur (%)		Product BTU/lb	Recovery (%)	Total Sulfur Rej. (%)	lb SO <sub>2</sub> per MBTU
	Product	Tailings				
+100	1.46		13,660			2.14
1	1.38	7.91	13,470	99.2	6.64	2.05
2	1.28	5.55	13,610	97.3	16.0	1.88
3	1.23	4.57	13,610	95.2	21.6	1.80
4	1.15	2.57	13,610	79.9	38.4	1.69
100 x 325	1.80		12,700			2.84
1	1.53	8.76	12,525	98.7	18.2	2.44
2	1.41	5.81	13,365	96.7	28.6	2.11
3	1.29	4.65	13,430	90.4	39.2	1.92
4	1.23	3.47	13,635	80.5	49.1	1.80
-325	1.73		5,830			5.93
1	1.44	7.86	5,855	98.5	20.5	4.92
2	1.38	6.80	6,175	97.4	25.4	4.47
3	1.32	4.99	6,220	93.5	36.0	4.25

### Column Flotation

A research project funded by the Illinois Clean Coal Institute investigated and compared 6 different commercially-available flotation column technologies, namely, the Jameson Cell, the Packed-Column, the Microcel, the Flotaire, the Turbo-air, and the Canadian column. The last four are typical open columns that differ only by the method of bubble generation. The Packed-Column utilizes plates placed approximately 1/4-inch apart inside the cell to enhance the bubble-particle collision environment. The Jameson Cell is self-aspirating and, thus, does not require a sparging system. Air is drawn in through an opening behind an orifice through which the feed enters under a pressure of about 20 psi. The bubbles are formed in the presence of the coal particles, thereby, providing a high probability of bubble-particle collision.

Although each of the flotation columns achieved a high separation efficiency for each of the coals tested in the investigation, the Jameson Cell was found to provide a high throughput capacity while requiring the least amount of support equipment. Basically, the only requirement is a pump or enough natural head to supply a feed pressure of

approximately 20 psi. Another advantage for preparation plant operators is the low headroom requirement due to the lack of need for long residence times. Excellent separation performances were achieved by the Jameson Cell. For an Illinois No. 5 flotation feed, the ash content was reduced by the Jameson Cell from 44.0% to 4.21% while achieving a recovery of 85.3%. This corresponds to a very high separation efficiency of 81.9% for a single stage cleaning operation. In fact, the separation performance achieved by the Jameson Cell was found to be near to that obtained by the theoretically optimum release analysis curve as shown in Figure 3. For these reasons and due to its simplicity of operation, the Jameson Cell was chosen to be tested as part of the proposed fine coal circuit.

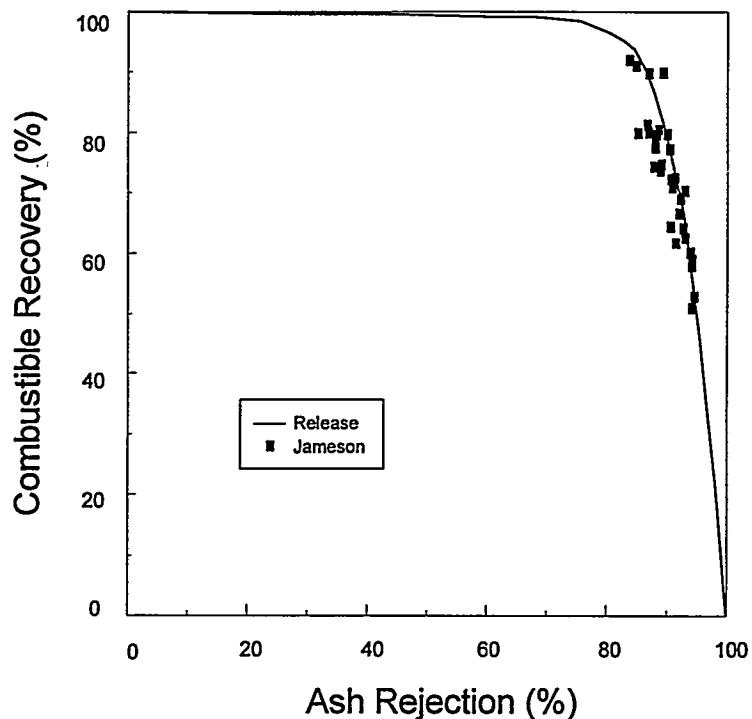


Figure 3. Results showing the separation performance achieved by the Jameson Cell from the treatment of nominally -100 mesh Illinois No. 5 coal.

