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March 1 through May 31, 1995

Project Title: **A FINE COAL CIRCUITRY STUDY USING COLUMN
FLOTATION AND GRAVITY SEPARATION**

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ABSTRACT

Column flotation provides excellent recovery of ultrafine coal while producing low ash content concentrates. However, column flotation is not efficient for treating fine coal containing significant amounts of mixed-phase particles. Fortunately, enhanced gravity separation has proved to have the ability to treat the mixed-phased particles more effectively. A disadvantage of gravity separation is that ultrafine clay particles are not easily rejected. Thus, a combination of these two technologies may provide a circuit that maximizes both the ash and sulfur rejection that can be achieved by physical coal cleaning while maintaining a high energy recovery. This project is studying the potential of using different combinations of gravity separators, i.e., a Floatex hydrosizer and a Falcon Concentrator, and a proven flotation column, which will be selected based on previous studies by the principle investigator.

During this reporting period, an extensive separation performance comparison between a pilot-scale Floatex Density Separator (18x18-inch) and an existing spiral circuit has been conducted at Kerr-McGee Coal Preparation plant for the treatment of nominally -16 mesh coal. The results indicate that the Floatex is a more efficient separation device ($E_p=0.12$) than a conventional coal spiral ($E_p=0.18$) for Illinois seam coals. In addition, the treatment of -100 mesh Illinois No. 5 fine coal from the same plant using Falcon concentrator, column flotation (Packed-Column) and their different combinations was also evaluated. For a single operation, both Falcon concentrator and column flotation can produce a clean coal product with 90% combustible recovery and 5% ash content. In the case of the combined circuit, column flotation followed by the Falcon achieved a higher combustible recovery value (about 75%) than that obtained by the individual units while maintaining an ash content less than 3%.

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EXECUTIVE SUMMARY

The Illinois coal industry is facing the potential loss of 25% of its coal market as a result of the sulfur dioxide emission restrictions contained in the Clean Air Act Amendment of 1990. Phase I of the Clean Air Act will begin in 1995, with more severe Phase II limits beginning in year 2000. Thus, it has never been more important than the present to develop pre-combustion coal cleaning strategies that will maximize the amount of sulfur and ash that can be rejected from a given coal while maintaining high energy recovery values. In this research project, a fine coal circuitry study will be conducted using advanced fine coal cleaning technologies in an effort to identify a circuit that will provide the best separation efficiency at a high mass flow rate.

The circuit arrangement that is commonly used to treat the fine coal (28 M x 0) in today's coal preparation plants utilizes coal spiral concentrators and conventional froth flotation. In this circuit, the coal spirals are used to treat the 28 x 100 mesh size fraction while the 100 x 0 mesh size fraction is treated using conventional flotation. However, despite its wide acceptance, this circuit has some inherent problems. Due to the low throughput of each spiral unit (4-5 tph) and its separation inefficiencies, a large number of spiral units are needed, thus, requiring a relatively large amount of floor space to treat a given mass throughput. In addition, the method of controlling the separation performance from each spiral makes it difficult to optimize product quality and energy recovery. The disadvantages of conventional flotation includes its inability to effectively recover ultrafine coal particles and reject finely dispersed clay particles.

Recently, column flotation and enhanced gravity concentration has received a great deal of attention for the treatment of fine coal. Column flotation provides excellent recovery of ultrafine coal while producing low ash content concentrates. However, like other flotation processes, column flotation is not efficient for treating fine coal containing significant amounts of mixed-phase particles. Current studies have shown that mixed-phased particles can be more effectively treated using enhanced gravity separators. A disadvantage of gravity separators is that ultrafine clay particles are not easily rejected. Thus, a combination of these two technologies may provide a circuit that maximizes both the ash and sulfur rejection that can be achieved by physical coal cleaning while maintaining a high energy recovery.

The work in the research project will be conducted in two phases. In the first phase, a proven flotation column and an enhanced gravity separator will be used individually or in combination to treat an Illinois No. 5 flotation feed (100 M x 0). The second phase involves a circuitry study for the treatment of a fine coal circuit feed (28 M x 0). In this circuit, a Floatex hydrosizer will be tested as a pre-cleaner to the advanced fine coal cleaning technologies. Past studies have found that the Floatex provides an economical and efficient rejection of the coarser gangue particles in the fine coal, thereby, unloading the downstream processes by as much as 54%. In addition, screening the Floatex overflow which contains coarse coal particles, fine coal particles, and fine gangue particles produces

a final clean coal product. In the Phase II circuit, the screen underflow is subsequently treated by either a flotation column or enhanced gravity separator.

The flotation column that provides the best separation efficiency at the highest possible throughput will be used for the tests based on the conclusions from last year's ICCI project. Considering the operation convenience and separation performance, the Falcon concentrator will be used for the circuitry experiments.

In the first phase of this project, the flotation feed sample will be first treated using column flotation, which will generate a recovery-ash or sulfur content relationship that equals or exceeds the release analysis results. The optimum parameter values used in the column comparison project will be used in the column tests. To generate the recovery-grade relationships, the critical parameter that slides the column result up-and-down the ultimate curve will be varied while the others are maintained at their optimum values.

Centrifugal washer tests using the Falcon C10 Concentrator (about 4 tph) will also be conducted on the flotation feed sample. As with the column test, the goal will be to obtain the best possible recovery versus grade relationship. The results will be compared to release and washability results obtained for the flotation feed sample. Desliming of the concentrate (overflow) will be tested since clays tend to be dispersed in both streams.

Past research conducted by Yoon and Luttrell (1993) has found that enhanced gravity separators (i.e., Multi-Gravity Separator, Carpc) are effective at rejecting the coal pyrite reporting to froth concentrates (i.e., Microcel flotation column) as middling particles. Thus, to demonstrate this on other separators, a column flotation test will be conducted utilizing the optimum parameter values corresponding to its maximum separation efficiency. The froth concentrate will be collected and retreated in the Falcon C10 gravity separator under conditions which provide for maximum pyritic sulfur rejection. In addition, research conducted at SIUC has shown that the Falcon Concentrator is effective at rejecting coal pyrite and fine mineral matter. However, clay slimes tend to be dispersed in both the underflow and overflow streams. Column flotation is an excellent process for treating materials containing clay slimes. Therefore, the Falcon C10 unit will be tested as a precleaner to column flotation.

