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

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ABSTRACT

A circuit comprised of advanced fine coal cleaning technologies was evaluated in an operating preparation plant to determine circuit performance and to compare the performance with current technologies used to treat -16 mesh fine coal. The circuit integrated a Floatex hydrosizer, a Falcon enhanced gravity concentrator and a Jameson flotation cell. A Packed-Column was used to provide additional reductions in the pyritic sulfur and ash contents by treatment of the Floatex-Falcon-Jameson circuit product.

For a low sulfur Illinois No. 5 coal, the pyritic sulfur content was reduced from 0.67% to 0.34% at a combustible recovery of 93.2%. The ash content was decreased from 27.6% to 5.84%, which equates to an organic efficiency of 95% according to gravity-based washability data. The separation performance achieved on a high sulfur Illinois No. 5 coal resulted in the rejection of 72.7% of the pyritic sulfur and 82.3% of the ash-forming material at a recovery of 81%. Subsequent pulverization of the cleaned product and re-treatment in a Falcon concentrator and Packed-Column resulted in overall circuit ash and pyritic sulfur rejections of 89% and 93%, respectively, which yielded a pyritic sulfur content reduction from 2.43% to 0.30%. This separation reduced the sulfur dioxide emission rating of an Illinois No. 5 coal from 6.21 to 1.75 lbs SO_2/MBTU, which is Phase I compliance coal. A comparison of the results obtained from the Floatex-Falcon-Jameson circuit with those of the existing circuit revealed that the novel fine coal circuit provides 10% to 20% improvement in mass yield to the concentrate while rejecting greater amounts of ash and pyritic sulfur. Although the magnitude of the improvement may vary due to liberation characteristics, the superior separation performance provided by the advanced fine coal circuit should be achievable on the -16 mesh size fraction of most run-of-mine coals. However, for coals containing a significant amount of pyritic sulfur in the -400 mesh size fraction, a Packed-Column may be needed to replace the Jameson Cell in order to achieve maximum pyritic sulfur rejections.

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EXECUTIVE SUMMARY

The goal of this project was 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 was 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

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 a 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. However, due to its highly efficient bubble-particle collision environment, the sulfur rejection achieved by the Jameson Cell is significantly lower than other column technologies. Thus, in this investigation, a Packed-Column was used to achieve additional pyritic sulfur and ash reductions from the product of the Floatex-Falcon-Jameson circuit.

In this project, a fine coal circuit comprised of the three aforementioned advanced coal cleaning technologies was 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 were: 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 pulverization and re-treatment of the clean coal product from the Floatex-Falcon-Jameson circuit using the Packed-Column.

In this investigation, a novel fine coal cleaning circuit comprised of an 18 x 18 in^2 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).

The results obtained in this study indicate that the Floatex-Falcon-Jameson fine coal circuit provides highly efficient cleaning of -16 mesh fine coal. For a -16 mesh high sulfur Illinois No. 5 coal, the Floatex-Falcon-Jameson circuit rejected 72.7% of the pyritic sulfur while reducing the ash content from 25.8% to 7.42% at a combustible recovery of 81.1%. The separation performance was more efficient when treating a -16 mesh low sulfur Illinois No. 5 coal for which the pyritic sulfur content was reduced from 0.67% to 0.34% while recovering 93.2% of the combustible material. The ash content was decreased from 27.6% to 5.8% which equates to an organic efficiency of 95% when compared to gravity-based washability data. The difference in the separation performance achieved on the high and low sulfur Illinois No. 5 coals is believed to be due to the oxidization of the surface of the high sulfur coal particles caused by an extensive duration in a stockpile and exposure to the atmosphere which hindered the flotation process.

Pulverization of the high sulfur product generated from the Floatex-Falcon-Jameson circuit and re-treatment in a Falcon Concentrator and Packed-Column arrangement resulted in a significant reduction in ash and pyritic sulfur contents. At a combustible recovery of 80%, the pyritic sulfur content was further reduced from 1.02% to 0.20% which corresponds to a pyrite rejection of 85.1%. Thus, for the overall treatment from the Floatex to the Packed-Column, a pyritic sulfur rejection of 93% was achieved at a circuit recovery of 72% and 96% at a recovery of 64%. The overall circuit ash reduction was from 25.8% to 2.8%. This separation resulted in a significant reduction in the sulfur dioxide emission rating from 6.21 to 1.75 lbs SO_2/MBTU.

The Floatex-Falcon-Jameson circuit provided superior separation performances when compared to those obtained from the existing conventional (spirals and flotation banks) circuit. For the high sulfur Illinois No. 5 coal, a 10.5% weight units improvement was obtained by the novel fine coal cleaning circuit while rejecting 6.5% greater amounts of ash-forming material. For the low sulfur coal, the increase in mass yield provided by the Floatex-Falcon-Jameson circuit was 23.9%. In addition to the improved yield, the novel circuit rejected 12.1% greater amount of pyritic sulfur. By comparing the metallurgical results with those obtained from the washability analyses of the -16 mesh feed coal, it was found that the organic efficiency of the novel circuit was approximately 95% while the conventional circuit efficiency was 64.0%. Based on the superior separation performance achieve on the high sulfur coal, significant economic benefits were determined for the use of the Floatex-Falcon-Jameson circuit over the conventional circuit. A $2.15 million enhancement in annual net profit was estimated by using the Floatex-Falcon-Jameson circuit over the conventional fine coal circuit despite the higher capital and operating costs of the novel circuit.

Partition curves generated from the Floatex-Falcon-Jameson circuit separations revealed that the circuit provided a highly efficient, low gravity cut point which is desirable and uncommon for fine coal separations. For the low sulfur coal treatment, the gravity cut point (D_{50}) was found to be approximately 1.42 with an excellent probable error (E_p) value of 0.10. As indicated by the metallurgical results, the E_p and D_{50} values for the separation on the high sulfur coal were significantly higher at 0.16 and 1.6, respectively.

During the investigation, several circuit arrangements were evaluated which mainly involved the inclusion or exclusion of the Falcon concentrator. The circuits utilizing the Falcon concentrator were found to provide a superior separation performance when compared to the circuit using only the Jameson Cell to treat the -28 mesh size fractions and the Packed-Column to treat the pulverized coal sample. For the pulverized coal, the use of the Falcon concentrator resulted in a further reduction in ash content from 3.8% to 2.8% and a decrease in pyritic sulfur content from 0.75% to 0.20% at a combustible recovery of 80%. This reduction in both ash and pyritic sulfur substantially reduced the sulfur dioxide emission rating from 2.50 to 1.60 lbs SO_2/MBTU.

Another finding was the ability of the Jameson Cell to efficiently recover 28 x 48 mesh coal in a rougher-scavenger arrangement. Recovery values greater than 90% were achieved for the 28 x 48 mesh size fraction. The high recovery values obtained for the coarse coal fractions may be due to the co-current bubble-particle collision environment provided in the Jameson Cell which tends to reduce the effect of particle inertia on detachment process.

An important characteristic of the Floatex-Falcon-Jameson circuit is the ability to automate the operation using process control. An on-line nuclear ash analyzer commercially known as the AMDEL system allows the determination of solids and ash contents from multiple streams. The AMDEL system was to be evaluated as part of this project. However, licensing approval from federal and state agencies has yet to be achieved, thereby, prohibiting the evaluation of the analyzer to date. The main components of the analyzer minus the nuclear sources are at SIUC and will be tested upon receiving the licensing agreements. This event did not hinder the evaluation of the in-plant circuit.

The Floatex-Falcon-Jameson circuit is comprised of commercially available advanced fine coal cleaning technologies. The circuit was found to efficiently treat -16 mesh fine coal in an operating coal preparation plant. Comparisons of the metallurgical results with those from the existing spiral-conventional froth flotation circuit indicate a 10 to 20% improvement in the fine circuit mass yield. This is due to the effective treatment of the entire fine coal stream which is not achieved in the conventional circuit. This superior performance should be achievable for the -16 mesh size fraction of most run-of-mine coals although the magnitude of the increased improvement may vary due to liberation and surface property characteristics. However, due to the efficient particle recovery mechanisms that are characteristic of the Jameson cell, pyritic sulfur reductions may be limited when the fine coal contains a significant amount of pyritic sulfur in the -400 mesh size fraction. In these cases, a Packed-Column may be needed to replace the Jameson cell in order to ensure the maximum reduction in pyritic sulfur content.

OBJECTIVES

The goal of this project was 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 were:

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 pulverization and re-treatment of the clean coal product from the proposed circuit.

These objectives have been achieved and the project successfully demonstrated the advanced fine coal cleaning circuit in an operating coal preparation plant. The production of Phase II compliance coal was not realized; however, the sulfur dioxide rating of a high sulfur Illinois No. 5 coal was substantially reduced to about 1.6 lbs. SO_2/Mbtu using advanced physical coal cleaning devices that are commercially available at industrial scale.

INTRODUCTION AND BACKGROUND

In this study, in-plant circuitry testing was conducted which incorporated 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^2 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^2. The tailings ash and total sulfur content was 79.8% and 6.28%, respectively. A summary of these results are provided in Table 1.