Although the Jameson Cell was found to be a high capacity flotation device which provides efficient ash rejection, the cell was found to be inefficient in the rejection of pyritic sulfur in a previous ICCI project. A more efficient flotation device for reducing total sulfur content was found to be the Packed-Column. Unlike the Packed-Column, the bubble-particle attachment in the Jameson Cell takes place in a relatively small downcomer which contains a very high air fraction of approximately 60%. Consequently, almost all of the hydrophobic particles, irrespective of their degrees of hydrophobicity, become attached to the air bubbles inside the downcomer. Because of a lower reflux action between the froth phase and the pulp phase, the weakly hydrophobic particles, such as the coal pyrites, never get a chance to become selectively detached from the air bubbles and, thus are recovered to the froth concentrate. As a result, the coal product from the aforementioned circuit is expected to contain a significant amount of pyritic sulfur. Due

to the finely disseminated pyrite in the Illinois Basin coal, the product from the proposed Floatex/Falcon/Jameson circuit will be ground to obtain a product having a -200 mesh size and then treated in the Packed-Column to produce a low sulfur coal to comply with the Phase II requirement of the Clean Air Act.

## EXPERIMENTAL PROCEDURES

### Fine Coal Circuit

In-plant testing of the novel fine coal cleaning circuit was performed at Kerr-McGee's Galatia coal preparation plant during this reporting period. The Galatia preparation plant treats run-of-mine coal extracted from the Illinois No. 5 coal seam. Presently, the -16 mesh fine coal stream is pumped to two banks of 15-inch diameter Krebs classifying cyclones which achieve a nominal size cut of 100 mesh. The -100 mesh cyclone overflow is treated in four banks of Wemco conventional flotation cells while the +100 mesh cyclone underflow is cleaned by 20 triple-start MDL spirals. A representative portion of the fine coal feed stream is obtained using a slotted-sampler that extends through the center of a pipe that feeds the classifying cyclone. This stream is directly fed to a Floatex hydrosizer.

The novel circuit involved the integration of an 18 x 18 in<sup>2</sup> Floatex hydrosizer, a 10-in diameter Falcon Concentrator and a pilot plant Jameson Cell that has two 18 x 18 in<sup>2</sup> separation cells arranged in a rougher-scavenger arrangement. The Floatex hydrosizer is being used as a primary cleaner for the nominally -16 mesh fine coal circuit feed. The overflow of the Floatex is screened at 48 mesh using a Sizetec vibratory screen to obtain a relatively coarse clean coal product from the screen overflow. The -48 mesh screen underflow is subsequently treated by the Falcon Concentrator and/or the Jameson Cell. Two circuit arrangements were evaluated during this reporting period for treating the -48 mesh size fraction: 1) Falcon Concentrator followed by the Jameson Cell in a rougher-cleaner arrangement and 2) Jameson Cell in a rougher-only and rougher-scavenger arrangements.

The Floatex hydrosizer utilizes a pressure transducer to monitor the bed level and a controller to automatically adjust the underflow rate to achieve the desired solids bed level. From an extensive in-plant study conducted as part of a previous ICCI investigation, a relative bed level setting of 70 and a fluidization water addition rate of 15 gpm were selected to obtain an optimum separation performance from the Floatex hydrosizer. These operating parameter values were evaluated in this study in 5 tests and the results confirmed the previous findings.

A continuous 10-inch diameter Falcon concentrator, which has a mass throughput capacity of 5 tph, is being used in the circuit to treat the 48 mesh screen underflow stream. The operating parameters that are being varied include the bowl speed and the opening time of the underflow discharge valves. Varying these parameters controls the

amount and quality of the product that is delivered to the Jameson Cell for subsequent treatment.

The Jameson Cell being tested is an 18 x 18 in<sup>2</sup> pilot plant unit that has the capability of treating a volumetric flow rate up to 45 gallons/min. The pilot plant unit has two cell compartments which can be used as a rougher-scavenger operation. The downcomers are 4 inches in diameter and utilize 12 to 18 mm orifices to draw the air into the cell under a feed pressure of about 20 lbs/in<sup>2</sup>. Experiments were conducted over a range in feed rates, aeration rates, frother concentrations and froth heights to obtain the most optimum separation performance.

#### Fine Coal Circuit Feed

A representative portion of the fine circuit feed is obtained from a classifying cyclone feed. The fine coal slurry contains approximately 13% solids by weight and was fed to the novel circuit at a volumetric rate of 60 gpm. This equates to a mass solids feed flow rate of 2 tph. Higher mass feed flow rates are not feasible due to the volumetric feed flow rate limitation of the Floatex hydrosizer.

