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TECHNICAL REPORT
December 1, 1994 through February 28, 1995

Project Title: **ADVANCED PHYSICAL COAL CLEANING TO COMPLY WITH POTENTIAL AIR TOXIC REGULATIONS**

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ABSTRACT

Studies have indicated that the potentially hazardous trace elements found in coal have a strong affinity for coal pyrite. Thus, by maximizing the rejection of pyrite, one can minimize the trace element content of a given coal while also reducing sulfur emissions. The pyrite in most Illinois Basin coals, however, is finely disseminated within the coal matrix. Therefore, to remove the pyrite using physical coal cleaning techniques, the pyrite must be liberated by grinding the coal to ultrafine particle sizes. Fortunately, the coals being fed to pulverized coal boilers (PCB) are already ground to a very fine size, i.e., 70% passing 200 mesh. Therefore, this research project will investigate the use of advanced fine coal cleaning technologies for cleaning PCB feed as a compliance strategy.

Work in this quarter has focused on the processing of a PCB feed sample collected from Central Illinois Power's Newton Power Station using column flotation and an enhanced gravity separator as separate units and in a circuitry arrangement. The PCB feed sample having a low ash content of about 12% was further cleaned to 6% while achieving a very high energy recovery of about 90% in a single stage column flotation operation. Enhanced gravity treatment is believed to be providing excellent total sulfur rejection values, although with inferior ash rejection for the -400 mesh size fraction. The circuitry arrangement with the Falcon concentrator as the primary cleaner followed by the Microcel column resulted in an excellent ash rejection performance, which out performed the release analysis. Trace element analyses of the samples collected from these tests will be conducted during the next report period.

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EXECUTIVE SUMMARY

The Clean Air Act Amendment of 1990 requires U. S. utilities to comply with an increasing variety of environmental regulations. The restrictions on sulfur dioxide emissions in particular have received the most attention due to their impacts on medium and high sulfur coal markets. Another regulation that the Clean Air Act Amendment will impose in 1995 is the limitation of air toxic emissions. It has been estimated that, due to the combustion of over 600 million tons of coal per year, thousands of tons of potentially hazardous trace elements are released into the atmosphere. Thus, it is important to develop a pre-combustion coal cleaning strategy that will effectively reduce the trace element and sulfur contents of Illinois Basin coal.

The results of conventional float-sink tests have indicated that most trace elements are largely inorganically associated with the coal matrix, although a few of them, such as boron, beryllium and germanium, are strongly bound to the organic portion of coal and probably present as metal chelates. This conclusion has provided a basis for the reduction of the levels of many trace elements by physical coal cleaning methods. For example, it was found that many elements of environmental concern, including arsenic, cadmium, mercury, lead, and zinc, generally have an affinity for the mineral portion of the coal and tend to associate with pyrite or accessory sulfide minerals. Therefore, an efficient physical coal cleaning process is very important for both sulfur rejection and trace element extraction. In the last two decades, efficiencies for trace element extraction have been reported for various physical cleaning processes, including wet concentrating tables, oil agglomeration, float-sink separation, and combinations of heavy-media cyclones, froth flotation and hydraulic classifiers. Generally, it was reported that using a wet concentrating table or float-sink separation in static baths, less than 50% of the trace elements of environmental concern were reduced. For some Appalachian coals, gravity separation was used to reduce the levels of arsenic, chromium, fluorine, mercury, manganese, lead, titanium, and zinc by 50 - 80%. However, cleaning of coals from other regions was found less effective in removing trace elements. On the other hand, oil agglomeration or a combination of heavy-media cyclones, froth flotation, and hydraulic classifiers can reduce levels of many elements, including arsenic, cadmium, chromium, copper, lead, manganese, nickel, selenium, and zinc, by more than 50% for some coals. Generally speaking, for a given cleaning technique, the efficiencies of trace element extraction varied widely among coals.

For Illinois Basin coal, the pyrite which is known to carry a significant portion of the trace elements is finely dispersed within the coal matrix. Therefore, to achieve a high pyrite rejection using physical coal cleaning, the coal must be ground to very fine sizes for nearly complete liberation of the pyrite. Based on past studies, the cost of grinding coal, however, to ultrafine sizes is prohibitively high. Fortunately, utilities using pulverized coal boilers (PCB) require a feed coal ground to 70% passing 200 mesh. Thus, a novel pre-combustion coal cleaning strategy may be to treat the PCB feed coal at the power plant to achieve maximum sulfur and trace element reductions using

advanced coal cleaning technologies. Using this strategy, it may be feasible to produce compliance coal from medium sulfur and some high sulfur content Illinois Basin coals.

In addition to environmental concerns, ash deposition and corrosion in pulverized coal boilers have also become near term problems. Over 90% of the combustion boilers used in the state of Illinois are pulverized coal boilers (PCB) and most have been in operation for several years. As a result, their efficiency and availability are decreasing. Significant interest has been expressed recently to reduce the ash and trace element content of the feed coal to reduce the amount of ash deposition and corrosion using pre-combustion physical coal cleaning.

In this project, three Illinois coal samples will be processed using column flotation, enhanced gravity separation, and the combination of these two technologies. The purpose of this study is to determine the capabilities of these technologies to reduce the content levels of the trace elements of environmental concern , total sulfur and ash from an Illinois Basin flotation feed and PC boiler feed streams. One of the PC boiler feed samples will be collected at a power plant that obtains its coal supply from the coal preparation plant that will provide the flotation feed sample. This will allow a comparison to be made of the separation performances achieved by the advanced fine coal cleaning processes for the treatment of 100 x 0 mesh flotation feed and PCB feed that has been ground in a roll race mill to 70% passing 200 mesh. It is believed that treating the ultrafine coal particles using advanced fine coal cleaning technologies will provide greater reductions in trace element concentrations than those achieved in past studies.

The flotation column that will be used in this investigation will be selected on the basis of maximum separation efficiency and throughput as determined by an on-going ICCI project that is comparing six different flotation column technologies. A Falcon Concentrator having a bowl diameter of 10 inches and a capacity of 5 tph will be used as the enhanced gravity separator. The optimum operating parameter values for both units as determined in on-going ICCI projects will be used in all of the proposed experiments.

The work in this investigation will be conducted in three separate phases. In the first phase, the selected flotation column will be used to process three coal samples while the second phase will involve the use of the enhanced gravity separator. Finally, the combination of column flotation and enhance gravity separation will be arranged to produce high quality clean coal from each of the samples. Different test flowsheets will be used in order to obtain an ideal separation result. The samples obtained from each experiment will be analyzed for their ash, total and pyritic sulfur, BTU, and trace element contents. The trace elements that will be considered are selenium, mercury, chlorine, and chromium. The results from each experiment will be compared to the release analysis and washability curves generated for each coal sample to evaluate the efficiencies of the two process units and circuit arrangements.

