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TECHNICAL REPORT

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Project Title: **A MODIFIED RELEASE ANALYSIS PROCEDURE USING
ADVANCED FROTH FLOTATION MECHANISMS**

OSTI

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ABSTRACT

Recent studies indicate that the optimum separation performances achieved by multiple stage cleaning using various column flotation technologies and single stage cleaning using a Packed-Flotation Column are superior to the performance achieved by the traditional release procedure, especially in terms of pyritic sulfur rejection. This superior performance is believed to be the result of the advanced flotation mechanisms provided by column flotation technologies. Thus, the objective of this study is to develop a suitable process utilizing the advanced froth flotation mechanisms to characterize the true flotation response of a coal sample.

Work in this reporting period concentrated on developing a modified coal flotation characterization procedure, termed as Advanced Flotation Washability (AFW) technique. The new apparatus used for this procedure is essentially a batch operated packed-column device equipped with a controlled wash water system. Several experiments were conducted using the AFW technique on a relatively high sulfur, -100 mesh Illinois No. 5 run-of-mine coal sample collected from a local coal preparation plant. Similar coal characterization experiments were also conducted using the traditional release and tree analysis procedures. The best performance curve generated using the AFW technique was found to be superior to the optimum curve produced by the traditional procedures. For example, at a combustible recovery of 80%, a 19% improvement in the reduction of the pyritic sulfur content was achieved by the AFW method while the ash reduction was also enhanced by 4%. Several tests are on-going to solidify the AFW procedure and verify the above finding by conducting Anova analyses to evaluate the repeatability of the AFW method and the statistical significance of the difference in the performance achieved from the traditional and modified coal characterization procedures.

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EXECUTIVE SUMMARY

The goals of this project are to evaluate the current status of the coal flotation characterization procedures, such as release and tree analyses with respect to the advanced froth flotation technologies presently being introduced and to modify the traditional procedures so that a true theoretical optimum recovery-grade curve for any froth flotation process can be obtained from the analysis.

The traditional release and tree analysis procedures are recognized internationally as the analyses which provide the ultimate recovery-grade relationship that can be achieved by any flotation process for the treatment of a given coal. An analogous to release analysis is the washability analysis for gravity-based separations. Dell introduced the concepts of release analyses in 1953 and refined the procedure in 1964 and 1972. To date, release analysis, which is conducted using a Denver flotation device, has been successfully used as a tool by preparation plant operators and researchers for evaluating the efficiency of new flotation technologies and for optimizing current flotation systems. However, Dell et al. (1972) recognized the fact that potentially better performances could be achieved by other flotation devices. "The (release) approach towards this absolute measurement is, however, a function of cell design, and it is yet impossible to say whether results even better than those with the Denver unit are possible."

In agreement with Dell's statement, the introduction of advanced flotation technologies has resulted in separation performances superior to that predicted by the traditional release analysis procedure. This fact was found to be especially true on the basis of pyritic sulfur rejection with single stage cleaning using the Packed-Column and multiple stage cleaning using other flotation column technologies. It is believed that the superior performance is due to an improvement in the hydrodynamic conditions in the flotation cell and to the utilization of selectivity mechanisms in the froth zone. Due to the inherent constraints associated with the Denver cell which prevent the use of deep froth depths, the phenomena, such as *reflux*, *selective detachment* and *froth washing* of entrained materials, are not easily achieved in the traditional release analysis process. It is believed that these deficiencies have resulted in several steady-state column flotation results being superior to the corresponding release data.

A theoretical simulation of the release analysis procedure conducted by the principal investigators supports the above statements that release analysis should be conducted with a flotation device providing a plug-flow hydrodynamic environment and a deep froth depth. Plug-flow conditions were found to provide a higher recovery of particles to the froth zone when compared to perfectly-mixed conditions, which is characteristic of the Denver conventional cell used in the release analysis procedure. It was also found that the selectivity between particles of varying hydrophobicity is best achieved in the froth phase where the selective detachment mechanism can be utilized. Deep froth depths provide more reflux and a separation performance approaching the optimum separation performance. Unfortunately, conventional cells do not support deep froth depths and, therefore, have limited ability to provide sufficient reflux. Since release analysis is based

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on selectivity, a flotation column apparatus is the desired separation device to replace the Denver cell for obtaining the optimum separation performance. Thus, the project objectives are: 1) to develop a new release analysis apparatus which will provide plug-flow conditions while allowing a significant froth reflux action; 2) to compare the optimum separation performance predicted by the modified release analysis procedure for the treatment of fine coal sample with that obtained by the traditional release and tree analyses, and washability analysis; 3) to compare the separation performances obtained for several coal samples using the proposed release procedure with the optimum recovery-grade curves obtained from the single-stage treatment provided by, Packed-Column flotation technology, which was found to produce the best separation performance among the six different flotation column technologies studied in a recently completed ICCI project. Achieving these objectives will result in a modified release analysis procedure which utilizes the advanced flotation mechanisms common to the modern flotation technologies and strategies being used today by coal preparation plant operators and researchers. Thus, a true optimum theoretical separation performance for any froth flotation process could be obtained for fine coal characterization.

