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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. The gravity/flotation circuits will be compared based on their optimum separation performance which will consider ash and total sulfur rejection and energy recovery as well as the probable error (E_p) value obtained from washability analyses.

During this reporting period, multi-stage treatment using the Falcon concentrator was conducted on a refuse pond (-100 mesh) coal sample and a -28 mesh run-of-mine coal sample. The results suggest that the Falcon concentrator can make an ideal separation for either sample in a single process. Recleaning was found to improve product grade, however, recovery was reduced sharply. In addition, the groups involved with the in-plant testing of the Floatex Hydrosizer met and organized the test plan which will be conducted at Kerr-McGee's Galatia preparation plant during the next reporting period. Coal samples for the circuitry tests will be collected during this time period.

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

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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, Carpco) 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.

The most efficient circuit arrangement for treating the 100 mesh x 0 and 28 mesh x 0 size fractions will be identified by comparing the separation performances achieved by each circuit on the basis of ash rejection, total sulfur and pyritic sulfur rejection, and energy recovery. In addition, the probable error (E_p) value, which is a commonly used measurement of solid-solid separation efficiency, will be obtained for each circuit from washability analyses. In addition, separation efficiency data from the current operation at Kerr-McGee's Galatia preparation plant, which utilizes spiral concentrators and conventional flotation to treat the 28 mesh x 0 fraction, will be obtained to compare with the results in this investigation.

During this reporting period, the desliming and recleaning potentials of Falcon concentrator have been investigated for a refuse pond coal slurry and -28 mesh run-of-mine coal sample. The results obtained suggest that the Falcon concentrator indeed has a size limitation below which the particles can no longer be separated despite the large centrifugal field. For most of ultrafine particles, the separator behaves like a splitter resulting in virtually no separation. When used as a recleaner for its own concentrates, the Falcon concentrator increased the ash rejection while sacrificing a loss in recovery. However, superclean coal products having an ash content below 3% were produced from a feed coal containing 8.25% ash using a rougher-cleaner Falcon concentrator arrangement.

A meeting between individuals from Kerr-McGee Coal Corporation, Carpco Inc., and Southern Illnois University was held during this reporting period. The plans for installing the Floatex Hydrosizer and the experimental test program to be conducted at the Galatia Preparation Plant was developed. Testing is scheduled to begin in January 1995 at which time the samples for the remaining test work will be collected.

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.

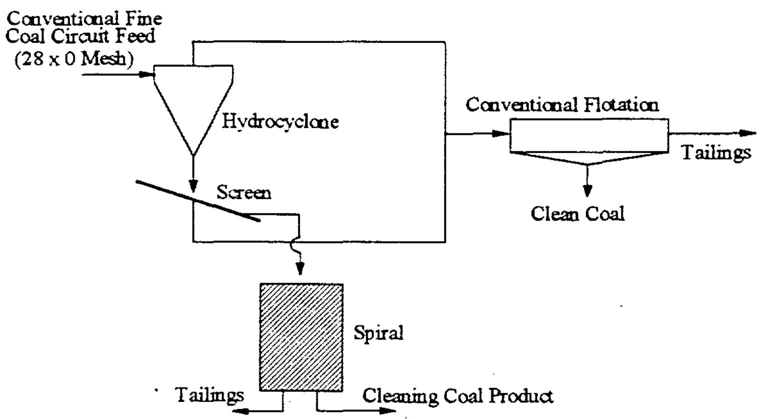

Figure 1. The conventional fine coal processing circuit.

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 silicious 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

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

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, both the coal sample (-200 mesh) collected from TVA Power Plant refuse pond and the run-of-mine Pittsburgh No. 8 coal sample (-16 mesh) were treated by Falcon C10 concentrator. Totally three 55-gallon barrels TVA sample were collected. The original solids percent for TVA sample was about 90% and was diluted and completely mixed to 16% in a pump-sump circuit. This solids percent value was chosen based on the optimum feed solids percent for Falcon concentrator obtained from previous study in Southern Illinois University. The Pittsburgh No. 8 coal sample was obtained from a hydrocyclone feed in a coal preparation plant. The solids percent was about 7% and was adjusted to about 16% similarly.

