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TECHNICAL REPORT
March 1, 1994 through May 31, 1994

Project Title: **PRODUCTION OF ILLINOIS BASE COMPLIANCE COAL
USING ENHANCED GRAVITY SEPARATION**

DOE Grant Number: DE-FC22-92PC92521 (Year 2)
ICCI Project Number: 93-1/5.1B-1P
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Southern Illinois University
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ABSTRACT

It is well known that froth flotation is inefficient for treating fine coal fractions containing a significant portion of middling particles. On the other hand, gravity-based processes can effectively remove middling particles containing only a small amount of coal. Falcon Concentrators Inc. and Knelson Gold Concentrators Inc. have developed full-scale, enhanced gravity separators for the treatment of heavy minerals. This project is evaluating the potential of using these concentrators to treat Illinois Basin coal fines.

During this reporting period, -28 mesh run-of-mine Illinois No. 5 and No. 6 coal samples were processed using a continuous Falcon concentrator having a 10-inch bowl diameter. For the Illinois No. 5 coal sample, the ash content was reduced in the 100 x 325 mesh size fraction from about 18% to 8% while achieving a high combustible recovery value of nearly 97%. In addition, the total sulfur content was substantially decreased from 2.6% to 1.7%. Similar results were obtained from the treatment of the Illinois No. 6 coal sample where ash rejections ranged from 40% - 70% for a 28 x 325 mesh feed having 7% ash. Combustible recovery values from these tests were greater than 87% while treating mass feed rates between 1 to 2 tons/hour. A parametric study found that lower feed solids contents provided marginally lower product ash and total sulfur contents while feed rate and bowl speed appeared to have no significant effect over the range of values tested.

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EXECUTIVE SUMMARY

Illinois Basin coals usually contain a significant portion finely dispersed pyrite. With Phase I of the Clean Air Act becoming effective in 1995, Illinois coal producers will need to produce a lower sulfur product to avoid loss of market. Physical coal cleaning can, in theory, remove pyritic sulfur from Illinois coals. In some cases, this will be sufficient in producing a marketable coal that meets the maximum Clean Air Act sulfur dioxide emission limits.

At coarse coal particle sizes (+28 mesh), most of the pyrite is not sufficiently liberated from the coal matrix. Thus, physical cleaning in many current preparation plants cannot remove enough pyrite to ensure compliance. Therefore, to achieve effective pyrite rejection, the coal particle size must be reduced to a very fine size, typically less than 28 mesh. Froth flotation is the process most commonly used to treat this fine fraction. The process, however, has poor selectivity with respect to middling particles. For example, a particle covered by 90% pyrite and 10% coal may have enough coal surface area for bubble attachment and flotation. On the other hand, the same particle would be rejected easily by a gravity-based process due to the large density differences between coal and pyrite. Unfortunately, in the past, gravity-based separators have been ineffective at treating fine particles due to the low particle inertia.

One way of achieving a gravity-based separation on fine particles is to exert an enhanced gravity force on these particles using a centrifugal action. Both the Falcon Concentrators Incorporated and Knelson Gold Concentrators Incorporated have developed large commercial gravity separators for the gold and metal mining industries based on this principal. These units are capable of operating continuously with throughputs of up to 200 tph. Because manufactures already have units sufficiently large for the fine circuits at most Illinois preparation plants, there would be no delay in creating large commercial units from small laboratory proto-types.

The problem with applying these enhanced gravity separators to Illinois coal fines is that there is almost no test data for these units operating on coal. Falcon Concentrators Incorporated has run a few tests on Canadian coals, and the investigators at SIUC have run numerous batch tests on Illinois coal using laboratory batch concentrators. The SIUC results which led to this project were very promising. A sample of high sulfur waste fines discarded by one local preparation plant was cleaned to less than 2.5 lbs SO₂ per million BTU and would thus be classified as a compliance fuel.