During this reporting period, a modified coal flotation characterization procedure, termed as Advanced Flotation Washability (AFW) technique was developed. The new apparatus used for this procedure is essentially a batch operated 2-inch diameter, 5 ft tall packed-column, in which the feed slurry was continuously recirculated to avoid deposition of solid particles in the cell and to provide a feed flow counter-current to that of the air bubbles to effect superior bubble-particle collision. The cell was equipped with a PID controlled wash water system, which was mainly used to mobilize the deep froth in the cell and to adjust the pulp level to operate the cell at a desired froth depth to facilitate column reflux action.

The general approach used in the traditional release analysis for removing the hydrophilic mineral particles in the first stage and collecting the concentrate samples having varying degrees of hydrophobicity in the second stage was pursued in the AFW procedure to obtain an ultimate combustible recovery-grade curve representing the true flotation response of a coal sample. Several experiments were conducted using the AFW device on a relatively high sulfur, -100 mesh Illinois No. 5 run-of-mine coal sample collected from a local coal preparation plant. Initial experiments, which were conducted without the wash water system, concentrated on determining the optimum aeration rate and reagent dosages required for an efficient operation of the cell. In the subsequent experiments, a wash water system was integrated to the AFW device, in which the flow rate of the wash water was controlled using a pulp level controller. In other words, the wash water rate was equal to the water flow rate leaving the cell with the froth concentrate.

The performance curve improved by operating the device at a reduced aeration rate, which resulted in a very controlled flow of product from the lip of the column and thereby reduced the amount of pulp water recovered to the product launder. The wash water addition mobilized the froth zone and allowed an efficient operation of the cell.

However, even three flotation steps (i.e., rougher-cleaner-cleaner) conducted with a froth depth of about 3 ft in the first stage of the procedure were not sufficient to produce significant improvement in the performance curve generated in the second stage of the procedure. In addition, since the flotation steps in the first stage were conducted at a very low aeration rate to minimize the recovery of pulp water to the product launder and thereby reduce the problem of hydraulic entrainment, each step took about 2 to 3 hours for complete flotation, which is much longer than that required for steps followed in the traditional release procedure. Therefore, in a few of the later experiments, the flotation steps of the first stage were conducted using the conventional cell. The experiment completed with four flotation steps conducted at high solids content in the first step produced the best performance curve in the second stage conducted using the AFW device.

Similar coal characterization experiments were also conducted using the traditional release and tree analysis procedures. The best performance curve generated using the AFW technique was superior to those of the traditional procedures. While treating an Illinois No. 5 coal having an ash, total sulfur and pyritic sulfur contents of about 20%, 2.7% and 1.55%, respectively, the AFW procedure produced a product of 4.8% ash, 1.75% total sulfur and 0.97% pyritic sulfur at a combustible recovery value of 80%. In comparison, the optimum performance results obtained to date from the traditional procedures at the same combustible recovery are 5.6% ash, 2.05% total sulfur and 1.28% pyritic sulfur.

Several experiments are on-going and will be conducted in the next reporting period to solidify the AFW procedure and verify the above finding by conducting Anova analyses to determine the statistical significance of the difference in the performance achieved from the traditional and modified coal characterization procedures. The AFW procedure will be evaluated on a micronized sample obtained from the bulk Illinois No. 5 coal sample used in this investigation. In addition, multiple-stage cleaning tests will be conducted using a continuously operated Packed-Column to determine the significance of the results obtained from the AFW procedure.

OBJECTIVES

The goals of this project are to evaluate the current status of the release analysis procedure with respect to the advanced froth flotation technologies presently being introduced and to modify the traditional release analysis procedure so that a true theoretical optimum recovery-grade curve for any froth flotation process can be obtained from the analysis. In light of these goals, the project objectives are:

1. To develop a new release analysis apparatus which will provide plug-flow conditions while allowing a significant reflux action. The reflux action is critical for obtaining maximum separation performance.
2. To compare the optimum separation performance predicted by the proposed release analysis procedure for the treatment of a fine coal sample (-100 mesh) with that obtained by the traditional release and tree analyses, and washability analysis.
3. To compare the separation performances obtained for several coal samples using the proposed release procedure with the optimum recovery-grade curves obtained from the single-stage treatment provided by two advanced flotation systems, i.e., Packed-Column and Microcel.

Achieving these objectives will result in a modified release analysis procedure which utilizes the advanced flotation mechanisms common to the modern flotation technologies and strategies being used today by coal preparation plant operators and researchers. Thus, a true optimum theoretical separation performance for any froth flotation process could be obtained for fine coal characterization.

INTRODUCTION AND BACKGROUND

The release analyses procedure has long been used to predict the theoretically best separation performance that can be achieved by a flotation process for the treatment of fine coal. The release analysis for flotation is analogous to the washability analysis for gravity separation. The release procedure was originally introduced by Dell in 1953 as a new method for characterizing coal. The procedure, which utilizes laboratory conventional flotation cells, was revised by Dell in 1964 and by Dell et al. in 1972. The separation performance results obtained by release analysis is commonly used by preparation plant operators and researchers to evaluate new technologies and to optimize current flotation processes. However, the introduction of column flotation technology has created some controversy with the release analysis process which can be attributed to better hydrodynamic conditions and the advanced flotation mechanisms utilized by flotation columns.