In the second phase, Floatex hydrosizer tests will be conducted on the fine coal circuit feed (16 x 0 mesh) at Kerr-McGee's Galatia preparation plant. The goal of the initial experiments will be to determine the optimum elutriation water rate and the screen size to produce coarser clean coal product. The optimum elutriation water rate will be used to collect the samples for the flotation column and enhanced gravity separator experiments.

The screen underflow from the Floatex circuit will be treated in a number of different circuitry arrangements utilizing enhanced gravity separation or column flotation in combination and separately. Complete proximate analyses to obtain the total sulfur, ash, and BTU content will be conducted on all products generated from each circuit.

In summary, the goal of this research project is to improve the efficiency of fine coal cleaning and maximize sulfur and ash rejection using column flotation and enhanced gravity separation, either in combination or separately.

During this reporting period, an extensive separation performance comparison between a pilot-scale Floatex Density Separator (18x18-inch) and an existing spiral circuit has been conducted at Kerr-McGee Coal Preparation plant for the treatment of nominally -16 mesh coal. The Floatex Density Separator was found to be capable of providing metallurgical results as good, or better, than coal spirals. Compared to the existing plant spiral circuit at an equivalent product ash using a 16x100 mesh Illinois seam coal the Floatex Density Separator provided a 10% higher weight yield. In addition to the improved weight yield, the Floatex product had a 0.2% lower total sulfur content.

Further evidence indicating that the separation efficiency provided by the Floatex is more efficient than spirals was provided by washability analyses of samples collected from the feed and product streams. The analyses results indicate that the Floatex provides a more efficient separation than a conventional coal spiral for typical Illinois seam coals. Specifically, the probable error for the Floatex and spiral were determined to be 0.125 and 0.185, respectively. Both separators provided approximately the same density-cut point of 1.8.

A unit capacity of 2.0-2.5 tph/ft² was achieved for the in-plant Floatex at product ash and weight yields of 10% and 89%, respectively. The results indicate that the Floatex Density Separator can be a cost-effective and high-capacity unit operation.

In addition, the treatment of -100 mesh flotation feed collected from the Galatia preparation plant was performed using the Falcon concentrator, column flotation and their different combinations. For a single operation, both Falcon concentrator and column flotation (Packed-Column) can produce a clean coal product with 90% combustible recovery and 5% ash content. In case of the combined circuits, the circuit consisting of column flotation followed by the Falcon concentrator can achieve higher combustible recovery (about 75%) while maintaining an ash content less than 3%. It seems that the arrangement of the Falcon unit followed by column flotation can not compete with the former arrangement for the treatment of very fine coal, i.e., containing a small amount of +100 mesh material and a large amount of -400 mesh material. This is most likely the result of the inability of Falcon concentrator to achieve a high recovery of combustibles found in the -400 mesh fraction, of which this sample has significant amounts. Analyses indicating product total and pyritic sulfur contents, which are currently being performed, may reveal a different optimum circuit arrangement.

During the next reporting period, the test work will be focused on the study of the ultimate circuit arrangement (Floatex, Falcon and Packed-Column) for the treatment of the fine circuit feed, i.e., nominally -16 mesh, collected from Kerr McGee's Galatia preparation plant.

OBJECTIVES

The goal of this project is to improve the efficiency of fine coal cleaning and maximize sulfur and ash rejection using column flotation and enhanced gravity separation, either in combination or separately. In light of this goal, the project objectives are:

1. To determine the circuitry arrangement, which uses column flotation and/or enhanced gravity separation, that will provide maximum pyritic sulfur and ash rejection while achieving high BTU recovery values for the treatment of flotation feed (-100 mesh);
2. To evaluate the feasibility of using a Floatex hydrosizer for achieving significant ash and pyritic sulfur rejection and a clean coal product prior to column flotation and enhanced gravity separation;
3. To identify the fine coal circuit, which may involve a combination of a Floatex hydrosizer, column flotation, and enhanced gravity separation, that will provide efficient cleaning with maximum pyritic sulfur and ash rejection for the treatment fine coal circuit feed (-16 mesh).

These objectives are to be achieved through the following tasks:

- Task 1: Treat An Illinois No. 5 flotation feed coal sample (-100 mesh) with column flotation and enhanced Gravity Separation separately or in different combination.
- Task 2: Conduct Floatex tests with the fine coal circuit feed (16 x 0 mesh) at Kerr-McGee's Galatia preparation plant.
- Task 3: Treat the screen underflow from the Floatex circuit (Task 2) in the Falcon C10 concentrator.
- Task 4: Treat the screen underflow from the Floatex circuit (Task 2) by column flotation.
- Task 5: Test two different circuit arrangements. The first circuit will involve the treatment of the screen underflow from the Floatex circuit (Task 2) by column flotation followed by the Falcon C10 concentrator. The second circuit will treat the same material by Falcon C10 concentrator and then by column flotation.
- Task 6: Prepare quarterly and final reports.

INTRODUCTION AND BACKGROUND

The treatment of the fine coal fraction (28 M x 0) in a number of today's preparation plants generally involves the use of both coal spiral concentrators and conventional flotation. The spiral concentrators are used to treat the 28 x 100 mesh size fraction while conventional flotation is commonly used to treat the 100 x 0 mesh size fraction (Figure 1). There are a few plants that simply discard the 100 x 0 mesh size fraction due to its insignificant quantity, inability of the flotation process to meet product grade requirements, and/or the high moisture content of the final coal product.

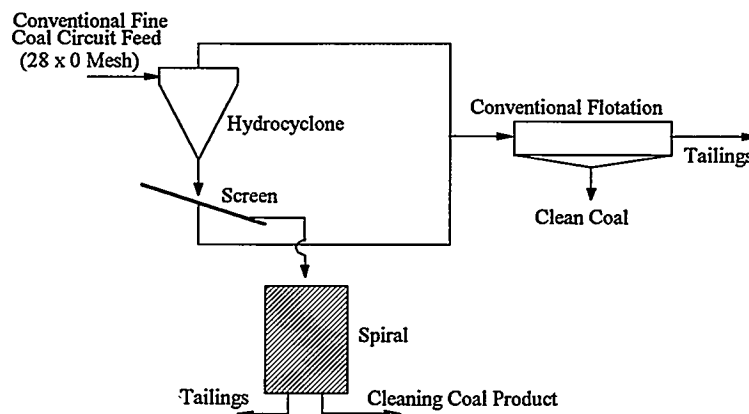


Figure 1. The conventional fine coal processing circuit.