The Falcon concentrator was originally designed to collect a few percent of the heaviest material from a feed stream. The

capacity is almost ideal for the removal of the pyrite fraction from Illinois coal. However, in addition, tests with the batch unit also indicate that high ash rejection can be achieved. Still other batch tests indicate that by changing only the percentage solids in the feed, the unit can be made to remove (deslime) fine clay particles. The reason most often given for not cleaning fine coal is that dewatering is too difficult or costly. Because clay particles are one of the main causes of dewatering difficulties, the enhanced gravity concentrators show promise both in producing a compliance coal product and decreasing the dewatering difficulties associated with fine coal.

A second reason sometimes given for not cleaning fine coal is the high cost of grinding. The mining and standard crushing processes already used on coal produce fine coal particles. As the Illinois coal industry moves from surface mines to underground high production longwall faces, the percentage of the coal product reporting to the fines circuit will probably increase to more than 10%. Discarding a few percent of the finest coal was considered acceptable to the industry in the past. The larger volumes of fines reporting to Illinois preparation plants in the future and the fact that the fine coal is the most readily cleanable fraction will make fine coal cleaning a more attractive alternative.

The current project will test the Falcon and Knelson continuous commercial units for their ability to remove pyritic sulfur from fine coal streams. The units will also be tested for their ability to de-ash fine coal. The specific objectives of the project are (1) to demonstrate the use of enhanced gravity concentrators for the efficient and economical treatment of fine coal, (2) to identify and optimize the critical operating parameters of the Falcon and Knelson centrifugal units, (3) to evaluate and compare the throughput capacity and scale-up factors of both units and (4) to determine the effect of the applied centrifugal field on the gravity cut point and process efficiencies.

To achieve the project objectives, the operating parameter values for the Falcon and Knelson concentrators will be tested over a large range of values to determine their effects on process performance and to establish their respective limiting values. The response variables to be evaluated will include total and pyritic sulfur rejection, ash rejection, BTU recovery, and separation efficiency. These tests will involve the treatment of a -28 mesh coal sample and a flotation concentrate from an Illinois Basin coal preparation plant.

The optimization of the operating variables will involve conducting an experimental program whose data will be used to develop empirical expressions describing the response variables as a function of the operating parameter values. The experimental program will be performed according to a Box-

Behnken test design. The range of values for the operating parameters will be based on the findings of the exploratory experiments.

After completion of the experimental program, a commercial statistical analysis program known as DESIGN-EXPERT will be used to analyze the test data collected for each bowl length and to produce the empirical expressions. Using these expressions, the operating parameter values will be optimized based on the desired values of the response variables using an off-line optimization technique, such as the Simplex and Hooke-Jeeves methods. Once the optimum parameter values have been determined, additional experiments will be conducted to verify the calculated optimum conditions.

Using the optimum operating parameter values corresponding to the maximum separation efficiency, tests will be performed over a range of feed rates to obtain the best possible recovery-grade curve achievable by the Falcon concentrator. These results will be compared to those obtained by release and washability analyses to determine the improvement in process performance over that achieved by flotation. A series of tests will also be conducted using different rotational speeds. A washability analyses of the samples collected from these tests will be conducted and partition curves constructed to determine the effect of the applied centrifugal field on the gravity cut point and process efficiencies. These test samples will also be analyzed for trace elements to determine the effectiveness of the centrifugal units for trace element reduction. These experiments will be conducted on both the Falcon and Knelson concentrators so that a comparison can be made to determine the most feasible unit for a given application.

During this reporting period, tests were conducted using the continuous Falcon concentrator for the treatment of -28 mesh run-of-mine Illinois No. 5 and No. 6 coal samples. For both coal samples, the Falcon concentrator was found to be effective for treating coal size fractions between 28 and 325 mesh, although the submicron material is thought to be the only fraction not greatly affected by gravity separation based previous research. The best results were obtained from the treatment of the 100 x 325 mesh size fraction from the Illinois No. 5 coal sample. At a mass feed rate of 1 ton/hour, the ash content was reduced from approximately 18% to 8% while achieving very high combustible recovery values, i.e., greater than 95%. This provided an ash rejection of nearly 60% and a separation efficiency of 55%. It is believed that increasing the underflow rate will further enhance the separation performance. For the 28 x 100 mesh size fraction, the ash content was also reduced from 10% to 8% with recovery values greater than 96%.