The release analysis procedure is a two phase process. In the first phase, hydrophobic particles are separated away from hydrophilic particles by repetitive flotation of the

concentrate to remove the entrained material. The key to the success of the first phase is to ensure complete flotation of the hydrophobic material while removing all of the entrained material. This must be accomplished while minimizing the amount of frother and collector additions. Excessive chemical additions result in a reduction in the selectivity of the second phase, which was confirmed in a study reported by Pratten et al. (1989). In this study, the release procedure was compared to another procedure known as the *tree analysis*. This procedure is similar to release analysis in that it uses conventional flotation cells to treat and retreat tailings. The apparent advantage of the tree procedure is its insensitivity to collector dosages at the low product ash region.

The second phase of the release procedure involves the separation of the hydrophobic particles comprising the first phase concentrate into fractions varying in their degrees of hydrophobicity. The ash content in coal particles typically increases with a decrease in surface hydrophobicity. Thus, a recovery-grade curve can be developed based on floatability. The first cleaning stage of Phase II in the release procedure is performed under starvation conditions (i.e., low aeration rate, low impeller speed and low chemical additions) to float the most hydrophobic particles. The conditions are then improved by increasing the amount of air which ideally floats the particles having the next highest degree of floatability. This process is continued until all of the coal has been floated and a total of 5 clean coal products and 1 tailings sample has been produced. A flowsheet of the release analysis process and the results obtained from a typical analysis are shown in Figure 1.

This procedure has been found to be very successful for comparisons with in-plant conventional cell plant. However, there are numerous reports of column flotation data out performing the release analysis, which is considered as being theoretically impossible. This phenomena may be due to the high mixing conditions of the conventional cell which is used to conduct the release analysis. This is compared to the near-plug flow conditions that are achieved in laboratory flotation columns. The Packed-Column, which is completely filled with corrugated plates spaced at 1/4-inch apart, is one column that consistently out performs the release analysis in the low ash content-low recovery region. Figure 2 shows a comparison of the results obtained by the principal investigators from the treatment of two different coals by the release analysis procedure and the Packed-Column. As shown, the Packed-Column produced cumulative product ash contents that were 1% to 2% lower than those achieved by release analysis in the low recovery region. Results showing a superior performance by the Packed -Column were also reported in a round-robin testing program conducted by the U. S. Department of Energy (Killmeyer et al., 1989). These findings are most likely due to the improved hydrodynamic conditions provided by the large length-to-diameter ratios of the column and the deep froth depths that provide better selectivity through drainage and selective detachment mechanisms.

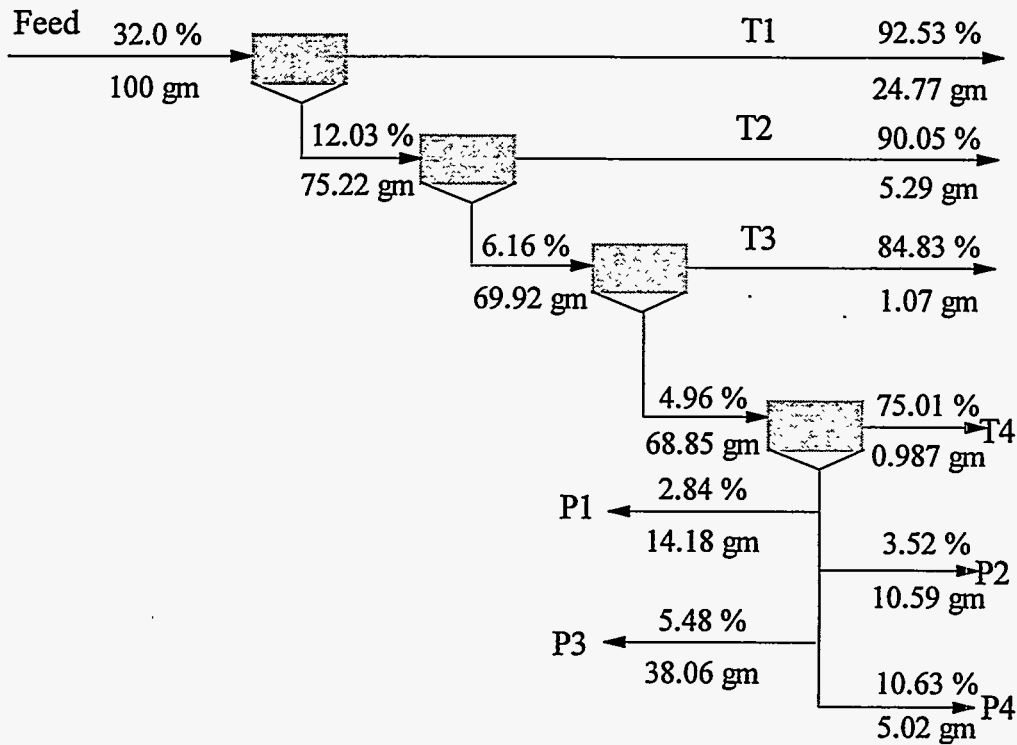


Figure 1. Step-by-step analysis of results obtained from a traditional release analysis conducted on a -65 mesh Illinois No. 6 coal sample.