Both samples were treated first based on the experience acquired from previous studies. For TVA sample, six samples were collected by varying the feed volumetric flow rate and pinch valve opening time. The centrifugal force was set as 127 g and the pinch valve closing time 4 seconds. Because this sample was very fine, relatively low feed volumetric flow rate was used (15 and 20 gallon/min). The pinch valve opening time was decided by the visual observation of the overflow and the underflow. For Pittsburgh No. 8 coal sample, eight samples were collected based on the same consideration. For this sample, the feed volumetric flow rate was changed from 20 to 40 gallon/min due to its coarser particle size. After collecting samples, the both coal products (overflow) at the best operation condition (visually determined) were collected and saved for the following treatments, respectively.

Next, two separation processes were conducted for both coal products collected before. In the first process, a certain amount of very fine particles was rejected from the Falcon overflow and the underflow was collected as clean coal product by increasing the pinch valve opening time and/or decreasing its closing time. The purpose of this process is to test the feasibility of Falcon concentrator as a de-sliming device. In the second process, the collected coal products were recleaned by reducing the pinch valve opening time in order to further increase the total ash and sulfur rejection.

The samples Collected were screened into +400 and -400 mesh size fractions for TVA samples while +65, 65x400 mesh and -400 mesh for Pittsburgh No. 8 samples. Then all the screened samples were filtered, dried, and weighed, and analyzed for their ash, and total sulfur content (the total sulfur data are not available during this reporting period).

RESULTS AND DISCUSSION

TVA Sample: The rougher cleaning operation conditions and the mass flowrates for both concentrate (overflow) and tailings (underflow) for TVA sample are shown in Table 1. From Table 1, it appears that the total feed mass flow was almost evenly distributed in concentrate and tailings. This is due to the fact the feed material contains a significant amount of heavy particles.

Table 1. The rougher cleaning operation conditions and the mass flowrates for TVA sample.

Test #	Feed FR (gallon/min)	Bowl Speed (Hz)	Open Time (sec)	Mass flow Conc.(g/s)	Mass flow Tail (g/s)
1	20	40	0.5	47.6	64.9
2	20	40	0.3	54.2	48.3
3	20	40	0.7	52.9	46.0
4	15	40	0.5	42.9	56.6
5	15	40	0.3	48.1	42.2

The size by size ash analysis results are given in Table 2. For +400 mesh size fraction, it can be seen that the Falcon concentrator can reduce the ash content from about 8.3% to 3.1%. About 59% ash rejection and 68% combustible recovery were obtained in this size fraction when total feed volumetric flow rate was set as 20 gallon/min. From

Table 2, the mass flowrates for concentrate can be found extremely low (from 0.7 to 2 gram/sec) compared with tailings mass flowrates. While for -400 mesh size fraction, the concentrate mass flowrates for all the tests were larger than those of the tailings. This finding suggests that the original feed material contains a significant amount of extremely fine particles and almost all +400 mesh particles are pure gangue and/or mixed-phase particles. In this size fraction, it can also be seen that the ash contents in concentrate and tailings are virtually same, which demonstrates again that the Enhanced gravity-based separation is not efficient to process ultrafine particles even for the particles with a larger density difference.

Table 2. The size by size ash analysis results for the rougher cleaning for TVA sample.

Test #	Mass Flowrate (g/s)		Ash %		Ash Rej.	Comb.Rec.	S.E.
	Conc.	Tail	Conc.	Tail	%	%	%
+400 Mesh Samples							
1	2.00	23.46	5.09	14.38	59.23	68.29	27.52
2	1.79	18.49	3.10	9.99	90.52	26.67	17.19
3	1.16	16.69	3.15	10.09	89.86	28.00	17.86
4	1.39	17.62	5.24	9.25	84.15	25.79	9.94
5	1.12	11.24	4.84	9.66	82.84	30.37	13.21
Feed			8.25				
-400 Mesh Samples							
1	45.56	41.47	56.47	55.56	47.25	51.83	-0.92
2	52.38	29.77	56.89	54.74	35.35	62.63	-2.02
3	51.69	29.34	57.04	55.47	35.56	62.96	-1.47
4	41.50	39.00	56.82	56.77	48.43	51.53	-0.05
5	47.02	30.98	56.13	49.21	36.62	56.73	-6.65
Feed			56.57				