The Falcon Concentrator demonstrated the ability to reduce the

ash content of low-ash fine coal. For the Illinois No. 6 coal, the ash content in the 100 x 325 mesh size fraction was typically reduced from 9.8% to 5.0% while the ash content in the 28 x 100 mesh fraction was decreased from 6% to 4%. The total sulfur content was also reduced on the average from 1.4% to 1.1%. Combustible recovery values for these two size fractions were generally greater than 90%. Feed rates for these tests varied between 0.8 and 1.6 tons/hr.

Mass feed rates were varied between 20 and 30 gallons/min while also changing the feed solids content from 25% to 40% by weight. An increase in solids content over the aforementioned range increased the product ash content from approximately 3.8% to 4.4% for the 28 x 325 mesh size fraction in the Illinois No. 6 coal. Combustible recovery was found to remain relatively unchanged at about 91%. The increase in feed rate from 20 to 30 gallons/min had very little effect on separation performance.

Tests conducted over a range of bowl speeds from 710 rpm to 1183 rpm indicate that bowl speed has little affect on separation performance. Thus, for industrial applications, lower speeds are preferred due to improved maintenance, availability and economics. Lower bowl speeds will be tested during the upcoming reporting period.

During the next reporting period, a parametric study using a Box-Behnken statistical test design will be conducted to evaluate the critical operating parameters. Empirical expressions will be developed describing the response variables as a function of the operating parameter values. Using these empirical relationships, separation performance for the Falcon Concentrator will be optimized for the treatment of both -28 mesh and -100 mesh run-of-mine Illinois No. 5 coal samples. Tests using the Knelson Concentrator will also be initiated.

DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

OBJECTIVES

The overall goal of this project is to provide the Illinois Basin coal industry with a means of reducing sulfur in the washed coal products they produce, in time to assist them with the phase I requirements of the Clean Air Act. To accomplish this goal the project is investigating enhanced gravity concentrators that have already been developed to the size required for preparation plant use (up to 200 tph), and that already have know capital, and operating costs, and whose space requirements are compatible with installation into existing preparation facilities. These enhanced gravity concentrators by Falcon Concentrators Incorporated and Knelson Concentrators Incorporated have not been tested and proven for coal. To demonstrate the application of these concentrators for the treatment of Illinois Basin coal fines, the project objectives are:

1. To demonstrate that continuous commercial size enhanced gravity concentrators can remove enough pyrite from Illinois coal fines to approach or exceed the Clean Air Act requirements of 2.5 lbs SO₂ per million BTU;
2. To determine the amount of ash rejection that can be achieved by enhanced gravity washing of Illinois coal fines;
3. To demonstrate the ability of commercial size enhanced gravity concentrators to deslime clay particles away from fine coal and thus reduce any dewatering problems;
4. To establish the operating parameter values for commercial size enhanced gravity concentrators used to clean coal. This will allow operators to use approximately correct initial settings when units are installed in the preparation plants, and to know which parameters to adjust to fine tune the unit to their needs.
5. To develop scale-up relations between laboratory batch tests and continuous full scale plant performance such as those now available for many column flotation systems.

These objectives are to be achieved through the following tasks:

Task 1: Acquire large samples of fines from the operating circuits at actual preparation plants.