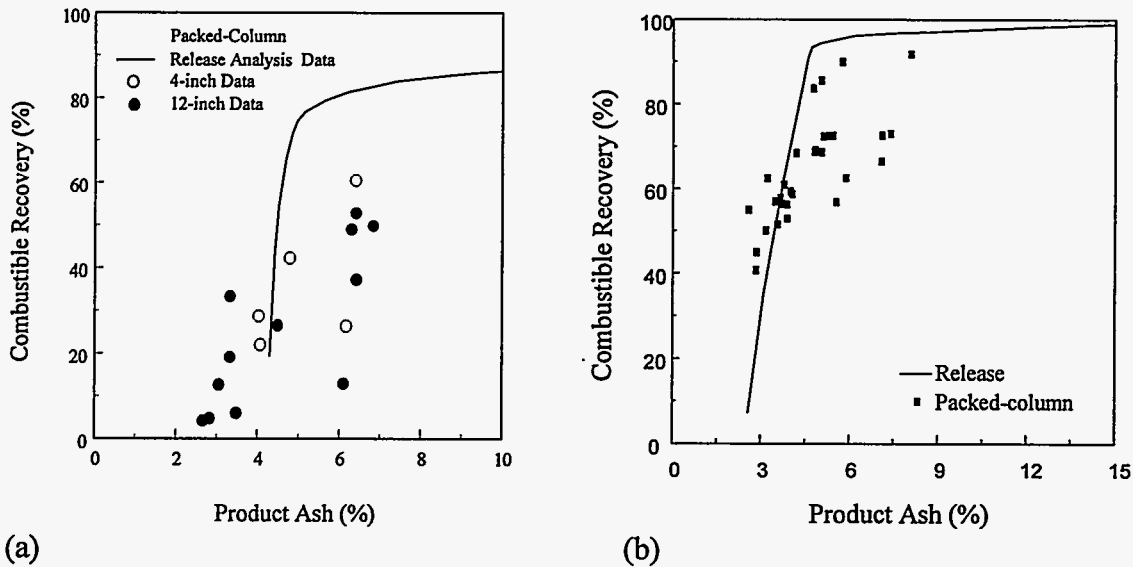


Figure 2. Flotation results showing the superior performance of the Packed-Column over that achieved by the traditional release analysis in the low recovery-low ash content region. Fine coal samples (-100 mesh) treated were from the (a) Paradise Preparation Plant and (b) Illinois No. 5 coal seam.

EXPERIMENTAL PROCEDURES

Sample

Three fifty-five gallon drums of dry Illinois No. 5 run-of-mine coal sample were collected from a local preparation plant to be used in the present investigation. The samples were crushed using a laboratory jaw crusher and a hammermill to obtain a -100 mesh product which was split into representative lots of about 5 lbs each and placed into storage bags. The sample bags were stored at -20°C to minimize surface oxidation of the coal particles. The coal sample was found to have ash, total sulfur and pyritic sulfur contents of 19.9%, 2.75% and 1.53%, respectively. Size-by-size sample characterization data are provided in Table 1.

Table 1. Size-by-size analysis data of the -100 mesh run-of mine Illinois No. 5 coal seam sample used in the present investigation.

Size Class (mesh)	Weight (gm)	Weight (%)	Cum. Wt. (%)	Ash (%)	Sulfur (%)
+200	83.0	35.8	100	14.8	2.61
200x325	57.5	24.8	64.2	15.6	2.68
325*400	7.00	3.0	39.4	16.1	3.03
-400	84.2	36.3	36.3	28.3	2.90
Total	231.7	100		19.9	2.75

AFW Apparatus

During this reporting period, a modified coal flotation characterization procedure, termed as Advanced Flotation Washability (AFW) technique was developed which used a flotation column in place of a conventional cell to measure the true flotation response of a coal sample. The new apparatus, as shown in Figure 3, consists essentially of a batch operated 2-inch diameter and about 5 ft long packed-column, in which the feed slurry was continuously recirculated to avoid deposition of solid particles in the cell and to provide a feed flow counter-current to that of the air bubbles to effect superior bubble-particle collision. The air was blown through a flow meter directly into the cell. The cell is equipped with a proportional, integral and derivative (PID) controlled wash water system mainly to mobilize the deep froth in the cell and to conveniently adjust the pulp level to operate the cell at a desired froth depth. When the flotation process begins the froth concentrate starts reporting to the product launder which lowers the pulp level in the cell. This reduction in the cell pulp level is received by a pressure transducer set at the lower section of the column, which activates a PID controller to send a constant analog signal to a peristaltic pump which pumps in wash water to the cell at a very slow rate, and thus maintains the pulp at a desired level.