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^2 Floatex hydrosizer. The mass feed rate was 1.2 tph/ft^2.

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^2 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.

Falcon Concentrator

The Falcon Concentrator is a spinning flowing film separator. The concentrator applies a centrifugal force up to 300 g's 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^o 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 moves up 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.

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

Test Number	Ash (%) Feed	Ash (%) Product	Ash (%) Tailings	Total Sulfur (%) Feed	Total Sulfur (%) Product	Total Sulfur (%) Tailings	Yield (%)
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

Research conducted over the past year has found that the Falcon Concentrator achieves an efficient separation on the 65 x 325 mesh coal size fraction. 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 dataprovided 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

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	Total Sulfur (%) Tailings	Product BTU/lb	Recovery (%)	Total Sulfur Rej. (%)	lb SO_2 per MBTU
+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

the low calorific values the inability of the process to effectively reject the ash bearing material in the -325 mesh material. Thus, it is required to deslime the Falcon overflow using a hydrocyclone or a flotation column.

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

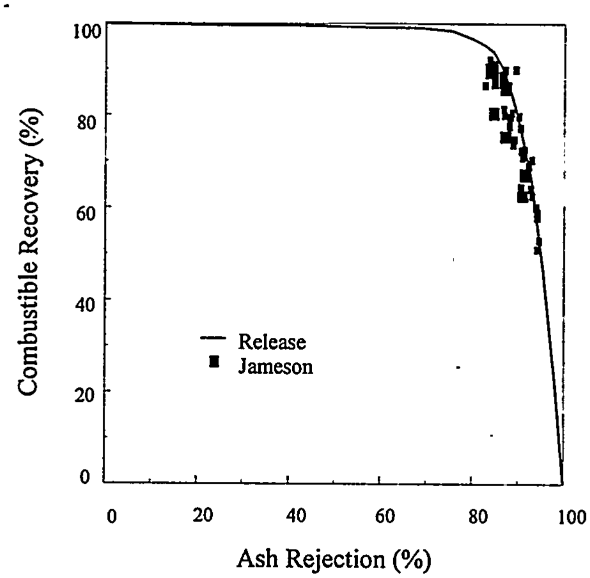


Figure 1. Results showing the separation performance achieved by the Jameson Cell from the treatment of nominally -100 mesh Illinois No. 5 coal.

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.

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

The novel fine coal circuit consisting of a Floatex hydrosizer, a Falcon Concentrator, and a Jameson Cell was installed and tested at Kerr-McGee's Galatia coal preparation plant during this investigation. 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 was obtained for the feed to the novel circuit using a slotted-sampler that extends through the center of the pipe that feeds a classifying cyclone. This stream was directly fed to a Floatex hydrosizer.

The novel circuit involved the integration of an 18 x 18 in^2 Floatex hydrosizer, a 10-in diameter Falcon Concentrator and a pilot plant Jameson Cell that has two 18 x 18 in^2 separation cells arranged in a rougher-scavenger arrangement. The flowsheet of the circuit evaluated in the plant is shown in Figure 2. The Floatex hydrosizer was used as a primary cleaner for the nominally -16 mesh fine coal circuit feed. The overflow of the Floatex was screened at 28 mesh using a Sizetec vibratory screen to obtain a relatively coarse clean coal product from the screen overflow. During the initial tests, a 48 mesh screen was used; however, the amount of solids reporting to the Falcon was too small to maintain a proper particle bed. Therefore, the 48 mesh screen was replaced with a 28 mesh screen. The -28 mesh screen underflow was subsequently treated by the Falcon Concentrator and/or the Jameson Cell. Two deviations of the circuit flowsheet in Figure 2 were evaluated during this investigation for treating the -28 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, was used in the circuit to treat the 28 mesh screen underflow stream. The operating parameters that were varied include the bowl speed and the opening time of the underflow discharge valves. Varying these parameters controlled the amount and quality of the product that was delivered to the Jameson Cell for subsequent treatment.

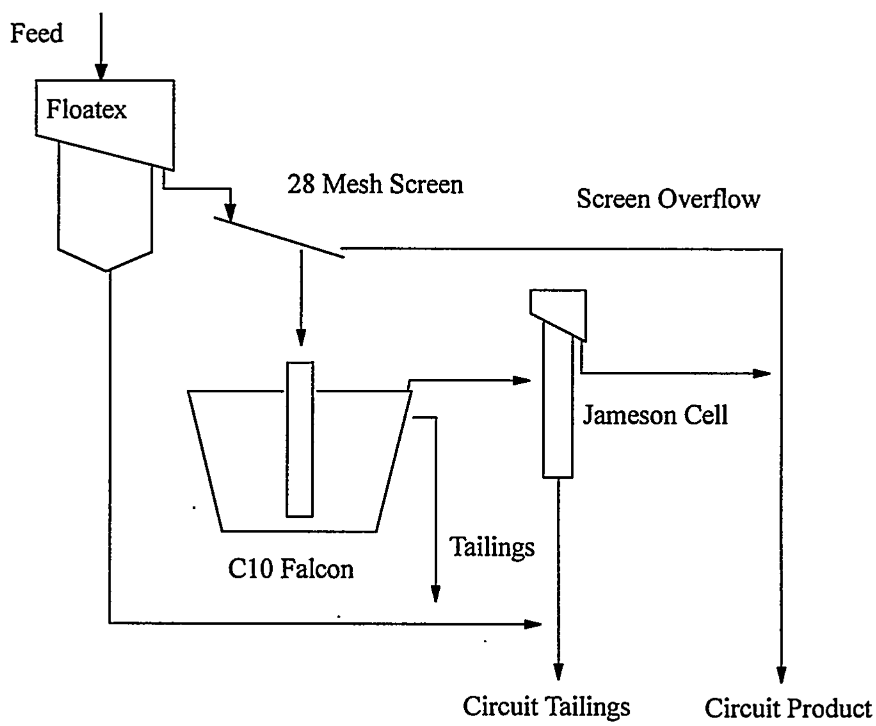


Figure 2. Flowsheet of the novel fine coal circuit evaluated in the Galatia preparation plant.

The Jameson Cell unit that was installed in the plant was an 18 x 18 in^2 pilot plant unit that had the capability of treating a volumetric feed flow rate up to 45 gallons/min. The pilot plant unit had two cell compartments which was used as a rougher-scavenger operation. The downcomers were 4 inches in diameter and utilized 15 mm orifices to draw the air into the cell under a feed pressure of about 20 lbs/in^2. Experiments were conducted over a range in feed rates, aeration rates, frother concentrations and froth heights to obtain the most optimum separation performance.

In an effort to produce Phase II compliance coal from a high sulfur Illinois No. 5 coal sample, the product from the circuit in Figure 2 was collected under optimum conditions, ground for liberation purposes, and retreated in a C10 Falcon concentrator and Packed-Column as shown in Figure 3. The Packed-Column was a 4 inches in diameter and 16 feet tall. Air was injected into the bottom of the cell at a rate of 4.0 cm/sec without the assistance of an external bubble generator while the feed was inserted approximately 8 ft from the top of the cell. A PID controller was used to maintain a constant pulp level during the tests which was approximately 12 ft from the top of the cell. Wash water was added near the top of the cell at a flow rate of 2 liters/min. A polyglycol was used as the frother at a concentration of 35 ppm while 4 lbs/ton of kerosene was added as the collector.

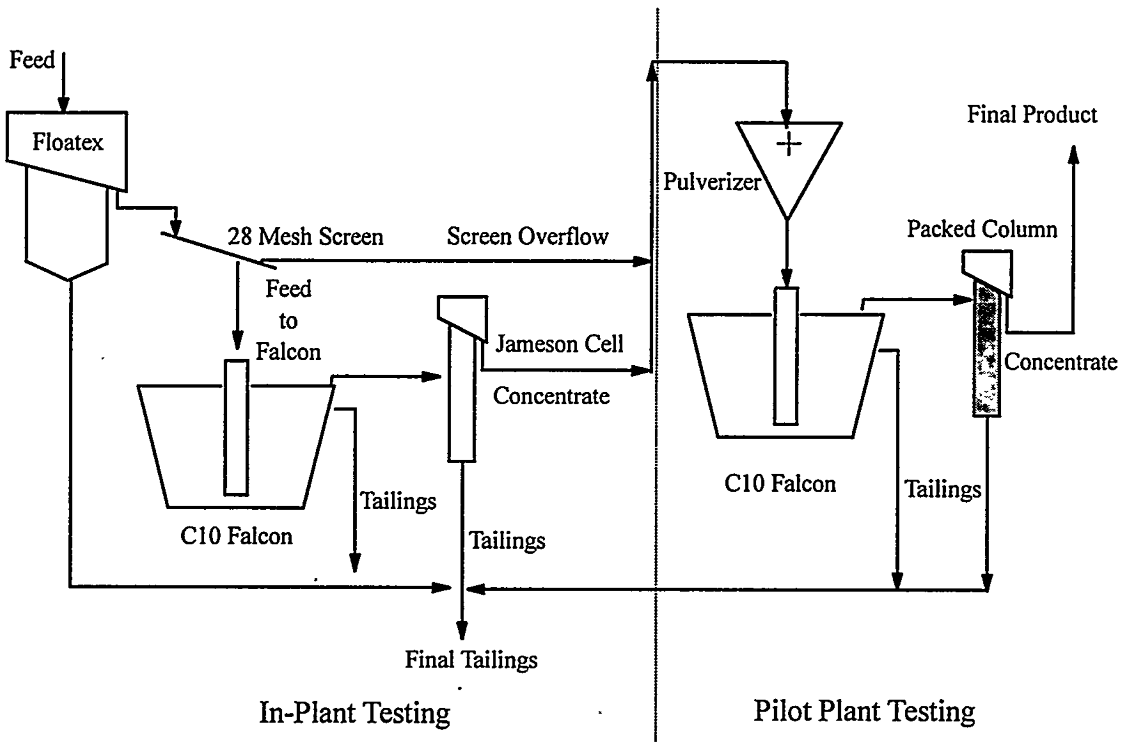


Figure 3. Flowsheet of the fine coal circuit used in an effort to produce Phase II compliance coal from a high sulfur Illinois No. 5 seam coal.