- Task 2:** Characterize representative samples taken from the slurry for parameters such as percent solids, particle size distribution, proximate analysis, total and pyritic sulfur content, and BTU.
- Task 3:** Preliminary screening of operating conditions will be done to determine such things as effect of feed rate, time to steady state operation, and impact of feed recirculation. Information gained from the preliminary screening will be used to select the operating parameter settings for later parametric study.
- Task 4:** A Box-Behnken design parametric study will be conducted of unit operating conditions on response variables such as ash rejection, sulfur rejection, and separation efficiency.
- Task 5:** An empirical model will be developed based on the results of the parametric study. The model will be analyzed by techniques such as the Simplex or the Hook-Jeeves method to determine the optimum settings for each response variable. Physical tests will then be conducted to ensure that an actual optimum was achieved.
- Task 6:** Quarterly and Final Reports will be prepared.

INTRODUCTION AND BACKGROUND

Illinois Basin coals usually contain finely dispersed, sulfur bearing pyrite. With phase I of the Clean Air Act becoming effective in 1995, Illinois coal producers will need to produce a lower sulfur product to avoid loss of market. Physical coal cleaning can, in theory, remove pyritic sulfur from Illinois coals, in some cases bringing the resulting product into compliance with Clean Air Act sulfur dioxide emission limits.

At coarse coal sizes (+28 mesh), much of the fine pyrite remains attached to coal particles (is not liberated) and the physical cleaning in many current preparation plants cannot remove enough pyrite to ensure compliance. Fine coal (-28 mesh fraction) has much more of the pyrite physically liberated and distinct from the coal. Froth flotation is the process most commonly used on this fine fraction. Bubbles attach to the water repellent (hydrophobic) coal surfaces causing the particle so attached to float. The process, however, has poor selectivity with respect to middlings particles. A particle made of 90% pyrite and 10% coal would still have enough coal surface area for bubble attachment and flotation. A gravity-based process would easily recognize such a

particle as far too heavy to contain much coal and could reject the particle. Unfortunately, at fine sizes the coal particles have a large surface area relative to their mass. Surface forces exert a large amount of drag resistance to prevent the separation of heavy and light particles. With the normal acceleration of gravity, the differences in pull between the heavy and light particles are too small to separate the particles against the large surface based drag forces.

One way of using a gravity based separation at fine particle size is to create a strong artificial gravity by such methods as rapidly spinning a separation bowl. Both Falcon and Knelson have developed large commercial gravity separators for the gold and metal mining industries based on this principal. These units are capable of continuous operation and can handle throughputs of up to 200 tons per hour per unit. The units require no more headroom than a typical jig and occupy only around 100 square feet of floor space. The cost for a large unit is around \$200,000. Integration of such units into existing preparation plant designs is easily within the technical and economic reach of Illinois basin coal producers. Because manufacturers already have units as large as would be needed for fines circuits at most Illinois preparation plants, there would be no delay in creating large commercial units from small laboratory proto-types.

The problem with applying these enhanced gravity separators to Illinois coal fines is that there is almost no test data for these units operating on coal. Falcon has run a few tests on Canadian coals, and the investigators at SIUC have run numerous batch tests on Illinois coal using laboratory batch concentrators. The SIUC results that led to this project showed very promising results. A sample of high sulfur waste fines discarded by one local preparation plant was cleaned to less than 2.5 lbs SO₂ per million BTU and would thus be a compliance fuel.

The Falcon concentrator was originally designed to collect a few percent of the heaviest material from a feed stream. The capacity is almost ideal for removal of the pyrite fraction from Illinois coal, but tests with the batch unit also indicate that high ash rejection can be achieved. Still other batch tests indicate that by changing only the percentage solids in the feed, the unit can be made to remove (deslime) fine clay particles. The Falcon and Knelson concentrators may thus be able to produce both a compliance coal product and one that can be easily dewatered.

The current project will test continuous commercial units by Falcon and Knelson for their ability to remove pyritic sulfur from fine coal streams. The units will also be tested for their ability to de-ash coal fines.