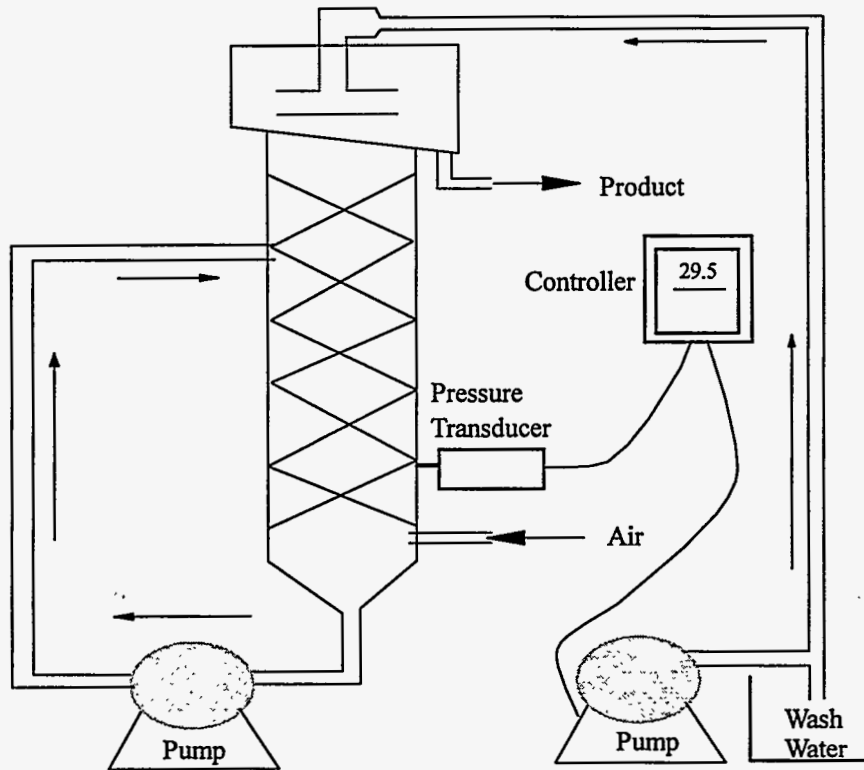
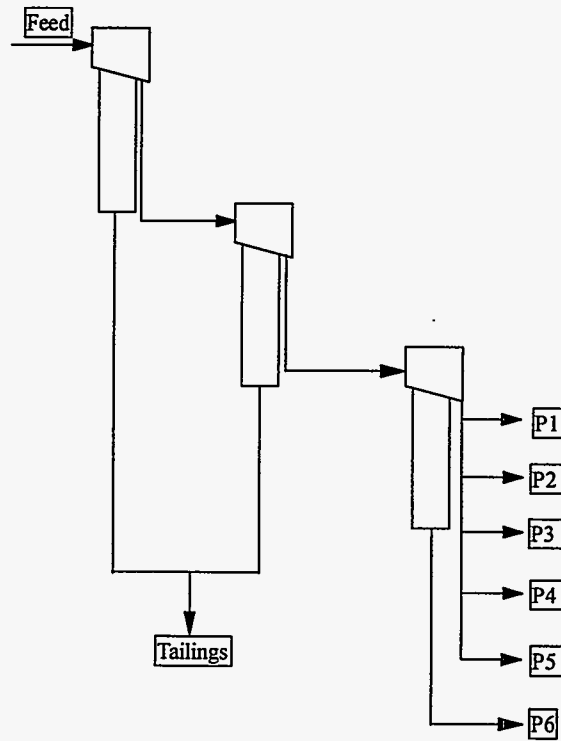


Figure 3. A schematic of the experimental apparatus used to conduct the AFW procedure.

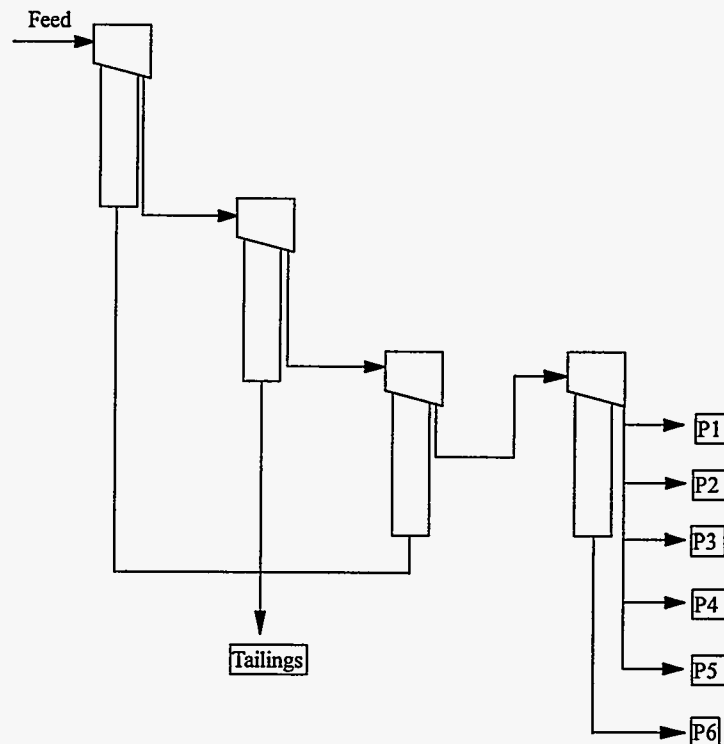
AFW Procedure

The traditional release analysis approach of attempting to remove all the hydrophilic mineral particles in the first stage and collect concentrate samples having varying degrees of hydrophobicity in the second stage was also pursued in the AFW procedure. The first stage of the procedure consisted of two to three flotation steps as shown in Figures 4-(a) and (b), which were conducted with the addition of desired amount chemical reagents to separate the hydrophilic mineral particles from the hydrophobic coal particles. The tailings obtained from each step of the first stage were mixed together to form the final tailings. The froth concentrate collected from the first stage, which is considered to be composed of only hydrophobic particles is segregated into about six different fractions according to a decreasing order of hydrophobicity by varying the aeration rate from 1.5 lpm to about 5 lpm and a deep froth of about 3 ft. to facilitate a superior column reflux action.