Representative samples from each stream in the circuit were obtained under steady-state conditions using a sampler cup. The samples were filtered, dried and weighed and the data recorded. Ash and total sulfur analyses were conducted on all samples while the calorific value and pyritic sulfur contents were analyzed on selected samples. ASTM procedures for all analyses were strictly followed on all samples.

Fine Coal Circuit Feed

A representative portion of the fine circuit feed was obtained from a classifying cyclone feed. The fine coal slurry contained approximately 13% solids by weight and was fed to the novel circuit at a volumetric rate of approximately 60 gpm. This equates to a mass solids feed flow rate of 2 tph. Higher mass feed flow rates were 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. The coal from the northern portion of the property is relatively low in total sulfur content while the southern portion contains a high sulfur content. The ash and total sulfur contents of the -16 mesh low sulfur feed coal are 23.7% and 1.23%, respectively, and the corresponding pyritic sulfur content is 0.73%. The coal had a calorific value on a dry basis of 10,112 BTU/lb which yields a sulfur dioxide emission rating of 2.29 lbs SO_2/MBTU. The ash, total and pyritic sulfur contents of the

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

Size Fraction (mesh)	Weight (%)	Ash Content (%)	Total Sulfur (%)
Low Sulfur Coal			
+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
High Sulfur Coal			
+48	51.1	17.1	3.33
48 x 65	8.32	19.6	3.64
65 x 100	4.92	14.8	3.04
100 x 200	7.92	17.1	3.44
200 x 400	6.00	16.9	3.25
-400	21.8	34.1	2.74
Total	100.00	20.9	3.22

high sulfur coal were 20.9%, 3.22%, and 2.43%, respectively. The corresponding calorific value on a dry basis was 10,461 BTU/lb which equates to a 5.72 lbs SO_2/MBTU. However, these values fluctuated during the test program due to variations in the in-seam characteristics, the mining practice, and the material handling system. A size-by-size analysis of the low and high sulfur Illinois No. 5 coals are provided in Table 4.

The +500 mesh size fraction of both feed samples were subjected to centrifugal washability analysis according to ASTM procedures. The -500 mesh size fraction was not included since the centrifugal washability technique is not effective on this size fraction. Commercial Testing & Engineering Company conducted the washability analyses. The data for each coal is provided in Table 5.

Table 5. Washability analysis data obtained for the high and low sulfur Illinois No. 5 seam coals being treated at the Galatia preparation plant.

Gravity Fraction	Low Sulfur Coal		High Sulfur Coal	
	Weight (%)	Ash (%)	Weight (%)	Ash (%)
Float x 1.30	57.6	3.23	59.3	2.76
1.30 x 1.40	11.6	10.1	10.9	8.90
1.40 x 1.50	5.9	14.9	4.7	13.8
1.50 x 1.60	3.6	23.1	2.9	21.1
1.60 x 1.80	3.4	34.7	2.9	32.3
1.80 x 2.00	2.5	48.1	2.6	46.5
2.00 x 2.20	2.7	60.7	2.3	59.9
2.20 x Sink	12.7	75.4	14.4	79.3
Total	100.0	18.3	100.0	18.8

As previously described, approximately 1 ton of product generated from the treatment of the high sulfur Illinois No. 5 coal using the novel circuit was collected during the in-plant testing program. This clean coal product was pulverized in the Coal Development Park and retreated in the Falcon concentrator and Packed-Column in an effort to produce Phase II compliance coal. The size-by-size analysis of the pulverized coal is shown in Table 6.

Table 6. Size-by-size analysis data of the pulverized, high sulfur Illinois No. 5 clean coal product collected from the in-plant test program.

Size Class (mesh)	Weight (%)	Ash Content (%)	Total Sulfur (%)
+200	9.20	5.74	1.82
200x325	8.10	4.11	1.65
325x400	6.60	3.85	1.64
400x500	10.4	3.76	1.71
-500	65.7	8.02	1.97
Total	100	6.80	1.88

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 (or rougher) operation of the 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.

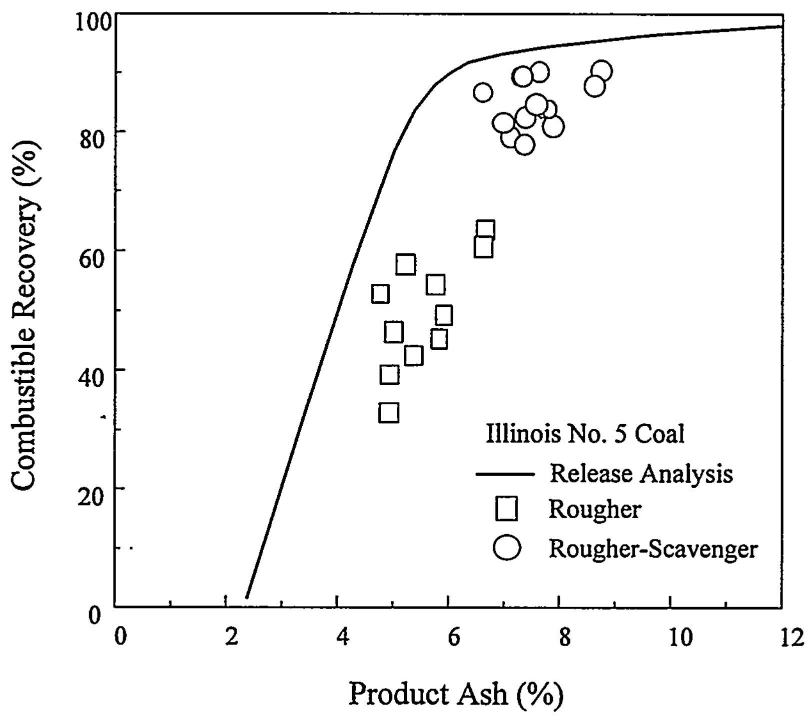


Figure 4. A comparison of the release analysis performance to that of Jameson cell obtained over a wide range of operating parameter values while treating the cyclone overflow material from a local preparation plant cleaning Illinois No. 5 coal.

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 as shown in Figure 5. 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. It should be noted that the Jameson Cell achieved recovery values greater than 90% for relative coarse particles, i. e., 28 x 48 mesh size fraction.

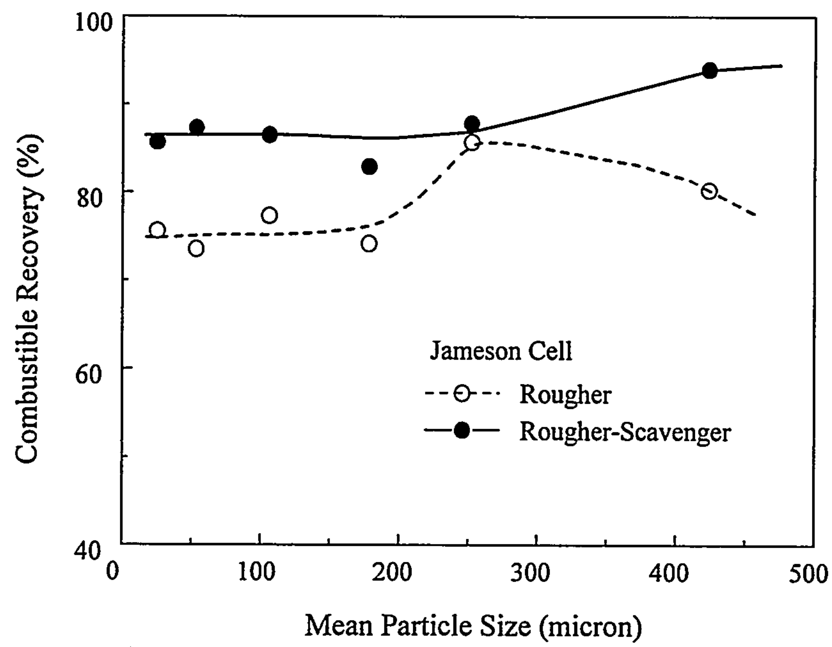


Figure 5. Size-by-size recovery achieved by a rougher and rougher-scavenger operation of the Jameson Cell during the in-plant testing program on the low sulfur Illinois No. 5 coal.