In summary, the objectives of this research project are: (1) to determine the capability of advanced coal cleaning technologies to economically and efficiently produce compliance coal for PCB feed, and (2) to evaluate a flowsheet comprised of commercially available technology that can be used by a power plant or coal company to maximize the amount of sulfur, ash, and trace element content reductions that can be achieved for a given fine coal while achieving the highest possible energy recovery.

Work in this quarter concentrated on processing a pulverized coal boiler feed (about 70% passing 200 mesh) obtained from Central Illinois Power's Newton Power Station using a Microcel Column and a Falcon gravity separator. Upon completion of the Microcel and Falcon unit tests, two circuit arrangements were investigated to combine the superior desliming and de-sulfurizing abilities of Microcel column and Falcon concentrator, respectively. The first circuit used Microcel column as a primary cleaner followed by the Falcon concentrator to further desulfurize the column concentrate. The second circuit used the Falcon concentrator as a primary cleaner followed by the Microcel column to remove the finely dispersed clay mineral particles from the Falcon overflow product. The analyses of the samples collected from the above mentioned tests are not yet complete. At the time of this report most of the ash analyses and some of the total sulfur analyses results are available. The samples are still being analyzed for their pyritic sulfur, BTU and trace element contents.

The pulverized coal boiler feed sample having a low ash content of about 12% was further cleaned to an ash content of 6% while achieving an energy recovery of about 90% in a single stage Microcel column operation. Falcon treatment of the PC boiler feed sample provided excellent total sulfur rejection values which indicates a high rejection of pyritic sulfur. However, ash rejection values achieved by a single stage Falcon operation were relatively inferior for the -400 mesh fraction at high energy recovery values.

The circuitry arrangement with the Falcon concentrator as the primary cleaner followed by the Microcel column resulted in an excellent ash rejection performance, which was superior to the release analysis performance. This was believed to be happening due to an efficient rejection of pyrites in the Falcon unit, thereby, generating a low sulfur coal for the following microcel treatment. Thus, the overall circuit outperforms the release analysis.

Although, none of the trace element analysis data are presently available, it is strongly believed that with a near complete removal of both sulfide and other ash forming minerals present in the PC boiler feed sample, the associated trace element contents will be significantly reduced, thereby, achieving the goal of this project.

OBJECTIVES

The goal of this project is to identify a fine coal cleaning circuit that can produce a compliance Illinois Basin coal product from low organic sulfur content coal while maintaining a high energy recovery. In light of this goal, the project objectives are:

1. To use a proven flotation column technology and an enhanced gravity separator separately or in combination to produce a compliance coal from an Illinois No. 6 flotation feed;

2. To identify a fine coal circuit arrangement which utilizes column flotation and/or enhanced gravity separation to reduce sulfur and trace element content to compliance levels for pulverized coal boiler feed (PCB).

These objectives are to be achieved through the following tasks:

Task 1: Collect 5 fifty-five gallon drums of race roll mill product and 25 fifty-five gallon drums of flotation feed (100 M x 0).

Task 2: Characterize the representative samples for their size distribution, best possible floatability and washability. Analyze all the products for ash, total and pyritic sulfur, BTU, and trace element contents using standard ASTM procedures.

Task 3: Conduct a total of 15 column flotation tests and analyze the collected samples for their ash, total and pyritic sulfur, BTU, and trace element contents.

Task 4: Conduct a total of 15 enhanced gravity separation tests and analyze the collected samples for their ash, total and pyritic sulfur, BTU, and trace element contents.

Task 5: Conduct column flotation/enhanced gravity circuitry tests in different combinations and evaluate the circuit performance for each coal sample.

Task 6: Prepare quarterly and final reports.

INTRODUCTION AND BACKGROUND

Statement of Problem

The state of Illinois is presently in danger of losing as much as 25% of its coal mining industry due to the sulfur dioxide (SO_2) emission limits specified in the Clean Air Act Amendments of 1990 (IDENR, 1992). The first phase of the Clear Air Act, which begins in 1995, restricts SO_2 emissions to a level less than 2.5 lbs/MBTU, while stricter Phase II limits of 1.2 lbs/MBTU start in the year 2000. Most Illinois Basin coals will not be able to meet these requirements without some form of advanced coal cleaning. In addition, from the combustion of nearly 600 millions tons of coal per year in the U. S., it is estimated that thousands of tons of potentially hazardous trace elements are released into the environment each year (Harvey et al., 1983; Akers, 1989). The airborne particulates that escape the post-combustion cleaning processes are respirable particles having an enriched concentration of trace elements on their surfaces (Natusch et al., 1973; Linton et al., 1976). As a result, the U. S. government is expected to place limits on trace element emissions as part of the Clean Air Act Amendment. However, emission allowances for each trace element is currently unknown. Thus, it has never been more important than the present to develop pre-combustion processing strategies that will economically and efficiently reduce the trace element and total sulfur content of Illinois Basin coal.

A total of 76 of the 92 naturally occurring elements have been detected in coal with most having concentration less than 0.1% (White et al., 1984). Many of these elements are thought to be toxic to animal and plant life (Van Hook, 1978). Gluskoter et al. (1977) found that Illinois Basin coals have relatively high content of boron, beryllium, bromine, cadmium, germanium, manganese, nickel, lead, zinc, iron, and sulfur. The trace elements that are of the greatest concern to the environment include arsenic, boron, mercury, lead, selenium, molybdenum, and sulfur. Many of the trace elements have a strong affinity for the mineral matter associated within coal, especially the pyrite and other sulfide minerals. Thus, physical coal cleaning studies conducted in the past have shown limited success at reducing the content of some of the trace elements. One such study investigated the trace element content reductions occurring from the treatment of six Appalachian and midwestern coals using heavy-media cyclones (Ford and Price, 1982). The results shown in Table 1 indicate that most of the trace elements were concentrated in the refuse stream. However, some of the elements were not concentrated in either stream, such as boron and antimony. The explanation for this result is that some of the trace elements found in coal have a strong affinity for the organic coal matrix. Thus, it is very difficult to reduce the content of these trace elements using physical coal cleaning. For Illinois Basin coals, elements having a high organic affinity include germanium, boron, beryllium, and antimony (Gluskoter et al., 1977).