EXPERIMENTAL PROCEDURE

In this project, the Falcon and Knelson concentrators are being tested for their ability to reject pyritic sulfur and mineral matter from Illinois coal fines. With Phase I SO₂ limits set to take effect in 1995, only technology that is already of commercial scale can be used to aid coal producers in meeting the immediate requirements of the act. The Falcon and Knelson concentrators were selected for testing because they are the only enhanced gravity units available in sizes needed by the coal industry. (The MGS and Kelsey Jig by CarpcO can clean coal but at best handle only 5 to 10 tons per hour).

In this work, the critical process parameters for a Falcon C10 and similarly sized Knelson concentrator are being identified and optimized in terms of maximum separation efficiency, sulfur and ash rejection, and BTU recovery. Trace element analyses will be conducted on selected samples to determine the feasibility of the units to reduce toxic element contents in the clean coal product. Maximum throughput rates will be evaluated and scale-up calculations conducted.

Since the C10 unit has the ability to process up to 60 gallons per minute, a sample size of approximately 4 fifty-five gallon drums are placed in a feed sump and mixed prior to conducting the experiments. A recirculation loop controlled by a centrifugal pump is used to transport slurry from the bottom of the sump to its top. During the tests, the C10 unit is fed from a split stream on the recirculation loop. The feed rate is controlled by valves on the recirculation line. The C10 unit is mounted slightly above the feed sump so that the overflow (product) and underflow (tailings) streams can be gravity fed back into the feed sump.

After allowing sufficient time for the process to reach steady-state, a timed-sample of the feed, product, and tailing streams are collected in short incremental time periods for approximately 5 minutes. The samples will be analyzed for ash content, total sulfur content, pyritic sulfur content and solids content. A size-by-size analysis of ash and sulfur content is conducted on the feed and product (overflow) samples.

RESULTS AND DISCUSSION

Illinois No. 5 Coal Sample (Kerr-McGee):

The Results obtained by treating Illinois No. 5 coal sample are shown in Figure 1. These data were obtained by changing the operating parameters, such as bowl speed, pinch valve

a)

b)

Figure 1. The gravity separation results for the treatment of Illinois No.5 (Kerr-McGee) coal sample using Falcon concentrator (Feed Solids = 28%, Feed flowrate = 20 gallon/min).

opening time. The pinch valve closing time was set as 4 seconds according to the previous studies. The feed solids content was kept at 28% by weight, and the mass feed rate 1 ton/hour. From Figures 1(a) and (b), it seems that the Falcon concentrator can be efficiently used to process the 100 x 325 mesh size fraction in terms of combustible recovery versus ash rejection as well as total sulfur rejection. Further comparison of the separation performance for three size fractions are shown in Table 1. For 100 x 325 mesh material, the feed ash and total sulfur were measured as about 18% and 2.6%, respectively. It can be seen that the product ash values were greatly reduced to 8% when the pinch valve opening time was increased from 0.1 to 0.3 seconds. This may indicate that the pyrite and mineral matter layer on the bowl wall was thick enough to allow a further reduction in ash content by increasing the underflow rate. For the total product sulfur content, a similar conclusion can also be drawn although the extent of the total sulfur rejection is not as large as the ash rejection. This is due to the fact that the feed coal contained only a small amount of pyritic sulfur.

The feed ash and total sulfur for the 28 x 325 mesh size fraction were determined to be 11% and 2.11%, respectively. The ash content of the products generated by the Falcon Concentrator ranged from 7.33% to 8.68% while the total sulfur content of the product varied from 1.79% to 1.85% for the pinch valve opening time of 0.3 second. The combustible recovery values ranged from 97 to nearly 100%. It is believed that much larger reductions in product ash and total sulfur content could be achieved by increasing the opening time of the pinch valve without realizing a substantial reduction in combustible recovery. As shown in Table 1, the data obtained for 28 x 100 mesh size fraction indicate that the ash and total sulfur content of relatively clean coal (i.e., 9.9% and 1.98%, respectively) can be further reduced by the Falcon Concentrator with the loss of only 1% or 2% combustible recovery.