Table 3 shows the deashing results for +400 mesh and -400 mesh size fractions. For +400 mesh size fraction, due to the extremely low mass flow for the overflow, the ash rejection for this single process is negligible. Based on the result of test 1 in rougher cleaning process (Table 2), total circuit (rougher-deashing) ash rejection and combustible recovery were calculated. It can be seen that with about 59.5% ash rejection and 67.5% combustible recovery, the separation efficiency can reach 27% when using Falcon concentrator only to precleaning and deashing ultrafine and very poor grade coal slurry such as TVA tailings material. However, for -400 mesh size fraction, as shown in Table 3, the ash rejection for the total circuit varied from 56% to 73% and the combustible recovery from 44% to 28%, which resulted in virtually no separation.

Table 3. The size by size deashing results for TVA sample.

Test #	Mass Flowrate (g/s)		Ash %		Ash Rej.	Comb.Rec.	S.E.	Cir.Total	Cir.Total	Cir.Total
	Conc.	Tail	Conc.	Tail	%	%	%	Ash Rej.	Com. Rec.	S.E.
+400 Mesh Samples										
6	0.02	2.56	4.35	6.38	0.40	99.40	-0.20	59.39	67.88	27.27
7	0.03	2.34	3.44	9.21	0.43	98.79	-0.78	59.40	67.46	26.87
8	0.03	2.51	2.11	7.88	0.32	98.72	-0.95	59.36	67.42	26.78
9	0.05	3.01	3.10	8.58	0.55	98.39	-1.05	59.46	67.19	26.65
-400 Mesh Samples										
6	7.80	40.16	59.12	56.32	16.94	84.61	1.56	56.19	43.86	0.05
7	10.03	38.16	58.58	56.08	21.54	80.14	1.68	58.61	41.54	0.15
8	11.71	36.23	58.68	56.16	25.25	76.64	1.90	60.57	39.73	0.30
9	16.23	30.09	58.42	55.52	36.20	66.48	2.68	66.34	34.46	0.80

The recleaning results for +400 mesh and -400 mesh size fractions are given in Table 4. For +400 mesh size fraction, the ash content in final product was reduced to about 2.3% and the ash rejection for the total circuit (rougher-recleaning) was as high as 93% with a 33% combustible recovery. The separation efficiency for this circuit was calculated to be 26%. Again for -400 mesh size fraction, the separation was so poor that the circuit discharged too much combustible into the tailings, which resulted in negative separation efficiencies.

Table 4. The size by size recleaning results for TVA sample.

Test #	Mass Flowrate (g/s)		Ash %		Ash Rej.	Comb.Rec.	S.E.	Cir. Total	Cir. Total	Cir. Total
	Conc.	Tail	Conc.	Tail	%	%	%	Ash Rej.	Com. Rec.	S.E.
+400 Mesh samples										
10	0.10	3.14	2.28	9.59	82.96	48.27	31.24	93.05	32.96	26.02
11	0.15	3.77	2.89	8.65	80.21	44.00	24.21	91.93	30.05	21.98
-400 Mesh Samples										
10	29.59	24.31	58.53	55.34	43.72	53.05	-3.22	70.31	27.50	-2.19
11	35.41	24.38	58.80	54.36	38.89	56.73	-4.38	67.76	29.40	-2.83

Pittsburgh No.8 Sample: The Operation conditions for the rougher cleaning of the Pittsburgh No.8 coal sample and mass flowrates for concentrate and tailings are shown in Table 5. From Table 5, it can be find that the mass flowrates for concentrate are much larger than those of tailings because the feed material is the run-of-mine coal sample. In contrast to the TVA sample processing, longer pinch valve opening times were used for separating Pittsburgh No. 8 coal because of larger feed volumetric flowrates.

Table 5. The rougher cleaning operation conditions and the mass flowrates for Pittsburgh No.8 coal sample.