As described above, to maximize the reduction in trace element content using physical cleaning methods, it is necessary to maximize the rejection of pyritic sulfur and the associated mineral matter. To achieve this goal, the pyrite and mineral matter must be liberated as completely as possible. However, past studies have found that the pyrite occurring in Illinois Basin coal is finely dispersed. In a study by Zitterbart et al. (1985), only approximately 45% of the pyritic sulfur was found to be completely

Table 1. Average trace element concentrations (ppm) in coal before and after physical coal cleaning using heavy-media hydrocyclones (Ford and Price, 1982).

Trace Element	Feed Coal	Clean Coal	Refuse
Arsenic	14	7.5	36
Boron	63	62	61
Beryllium	1.6	1.2	3.3
Cadmium	0.22	0.12	0.59
Cobalt	6.5	4.1	16
Chromium	30	18	72
Copper	15	9.0	39
Fluorine	132	65	380
Mercury	0.19	0.17	0.28
Manganese	78	29	230
Nickel	21	13	49
Lead	31	9.8	47
Antimony	0.77	0.70	1.0
Selenium	3.9	2.6	6.9
Vanadium	49	37	91
Zinc	39	20	120

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 and, thus, is not completely liberated in the finest coal fraction. Thus, fine grinding of the coal is required to achieve significant reductions in pyritic sulfur and, thus, trace element content. As a result of the grinding, advanced physical coal cleaning technologies will be required to treat the ultrafine (-100 mesh) coal.

Past studies have found, however, that the grinding of coal to ultrafine sizes may be prohibitively expensive. Estimates ranging from $12 to $45 per ton have been cited by the current Illinois Clean Coal Institute's request for proposal. Fortunately, most power utilities use pulverized coal boilers which requires that the coal be ground to 70% passing 200 mesh. Thus, a solution to the costly grinding problem could be to treat the pulverized coal prior to combustion. In this way, advanced coal cleaning processes can produce a clean coal product at a reasonable cost using commercially available fine coal cleaning technologies. It may be possible that compliance coal can be produced using this strategy from medium sulfur content Illinois Basin coals and some high-sulfur content coals.

In addition to environmental concerns, ash deposition and corrosion in pulverized coal boilers have also become near term problems. Over 90% of the combustion boilers used in the state of Illinois are pulverized coal boilers (PCB) and most have been in operation for several years. As a result, their efficiency and availability are decreasing. Significant interest has been expressed recently to reduce the ash and trace element content of the feed coal to reduce the amount of ash deposition and corrosion using pre-combustion physical coal cleaning.

Related and Current Research

An investigation was conducted by the principal investigator to evaluate the feasibility of using the Falcon Centrifugal Concentrator for cleaning run-of-mine Illinois Basin coal fines (Honaker et al., 1994). A semi-batch Falcon concentrator having a bowl diameter of 6 inches was used in this study. The rotational speed of the bowl was 2000 rpm which supplied a centrifugal force of 300 g's. Since the goal of the project was to evaluate the Falcon concentrator on the basis of ash and sulfur rejection, the overflow was retreated several times to ensure that heavy particles reporting to the overflow was not due to the over-spilling of a full bowl. However, the underflow was not retreated which resulted in a significant loss in combustible recovery due to the beached coal particles that could not reach the overflow lip before the end of the test. This problem is strictly a function of the batch system and, thus, should not occur in a continuous unit. Recent experiments using a continuous unit have verified this statement.

Treatment of the 28 x 0 mesh fine circuit feed resulted in a reduction in the total sulfur content from 2.9% to 1.59%. The corresponding decrease in the ash content was from 20.27% to 13.54%. A screening analysis of the final overflow product revealed that most of the ash-forming material reporting to the final product was in the -325 mesh fraction, indicating the presence of a large amount of sub-micron clay particles. In fact, after screening out the -325 fraction from the overflow product, an ash content of 8.2% was achieved while the final sulfur content value remained approximately 1.6%.

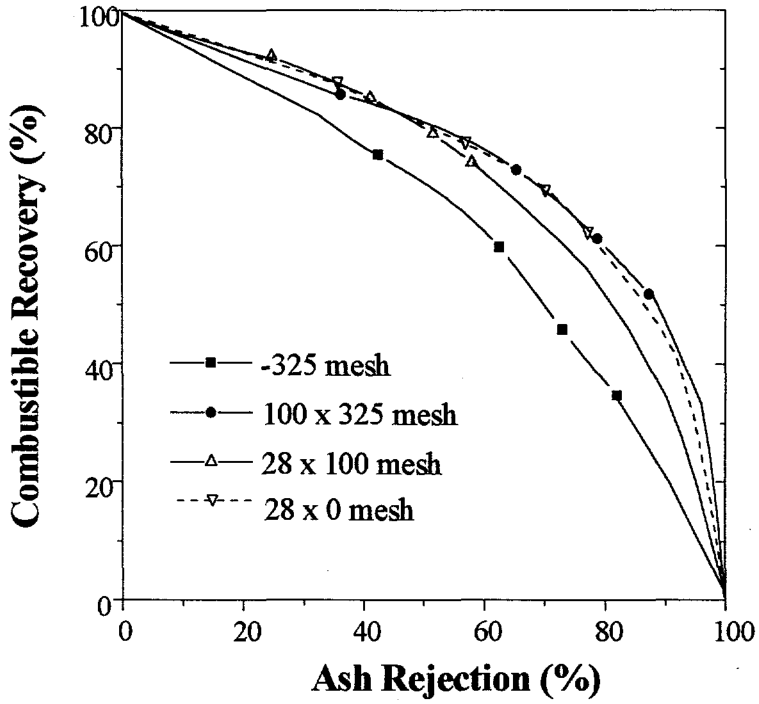
The final overflow and underflow products generated from the treatment of the 28 x 0 fine circuit feed were screened into the size fractions of 28 x 100 mesh, 100 x 325 mesh, and 325 x 0 mesh. These size fractions were analyzed for their ash and total sulfur content. Figures 1(a) and 1(b) show the recovery versus ash rejection and total sulfur rejection plots, respectively, generated on a size-by-size basis. As indicated in Figure 1(a), the best ash rejection was achieved in the 100 x 325 mesh size fraction while the worst was obtained by the -325 mesh size fraction. The low separation performance of the -325 mesh size fraction most likely indicates the inability of the Falcon concentrator to achieve a gravity separation on the clay particles. However, the ash content was reduced in this fraction from 51.2% in the feed to 35.01% in the final overflow product. The ash content in the 28 x 100 was reduced from 14.0% to 8.42%. These results indicate that the Falcon concentrator is able to provide excellent ash rejections for the size fractions between 28 and 325 mesh.