For these three size fractions, the combustible recovery values are larger than 96%. Obviously, a very large centrifugal force ranging from 72g to 200g with the norm being 130g was responsible for pulling all particles containing mineral matter and pyrite to the bowl wall. This high combustible recovery also indicates that increasing the pinch valve opening time could provide further reductions in the ash and total sulfur contents of the product without the loss of substantial amounts of combustible recovery.

The data given in Table 1 also reveal the fact that the bowl speed has no significant effect on the separation performance. This means that, at the lower speed of 710 rpm, the particles were well separated. Therefore, for industrial applications, lower speeds are preferred due to improved maintenance,

Table 1. The size by size separation results for the treatment of Illinois No. 5 coal sample using Falcon concentrator.

100 x 325 Mesh Illinois No. 5 Coal Sample Results						
Speed (rpm)	Open time (sec.)	Product Ash (%)	Product T.Sul (%)	Ash Rej. (%)	T. Sul. Rej. (%)	Comb. Rec. (%)
710	0.1	10.10	2.10	40.0	24.6	98.0
710	0.3	8.30	1.63	59.1	45.0	96.7
947	0.1	11.20	2.41	45.3	19.1	92.9
947	0.3	8.35	1.71	58.2	41.2	98.2
1183	0.1	11.34	1.83	42.6	36.5	96.0
1183	0.3	7.80	1.86	64.2	28.4	90.5
28 x 325 Mesh Illinois No. 5 Coal Sample Results						
Speed (rpm)	Open time (sec.)	Product Ash (%)	Product T.Sul (%)	Ash Rej. (%)	T. Sul. Rej. (%)	Comb. Rec. (%)
710	0.1	9.43	1.96	17.7	9.6	99.2
710	0.3	7.33	1.79	42.4	21.9	97.0
947	0.1	9.64	2.00	22.1	10.3	97.3
947	0.3	8.68	1.85	30.9	18.1	96.9
1183	0.1	9.71	1.94	19.4	10.9	98.7
1183	0.3	8.45	1.85	31.4	13.2	97.1
28 x 100 Mesh Illinois No. 5 Coal Sample Results						
Speed (rpm)	Open time (sec.)	Product Ash (%)	Product T.Sul (%)	Ash Rej. (%)	T. Sul. Rej. (%)	Comb. Rec. (%)
710	0.1	9.25	1.92	7.4	3.9	99.6
710	0.3	7.05	1.84	32.9	12.4	97.0
947	0.1	9.20	1.89	8.9	6.6	98.6
947	0.3	8.78	1.90	15.2	8.5	96.5
1183	0.1	9.28	1.98	7.2	1.2	99.4
1183	0.3	8.60	1.85	15.2	8.8	98.8

availability and economics. Lower bowl speeds will be tested during the upcoming reporting period.

Illinois No. 6 Coal Sample (Rend Lake):

The test results for the treatment of Illinois No. 6 coal using Falcon concentrator are shown in Figure 2.

a)

b)

Figure 2. The gravity separation results for the treatment of Illinois No.6 (Rend Lake) coal sample using Falcon concentrator (Feed Solids = 25-40%, Feed flowrate = 20-30 gallon/min).

Again, the particles in the 100 x 325 mesh size fraction were separated most efficiently in terms of combustible recovery versus ash rejection as well as total sulfur rejection. Thus, it can be safely stated that the Falcon concentrator is ideal for treating 100 x 325 mesh Illinois fine coal. Due to the space limitation, only 100 x 325 mesh coal sample results are shown in Table 2 to examine the effects of solids percent and feed flowrate. The average feed ash and total sulfur values were 9.8% and 1.4%, respectively. The bowl speed was kept at 947 rpm and pinch valve closing time 4 seconds.

Table 2. The size by size separation results for the treatment of Illinois No. 6 coal sample using Falcon concentrator.