One of the most important developments in fine coal cleaning in the 1980's was the development of spiral concentrators, a gravity-based separation method, made specifically for coal applications. Their popularity among coal preparation plant personnel is very high due to their operational simplicity and cheap cost. However, the throughput of each spiral is relatively low (i.e., 4 - 5 tph) which results in the requirement of a large number of spirals to treat a typical plant mass flow rate. This results in a large floor space requirement. In addition, due to the inefficiencies associated with spirals, secondary treatment of the primary spiral middling is commonly practiced (Bethell, 1988). The splitter position control for separation performance combined with the large number of spirals required makes spirals very difficult for plant operators to effectively control the final product grade and coal recovery. This is especially true when fluctuations in feed rate, feed solids content, and feed grade are quite common.

The treatment of the ultrafine coal fraction (100 M x 0) in today's coal preparation plants is generally limited to froth flotation. Conventional flotation, which is the most

commonly used flotation method, has proven to be very successful for treating fine particle fractions from several coal seams. Unfortunately, conventional flotation becomes ineffective when the particle size is very small or when the flotation pulp contains a large amount of finely dispersed clay or siliceous gangue. Small hydrophobic particles, such as fine coal, have a low probability of collision with air bubbles, resulting in a low recovery (Yoon and Luttrell, 1989; Reay and Ratcliff, 1973; Sutherland, 1948). In addition, fine mineral matter particles are entrained into the froth product along with the process water, resulting in poor selectivity (Engelbrecht, and Woodburn, 1975; Bishop and White, 1976; Lynch et al., 1981). When processing the fine particles in a typical flotation feed, both of these problems must be resolved to obtain the desired separation performance.

A solution to the entrainment problem is the use of flotation columns. In such devices, the smaller cross-sectional area provides the support needed for deeper froths as compared to those found in conventional flotation. Wash water is added to the froth phase to create a net downward flow of water so that the flow of pulp water to the froth phase is prevented. As a result, entrained gangue particles entering the flotation froth are rejected back into the pulp phase. Therefore, flotation columns can be used to obtain high product quality.

There are several flotation column technologies commercially available. The largest difference in these technologies is their method of bubble generation. In general, the generation of small bubble sizes produced by these technologies is controlled by increasing the shear rate at the bubble nucleation point. The importance of small bubbles in flotation having size D_b can be realized by the following equation:

in which P_c is the probability of bubble-particle collision, D_p the particle diameter, and

$$P_c \propto \left(\frac{D_p}{D_b} \right)^n, \quad [1]$$

n equals 2 for most flotation conditions. Equation [1] suggests that the probability of bubble-particle collision decreases at a given bubble size as particle size is reduced, thereby, decreasing recovery. A solution to this problem is to use smaller bubbles to treat ultrafine particles. Conventional flotation machines provide bubble sizes much larger than those produced by the flotation columns. Therefore, by using column flotation, smaller bubbles can be generated to improve combustible recovery and wash water can be applied directly to the froth phase to improve the grade of the final products.

However, a disadvantage of column flotation and any other froth flotation process is their inability to effectively treat fine coal containing a large portion of mixed-phase particles. The reason for this inefficiency is due to the non-selective nature of the

flotation process towards middling particles. For instance, a particle that contains as little as 10% coal on its surface and, thus, represents a high ash content particle, has a good chance to report to the flotation product as a result of bubble attachment to the coal portion of the particle surface. Therefore, achieving a high combustible recovery value for coal fines containing a large amount of middling particles results in high product ash and sulfur content values. Also, producing a low product ash and sulfur content concentrate results in a low combustible recovery.

The inability to treat the middling particles may be part of the explanation for the low pyritic sulfur rejections achieved by froth flotation. Past research has found that the pyrite and ash-forming minerals in some coals are not well liberated even at micronized sizes (Hsieh and Wert, 1983; Kneller and Maxwell, 1985; Adel et al., 1989; Remesh and Somasundaran, 1990). In a study by Zitterbart et al. (1985), only approximately 45% of the pyritic sulfur was found to be completely liberated in several Illinois No. 6 coal samples having a mean size of 600 μm . At a mean size of 100 μm , approximately 73% of the pyrite was liberated. Several other studies have found that the pyrite in Illinois Basin coals is finely dispersed within the coal matrix and, thus, is not completely liberated in the finest coal fraction. This indicates a large middling content in the fine fractions of these coals which results in poor selectivity using any froth flotation process (Adel et al., 1989; Wang et al., 1992).

Another possible explanation for the low pyritic sulfur rejection values achieved by flotation involves the natural hydrophobicity of the coal pyrite due to a sulfur-rich surface. This problem has been the topic of many research investigations and publications over the past two decades. The actual flotation mechanism of the pyrite is still being debated and researched in several laboratories across the country (Kawatra and Eisle, 1991; Yoon, 1992). To alleviate this problem, several new processing schemes have been suggested such as primary flotation of the coal followed by reverse flotation to float the pyrite from the coal using xanthates (Hucko and Miller, 1980). However, the operating costs of using this type of approach would be prohibitively high.

A better technical and economical means of treating fine coals that have a high middlings and/or pyrite content may be to use a gravity-based separation method. Past research compared the washability curves obtained from a laboratory centrifuge with the release curve generated from froth flotation and found that gravity-based processes are much more efficient than flotation at treating middling particles (Perry and Aplan, 1985; Luttrell, 1992; Wang, 1994). However, past full-scale gravity-based processes were ineffective for treating fine sizes due to a lack of particle inertia.