In contradiction to the ash content results, the best sulfur rejection values were obtained from the -325 size fraction. The total sulfur content in this fraction was reduced from 5.2% in the feed to 1.0% in the overflow product generated after 4 cleaning stages. The large reduction in sulfur content may be a result of the presence of a large amount of free pyrite particles in the -325 mesh fraction. The sulfur rejection in the 28 x 100 mesh size fraction was found to be the lowest which is probably due to a large content of non-liberated pyrite. However, a substantial sulfur reduction was achieved for the 28 x 100 mesh size fraction from 2.7% in the feed to 1.82% in the final overflow product.

Presently, to best of the principal investigator's knowledge, there are two projects that are being conducted to evaluate the feasibility of using enhanced gravity separation for cleaning fine coal. The first study is being conducted by Virginia Tech at the Pittsburgh Energy Technology Center (PETC) of the U. S. Department of Energy. In this study, the Multi-Gravity Separator (MGS) is being evaluated as a cleaner for the Microcel flotation column concentrate to achieve further desulfurization and as a primary cleaner for flotation feed. Based on verbal communications, the MGS achieved excellent pyritic sulfur rejection values while achieving very high recovery values (Luttrell, 1994). However, the limited throughput of the largest MGS unit combined with its high capital cost of nearly a quarter of a million dollars remains a problem for commercial utilization.

In addition, Virginia Tech is also conducting a separate study on another U. S. Department of Energy project which involves testing the MGS and the Kelsey Jig in a coal preparation plant. The Kelsey Jig operates based on jigging principles in a centrifugal field. The results of these tests are presently not known.

The second study evaluating the use of centrifugal concentrators for fine coal cleaning is being conducted by the Department of Mining Engineering at Southern Illinois University-Carbondale (SIUC) as part of the 1993 ICCI research program. In this study, continuous Falcon and Knelson concentrators having capacities of 5 tph are being evaluated for the treatment of a run-of-mine (28 M x 0) Illinois No. 6 fine coal sample and an Illinois No. 5 conventional flotation concentrate. From an initial test using the C10 Falcon Concentrator, the total sulfur content of a flotation concentrate was reduced from 2.1% to 1.5% in a single stage of treatment. The ash content was also reduced substantially from 7.8% to 4.3% while achieving a high energy (BTU) recovery value of 91%. This test was performed at a throughput of nearly 3 tph at a solids concentration of 25.0% by weight. Since this test was not conducted under



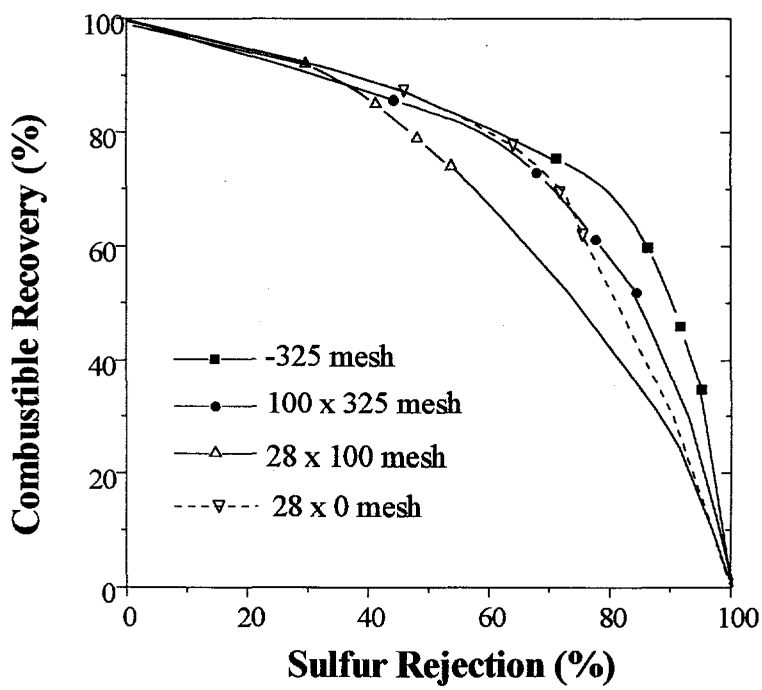


Figure 1. The combustible recovery versus ash rejection and sulfur rejection for a semi-batch falcon concentrator on the size-by-size basis.

optimum conditions, it is expected that this separation performance can be further improved. An experimental testing program is presently being conducted and results are expected in the near future.

A study being conducted this year by the principal investigator is comparing six commercially available column technologies for the treatment of Illinois Basin coal fines as part of the 1993 ICCI research program. The flotation columns being studied include the Packed-Column, Microcel Column, Flotaire Column, Turboair Column, Canadian Column, and the Jameson Cell. These columns are being compared based on their separation performance and throughput. The flotation column providing the maximum separation efficiency at the largest possible throughput will be used in the circuit described in this proposed research project.

EXPERIMENTAL PROCEDURE

During this reporting period, 5 fifty five gallon drums of race roll mill product were collected from the Central Illinois Power's Newton Power Station. Upon arrival, representative samples were obtained from the bulk samples for size analysis and release analysis purpose. Then the bulk sample was processed using column flotation, enhanced gravity separation, and the combination of these two technologies.

Microcel column, which was found to be one of the best column technologies on the basis of a recently completed ICCI project, was used in this investigation for cleaning the race roll mill product. The column assembly used in this study consists of a 4-inch diameter, 16 ft long plexiglass column, a wash water distributor, a PID pulp level controller and a microbubble generation system. The general process parameters used for the column operation are listed below:

Frother (Dowfroth-M150) Concentration	25 ppm
Collector (Kerosene)	3.5 lbs/ton
Aeration rate (corrected for pressure)	9.7 lpm
Wash Water rate	2 lpm

A C10 Falcon concentrator having a bowl diameter of 10 inches and a capacity of 5 tph was used as the enhanced gravity separator for cleaning the race roll mill product. The Falcon assembly includes a recirculation loop controlled by a centrifugal pump. The C10 concentrator is fed from a split stream on the recirculation loop. The C10 unit is mounted slightly above the feed sump so that the overflow and underflow streams can be gravity fed back into the feed sump. The general process parameters used for the Falcon operation are listed below:

Bowl Speed	910 rpm
Pinch Valve Opening time	0.5 to 2.0 seconds
Pinch Valve Closing time	4 seconds

Upon completion of the Microcel and Falcon unit tests, two circuitry arrangements combining Microcel column and Falcon concentrate were investigated. As shown in Figure 2, the first circuit used Microcel column as a primary cleaner followed by the Falcon concentrator to further desulfurize the column concentrate. The column was operated using the general operating parameters discussed previously and a feed rate of about 150 gms per minute for a long time to produce sufficient amount of concentrate. The column concentrate was then fed to the Falcon unit at a volumetric feed rate of about 35 gpm (8% solid by weight). Five Falcon tests were conducted on the column concentrate varying pinch-valve opening time.