Several tests were conducted initially to determine the optimum amount of air required in each flotation step of the first stage to ensure proper flow of froth concentrate and at the same time to minimize the pulp water recovery to the product launder. The chemical



(a)



(b)

Figure 4. A schematic illustration of the step-by-step AFW procedure.

reagent dosages were also varied to arrive at an optimum level to ensure a complete flotation of all the hydrophobic particles in the first stage. The step-by-step configuration and the operating parameter values used in the first step of some of the important tests are listed in Table 2. As shown, the first four experiments were conducted using the configuration types illustrated in Figures 4(a) and (b). For experiment 5 and 7, the flotation steps in the first stage were conducted using the Denver cell, whereas experiment 6 started by segregating the feed into three initial fractions using the AFW device and then separately floating the three fractions using variable amount of air to obtain a series of concentrate samples of varying degrees of hydrophobicity.

Table 2. A summarized list operating parameter values used in the first stage of several important experiments conducted using the AFW procedure.

Test #	Configuration	Collector (lb/ton)	Frother (lb/ton)	Air (lpm)	Froth Height (ft)	Wash Water
1	Figure 4-b	1.0	0.88	4	1.5	No
2	Figure 4-a	1.39	0.88	2	2.0	Yes
3	Figure 4-b	1.70	0.66	2	2.5	Yes
4	Figure 4-b	1.70	0.66	2	2.5	No
5	Denver cell	2.0	0.88	-	-	No
6	Fractionation	0.55	0.66	2	2.5	Yes
7	Denver cell	2.58	0.88	-	-	Yes

Similar coal characterization experiments were also conducted using the traditional release and tree analysis procedures using conventional cells.

RESULTS AND DISCUSSION

Work in this reporting period concentrated on developing a modified coal flotation characterization procedure, termed as Advanced Flotation Washability (AFW) technique. Several experiments were conducted using the AFW device on a relatively high sulfur, -100 mesh Illinois No. 5 run-of-mine coal sample collected from a local coal preparation plant. Similar coal characterization experiments were also conducted using the traditional release and tree analysis procedures, to compare the flotation response curves generated with that obtained from the AFW procedure.

The AFW flotation response data points generated from the ash analysis results are shown in Figure 5 (a). As shown, Test 1 and Test 6 provide inferior flotation response data points. Test 1 was conducted at a relatively high aeration rate of 4 lpm through out the entire first stage of the procedure. Although, high aeration provided a better froth mobility, apparently, it helped recover a significant amount of pulp water along with the froth concentrate, which in turn, affected the product quality in the second stage. The fractionation technique that was used for Test 6, most-likely required more cleaning steps. This technique will be further investigated in the next reporting period. The