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 6 (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 6(b) shows that the pyrite rejection performance achieved by the Falcon-based circuit is also better than that provided by the Floatex-Jameson circuit.

Of significant importance in Figure 6(a) is the comparison between the separation performance achieved by the Floatex-Falcon-Jameson circuit and the theoretically "best" performance obtained from centrifugal washability data for the +500 mesh material. As shown, the separation achieved by the novel fine coal circuit is close to the washability curve. In fact, an excellent organic efficiency of about 95% was obtained while producing a product ash content of 5.0%. On the other hand, the performance achieved by the conventional circuit presently used in the Galatia preparation plant largely inferior in terms of both product ash and pyritic sulfur contents.

The separation performances achieved on the -16 mesh high sulfur Illinois No. 5 coal, however, were not as efficient as shown by the data in Figures 7(a) and (b). At a combustible recovery of 81%, the ash content was reduced from 25.8% to 7.42% while the pyritic sulfur content was decreased from 2.43% to 1.02%. The corresponding ash and pyritic sulfur rejections were 81.3% and 72.7%, respectively. By comparing these results with the washability curve, the organic efficiency was determined to be 85%, which is substantially lower than the value achieved for the low sulfur coal. This finding may be due to the method of handling the two coals at the preparation plant. The low sulfur coal is stored in two 10,000 ton silos while the high sulfur coal is stored in a stockpile. Since there is a greater demand for the low sulfur coal, the high sulfur coal remains in open atmosphere for a longer period of time, thereby, causing oxidation of the coal surface. Since the Jameson Cell treats a large portion of the high sulfur feed, the inability to effectively float the coal reduces the overall circuit recovery.

Despite the lower recovery values, the Floatex-Falcon-Jameson circuit provided a superior separation performance as shown in Figure 7(a) and (b). The flowsheets in Figures 8(a) and (b) provide an explanation for the poor performance of the existing spiral concentrator-conventional flotation circuit. The problems associated with the existing circuit include: (1) misplaced -100 mesh coal to the underflow of the classifying cyclone which reports to the underflow of the spiral product sieve bend and to the final tailings stream and (b) the high content of clay which requires a deep froth depth to produce a desirable product and, thus, results in a poor recovery of combustible material. The sieve bend underflow can not be treated by the conventional cells due to its high pyritic sulfur content.

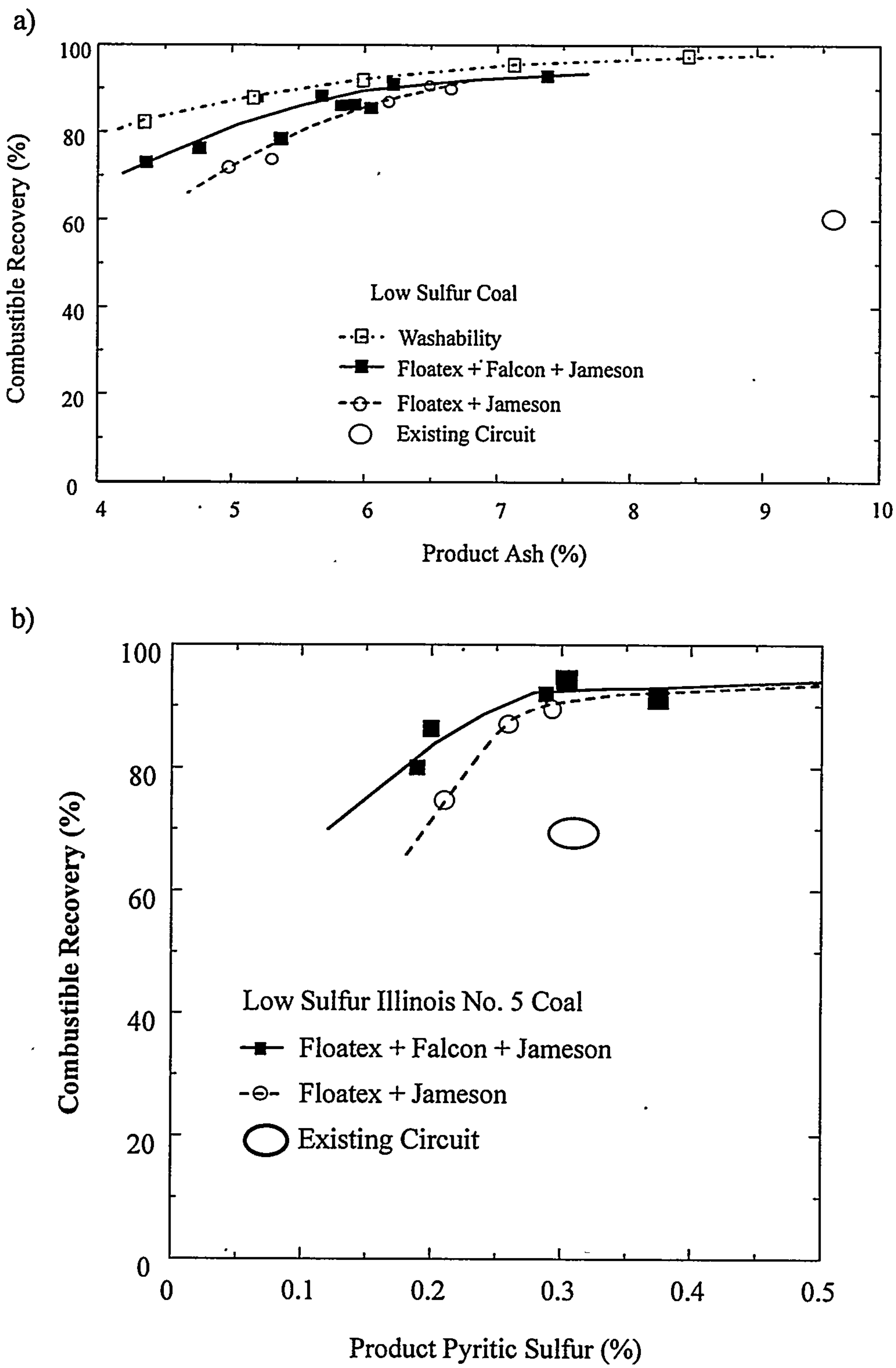
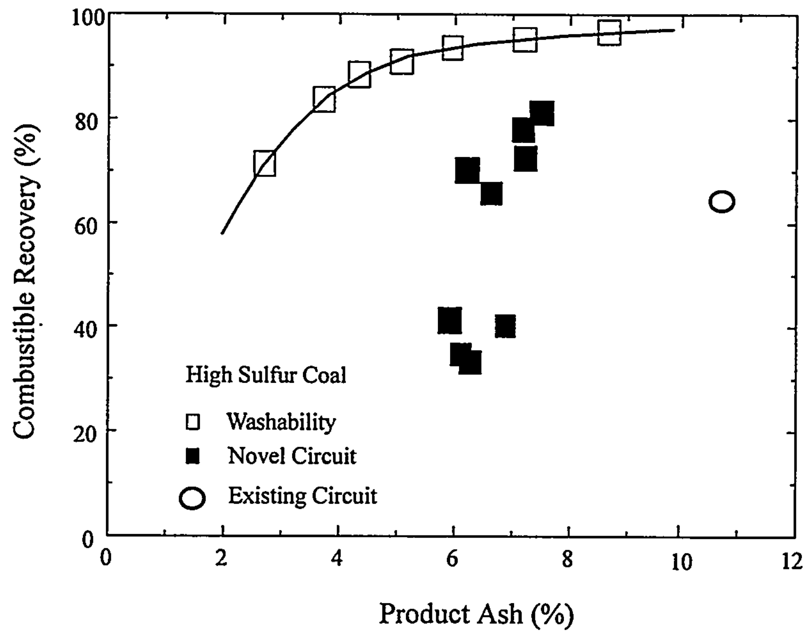


Figure 6. A comparison of the separation performance obtained from the Floatex-Falcon-Jameson circuit with that from Floatex-Jameson circuit for treating the -16 mesh fine coal feed of a preparation plant cleaning low sulfur Illinois No. 5 coal; feed ash = 23.7%, feed pyritic sulfur = 0.73%.