The second circuit used the Falcon concentrator as a primary cleaner followed by the microcel column to remove the finely dispersed clay mineral particles from the Falcon overflow product. The Falcon unit was operated at a volumetric feed rate of about 30 gpm (15% solid by weight) with a pinch valve opening time of 1.8 seconds to produce a sufficient amount of overflow product. The overflow product was then fed to the Microcel column at feed rates varying from 40 to 150 gms per minute conducting five column tests. Thus, the purpose of the circuitry study was to maximize both ash and pyrite rejection in an effort to minimize the trace element content of the cleaned coal product.

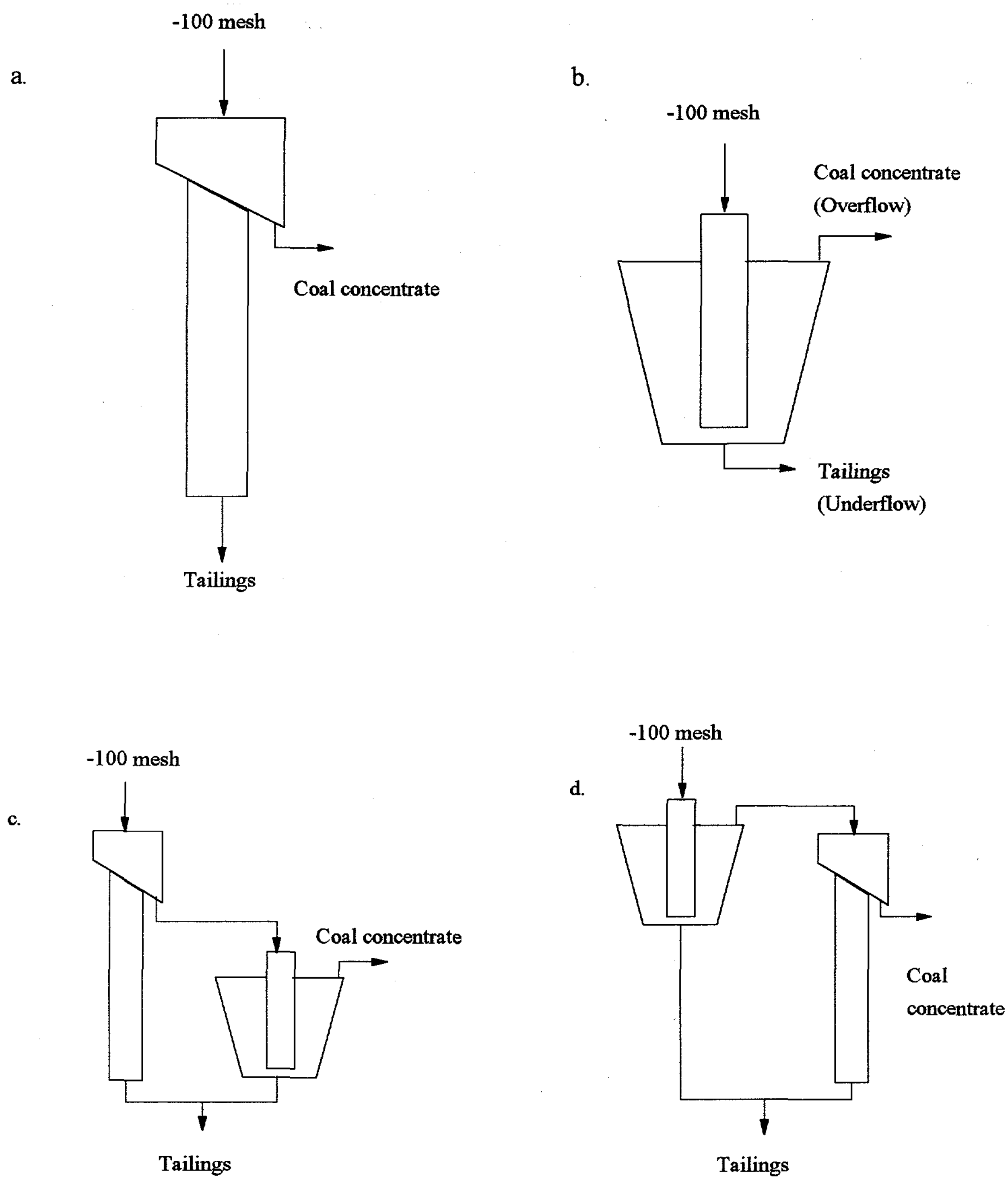


Figure 2. Circuit flowsheets that was tested for the treatment of the PCB feed sample.

RESULTS AND DISCUSSION

As previously discussed, the goal of this study is to develop a pre-combustion coal cleaning strategy that will effectively reduce the trace element and sulfur contents of Illinois Basin coal and thus comply with the potential air toxic regulations. Since, past studies have indicated that a majority of these trace elements have a strong affinity for the pyrite and ash forming minerals found in coal, maximizing both ash and sulfur rejection and thereby minimizing the trace element content in the cleaned product has been the major objective of this investigation. Column flotation and enhanced gravity separation techniques, which are known to have excellent de-sliming and de-sulfurizing abilities, respectively, have been utilized in this investigation to clean and produce compliance coal.

Work in this quarter concentrated on processing a pulverized coal boiler feed (about 70% passing 200 mesh) obtained from Central Illinois Power's Newton Power Station using Microcel Column and Falcon gravity separator. Upon completion of the Microcel and Falcon unit tests, two circuit arrangements combining Microcel column and Falcon concentrate were investigated. However, the analyses of the samples collected from the above mentioned tests are not yet complete. At the time of this report most of the ash analyses and some of the total sulfur analyses results are available. The samples are still being analyzed for their pyritic sulfur, btu and trace element contents. Based on the ash results, grade (product ash) and recovery (combustible recovery) values were calculated for both microcel column and Falcon concentrator tests. The grade recovery data points for both Microcel and Falcon have been plotted against the release analysis results, as shown in Figure 3.