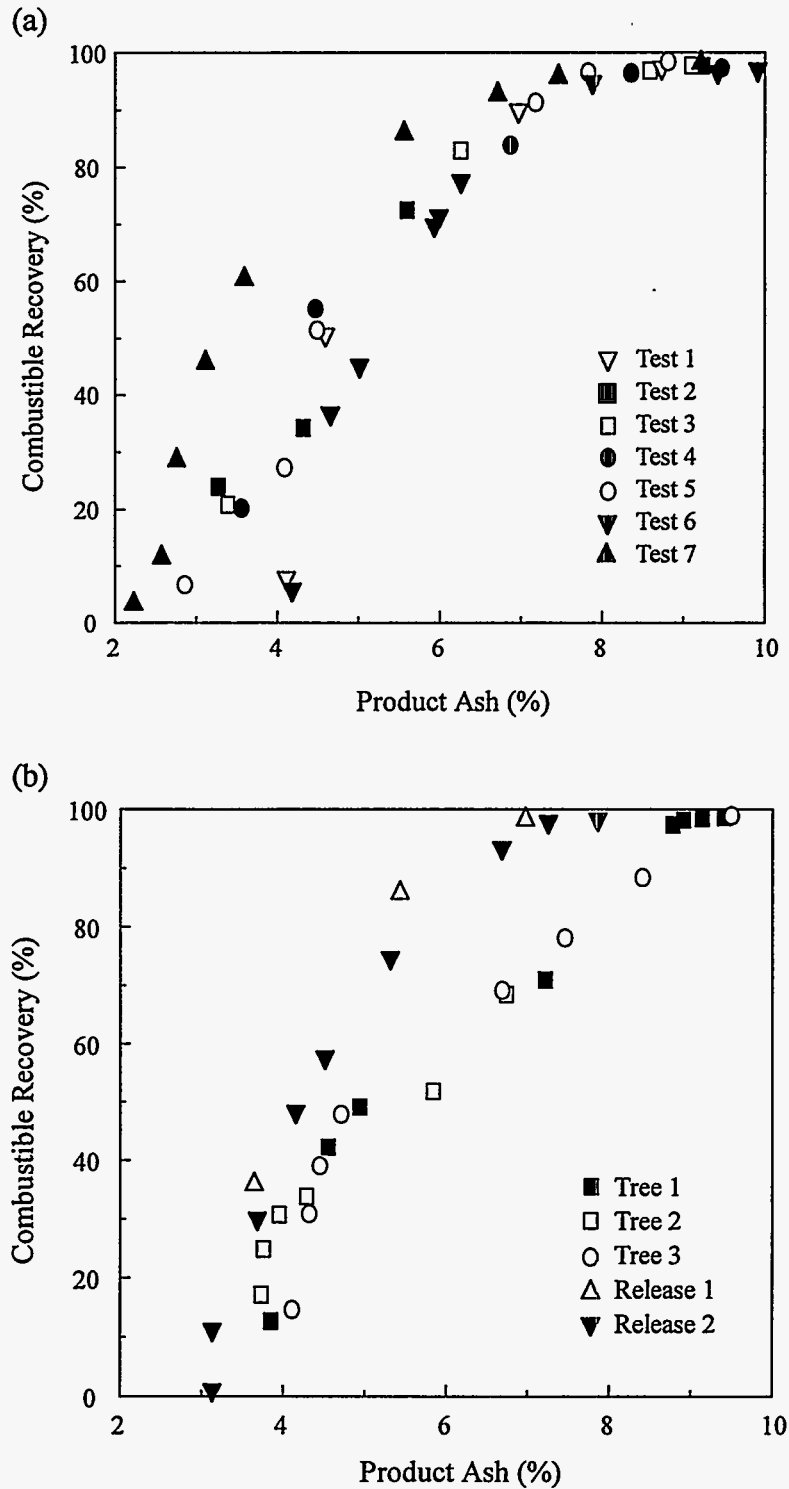


Figure 5. The flotation response data-points generated from the a) AFW experiments and b) traditional tree and release experiments conducted on an -100 mesh Illinois No. 5 coal sample the basis of ash analysis; feed ash: 19.9%.

flotation response data points generated from Test 2, 3 and 4 are fairly close to each other although, Test 2 was conducted using only two flotation steps, whereas Test 3 and 4 used three flotation steps in the first stage. Test 7 was clearly the best performance that was obtained from the AFW procedures, where the removal of hydrophilic particles performed in the first stage of the process was conducted at a high solids content using a Denver cell. Most likely, a high solids content environment maintained for the first stage minimized the proportion of hydraulically entrained mineral particles to the froth concentrate significantly and provided a clean concentrate to be fractionated according to their degree of hydrophobicity in the second stage.

The flotation response data-points obtained from the traditional procedures using the Denver cell are presented in Figure 5 (b). As shown, the tree procedures consistently produced inferior performance in the high recovery-high ash region of the combustible recovery-grade curve. Since a substantial portion of the combustibles in the tree procedure is recovered in the scavenger flotation steps, the heavy middling type particles tend to report to the concentrate, which considerably raise the ash content of the concentrate. In addition, elimination of hydraulic entrainment in the tailings flotation steps is extremely difficult. These phenomena are believed to cause the high ash contents of the products generated from the scavenger steps of the tree procedure, which negatively affects the overall grade-recovery curve. However, since during the present study, a substantial improvement in the release analysis performance has been obtained by starting with a high solid contents flotation environment, similar approach will be investigated for the tree procedure in the next reporting period.

Filtering the first stage product before retreating it in the second stage have been found to be very beneficial, which was observed towards the end of this reporting period. This filtering process eliminates some of the excess reagents that is dissolved in the feed water, which improves the selectivity in the second stage. In addition, this process also eliminates the pre-existing bubble-particle attachment in the froth concentrate obtained from the first stage, which helps provide a better selectivity in the second stage of the procedure. This observation will be investigated in a more systematic manner in the next reporting period.

Figure 6 presents the flotation response data points obtained from both conventional and AFW procedures on the basis of the available total sulfur analysis results. As clearly shown, the sulfur content of the products obtained from the entire series of AFW experiments are superior to those obtained from the traditional procedures. This consistency in the low sulfur content, which is a result of efficient rejection of coal pyrites is a clear indication of the superior selectivity provided by the column reflux mechanism and a superior mixing condition prevailing in the AFW device.