(a)



(b)

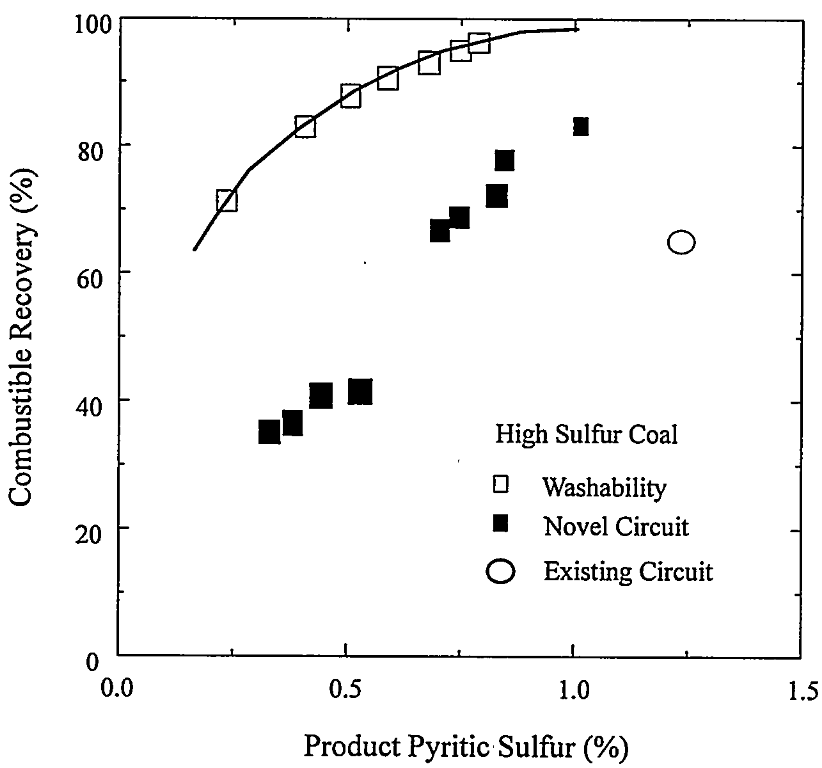
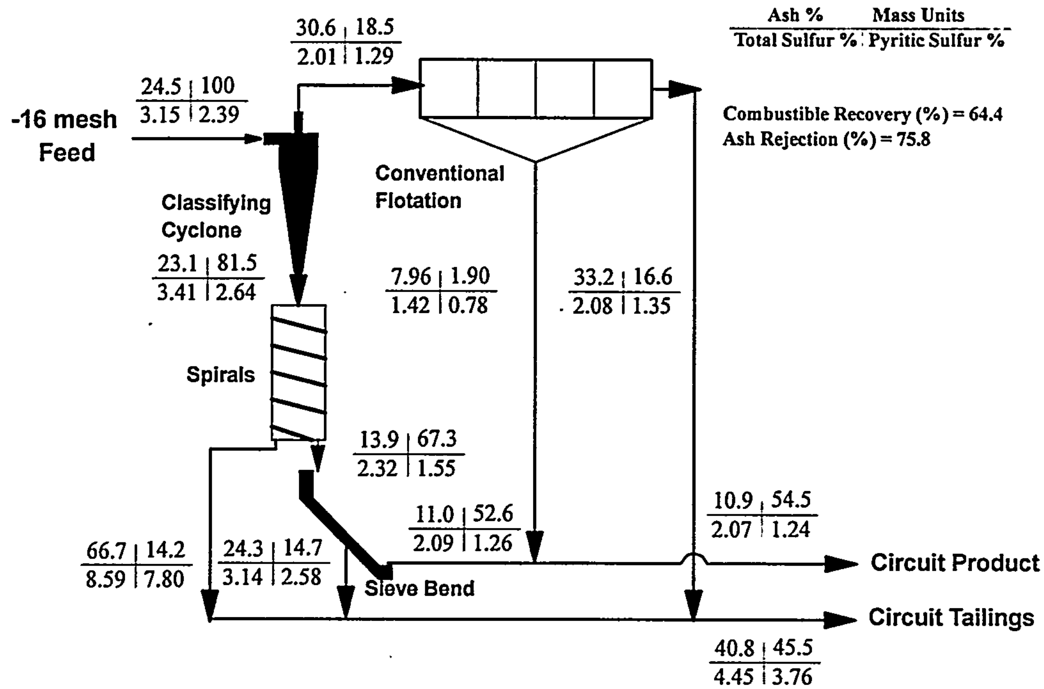


Figure 7. A comparison of the separation performances achieved on the basis of (a) product ash and (b) pyritic sulfur contents by the novel and conventional fine coal circuit for -16 mesh high sulfur Illinois No. 5 coal; feed ash and pyritic sulfur equals 25.8 and 2.43%, respectively

(a)



(b)

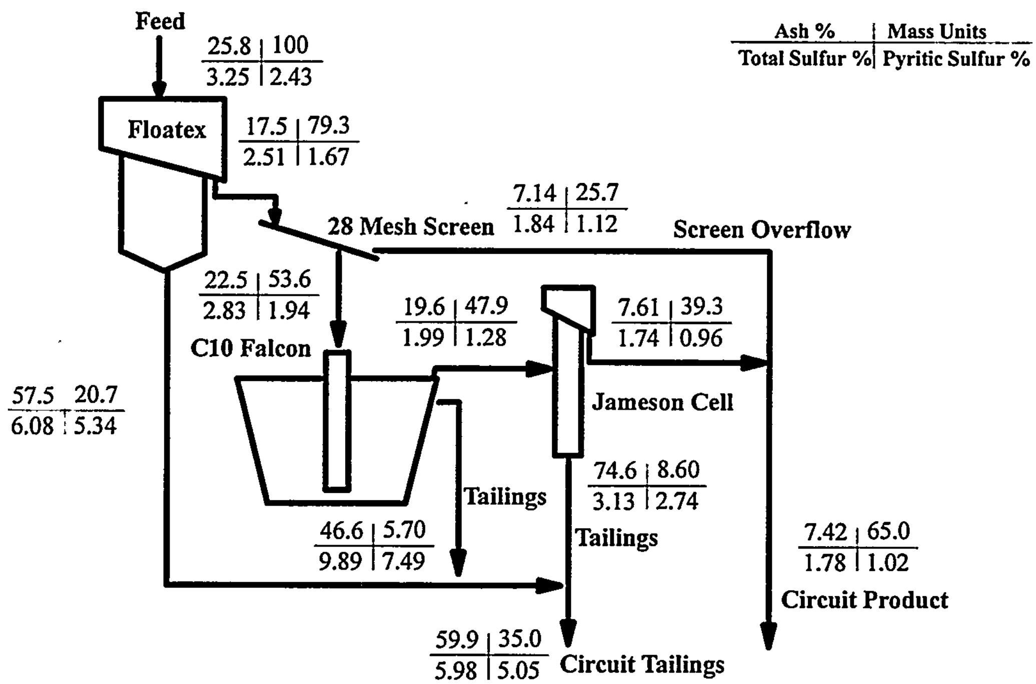


Figure 8. A comparison of the stream-by-stream separation performances achieved on the -16 mesh high sulfur Illinois No. 5 feed coal by the (a) existing spiral-conventional flotation and (b) novel Floatex-Falcon-Jameson circuits.

A final comparison of the separation performances achieved by the conventional and novel fine coal circuits is provided in Table 7. For the -16 mesh high sulfur coal, the novel Floatex-Falcon-Jameson circuit provided a 10.5% improvement in mass yield while rejecting approximately the same amount of pyritic sulfur and 6.5% more ash-bearing material. A larger increase in mass yield of 23.9% was obtained by the novel circuit from the treatment of the low sulfur Illinois No. 5 coal. In addition, a 12% greater amount of pyritic sulfur was rejected by the novel circuit while removing approximately the same amount of ash-forming material. This performance nearly produced a Phase II compliance coal at 1.28 lbs SO_2/MBTU.

Table 7. A comparison of the separation performance results obtain from the treatment of the -16 mesh high and low Illinois No. 5 feed coals using the existing spiral-conventional flotation circuit and the novel Floatex-Falcon-Jameson circuit.

Test Results	Low Sulfur Coal		High Sulfur Coal	
	Existing Circuit	Novel Circuit	Existing Circuit	Novel Circuit
Feed Ash	28.6	27.6	24.5	25.8
Product Ash	9.53	5.84	10.9	7.42
Tailings Ash	46.0	82.5	40.8	59.9
Feed T. Sulfur	1.22	1.16	3.15	3.25
Product T. Sulfur	0.96	0.87	2.07	1.78
Tailings T. Sulfur	1.46	1.89	4.45	5.98
Feed P. Sulfur	0.67	0.67	2.39	2.43
Product P. Sulfur	0.47	0.34	1.24	1.02
Tailings P. Sulfur	0.85	1.50	3.76	5.05
Feed Btu/lb	10076	10112	10948	10461
Product Btu/lb	12910	13600	13066	13548
Tailings Btu/lb	7498	1289	8411	3677
Feed lb SO_2/MBTU	2.42	2.29	5.75	6.21
Product lb SO_2/MBTU	1.49	1.28	3.17	2.63
Tailings lb SO_2/MBTU	3.89	29.3	10.58	32.5
Ash Rejection (%)	84.1	84.8	75.8	82.3
T. Sulfur Rejection (%)	62.5	46.3	64.2	64.4
P. Sulfur Rejection (%)	75.8	63.7	71.7	72.7
Mass Yield (%)	47.7	71.6	54.5	65.0
Combustible Recovery (%)	60.5	93.2	64.4	81.1
Organic Efficiency (%)	64.0	95.0	68.0	85.0

Figure 9 shows the partition curves generated for the Floatex-Falcon-Jameson circuit during the treatment of the nominally -16 mesh high and low sulfur Illinois No. 5 fine circuit feeds. The partition curves were developed using data obtained from centrifugal washability analysis of the +500 mesh size fraction of the circuit feed and products. As indicated by the excellent metallurgical performance discussed previously, the Floatex-Falcon-Jameson circuit achieved an efficient, low-gravity cut point of 1.42 on the +500 size fraction of the low sulfur Illinois No. 5 feed. The probable error (E_p) was a relatively low 0.10, indicating a very efficient separation. This finding is significant since highly efficient, low gravity cut points are uncommon, especially for high capacity unit operations. The separation achieved on the high sulfur Illinois No. 5 feed was not as efficient as indicated by an E_p of 0.16 at a gravity cut point of 1.61. However, compared to current fine coal cleaning technology used in operating preparation plants, the separation on the high sulfur coal is relatively efficient. As discussed previously, the difference in the efficiency achieved from the treatment of the high and low sulfur feed coals is likely due to the oxidation of the high sulfur coal surface caused by the stockpiling practice at the Galatia preparation plant.