The Galatia preparation plant treats coal from two portions of the Illinois No. 5 seam which differ in their sulfur content. Due to plant scheduling, the majority of the tests during this reporting period were conducted using the low sulfur coal. Efforts to perform tests on the high sulfur coal will be provided during the next reporting period. The ash and total sulfur contents of the -16 mesh feed coal are 23.7% and 1.23%, respectively, and the corresponding pyritic sulfur content is 0.73%. However, these values fluctuated during the test program due to variation in the in-seam characteristics, the mining practice, and the material handling system. A size-by-size analysis is provided in Table 4.

Table 4. Size-by-size analysis of the low sulfur, Illinois No. 5 fine circuit feed material obtained during a circuitry test in this reporting period.

Size Fraction (mesh)	Weight (%)	Ash Content (%)	Total Sulfur (%)
+48	44.18	18.1	1.26
48 x 65	8.12	17.3	1.41
65 x 100	5.08	17.7	1.51
100 x 200	6.73	15.6	1.46
200 x 400	6.73	17.6	1.39
-400	29.16	38.4	1.00
Total	100.00	23.7	1.23

## RESULTS AND DISCUSSION

Jameson Cell Testing

Before beginning the circuitry work, Jameson cell performance was optimized by conducting several tests under various operating conditions using the cyclone overflow stream from the plant. The wide spread of the Jameson cell performance data-points shown in Figure 4 is caused by the wide range of operating parameter values tested during this investigation. As shown, with a single cell operation, the ash content was reduced from 30% to values in the vicinity of 5 to 6%. This reduction equates to about 95% rejection in ash-bearing material. However, the maximum combustible recovery that was obtained from a single stage operation of Jameson cell was about 65%. Low recovery values of 60% to 70% are typical for single stage cleaning operations using the Jameson Cell when treating a feed in which the majority of the particles need to be floated. Most Jameson Cell operations utilize a rougher-scavenger circuit arrangement to obtain high overall recovery values.

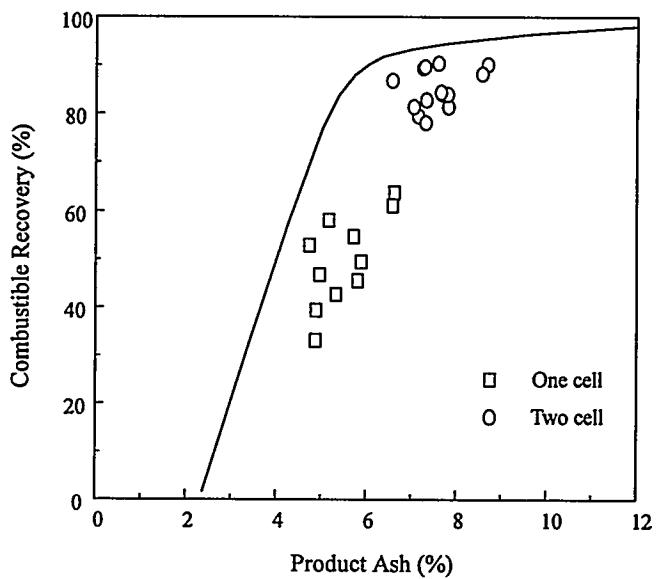


Figure 4. A comparison of the release analysis performance to that of Jameson cell obtained over a wide range of operating parameter values while treating the cyclone overflow material from a local preparation plant cleaning Illinois No. 5 coal.

As shown in Figure 4, the combustible recovery values were significantly improved by utilizing a two stage (i.e., rougher-scavenger) Jameson cell circuit in the plant. High combustible recovery values close to 90% were obtained while realizing a product ash content of about 7.5%, which equates to an ash rejection value of about 85%. From a size-by-size analysis of the process samples, it was found that the low recovery values obtained in a rougher Jameson cell was mainly due to the by-pass of combustible material through the downcomer. The addition of a scavenger cell operation substantially

increased the combustible recovery in all size fractions. It is believed that the co-current system in the downcomer (i.e., bubbles and particles moving in the same downward direction) results in an increase in particle by-pass as the length-to-diameter ratio of the downcomer is increased toward the value of the industrial units. This explains the need for two-stage Jameson Cell operations.

Table 5. Improvement in the size-by-size combustible recovery values achieved by the Jameson Cell with a two-stage cleaning operation, i.e., rougher-scavenger arrangement.