100 x 325 Mesh Illinois No. 6 Coal Sample Results (Feed Rate = 20 gallon/min)						
Solids (%)	Open time (sec.)	Product Ash (%)	Product T.Sul (%)	Ash Rej. (%)	T. Sul. Rej. (%)	Comb. Rec. (%)
40	0.5	5.68	1.06	50.0	29.1	90.3
40	1.0	5.59	1.06	45.7	28.9	89.6
40	1.5	5.05	1.16	49.7	24.4	90.9
40	2.0	4.92	1.15	51.0	22.2	91.0
30	0.3	4.95	1.25	43.7	14.1	91.3
30	0.5	4.34	1.15	58.0	24.3	89.1
30	1.0	4.55	1.16	61.3	25.2	88.8
30	1.5	4.58	1.15	64.1	36.6	81.1
25	0.5	3.97	1.13	59.2	24.0	91.3
100 x 325 Mesh Illinois No. 6 Coal Sample Results (Feed Rate = 30 gallon/min)						
Solids (%)	Open time (sec.)	Product Ash (%)	Product T.Sul (%)	Ash Rej. (%)	T. Sul. Rej. (%)	Comb. Rec. (%)
30	0.5	4.89	1.23	34.2	12.7	93.4
30	1.0	4.89	1.16	61.2	29.5	91.3
25	0.5	4.04	1.18	66.1	33.1	87.4

It can be seen in Table 2 for a mass feed rate of 20 gallon/min, when solids percent was reduced from 40 to 25, the product ash value was decreased from around 5.3% down to 4%

while the product total sulfur values were not affected. The finding is true for combustible recovery.

When the feed flowrate was increased from 20 to 30 gallon/min, all the separation responses (product ash, total sulfur etc.) remained relatively constant. This may be due to the fact that the feed coal was fairly clean.

By comparing the data shown in Table 2 with that in Table 1, one can find that a larger underflow rate did increase the ash rejection at the cost of decreasing combustible recovery. This conclusion will be varified using the same coal sample containing higher ash and total sulfur contents. It is believed that changing the underflow rate slides the separation performance of the Falcon Concentrator along a recovery versus grade curve rather than producing a new curve.

CONCLUSIONS AND RECOMMENDATIONS

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

1. The Falcon concentrator is effective for treating coal size fractions between 28 and 325 mesh. However, based on previous research conducted by the principal investigators, it is believed that only the submicron material is not effectively treated by the Falcon unit.

The best results were obtained from the 100 x 325 mesh size fraction from the Illinois No. 5 coal sample. At a mass feed rate of 1 ton/hour, the ash content was reduced from approximately 18% to 8% while achieving very high combustible recovery values greater than 95%. This provided an ash rejection of nearly 60% and a separation efficiency of 55%. It is believed that increasing the underflow rate will further enhance the separation performance. For the 28 x 100 mesh size fraction, the ash content was also reduced from 10% to 8% with recovery values greater than 96%.

2. The Falcon Concentrator demonstrated the ability to reduce the ash content of fine coal that would be considered sufficiently clean for commercial use. For the Illinois No. 6 coal, the ash content in the 100 x 325 mesh size fraction was typically reduced from 9.8% to 5.0% while the ash content in the 28 x 100 mesh fraction was decreased from 6% to 4%. The total sulfur content was also reduced on the average from 1.4% to 1.1%. Combustible recovery values for these two size fractions were generally greater than 90%. Feed rates for these tests varied between 0.8 and 1.6 tons/hr.

3. Feed rates were varied between 20 and 30 gallons/min while also changing the feed solids content from 25% to 40% by weight. An increase in solids content over the aforementioned range increased the product ash content from approximately 4% to 5.3% for the 28 x 325 mesh size fraction in the Illinois No. 6 coal. Combustible recovery was found to remain relatively unchanged at about 91%.

The increase in feed rate from 20 to 30 gallons/min had very little effect on separation performance.

4. Tests conducted over a range of bowl speeds from 710 rpm to 1183 rpm indicate that bowl speed has little effect on separation performance. Thus, for industrial applications, lower speeds are preferred due to improved maintenance, availability and economics. Lower bowl speeds will be tested during the upcoming reporting period.