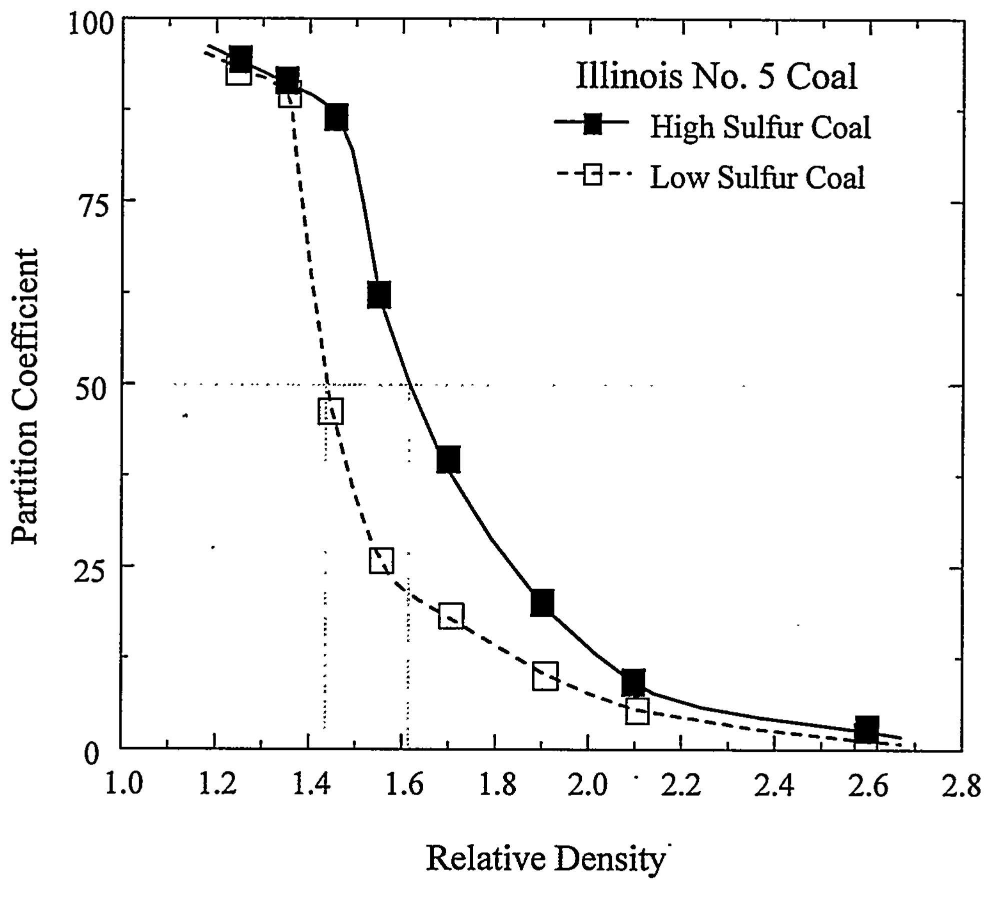


Figure 9. Partition curves representing the effective gravity separations achieved by the Floatex-Falcon-Jameson circuit for the treatment of the -16 mesh high and low sulfur Illinois No. 5 fine circuit feeds.

Phase II Compliance Testing

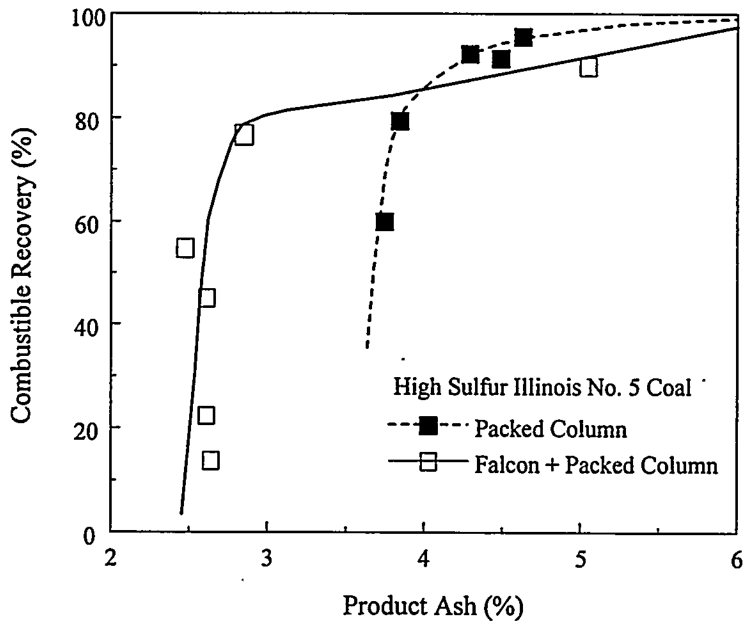
An objective of the investigation was to use advanced physical cleaning processes to produce Phase II compliance coal from a high sulfur Illinois No. 5 seam coal. To achieve this objective, the product generated from the Floatex-Falcon-Jameson circuit was collected under optimum conditions during the in-plant testing program. The in-plant circuit produced a clean coal concentrate containing 7.42% ash, 1.02% pyritic sulfur and a 2.60 lbs SO_2/MBTU. The coal was subsequently pulverized to a mean particle size of approximately 18 μm using an air jet mill and treated in a Packed-Column and a Falcon-Packed Column circuit.

Figure 10 (a) and (b) show the separation performances achieved on the basis of product ash and pyritic sulfur contents, respectively. The Packed-Column was able to substantially reduce the ash content from 7.4% to 4.2% while recovering 90% of the combustible material which equates to an additional ash rejection of 51%. However, a minimal amount of pyritic sulfur rejection was achieved (i.e., 32%) which was most likely due to the free pyrite particles having a relatively high degree of hydrophobicity.

The use of the Falcon prior to the Packed-Column resulted in substantial reductions in both ash and pyritic sulfur content as indicated by the results in Figures 10(a) and (b). At a combustible recovery of about 80%, the product ash was reduced from 7.4% to 2.8% which corresponds to an ash rejection of 71.2%. The pyritic sulfur content decreased from 1.02% to about 0.20% which equates to a relatively high pyrite rejection of 85.1%. The reduced combustible recovery in the upper portion of the recovery-product ash curve in Figure 10(a) was a result of coal being lost to the underflow (tailings) stream of the Falcon concentrator. This event occurs due to the lack of a sufficient amount of ash-bearing particles in the feed stream to form a particle bed, thereby, creating a natural by-pass of light particles to the overflow (product) stream. It is interesting to note that, although very little ash reduction was achieved at a recovery value of nearly 90%, the Falcon-Packed Column arrangement provided a substantial reduction in the pyritic sulfur content.

The overall reductions in the lbs SO_2/MBTU resulting from both the decrease in ash and sulfur are shown in Figure 11. The project objective of producing a Phase II compliance coal from a high sulfur content source was not achieved; however, significant reductions in the potential sulfur dioxide emissions were obtained. It should be noted that the calculated results in Figure 11 were obtained assuming that all of the sulfur is emitted into the atmosphere upon combustion; however, it is well known that a portion of the sulfur is captured as part of the combustion residues. The Falcon-Packed Column circuit arrangement was found to reduce the lbs SO_2/MBTU from 2.76 to 1.75 at a recovery of about 90% and further to 1.60 at a recovery of nearly 80%.