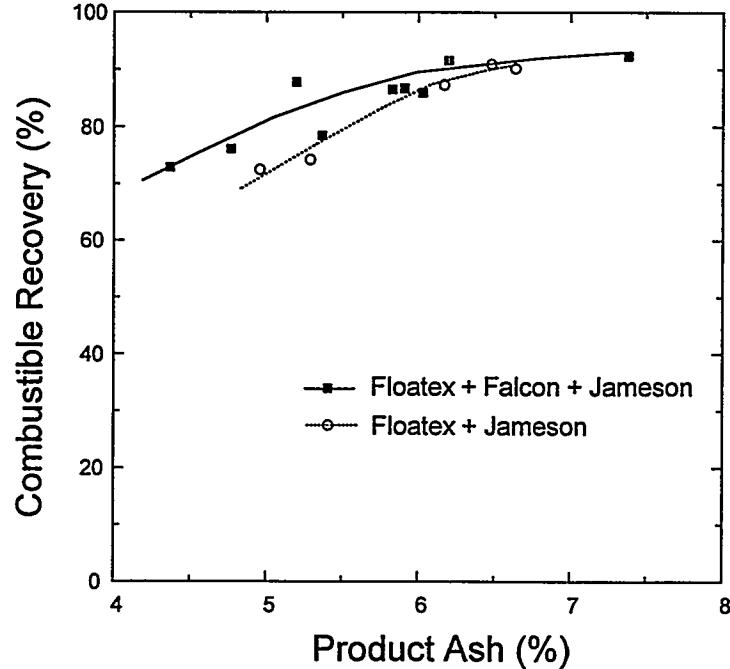
Size Class (mesh)	Weight (%)	Combustible Recovery (%)	
		Single Stage	Two Stage
+ 48	3.33	80.31	93.97
48 x 65	12.11	89.77	87.82
65 x 100	11.16	74.18	82.95
100 x 200	15.44	77.35	86.51
200 x 400	9.50	73.53	87.26
-400	48.46	75.59	85.74
Total	100.0	76.98	86.66

#### Novel Fine Coal Circuit

A series of 30 tests was conducted on the -16 mesh fine coal circuit feed to evaluate the separation performance achieved by the novel fine coal circuit over a range of operating conditions and different circuit configurations. Under a few operating conditions, the circuit was unable to operate satisfactorily and, thus samples were not collected. The samples collected during the remaining tests were screened into relatively small particle size fractions, i.e., +10 mesh, 10 x 16 mesh, 16 x 28 mesh, 28 x 48 mesh, 48 x 65 mesh, 65 x 100 mesh, 100 x 200 mesh, 200 x 400 mesh and -400 mesh. The samples from each size fraction were weighed and analyzed for ash and total sulfur content and, in some cases, pyritic sulfur content. These analyses allowed size-by-size evaluation of the separation performance achieved by the novel circuit.

Figures 5 (a) and (b) compare the separation performance achieved by two different circuit configurations. The separation performance achieved by the Floatex-Falcon-Jameson Cell circuit was found to be superior to that obtained by the Floatex-Jameson Cell circuit. For example, at a combustible recovery of about 85%, the reduction in ash content achieved from the Falcon-based circuit was from 23.7% to 5.2% while the Floatex-Jameson circuit provided a higher product ash content of 6.1%. The separation performance obtained from the Floatex-Falcon-Jameson circuit corresponds to an ash rejection of 87% which equates to an overall circuit separation efficiency of 72%. Figure 5(b) shows that the pyrite rejection performance achieved by the Falcon-based circuit is also better than that provided by the Floatex-Jameson circuit.

a)



b)