Over the past few years, several continuous enhanced gravity separators have been developed for the treatment of particles less than 28 mesh. These units include the Multi-Gravity Separator, the Knelson Concentrator, the Falcon Concentrator, and the Kelsey Jig. The advantages of the centrifugal washers over flotation columns are a

larger mass throughput per cross-sectional area and a better rejection of pyritic sulfur. In comparison to spiral concentrators, a commercially-available centrifugal washer unit having a capacity of 40 tph can be used to replace several coal spirals. This reduces floor space requirements and allows for better process control.

Past research conducted on a Falcon Concentrator at Southern Illinois University has found that the separator was very effective at reducing the total sulfur content of a 28 x 0 Illinois No. 5 seam coal sample. Excellent ash rejections were also achieved down to a particle size of approximately 10 μm . The high ash content in the -10 μm fraction of the products indicated that significant quantities of sub-micron clay particles can not be separated from the clean coal particles using enhanced gravity separation. One possible solution to this problem is to possibly size the enhanced gravity separator overflow product using high-pressurized hydrocyclones to produce a final coarse clean coal product (say 28 x 200 mesh) and a fine stream that would be treated using column flotation. As a result, spiral concentrators would be eliminated and the number of flotation columns required minimized.

The current project will conduct circuitry testing which incorporates both enhanced gravity separation and column flotation in combination and separately. This study will be conducted on both a Illinois No. 5 fine coal circuit feed (16 M x 0) and a flotation feed (100 M x 0) from Kerr-McGee's Galatia Preparation Plant. In addition, a Floatex hydrosizer will be tested on the fine circuit feed to evaluate its ability to provide an initial rejection of ash-forming minerals and pyritic sulfur which will reduce the amount of material to be treated by down-stream processes.

EXPERIMENTAL PROCEDURE

During this reporting period, an extensive separation performance comparison in terms of probable error, gravity cut-point, product ash, product total sulfur and weight yield between a pilot-scale Floatex Density Separator (18x18-inch) and an existing spiral circuit has been conducted at Kerr-McGee Coal Preparation plant.

The sample used for this test program was a nominal 16 x 100 mesh Illinois seam coal. The feed stream for the test circuit was taken directly from the existing spiral distributor, which is fed from the underflow of a bank of 15-inch classifying cyclones at a pulp density of approximately 35-40% solids (by weight). The ash, sulfur and particle size distributions are shown in Table 1.

The existing spiral circuit has a total of 20 triple-start spirals arranged in four banks, processing a total solids feed rate of approximately 200 tph (3.3 tph/start) at a pulp density of 35% (by weight). For this test circuit, the feed from one spiral in the bank (1/12) was routed directly to the Floatex unit. The product and reject streams were returned to the existing spiral launders. Feed rate was varied from 3.3 to 6.5 tph by

blocking off various numbers of discharge ports from the existing spiral distributor to increase the overall volumetric feed rate (i.e., 1/12, 1/8 and 1/6 of the total feed to the distributor).

Table 1. Ash, Sulfur and Particle Size Distribution for Illinois seam coal.

Particle Size (Mesh)	Weight (%)	Ash (%)	Sulfur (%)
+16	13.50	19.03	2.05
16x28	27.93	18.35	2.17
28x48	25.89	18.47	2.14
48x65	9.71	18.58	2.27
65x100	6.51	19.65	2.47
-100	16.46	40.20	3.70
Total	100.0	22.19	2.43

The work in the first phase of the test program involved several series of tests using various feed rates, teeter water rates and bed levels to evaluate the performance of the Floatex. Additionally, tests were conducted on the existing spirals for comparison purposes. Samples of the feed, product and reject streams from both the Floatex and the existing spiral circuit were collected, screened at 100 mesh and analyzed for pulp density, particle size distribution, and ash and total sulfur contents.

The treatment of -100 mesh Illinois No. 5 fine coal (flotation feed from Galatia Preparation Plant) using Falcon concentrator, column flotation and their combinations were also conducted during this reporting period. Table 2 shows the characterization results for this sample. The samples from these tests are presently being analyzed for total and pyritic sulfur content. The ash content data for each test will be discussed in the following section.

Table 2. The characterization for Illinois No. 5 flotation feed coal sample.

Size Class (mesh)	Weight (%)	Cum. Wt. (%)	Ash (%)	Cum. Ash (%)
+ 70	2.62	2.62	4.68	4.7
70 x 100	1.99	4.61	5.16	4.9
100 x 200	10.03	14.63	6.48	6.0
200 x 325	11.7	26.38	16.75	10.8
325 x 400	10.3	36.68	12.46	11.2
-400	63.3	100.00	34.42	25.9
Total	100		25.9	

RESULTS AND DISCUSSION

Floatex and Spiral Circuit Comparison

The product ash versus weight yield results from 15 statistically-designed Floatex test samples and several simultaneous samples collected from the existing spiral circuit are presented in Figure 2.

These results indicate that weight yields ranging from approximately 70-90% can be obtained at corresponding product ash contents of 8-12%. It can also be seen that the Floatex provides a significantly higher weight yield as compared to the existing spiral circuit. In fact, at an equivalent product ash of 10%, the Floatex weight yield is 7-15% greater than that of the existing spirals.

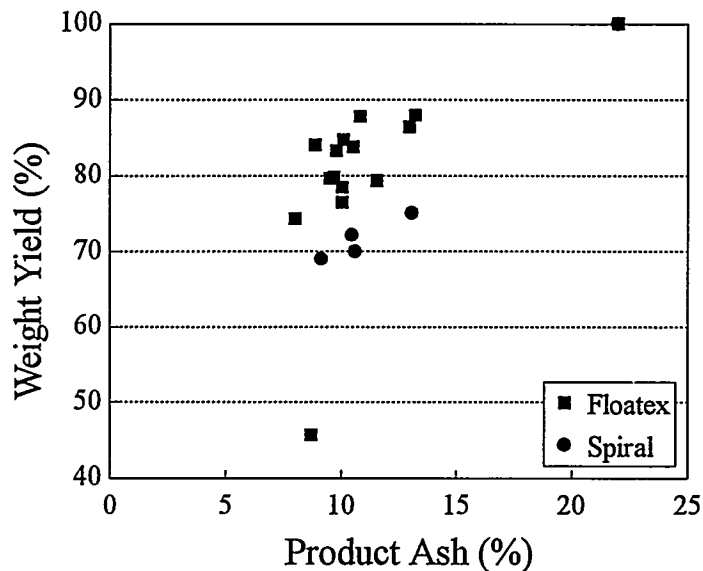


Figure 2. Product Ash Versus Weight Yield for In-Plant Testing of the Floatex Density Separator and Existing Spirals.