(a)



(b)

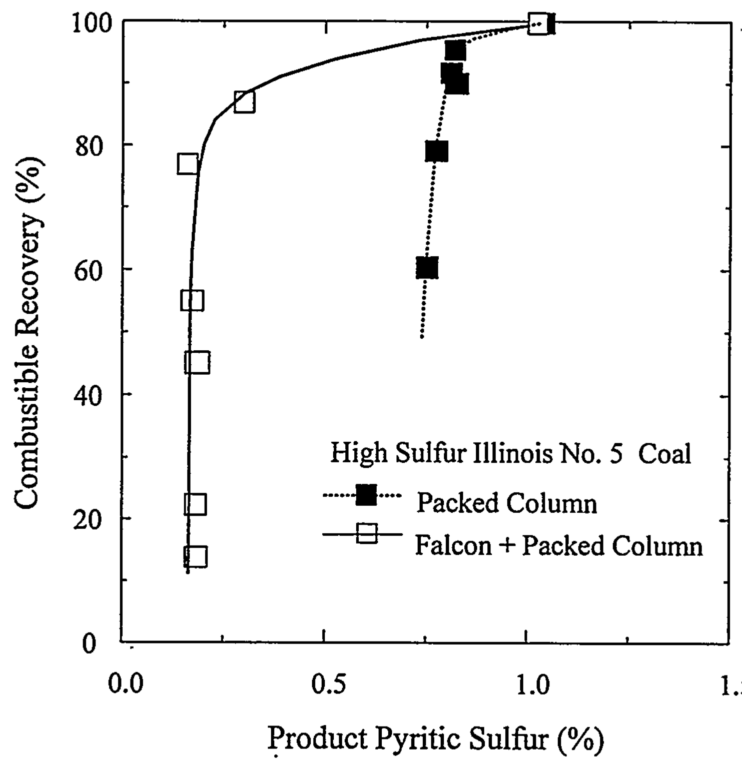


Figure 10. A comparison of the separation performances achieved on the basis of (a) product ash and (b) pyritic sulfur contents by the Packed-Column and Falcon-Packed-Column circuit from the treatment of the pre-cleaned and pulverized, high sulfur Illinois No. 5 coal; feed ash = 7.42% and feed pyritic sulfur = 1.02%.

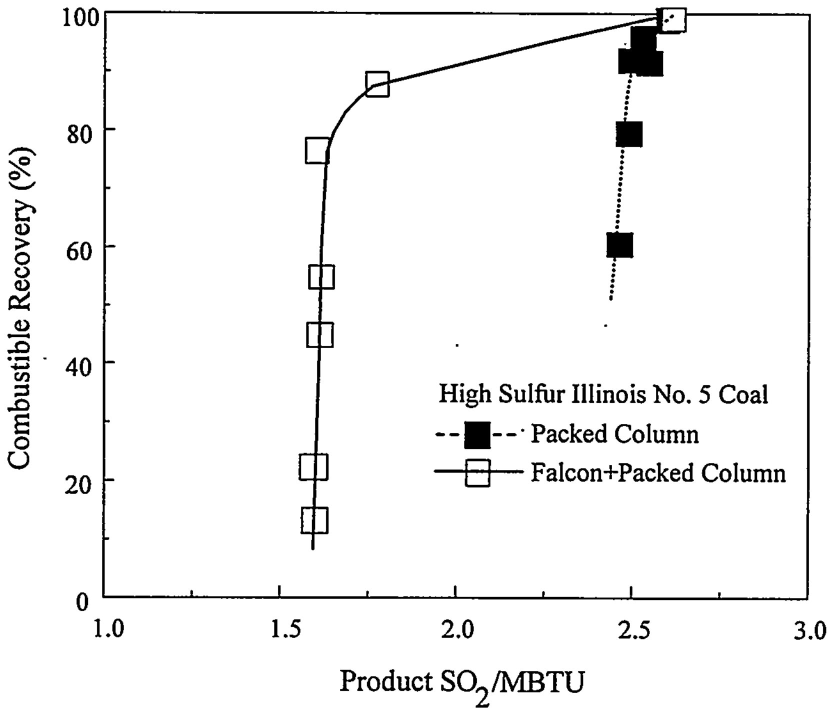


Figure 11. The sulfur dioxide emission rating reductions achieved for the pre-cleaned and pulverized, high sulfur Illinois No. 5 coal sample using the Falcon concentrator and the Packed-Column; raw and pre-cleaned feed coal equal 5.72 and 2.60 lbs. SO_2/Mbtu, respectively.

Results obtained at two recovery values from the overall circuit treatment, including the in-plant treatment and the Falcon-Packed Column treatment of the pulverized coal, are provided in Table 8. These results were obtained with only a modest amount of grinding which resulted in a mean particle size in the product of approximately 18 μm and 10% of the material was greater than 75 μm. The relatively low recovery values are a result of the multiple stages of cleaning with no feedback streams which, if used, would result in higher recovery values. Also the tailings from the Packed-Column were sufficiently clean to be used as a clean coal product in other markets. However, as a result of the treatment using advanced physical cleaning technologies, 95% of the ash and pyritic sulfur was rejected which yielded a product that is near Phase II compliance.

Economic Analysis

The economic evaluation was conducted based on a comparison of costs and improved mass yields associated with the current fine coal circuit at the Galatia preparation plant and the Floatex-Falcon-Jameson circuit. The equipment costs for both circuits are summarized in Table 9. Common costs associated with both circuits such as dewatering equipment, piping, etc. were not considered. A 7 year straight line depreciation at 10% annual interest was used to determine the annual capital costs. A mass throughput

Table 8. A summary of the separation performance results obtained from the overall circuit shown in Figure 3 which involves the Floatex, Falcon, Jameson Cell and Packed-Column.

Response Variable	Total Circuit Recovery	
	64%	72%
Feed Ash (%)	25.8	25.8
Product Ash (%)	2.8	5.0
Feed Pyritic Sulfur(%)	2.43	2.43
Product Pyritic Sulfur (%)	0.20	0.30
Feed lbs SO_2/MBTU	6.21	6.21
Product lbs SO_2/MBTU	1.60	1.75
Circuit Ash Rejection	94.7	89.1
Circuit Pyrite Rejection	96.0	93.1
Circuit Mass Yield	48.9	56.2

Table 9. A summary of the capital and operating costs for the major equipment items in the conventional and Floatex-Falcon-Jameson Circuit.

Existing Circuit			Floatex-Falcon-Jameson Circuit		
Equipment	Capital Cost ($)	Oper. Cost ($/year)	Equipment	Capital Cost ($)	Oper. Cost ($/year)
Cyclones	100,000	124,800	Floatex	242,000	62,400
Spirals	264,000	50,400	Screens	180,000	144,000
Screens	180,000	125,952	Falcon	300,000	57,600
Float Banks	600,000	179,712	Jameson	1,000,000	499,200
Total	1,144,000	480,860		1,722,000	

through the fine coal circuit of 260 tons/hr was used for a production time of 16 hrs/day, 6 days/week and 52 weeks/year.

As shown in Table 10, the 10.5% improvement in mass yield provides a greater annual gross profit despite the larger capital and operating costs. The Floatex-Falcon-Jameson circuit provides an increase in annual net profit of $2.15 million assuming a 34% corporate tax rate for the treatment of the high sulfur Illinois No. 5 fine coal. This increase in profit would be significantly greater for the treatment of the low sulfur Illinois No. 5 coal based on the separation performance data in Table 7.

Table 10. A comparison of the economic performance data for the existing conventional circuit and the Floatex-Falcon-Jameson circuit for the 260 ton/hr high sulfur fine coal feed.

	Existing Circuit	Novel Circuit
Mass Yield	54.5	65.0
Annual Production (clean tons)	680,167	811,200
Annual Revenue ($ x 10^6)	19.04	22.71
Annual Cost ($ x 10^6)	0.72	1.13
Annual Gross Profit ($ x 10^6)	18.32	21.58

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. For a -16 mesh high sulfur Illinois No. 5 coal, the Floatex-Falcon-Jameson circuit rejected 72.7% of the pyritic sulfur while reducing the ash content from 25.8% to 7.42% at a combustible recovery of 81.1%. The separation performance was more efficient when treating a -16 mesh low sulfur Illinois No. 5 coal for which the pyritic sulfur content was reduced from 0.67% to 0.34% while recovering 93.2% of the combustible material. The ash content was decreased from 27.6% to 5.8% which equates to an organic efficiency of 95% when compared to gravity-based washability data.

2. Pulverization of the product generated from the Floatex-Falcon-Jameson circuit and re-treatment in a Falcon Concentrator and Packed-Column arrangement resulted in a significant reduction in ash and pyritic sulfur contents. At a combustible recovery of 80%, the pyritic sulfur content was further reduced from 1.02% to 0.20% which corresponds to a pyrite rejection of 85.1%. Thus, for the overall treatment from the Floatex to the Packed-Column, a pyritic sulfur rejection of 93% was achieved at a circuit recovery of 72% and 96% at a recovery of 64%. The overall circuit ash reduction was from 25.8% to 2.8%. The overall circuit performance produced a Phase I compliance coal by reducing the sulfur dioxide emission rating from 6.21 to 1.75 lbs SO_2 /MBTU.