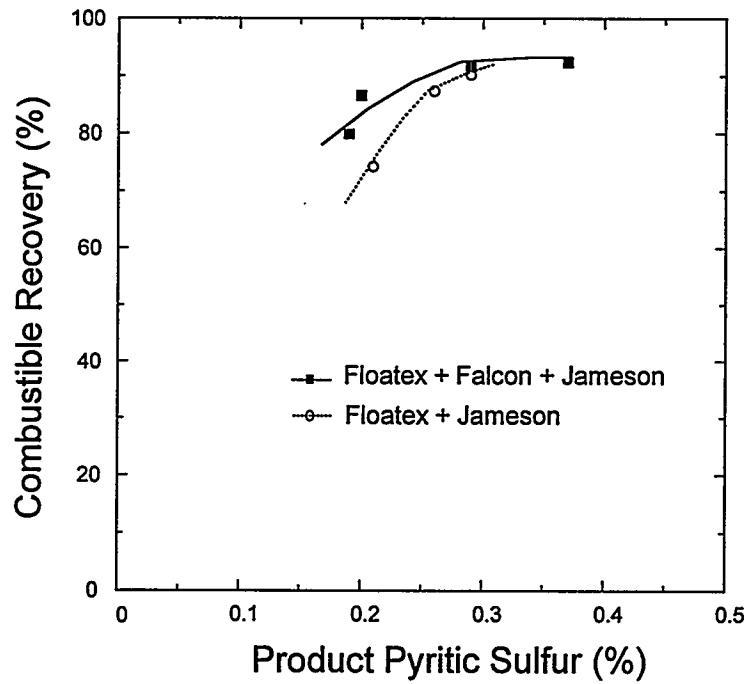


Figure 5.

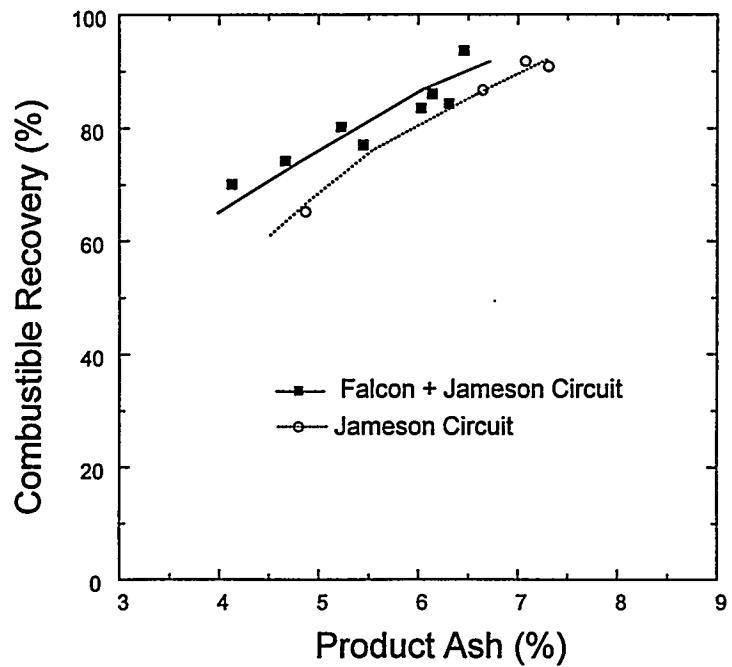
A comparison of the separation performance obtained from the Floatex-Falcon-Jameson circuit with that from Floatex-Jameson circuit for treating the -16 mesh fine coal feed of a preparation plant cleaning Illinois No. 5 coal; feed ash = 23.7%, feed pyritic sulfur = 0.73%.

Table 6 shows the size-by-size ash contents obtained from various process streams during a typical test of the Floatex-Falcon-Jameson Cell circuit. In addition, the overall circuit combustion recovery and ash rejection values are provided on a size-by-size basis. An important finding is the excellent separation performance achieved on the +48 mesh size fraction by the Floatex hydrosizer. The ash content in this size fraction was reduced from 18.1% to 4.68% while recovery 93.0% of the combustible material, which equates to a high separation efficiency value of 72.3%. In fact, a lower product ash value of 3.8% was produced from the +28 mesh size fractions with a combustible recovery of 89%. The excellent separation performance achieved in treating the +48 mesh size fraction had a significant effect on the overall circuit performance due to the relatively large portion of +48 mesh material in the feed mass flow (Table 4). However, the ash contents in the -48 mesh size fractions were also significantly reduced to an overall average of 6.14% by the Falcon-Jameson Cell rougher-cleaner circuit arrangement while recovering about 85% of the combustibles. The overall circuit separation efficiency achieved from the treatment of the -16 mesh material for this test was 72.8%.

The superior separation performance achieved on the -48 mesh size fractions by the Falcon-based circuit is shown in Figures 6 (a) and (b). The combustible recovery values achieved by the Falcon-based circuit while producing a given product ash content are approximately 5% greater than those obtained from the Jameson only circuit. This is due to an improved treatment of the +400 mesh material by the Falcon Concentrator as compared to the Jameson Cell. Pyritic sulfur rejections were also greater for the Falcon-based circuit as shown in Figure 6 (b). This finding was expected due to the natural floatability of the coal pyrite and the high bubble-particle collision efficiency of the Jameson Cell.