Similar findings can be observed for the product total sulfur versus weight yield relationship shown in Figure 3. In this instance, the Floatex continues to demonstrate a substantially higher weight yield; however, the product total sulfur content is approximately 0.2% lower than that of the spirals. Based on the pyritic to organic sulfur ratio in the feed (i.e., 1:1 for the Illinois #5 seam coal), this represents an improvement in pyritic sulfur rejection of nearly 20%. This improvement is attributed to the fact that fine heavy material (pyrite) can be entrained in the high-velocity region of a spiral. As a result, this material cannot be selectively removed from the clean coal product. In the Floatex separator, the high settling rate of the fine pyrite particles (due

to their high density) allows this material to settle through the teeter bed and report with the rejects.

The improved selectivity of the Floatex as compared to the existing coal spirals is further illustrated in Figure 4, which shows the sulfur versus ash content for both the Floatex and the coal spirals. This result clearly shows that the Floatex is capable of providing a lower sulfur product than the existing spirals at similar product ash contents.

An important consideration in evaluating a new unit operation is the long-term performance under various plant conditions. Therefore, a continuous 9-hour test was conducted during which samples of the feed, product and reject streams were collected every hour. The results from these tests are shown in Figure 5. It can be seen from these results that both the product ash and total sulfur content remained quite constant even though several fluctuations in the feed grade occurred during this time period. These fluctuations can be observed in the change in product recovery, since this parameter is a function of the feed ash content.

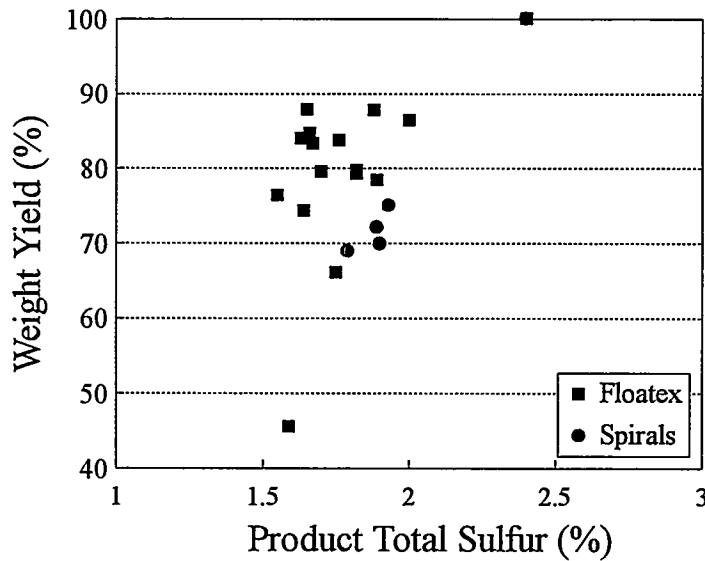


Figure 3. Product Total Sulfur Versus Weight Yield for In-Plant Testing of the Floatex Density Separator and Existing Spiral Circuit.

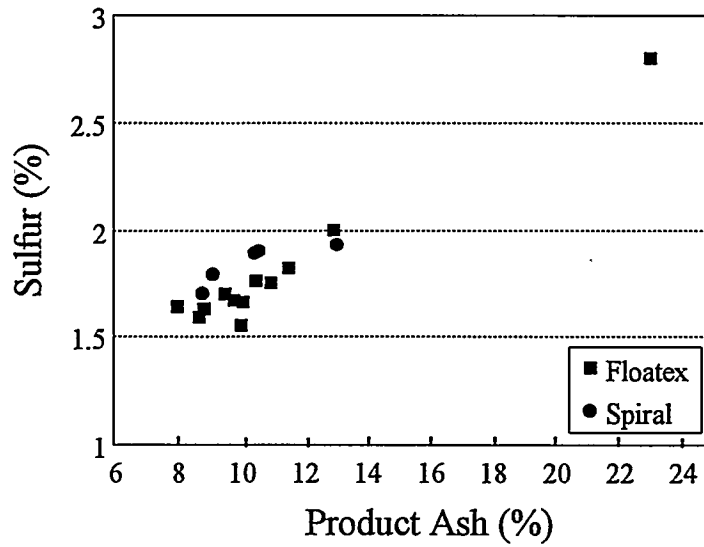


Figure 4. Product Ash Versus Total Sulfur for In-Plant Testing of the Floatex Density Separator and the Existing Spiral Circuit.

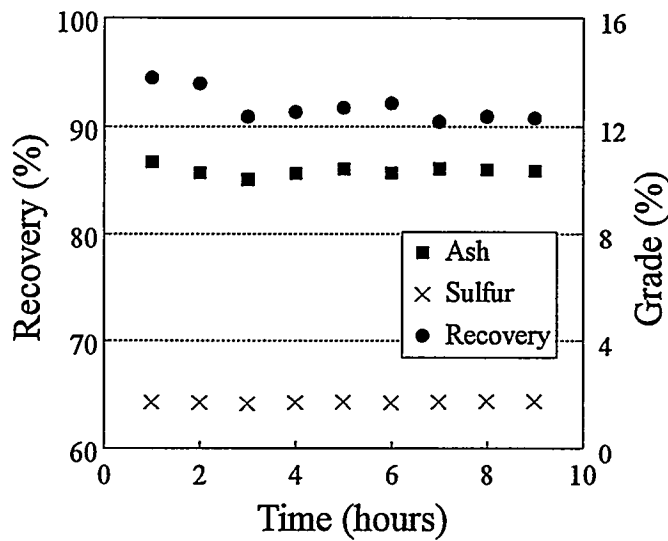


Figure 5. Long-Term Test Results for In-Plant Testing of the Floatex Density Separator.

Based on a thorough examination of the fundamental operating principles of the Floatex, it is apparent that the capacity should be a function of the unit cross-sectional area. Therefore, the normalized unit capacity (tph/ft²) for both the laboratory- and pilot-scale separators should be identical when compared under similar metallurgical conditions (i.e., the same product grade and weight yield). Figure 6 shows the scale-up relationship in term of capacity (tph) versus unit size (feet). It can be seen that the projected capacity of a 7 x 7 foot separator would be nearly 100 tph (or 2 tph/ft²).