Test #	Feed FR (gallon/min)	Bowl Speed (Hz)	Open Time (sec)	Mass Flowrate (g/s)	
				Conc.	Tail
1	20	40	0.7	222.3	23.6
2	20	40	1.5	199.6	34.6
3	30	40	1.0	259.9	29.1
4	30	40	0.7	273.6	22.2
5	40	40	1.0	293.2	28.2
6	40	40	1.5	292.3	38.0
7	40	40	2.0	277.4	44.4

The rougher cleaning results for +65 mesh, 65x400 mesh and -400 mesh size fractions are provided in Table 6. For +65 mesh size fraction, the ash content was reduced from 14% to about 4.1. It also can be seen that the ash rejection as high as 92% was obtained with 71% combustible recovery,

which resulted in high separation efficiency of 63.4%. The similar good separation performance can also be seen for 65x400 mesh size fraction, in which the ash content was reduced from 15.5% to about 5%. The separation efficiency was about 63%. As explained above, relatively low separation efficiencies are observed in the -400 mesh size fraction.

Due to longer pinch valve opening time and shorter closing time used in deashing process, the overflow contained no +65 mesh particles. The deashing results for 65 x 400 mesh and -400 mesh size fractions are shown in Table 7. It appears that the deashing performance for the total feed material was carried out very successfully because of rather small amount of 65 x 400 mesh particles in the overflow. The ash rejection, combustible recovery for the total circuit were calculated about 74% and 56%, respectively. The separation efficiency obtained is about 56%. When checking the -400 mesh size fraction, it appears that while the ash rejection in rougher cleaning process is 18% (test 3 in Table 6), the total ash rejection for this size fraction in the rougher-deashing circuit increases to about 53% with a 50.3% combustible recovery. The total circuit separation efficiency is about same compared with that of rougher only process (Table 6). This may suggests that the Falcon concentrator is indeed a poor deashing equipment due to very small inertia of ultrafine particles.

Table 6. The size by size ash analysis results for the rougher cleaning for Pittsburgh No.8 coal sample.

Test #	Mass Flowrate (g/s)		Ash %		Ash Rej.	Comb.Rec.	S.E.
	Conc.	Tail	Conc.	Tail	%	%	%
+65 Mesh Samples							
1	63.69	13.16	7.46	43.66	54.68	88.85	43.53
2	52.63	20.90	6.26	32.58	66.99	78.09	45.08
3	64.98	16.52	6.60	45.21	60.50	88.41	48.91
4	68.56	15.39	7.96	40.58	51.84	88.00	39.84
5	68.31	19.48	7.13	42.40	57.40	87.67	45.07
6	52.97	25.77	4.11	23.22	84.90	55.62	40.53
7	44.73	27.26	5.08	21.13	82.67	51.21	33.89
Feed			13.65				
65 x 400 Mesh Samples							
1	49.68	7.55	4.94	52.76	75.23	87.63	62.86
2	46.82	9.76	5.43	39.17	75.46	78.47	53.93
3	61.25	9.00	5.06	42.86	76.43	81.28	57.71
4	66.11	3.84	5.17	46.03	75.11	83.82	58.94
5	72.86	5.10	4.87	36.42	79.23	74.59	53.82
6	71.87	7.66	4.48	34.29	81.84	71.18	53.03
7	66.31	12.19	4.09	24.29	88.56	49.28	37.84
Feed			15.52				
-400 Mesh Samples							
1	108.91	2.87	49.37	61.06	16.89	88.78	5.67
2	100.16	3.97	49.71	58.01	17.95	86.47	4.41
3	133.69	3.61	49.53	59.19	17.89	87.15	5.04
4	138.95	2.92	50.72	60.50	3.64	97.53	1.16
5	152.05	3.61	49.22	58.20	22.87	82.89	5.76
6	167.45	4.57	49.06	55.50	33.11	72.35	5.46
7	166.38	4.93	48.93	53.20	51.04	53.23	4.27
Feed			51.02				

Table 7. The size by size deashing results for Pittsburgh No. 8 coal sample.