Table 6. Size-by-size ash content values obtained from the various streams in one of the tests performed on the Floatex-Falcon-Jameson Cell circuit and the circuit size-by-size recovery and ash rejection values: FX = Floatex, FN = Falcon, and FC = Jameson Cell.

a)



b)

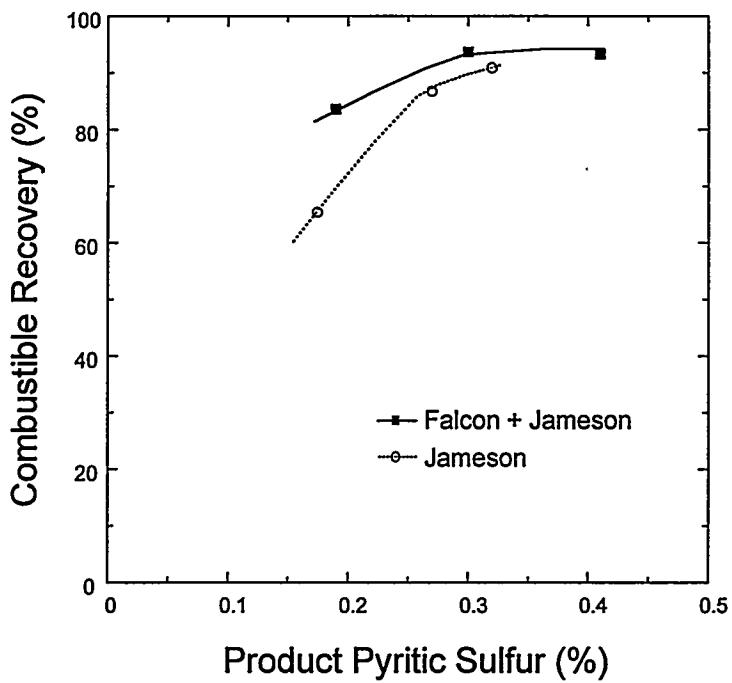


Figure 6. A comparison of the separation performances achieved from the treatment of the 48 mesh screen underflow using a Falcon-Jameson rougher-cleaner arrangement and a Jameson Cell only on the basis of (a) product ash content and (b) product pyritic sulfur contents.

## CONCLUSIONS AND RECOMMENDATIONS

Conclusions

1. The novel fine coal cleaning circuit consisting of a Floatex hydrosizer, Falcon Concentrator, and a Jameson Cell provides highly efficient cleaning of -16 mesh fine coal. Results obtained from in-plant testing found that the circuit was able to reduce the ash content of a nominally -16 mesh fine coal circuit feed from 23.7% to 5.2% while recovering greater than 85% of the combustible material. This metallurgical performance equates to a relatively high separation efficiency of 72%. In addition, the pyritic sulfur content was reduced from 0.73% to 0.20% at the same recovery value, which corresponds to a pyritic sulfur rejection of 84%.
2. The Floatex hydrosizer was found to provide an excellent metallurgical performance over a relatively narrow size fraction of 16 x 48 mesh. The ash content in this size fraction was reduced from about 18.1% to a remarkably low value of 4.68% while achieving a 93% combustible recovery. In addition, the pyritic sulfur content was reduced in this size fraction from 0.56% to 0.18%. Due to the significant amount (i.e., 44%) of +48 mesh material in the fine circuit feed, the excellent separation performance had a substantial and positive impact on the overall circuit performance.
3. The combustible recovery values obtained from the Jameson Cell were substantially increased by the use of a two stage operation in a rougher-scavenger circuit arrangement. In fact, high combustible recovery values of about 90% and greater were achieved on particle size fractions up to 48 mesh. Ash contents were significantly reduced from about 40% in the -400 mesh size fraction to about 7.0% while overall ash contents of 6.0% and lower were achieved for the -48 mesh size fraction.
4. The circuit utilizing the Falcon concentrator was found to provide a superior separation performance when compared to the circuit using only the Jameson Cell to treat the -48 mesh size fraction. For a given product quality, the Falcon-based circuit provided 5 percentage points improvement in the circuit combustible recovery values.

Recommendations

1. Due to plant scheduling, the majority of the tests conducted to date have involved the treatment of a relatively low sulfur coal. Efforts will be provided during the next reporting period to perform a substantial number of tests on the medium-to-high sulfur coal that is periodically treated by Galatia preparation plant.
2. The solids content reporting to the Falcon concentrator was found to be sufficiently low, i.e., 3 - 4% by weight, to cause some problems in the operation of the process unit. To alleviate this problem, a 28 mesh screen is being installed in place of the existing 48 mesh screen so that additional solids will be sent to the Falcon unit. This

will allow a larger particle bed to be formed within the Falcon unit and, thus larger underflow rates can be used.