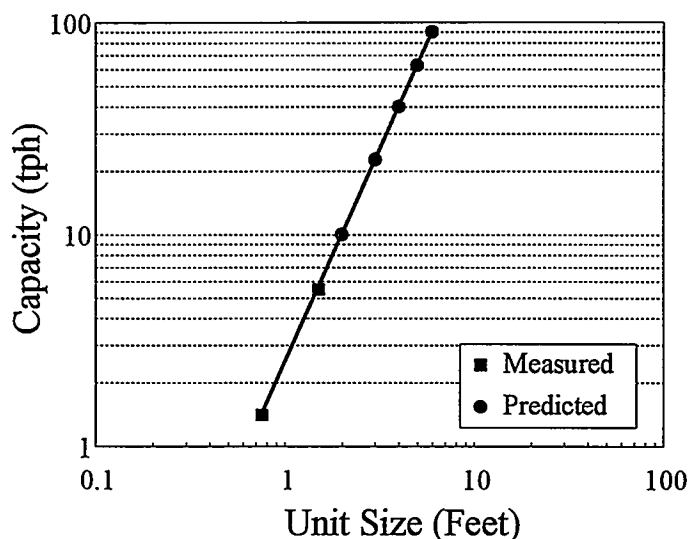


Figure 6. Capacity Versus Unit Size for the Floatex Density Separator.

To compare the separation efficiency of the Floatex hydrosizer and the existing plant spirals, washability analyses were conducted on feed and product coal samples collected simultaneously from both units. The volumetric feed rate to both units was approximately 30 gallons/min at a solids concentration of approximately 35% by weight. As currently practiced in the plant, the spiral middlings stream was combined with the tailings stream to obtain the total spiral tailings. A comparison of the reduced-efficiency curves achieved by both separations is shown in Figure 7.

As can be seen, the steeper slope of the reduced partition curve of the Floatex provided a superior separation compared to the spiral concentrator. The probable error (E_p) value achieved by the Floatex hydrosizer was about 0.125, which is significantly better than the 0.185 value obtained by the spiral concentrator. In fact, the curves indicate a 5 - 10% improvement in both the recovery of the light gravity fractions (coal) and in the rejection of the heavy gravity fractions (gangue material). This finding agrees with the metallurgical performance comparison previously presented.

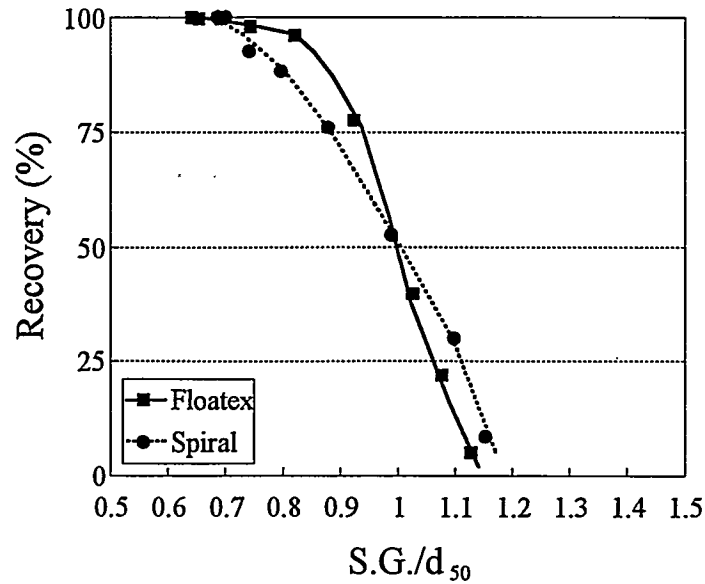


Figure 7. Reduced Efficiency Curves for the Floatex Density Separator and the Existing Spiral Circuit.

Table 3 compares the separation efficiency and metallurgical performance results achieved by the Floatex hydrosizer and the spiral concentrator. An interesting finding in light of the superior metallurgical performance provided by the Floatex unit is the lower gravity cut-point (d_{50}) of the spiral concentrator. In addition to the 10% greater weight yield, the total sulfur content of the Floatex product was lower than that produced by the spiral while the ash contents were nearly equal. The improved metallurgical performance at a higher d_{50} illustrates the importance of the sharper density separation as evident by the partition curves shown in Figure 7 and the E_p values.

Table 3. Comparison of Floatex and Spiral Efficiency.

Parameter	Floatex	Spirals
Probable Error	0.125	0.185
Cut-Point, d_{50}	1.94	1.82
Product Ash (%)	10.3	9.5
Product Total Sulfur (%)	1.67	1.85
Weight Yield (%)	88.2	77.2

Treatment of -100 Mesh Illinois No. 5 Coal

In order to determine the ideal separation performance by means of flotation, release analysis was conducted for this sample. The result is given in Table 4.

Table 4. The release analysis for Illinois No.5 flotation feed coal sample.

Sample #	Weight (%)	Ash (%)	Cum. Ash Rej. (%)	Cum. Comb. Rec. (%)
P1	8.28	2.38	99.31	11.29
P2	20.28	3.49	96.82	38.62
P3	21.97	4.93	93.00	67.80
P4	16.77	7.47	88.59	89.48
P5	4.99	12.53	86.39	95.58
T	27.71	88.57	0.00	100.00
Total	100			

The separation performance results in term of combustible recovery versus product ash using different circuitry arrangements are plotted in Figure 8.