Test #	Mass Flowrate (g/s)		Ash %		Ash Rej.	Comb.Rec	S.E.	Cir. Total	Cir. Total	Cir. Total
	Conc.	Tail	Conc.	Tail	%	%	%	Ash Rej.	Com. Rec.	S.E.
65 x 400 Mesh										
8	0.46	29.55	4.05	7.35	0.85	98.41	-0.74	76.64	79.98	56.62
9	0.34	33.36	3.87	6.50	0.60	98.97	-0.43	76.57	80.44	57.02
10	0.22	31.88	6.59	6.76	0.68	99.30	-0.02	76.60	80.71	57.30
11	0.10	29.60	3.63	6.72	0.17	99.67	-0.16	76.48	81.01	57.48
-400 Mesh										
8	13.66	72.87	49.69	49.36	42.59	57.74	0.32	52.86	50.32	3.18
9	10.37	76.55	50.56	48.89	37.31	64.24	1.55	48.53	55.98	4.51
10	8.06	75.53	49.87	49.30	35.35	65.17	0.52	46.92	56.79	3.71
11	4.57	73.15	50.02	49.26	31.91	68.75	0.66	44.09	59.91	4.01

The recleaning results for these three size fractions are given in Table 8. In +65 mesh size fraction, the increase of the ash rejection from 60.5% (test 3 in Table 6) to 87% due to the further cleaning was at the cost of the decrease in combustible recovery (from 88% to 40%). On the other hand, the ash content was reduced only about 1.8%. The same thing is true for 65x400 mesh and -400 mesh size fractions. This fact may suggest that due to the high centrifugal force used in enhanced gravity separation, the +400 mesh particles can be efficiently separated in rougher only process by choosing appropriate operating parameter values.

Table 8. The size by size recleaning results for Pittsburgh No. 8 coal sample.

Test #	Mass Flowrate (g/s)		Ash %		Ash Rej.	Comb.Rec	S.E.	Cir. Total	Cir. Total	Cir. Total
	Conc.	Tail	Conc.	Tail	%	%	%	Ash Rej.	Com. Rec.	S.E.
+65 Mesh										
12	6.21	13.42	4.41	8.27	80.19	32.54	12.73	92.17	28.77	20.94
13	6.80	8.38	4.85	7.86	66.63	45.59	12.22	86.82	40.31	27.13
65 x 400 Mesh										
12	15.19	6.85	3.18	7.40	51.21	69.86	21.07	88.50	56.78	45.28
13	16.03	8.02	3.26	8.54	56.69	67.90	24.59	89.79	55.18	44.98
-400 Mesh										
12	81.67	2.84	48.80	49.34	3.39	96.68	0.07	20.68	84.25	4.93
13	78.63	2.14	47.87	51.44	47.45	56.10	3.54	56.85	48.89	5.74

CONCLUSIONS AND RECOMMENDATIONS

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

1. When using as a rougher-cleaner, Falcon concentrator can reduce the ash content from 8.3% to 3.1% for +400 mesh TVA sample, with a 59% ash rejection and 68% combustible recovery. However, if used as a desliming equipment, the performance was so poor for -400 mesh size fraction that virtually no separation behavior can be identified. The recleaning for the same sample resulted in a dramatic ash rejection increase at the cost of the decrease of combustible recovery for the +400 mesh size fraction. For -400 mesh size fraction, the recleaning made the separation performance worse.

2. For Pittsburgh No. run-of-mine coal, Falcon concentrator reduced the ash content in +65 mesh and 65 x 400 mesh size fractions from 14% to 4% and from 15.5% to 5%, respectively. The separation efficiencies were obtained to be about 45% and 60%. The desliming resulted in a little bit decrease in separation efficiency for 65 x

400 mesh size fraction and no apparent change for -400 mesh. The recleaning resulted in about 20% separation efficiency decrease in both +65 mesh and 65 x 400 mesh size fractions. Again the -400 mesh size fraction was not affected.

3. Based on these findings, it seems that a ideal separation can be made in a single gravity separation process by operating Falcon concentrator at its optimum parameter values.

During the next reporting period, the column flotation and enhanced gravity separation tests will be conducted separately or in different combination for an Illinois No. 5 flotation feed coal sample. Also, the Floatex tests with the fine coal circuit feed (16 x 0 mesh) will be conducted at Kerr-McGee's Galatia preparation plant.

DISCLAIMER STATEMENTS

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