3. A sampling program will be performed on the conventional spiral-conventional flotation circuit that is currently used at the Galatia preparation plant in order to obtain comparative information.
4. The optimum conditions and circuit arrangement will be identified and samples collected for analysis of ash, total and pyritic sulfur and BTU contents. In addition, washability analysis will be conducted on selected samples to obtain the necessary process efficiency information.
5. A bulk sample of the circuit product obtain under optimum conditions will be collected and ground to further liberate the ash-bearing material and the coal pyrite. The sample will then be treated using a Packed-Column.

#### DISCLAIMER STATEMENTS

This report was prepared by Dr. R. Q. Honaker of Southern Illinois University at Carbondale with support, in part by grants made possible by the U. S. Department of Energy Cooperative Agreement Number DE-FC22-92PC92521 (Year 4) and the Illinois Department of Commerce and Community Affairs through the Illinois Coal Development Board and the Illinois Clean Coal Institute. Neither Dr. R. Q. Honaker of Southern Illinois University at Carbondale nor any of its subcontractors nor the U. S. Department of Energy, the Illinois Department of Commerce and Community Affairs, Illinois Coal Development Board, Illinois Clean Coal Institute, nor any person acting on behalf of either:

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PROJECT MANAGEMENT REPORT  
March 1, 1996, through May 31, 1996

Project Title: **IN-PLANT TESTING OF A NOVEL COAL CLEANING CIRCUIT  
USING ADVANCED TECHNOLOGIES**

DOE Cooperative Agreement Number: DE-FC22-92PC92521(Year 4)  
ICCI Project Number: 95-1/1.1A-1P  
Principal Investigator: R.Q. Honaker, Department of Mining  
Engineering, Southern Illinois University at  
Carbondale  
Other Investigators: S. Reed and M.K. Mahonty  
Kerr-McGee Coal Corporation  
Project Manager: K. Ho, ICCI

**COMMENTS**

None.

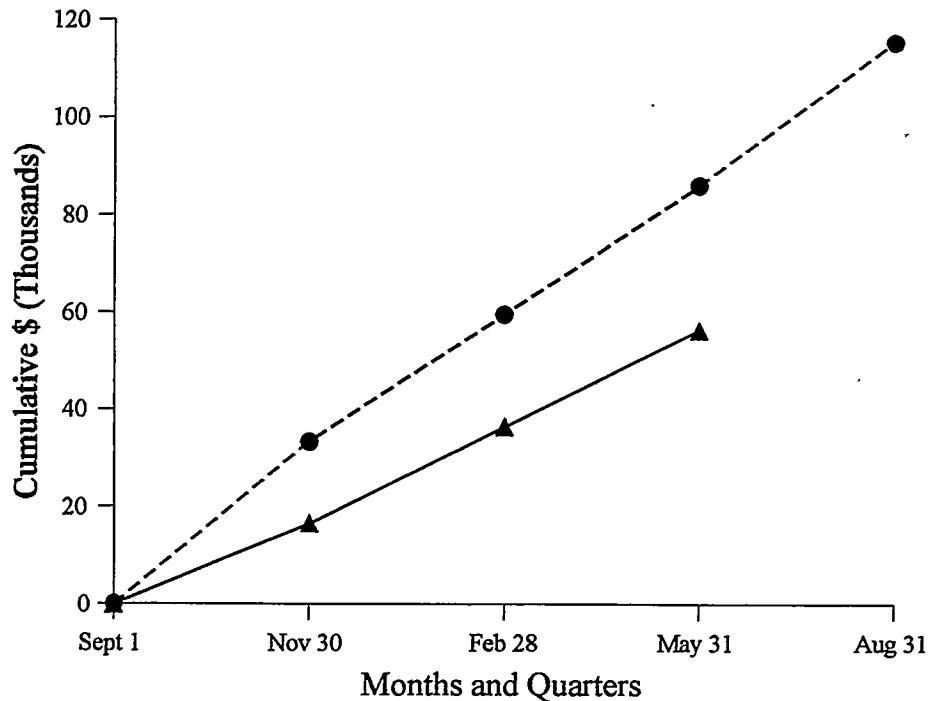
## PROJECTED AND ESTIMATED EXPENDITURES BY QUARTER