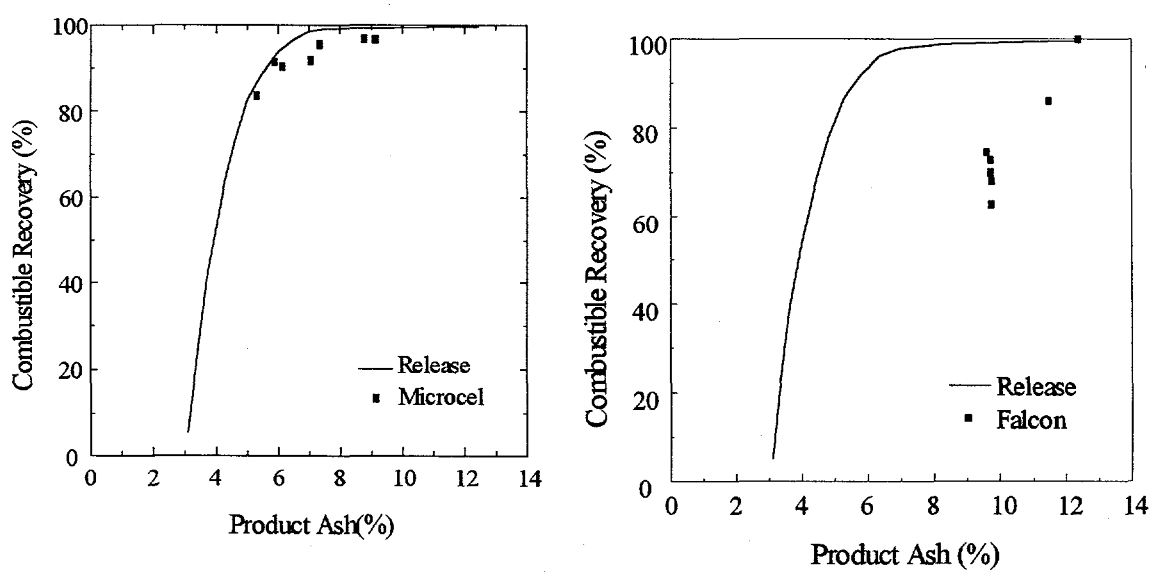


Figure 3. Product ash vs combustible recovery results for microcel column and Falcon concentrator in comparison to release analysis performance for cleaning the PC boiler feed sample obtained from Newton Power Station.

A total of 7 microcel tests and 5 Falcon tests were conducted using the general operating parameter values listed in the previous section. The ash results for these tests have been summarized in Tables 2 and 3. For Microcel tests, the grade-recovery data points shown along the release curve were generated by varying the feed rate from about 40 to 200 gms per minute. Whereas, the data-points for the falcon concentrator were generated by varying the pinch-valve opening time from 0.5 to 2.0 seconds, while keeping the feed rate constant at a volumetric rate of 30 gpm (15% solid by weight).

As shown in Figure 3, the ash cleaning (de-sliming) ability of microcel column is much superior to that of falcon concentrate. Since ash forming minerals are hydrophilic, they are easily rejected in the advanced flotation process, whereas, partly because of their ulltrafine size, they get entrained with the water reporting to the Falcon overflow. In addition, the relatively low density difference between pure coal particles and some of the mineral particles can also cause misplacement of some relatively low dense mineral particles in the Falcon overflow. On the other hand, pyrite being about 3 to 4 times heavier than pure coal particles tend to report to the Falcon underflow, providing excellent pyrite rejection values for the Falcon concentrator. Since, most of the coal pyrites are weakly hydrophobic, they have a tendency to report to the column froth product, thereby, providing relatively low pyrite rejection values for microcel column. At the present time, the pyrite analyses data are not available to corroborate this hypothesis for the present investigation. However, the visual analyses of the tailings/underflow samples while conducting the experiments completely agree with this explanation. The high total sulfur rejection values shown in Table 4, generated from the available sulfur analysis data for the treatment of +400 mesh fraction of the PC boiler feed sample in Falcon indicates the superior de-sulfurizing ability of the Falcon concentrator.

Table 2. The ash analyses results of the Microcel column tests conducted on the PC boiler feed sample collected from Central Illinois Power's Newton Power Station.

Test #		ASH (%)		Yield	Comb.Recovery	Ash Rejection
	Feed	Concentrate	Tailings	(%)	(%)	(%)
1	12.23	7.05	45.92	86.67	91.8	50.0
2	12.23	9.13	55.87	93.37	96.7	30.3
3	12.23	8.77	59.18	93.14	96.8	33.2
4	12.23	7.34	58.75	90.49	95.5	45.7
5	12.23	5.88	48.98	85.27	91.4	59.0
6	12.23	5.31	36.04	77.48	83.6	66.4
7	12.23	6.14	45.5	84.53	90.4	57.6

Table 3. The ash analyses results of the Falcon tests conducted on the +400 mesh, -400 mesh fraction and the overall PC boiler feed sample collected from Central Illinois Power's Newton Power Station.

Test #	ASH (%)			Yield	Comb.Recovery	Ash Rejection
+400 mesh fraction	Feed	Concentrate	Tailings	(%)	(%)	(%)
1	7.03	4.12	8.53	34.01	35.08	80.07
2	6.99	4.05	8.28	30.50	31.46	82.33
3	7.06	3.80	9.26	40.29	41.71	78.31
4	7.01	3.65	7.85	20.00	20.72	89.59
5	7.04	3.97	9.60	45.47	46.97	74.36
-400 mesh fraction						
1	14.04	13.31	22.74	92.26	93.04	77.26
2	14.04	13.41	21.82	92.51	93.19	78.18
3	14.04	13.52	20.07	92.06	92.62	79.93
4	14.04	13.62	18.18	90.79	91.23	81.82
5	14.04	13.21	23.11	91.62	92.50	76.89
Over-all Feed						
1	11.32	9.73	17.19	69.5	69.9	39.2
2	11.32	9.76	16.52	68.3	67.9	39.9
3	11.32	9.73	15.85	71.9	72.7	37.5
4	11.32	9.73	14.13	63.2	62.7	42.8
5	11.32	9.61	17.83	73.6	74.4	37.6

Table 4. The sulfur analyses results of the Falcon tests conducted on the +400 mesh, mesh fraction of the PC boiler feed sample collected from Central Illinois Power's Newton Power Station.

Test #	Sulfur (%)			Yield	Comb.Recovery	Sulfur Rejection
+400 mesh fraction	Feed	Concentrate	Tailings	(%)	(%)	(%)
1	3.03	2.05	3.54	34.01	35.08	80.07
2	3.05	2.08	3.47	30.50	31.46	82.33
3	3.01	2.03	3.67	40.29	41.71	78.31
4	3.05	2.01	3.31	20.00	20.72	89.59
5	3.03	2.10	3.80	45.47	46.97	74.36

Upon completion of the Microcel column and Falcon concentrator unit tests, two circuitry arrangements were investigated to combine the advantages of both separators and thus obtain a superior cleaned product. As shown previously in Figure 2, the first circuit used Microcel column as a primary cleaner followed by the Falcon concentrator to further desulfurize the column concentrate. Five Falcon tests were conducted on the column concentrate varying pinch-valve opening time. At the present time, the test samples are being analyzed for their ash, total sulfur, pyrite and btu contents.