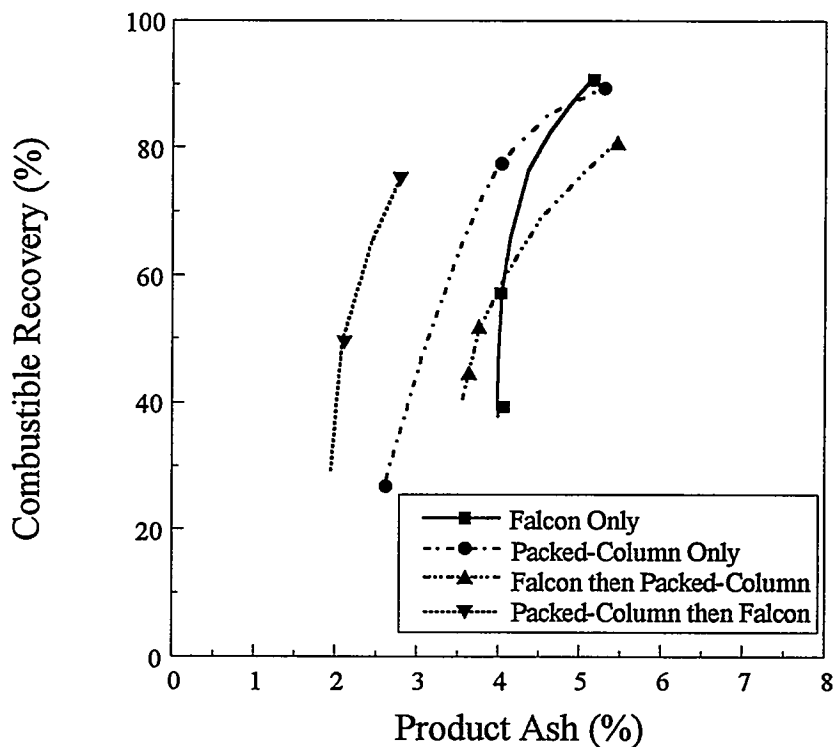


Figure 8. The separation performance using Falcon concentrator, Packed-column, and their different combinations for -100 mesh Illinois No. 5 coal sample.

As can be seen, using either Falcon concentrator or column flotation about 90% combustible recovery can be achieved with a product ash content about 5%. Further treatment of the Falcon product by column flotation seems to provide very little advantage, i.e., the final product has roughly the same ash content but the total combustible recovery decreased by about 10% which was caused by further treatment. However, if the ash content of the final product is to be reduced to less than 4%, this combined separation technique does provide a higher combustible recovery.

It is interesting to note that using the Falcon concentrator to treat the column flotation product can reduce the ash content from 5% to 2.8% while maintaining a combustible recovery of 75%. Considering the fundamental separation principles of these two techniques, it seems that using column flotation to remove clay then using enhanced gravity separation to reject entrained fine pyrite particles would be a very promising alternative for the future fine coal cleaning. On the other hand, because Falcon concentrator can not reject very fine clay material and some -400 mesh mineral matter, the further treatment of its product by column flotation may have a problem in removing some very fine heavy particles. Therefore, the separation performance by this combined technique (Falcon then column) may not as efficient as that of a flotation column.

CONCLUSIONS AND RECOMMENDATIONS

The following conclusions were obtained from the test results achieved during this reporting period:

1. The Floatex Density Separator is capable of providing metallurgical results as good, or better, than coal spirals. Compared to the existing plant spiral circuit at an equivalent product ash using a 16x100 mesh Illinois seam coal the Floatex Density Separator provided a 10% higher weight yield. In addition to the improved weight yield, the Floatex product had a 0.2% lower total sulfur content.
2. A unit capacity of 2.0-2.5 tph/ft² was achieved for the in-plant Floatex at product ash and weight yields of 10% and 89%, respectively. The results indicate that the Floatex Density Separator can be a cost-effective and high-capacity unit operation.
3. Washability results indicate that the Floatex is a more efficient separation device than a conventional coal spiral for typical Illinois seam coals. Specifically, the probable error for the Floatex and spiral were determined to be 0.125 and 0.185, respectively.
4. For a single operation, both Falcon concentrator and column flotation can produce a clean coal product with 90% combustible recovery and 5% ash content.

5. In case of combined circuit, Column then Falcon arrangement can achieve higher combustible recovery (about 75%) while maintaining an ash content less than 3%. It seems that the arrangement of the Falcon unit followed by column flotation can not compete with the former arrangement for the treatment of very fine coal, i.e., containing a small amount of +100 mesh material and a large amount of -400 mesh material.

During the next reporting period, the test work will be focused on the study of the ultimate circuit arrangement for the treatment of the fine circuit feed, i.e., nominally -16 mesh, collected from Kerr McGee's Galatia preparation plant.

DISCLAIMER STATEMENTS

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PROJECT MANAGEMENT REPORT
March 1 through May 31, 1995

Project Title: **A FINE COAL CIRCUITRY STUDY USING COLUMN FLOTATION
AND GRAVITY SEPARATION**

DOE Cooperative Agreement Number: DE-FC22-92PC92521 (Year 3)
ICCI Project Number: 94-1/1.1A-1P
Principal Investigator: Ricky Q. Honaker, Department of Mining
Engineering, Southern Illinois University at
Carbondale
Other Investigators: Stephen Reed, Kerr-McGee Coal Corporation
Project Manager: Ken Ho, Illinois Clean Coal Institute

COMMENTS

None.