Quarter*	Types of Cost	Direct Labor	Fringe Benefits	Materials and Supplies	Travel	Major Equipment	Other Direct Costs	Indirect Cost	Total
Sept. 1, 1995 to Nov. 30, 1995	Projected	13,348	3,849	2,500	500	4,500	5,700	3,040	33,437
	Estimated	12,811	1,041	1084	0	0	182	1,512	16,630
Sept. 1, 1995 to Feb. 28, 1996	Projected	26,696	7,698	4,500	1,000	4,500	9,900	5,429	59,723
	Estimated	28,734	2,846	1,123	564	0	354	2,832	36,453
Sept. 1, 1995 to May 31, 1996	Projected	40,044	11,547	5,900	1,500	4,500	14,900	7,839	86,230
	Estimated	39,159	4,810	2,280	1,047	1,488	2,705	5,020	56,509
Sept. 1, 1995 to Aug. 31, 1996	Projected	53,392	15,136	6,800	2,500	4,500	22,800	10,513	115,641
	Estimated								

\*Cumulative by Quarter

## CUMULATIVE COSTS BY QUARTER

In-Plant Testing of a Novel Coal Cleaning Circuit Using Advanced Technologies

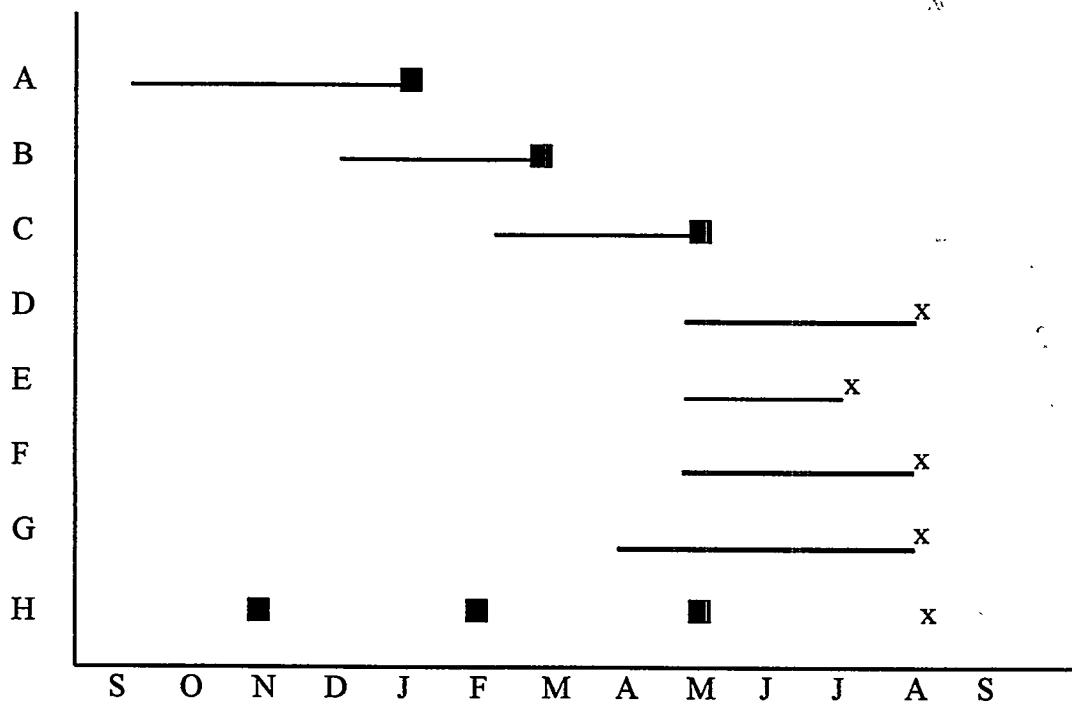


● = Projected Expenditures -----

▲ = Actual Expenditures \_\_\_\_\_

Total Illinois Clean Coal Institute Award \$115,641

## SCHEDULE OF PROJECT MILESTONES



Begin  
Sept. 1  
1995

## Hypothetical Milestones:

- A: Pilot Plant Testing of the On-line Coal Slurry Sensor completed (Task 1)
- B: Fine Coal Circuit installed (Task 2)
- C: Circuit Process Parameters optimized (Task 3)
- D: Fine Coal Circuit compared with existing Circuit (Task 4)
- E: Long Term Testing completed (Task 5)
- F: Economic Comparison completed (Task 6)
- G: Tests for Phase II Compliance Coal completed (Task 7)
- H: Quarterly and Final Reports completed as submitted (Task 8)

## Comments:

None.