The second circuit used the Falcon concentrator as a primary cleaner followed by the microcel column to remove the finely dispersed clay mineral particles from the Falcon overflow product. The overflow product was then fed to the Microcel column at feed rates varying from 40 to 150 gms per minute conducting five column tests. The analysis of the product, tailings and feed samples is still going on. At the present time, only the ash analyses results are available. A summarized list of these ash results of the individual unit and the complete circuit based is shown in Table 5. The grade-recovery values calculated on the basis of the ash assays for the Falcon unit and the overall circuit (Falcon and Microcel combined) are compared with the release analyses performance in Figure 4. As shown, the overall circuit performance is superior to the release analysis performance, indicating a distinct advantage of the circuitry arrangement.

Table 5. The ash results of the circuitry test conducted on the Newton Power Station PC boiler feed sample using Falcon concentrator as the precleaner followed by Microcel column.

Test #	ASH(%)			Yield	Comb.Recovery	Ash Rejection	Circuit Comb.	Circuit
	Feed	Concentrate	Tailings	(%)	(%)	(%)	Recovery (%)	Product Ash (%)
Falcon								
1	12.42	11.51	16.52	81.84	82.69	24.16		
Microcel								
1	11.51	3.33	28.46	67.45	73.68	81.9	60.9	3.33
2	11.51	3.91	38.02	77.72	84.39	75.2	69.8	3.91
3	11.51	2.58	20.47	50.08	55.14	89.9	45.6	2.58
4	11.51	4.18	45.85	82.41	89.24	71.8	73.8	4.18
5	11.51	2.61	16.33	35.13	38.66	93.2	32.0	2.61

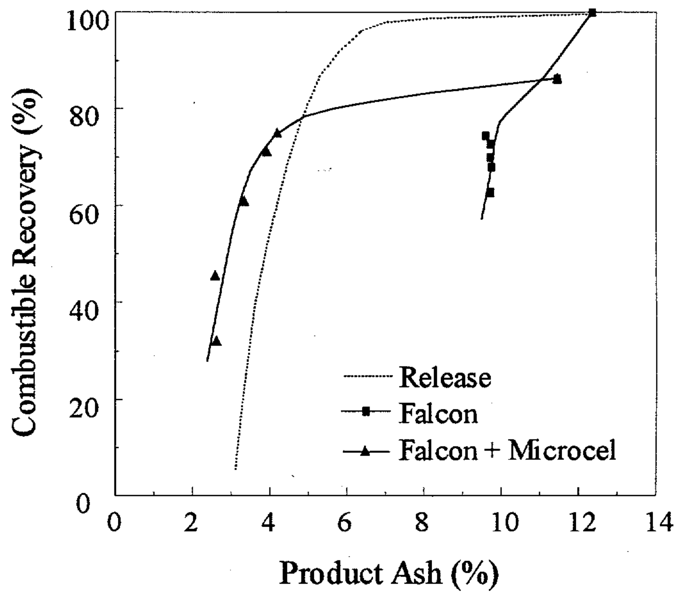


Figure 4. The grade-recovery results of the circuitry test conducted on the Newton Power Station PC boiler feed sample using Falcon concentrator as the precleaner followed by Microcel column, in comparison to the release analysis performance.

The ash rejection values obtained from the Microcel treatment of the Falcon concentrate in the second circuitry study (shown in Table 4) is superior to those obtained from the treatment of the original PC boiler feed sample (shown in Table 1). In the circuitry study, although, Falcon treatment does not significantly reduce the ash content of the product, it is believed to be reducing the pyrite and total sulfur content significantly. Therefore, the Falcon concentrate containing less pyrite gets more efficiently cleaned by the following Microcel treatment than the original PC boiler feed sample. While treating the Falcon concentrate sample having a ash content of 11.5% in the Microcel, about 90% combustible recovery was obtained at a product ash content as low as about 4% . Whereas, the same amount of combustibles was recovered from the original feed sample containing 12.2% ash at a higher product ash content of about 6%.

Similar type of superior results are also expected from the first circuitry study, whose samples are still being analyzed. Although, none of the trace element analysis data are presently available, it is strongly believed that with a near complete removal of both sulfide and other ash forming minerals present in the PC boiler feed sample, the associated trace element contents will be significantly reduced, thereby, achieving the goal of this project.

CONCLUSIONS AND RECOMMENDATIONS

1. A cleaned pulverized coal boiler feed sample having an ash content of about 12% was further cleaned to an ash content of 6% while achieving an energy recovery of about 90% in a single stage advance flotation column (Microcel) operation.

2. Falcon treatment of the PC boiler feed sample provided excellent total sulfur rejection values which indicates removal of the pyrtic sulfur. However, ash rejection values achieved by a single stage Falcon operation were relatively inferior for the -400 mesh size fraction as compared to the flotation column at high energy recovery values.

3. The circuitry arrangement with the Falcon concentrator as the primary cleaner followed by the Microcel column resulted in an excellent ash rejection performance, which was superior to the release analysis performance. This was believed to be happening due to an efficient rejection of pyrites in the Falcon unit, thereby, generating a low sulfur coal for the following microcel treatment. Thus, the overall circuit outperforms the release analysis.

4. Although, none of the trace element analysis data are presently available, it is strongly believed that with a near complete removal of both sulfide and other ash forming minerals present in the PC boiler feed sample, the associated trace element contents will be significantly reduced without any additional grinding beyond current practice, thereby, achieving the goal of this project.

DISCLAIMER STATEMENTS

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PROJECT MANAGEMENT REPORT
December 1, 1994 to February 28, 1995

Project Title: **ADVANCED PHYSICAL COAL CLEANING TO COMPLY WITH POTENTIAL AIR TOXIC REGULATIONS**

DOE Cooperative Agreement Number: DE-FC22-92PC92521 (Year 3)
ICCI Project Number: 94-1/1.1B-2P
Principal Investigator: Ricky Q. Honaker, Department of Mining Engineering, Southern Illinois University at Carbondale
Other Investigators: B. C. Paul and D. Wang, Department of Mining Engineering, Southern Illinois University at Carbondale
Project Manager: Ken Ho, Illinois Clean Coal Institute

COMMENTS

None.