During the next reporting period, a parametric study using a Box-Behnken statistical test design will be conducted to evaluate the critical operating parameters. Empirical expressions will be developed describing the response variables as a function of the operating parameter values. Using these empirical relationships, separation performance for the Falcon Concentrator will be optimized for the treatment of both -28 mesh and -100 mesh run-of-mine Illinois No. 5 coal samples.

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PROJECT MANAGEMENT REPORT**March 1, 1994 through May 31, 1994****Project Title: Production of Illinois Base Compliance Coal
Using Enhanced Gravity Separation**

DOE Grant Number: DE-FC22-92PC92521 (Year 2)
ICCI Project Number: 93-1/5.1B-1P
Principal Investigator: Bradley Paul
Department of Mining Engineering
Southern Illinois University
at Carbondale
Project Manager: Ken Ho, Illinois Clean Coal
Institute

COMMENTS

The work schedule with the Falcon Concentrator is now approximately on time and delays resulting from the earlier coal strike have been made up. The project remains under budget but the Knelson Concentrator did not arrive in the third quarter due to scheduling problems at Knelson Concentrators, so expenses will be high in the fourth quarter as this work is made up. The tickets for John Pyper's (of Knelson Concentrators) visit have been booked for July 4th to July 10th. Since the ticket was purchased with project funds, approval of Dr. K. Hoe was required.

Contractual service expenses on the project have been low because of matching analysis support monies from Consolidation Coal Company. The Kerr-McGee feed, however, provides a greater cleaning challenge, so high expenses are anticipated for analysis work next quarter. The project has required more graduate student and student labor than was originally projected, and will continue to do so because of the addition of the Knelson Concentrator to the project. Some reduction in P.I. salaries and increase in student wages are expected next quarter, and minor budget adjustments involving a few hundred dollars in fringes to commodities are likely. The nature of the parts needed to set up the Knelson Concentrator circuit will influence whether remaining equipment monies are spent in equipment or commodities. The project should finish on time and in or under budget with under 5% in budget adjustments.

Projected and Estimated Expenditures by Quarter

Quarter*	Types of Cost	Direct Labor	Fringe Benefits	Materials & Supplies	Travel	Major Equipment	Other Direct Costs	Indirect Costs	Total
Sept. 1, 1993 to Nov. 30, 1993	Projected	2,908	0	2,000	333	34,800	3,000	4,304	47,345
	Estimated	0	0	2,430	0	32,200	0	3,460	38,090
Sept. 1, 1993 to Feb. 28, 1994	Projected	5,908	1,218	2,650	666	34,800	6,000	5,124	56,366
	Estimated	3,852	0	3,364	0	33,500	452	3,920	45,088
Sept. 1, 1993 to May 31, 1994	Projected	6,158	1,218	3,300	1,000	34,800	9,000	5,548	61,024
	Estimated	8,668	468	3,863	533	34,063	455	4,805	52,855
Sept. 1, 1993 to Aug. 31, 1994	Projected†	25,291	4,298	4,600	1,500	34,800	16,200	8,069	95,358
	Estimated								

*Cumulative by Quarter

†These changes reflect the addition of the Knelson Concentrator as per the request from ICCI.

COSTS BY QUARTER

Production of Illinois Base Compliance Coal Using
Enhanced Gravity Separation

Cumulative \$
(thousands)

O = Projected Expenditures -----

Δ = Estimated Actual Expenditures _____

Total Illinois Clean Coal Institute Award \$95,358

SCHEDULE OF PROJECT MILESTONES

Milestones:

- A. Research assistants employed.
- B. Equipment ordered and received.
- C. Sample acquisition completed (Task 1).
- D. Sample characterization completed (Task 2).
- E. Exploratory testing completed (Task 3).
- F. Evaluation of process parameters completed (Task 4).
- G. Empirical modeling and optimization completed (Task 5).
- H. Reports written and submitted (Task 6).

DATE

FILMED

10 / 5 / 94

END