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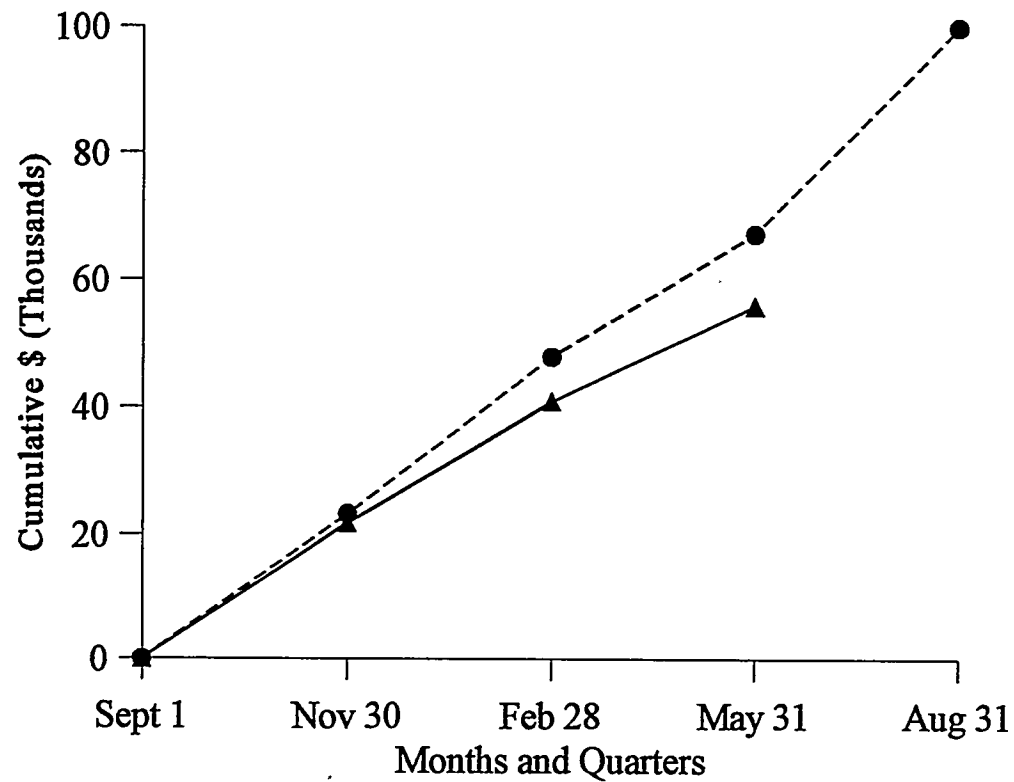
PROJECTED AND ESTIMATED EXPENDITURES BY QUARTER

Quarter*	Types of Cost	Direct Labor	Fringe Benefits	Materials and Supplies	Travel	Major Equipment	Other Direct Costs	Indirect Cost	Total
Sept. 1, 1994 to Nov. 30, 1994	Projected	10,876	1,440	1,650	0	3,600	3,578	2,114	23,258
	Estimated	10,145	1,813	603	499	4,923	2,242	1,530	21,755
Sept. 1, 1994 to Feb. 28, 1995	Projected	21,753	2,881	3,300	1,200	7,200	7,075	4,341	47,750
	Estimated	21,541	3,013	2,547	450	5,084	4,938	3,369	40,942
Sept. 1, 1994 to May 31, 1995	Projected	32,629	4,321	4,950	1,200	7,200	10,653	6,065	67,018
	Estimated	27,386	3,746	2,983	990	5,084	10,533	5,072	55,794
Sept. 1, 1994 to Aug. 31, 1995	Projected	53,335	7,726	6,600	1,700	7,200	14,150	9,071	99,782
	Estimated								

*Cumulative by Quarter

CUMULATIVE COSTS BY QUARTER

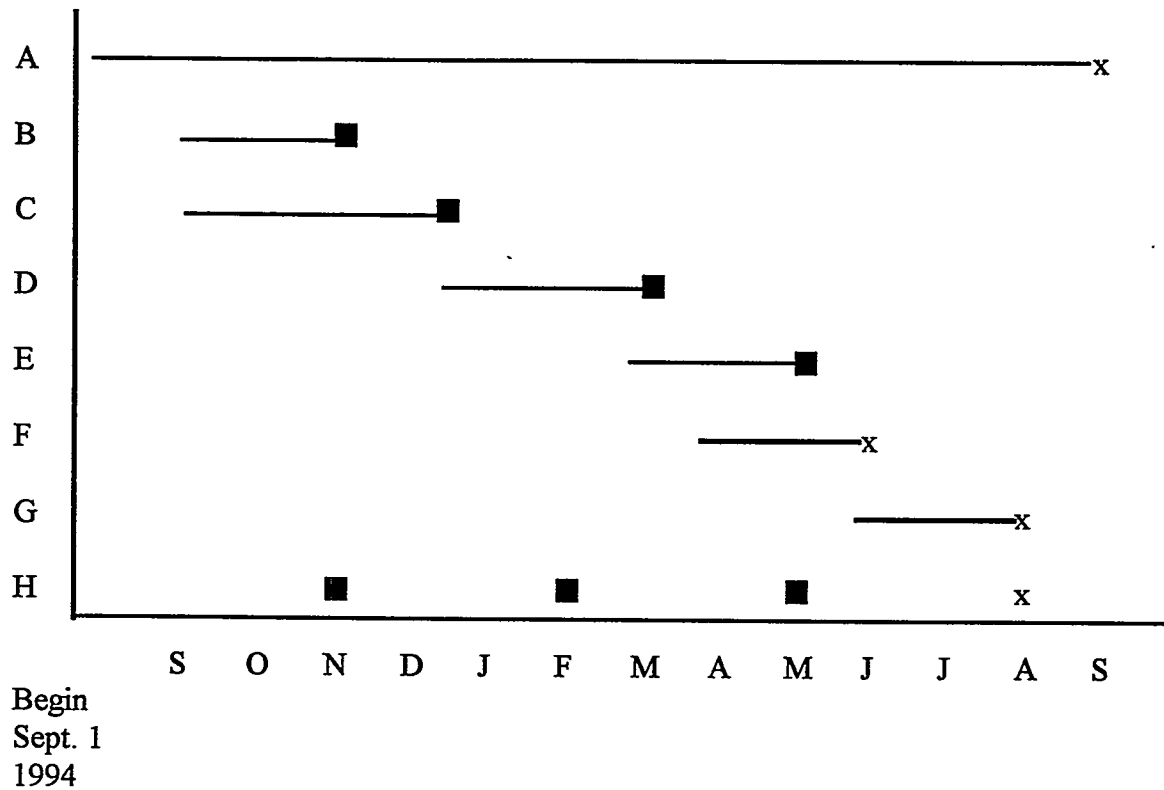
A Fine Coal Circuitry Study Using Column Flotation and Gravity Separation



● = Projected Expenditures -----
▲ = Actual Expenditures _____

Total Illinois Clean Coal Institute Award \$99,782

SCHEDULE OF PROJECT MILESTONES



Hypothetical Milestones:

- A: Research assistants employed
- B: Equipment ordered and received
- C: Column flotation/Enhanced gravity separation (Task 1)
- D: Floatex testing (Task 2)
- E: Floatex/Enhanced gravity separation (Task 3)
- F: Floatex/Column flotation (Task 4)
- G: Floatex/Column flotation/Gravity separation (Task 5)
- H: Reporting (Task 6)