3. The Floatex-Falcon-Jameson circuit provided superior separation performances when compared to those obtained from the existing conventional (spirals and flotation banks) circuit. For the high sulfur Illinois No. 5 coal, a 10.5% weight units improvement was obtained by the novel fine coal cleaning circuit while rejecting 6.5% greater amounts of ash-forming material. For the low sulfur coal, the increase in mass yield provided by the Floatex-Falcon-Jameson circuit was 23.9%. In addition to the improved yield, the novel circuit rejected 12.1% greater amount of pyritic sulfur. The organic efficiency of the novel circuit was found to be 95% while the conventional

circuit efficiency was 64.0%. Significant economic benefits were determined for the use of the Floatex-Falcon-Jameson circuit over the conventional circuit.

4. Partition curves generated from the Floatex-Falcon-Jameson circuit separations revealed that the circuit provided a highly efficient, low gravity cut point which is desirable and uncommonly for fine coal separations. For the low sulfur coal treatment, the gravity cut point (D_{50}) was found to be approximately 1.42 with an excellent probable error (E_p) value of 0.10. The E_p and D_{50} values for the separation on the high sulfur coal were significantly higher at 0.16 and 1.6, respectively.

5. The Jameson Cell was found to efficiently recover 28 x 48 mesh coal in a rougher-scavenger arrangement. Recovery values greater than 90% were achieved for the 28 x 48 mesh size fraction.

6. 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.

7. 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 -28 mesh size fractions and the pulverized coal sample. Substantial improvements in both the product ash and pyritic sulfur contents were obtained.

The superior performance provided by the Floatex-Falcon-Jameson cell should be achievable for the -16 mesh size fraction of most run-of-mine coals although the magnitude of the increased improvement may vary due to liberation and surface property characteristics. However, due to the efficient particle recovery mechanisms that are characteristic of the Jameson cell, pyritic sulfur reductions may be limited when the fine coal contains a significant amount of pyritic sulfur in the -400 mesh size fraction. In these cases, a Packed-Column may be needed to replace the Jameson cell in order to ensure the maximum reduction in pyritic sulfur content.

Due to the inability to obtain licensing from federal and state agencies, the evaluation of the AMDEL on-line nuclear analyzer was not achieved during the project period. The main components of the AMDEL analyzer minus the nuclear sources are present at SIUC and will be evaluated upon receiving the licensing agreement.

Recommendations

1. Technical and economical methods for evaluating the influence of the highly efficient fine coal separation on the overall plant performance must be investigated.

2. New technologies for achieving efficient low-gravity cut points on fine coal must be evaluated for potential commercial use. These technologies will enhance the economics of both the processing and mining operations.

DISCLAIMER STATEMENTS

PROJECT MANAGEMENT REPORT
September 1, 1995, through August 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. Mohanty*
Kerr-McGee Coal Corporation
Project Manager: K. Ho, ICCI

COMMENTS

All goals and objectives of the project were achieved. The equipment required to complete the project were found to cost substantially less than the originally estimated amount. Therefore, excess equipment money exists.

One of the main advantages of the novel circuit studied in this investigation is the ability to automate and control. In this regard, an unique on-line analyzer commercially known as the AMDEL system was proposed for evaluation as part of this project. However, due to the inability to receive licensing of the nuclear sources from federal and state agencies, the AMDEL system was not evaluated during the project period. However, the main components of the analyzer minus the nuclear sources are presently at SIUC and the evaluation will be performed upon receiving the nuclear licensing from the state of Illinois. Cost-sharing from CONSOL Inc. has been provided to ensure completion of the evaluation.

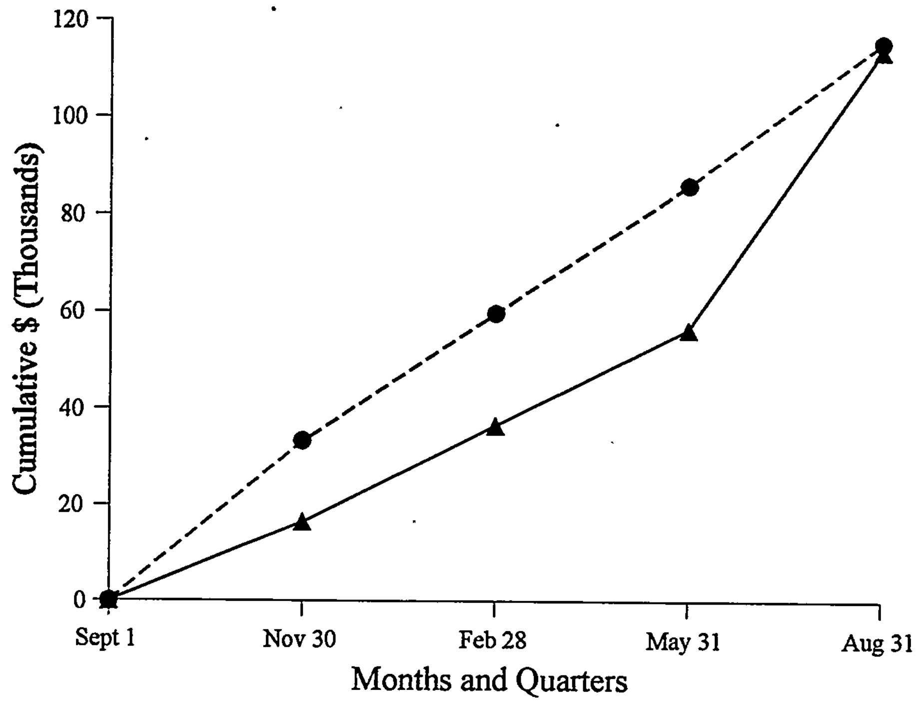
PROJECTED AND ESTIMATED EXPENDITURES BY QUARTER

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	53,392	15,136	6,800	2,500	3,000	22,800	10,363	113,991

*Cumulative by Quarter

CUMULATIVE COSTS BY QUARTER

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

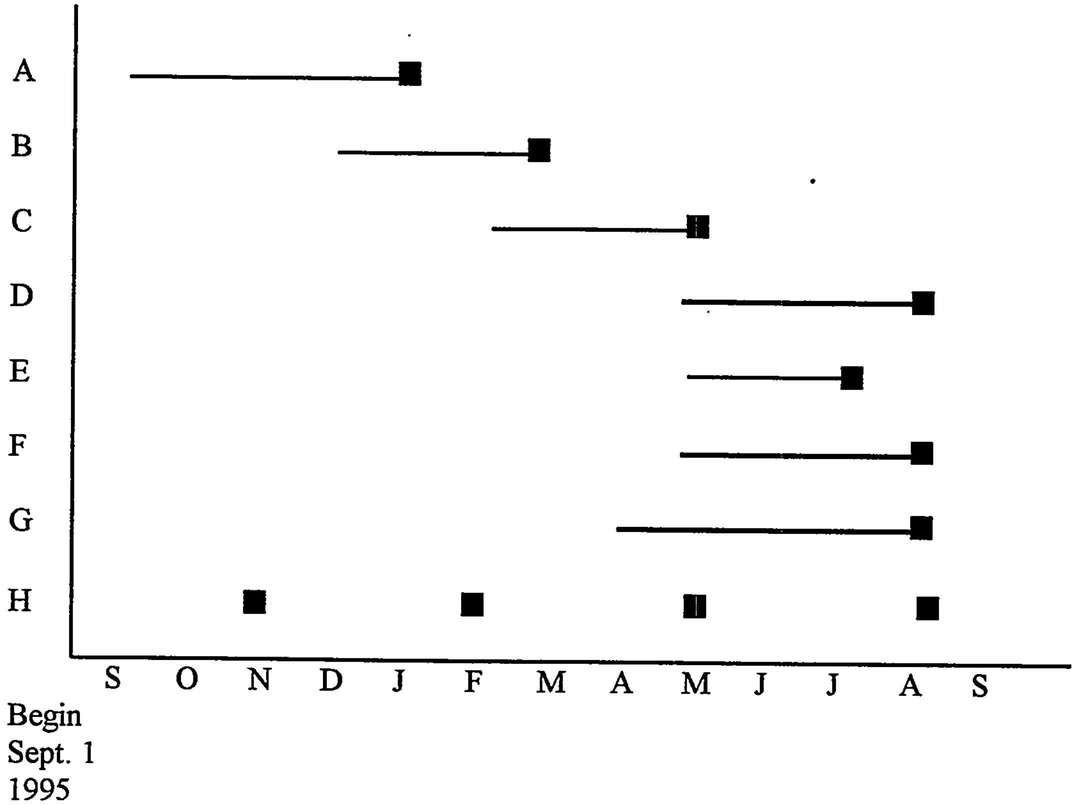


● = Projected Expenditures - - - - - - -

▲ = Actual Expenditures ______________

Total Illinois Clean Coal Instutute Award $115,641

SCHEDULE OF PROJECT MILESTONES



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.

HAZARDOUS WASTE REPORT
June 1, 1996, through August 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

HAZARDOUS WASTE REPORT

All hazardous wastes were turned over to SIUC Center for Environmental Health and Safety to be disposed of in accordance with EPA/SIUC approved disposal plan.