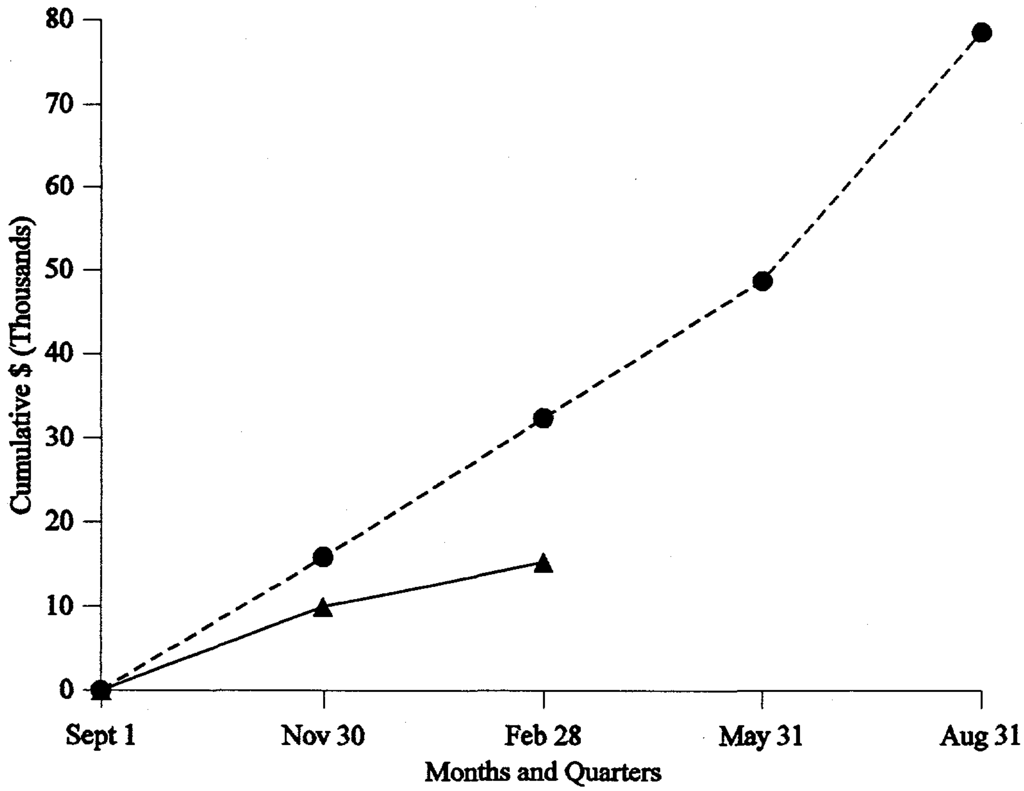
PROJECTED AND ESTIMATED EXPENDITURES BY QUARTER

Quarter*	Types of Cost	Direct Labor	Fringe Benefits	Materials and Supplies	Travel	Major Equipment	Other Direct Costs	Indirect Cost	Total
Sept. 1, 1994 to Nov. 30,1994	Projected	9,444	994	1,500	0	0	2,525	1,446	15,909
	Estimated	6,958	402	1047	586	0	55	905	9,953
Sept. 1, 1994 to Feb. 28, 1995	Projected	18,888	1,989	3,000	500	0	5,050	2,943	32,370
	Estimated	10,910	402	1,521	495	0	577	1,391	15,296
Sept. 1, 1994 to May 31, 1995	Projected	28,332	2,982	4,500	1,000	0	7,575	4,439	48,828
	Estimated								
Sept. 1, 1994 to Aug. 31, 1995	Projected	47,861	5,970	6,000	1,500	0	10,100	7,143	78,574
	Estimated								

*Cumulative by Quarter

CUMULATIVE COSTS BY QUARTER

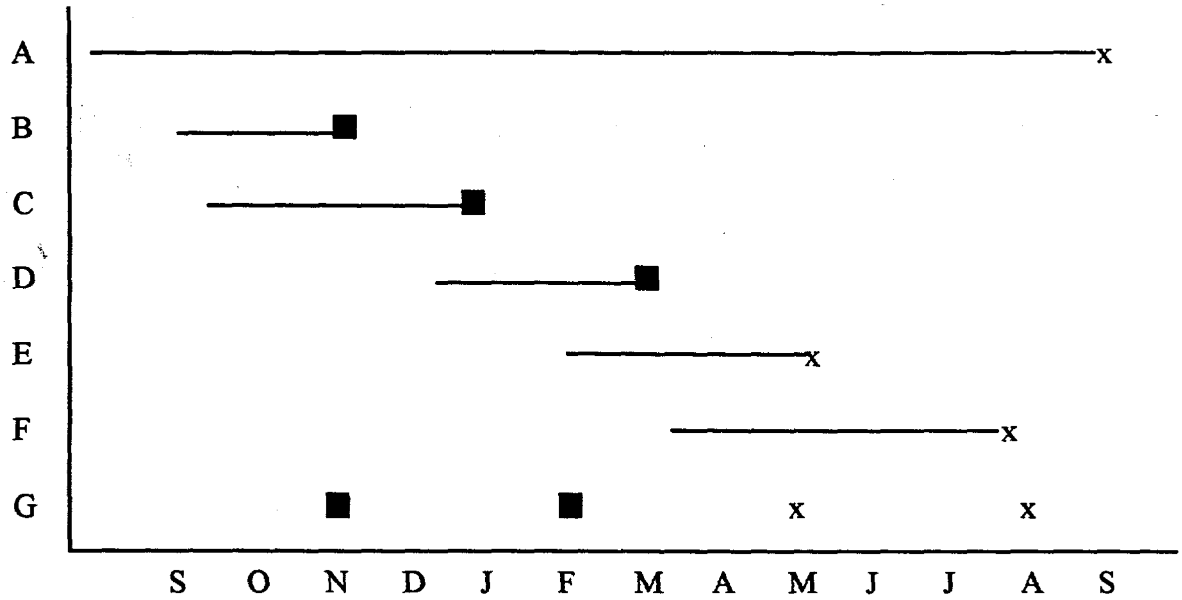
Advanced Physical Coal Cleaning to Comply with Potential Air Toxic Regulations



● = Projected Expenditures - - - - - - -
▲ = Actual Expenditures _________

Total Illinois Clean Coal Instutute Award $78,574

SCHEDULE OF PROJECT MILESTONES



Begin
Sept. 1
1994

Hypothetical Milestones:

A: Research assistants employed
B: Sample Acquisition (Task 1)
C: Sample Characterization (Task 2)
D: Column Flotation (Task 3)
E: Enhanced gravity separation (Task 3)
F: Column flotation/Gravity separation (Task 5)
G: Reporting (Task 6)