Figures 7 and 8 (a) - (b) compare the best flotation response obtained from AFW procedure to that obtained from the traditional procedures on the basis of ash, total sulfur and pyritic sulfur analysis results. The AFW procedure clearly demonstrates its superiority over the conventional procedures which is believed to be occurring because of

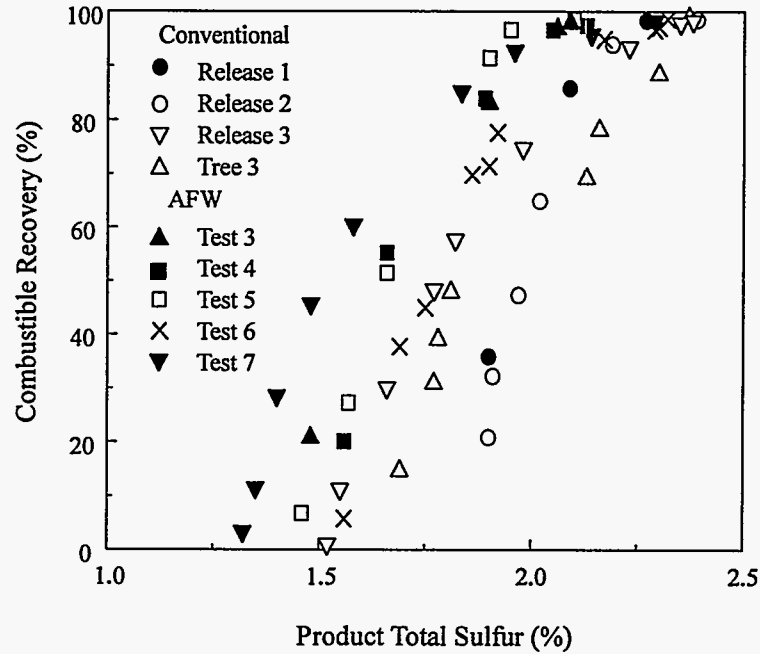


Figure 6. A comparison of the flotation response data-points generated from the AFW experiments and traditional tree and release experiments on conducted on an -100 mesh Illinois No. 5 coal sample the basis of total sulfur analysis. Feed total sulfur: 2.75%.

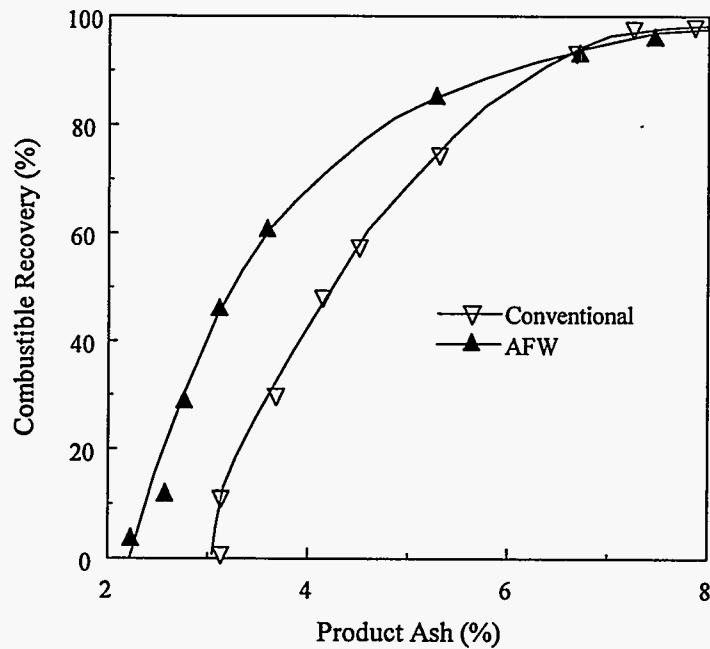
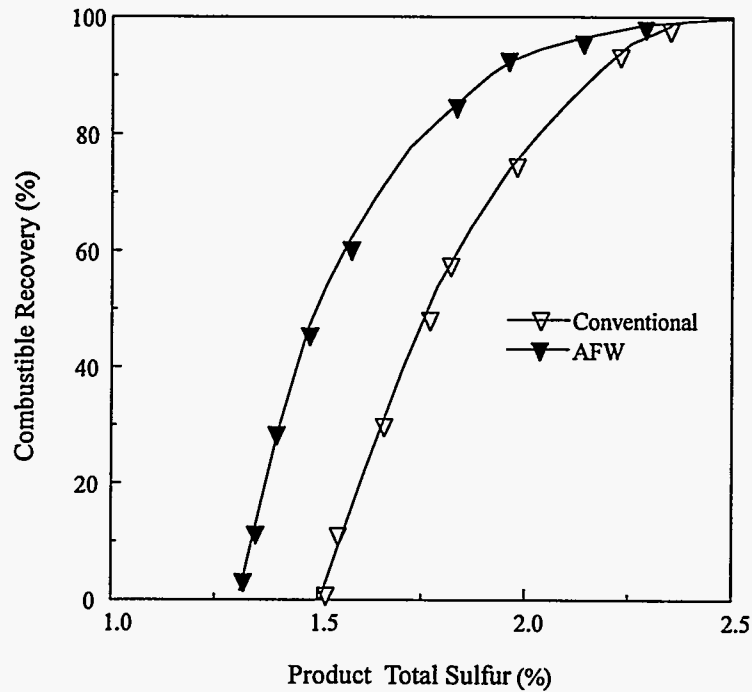


Figure 7. A comparison of the best flotation response curve generated from the conventional release and AFW procedures on the basis of product ash content obtained from the treatment of an -100 mesh Illinois No.5 coal sample; feed ash = 19.9%.

(a)



(b)

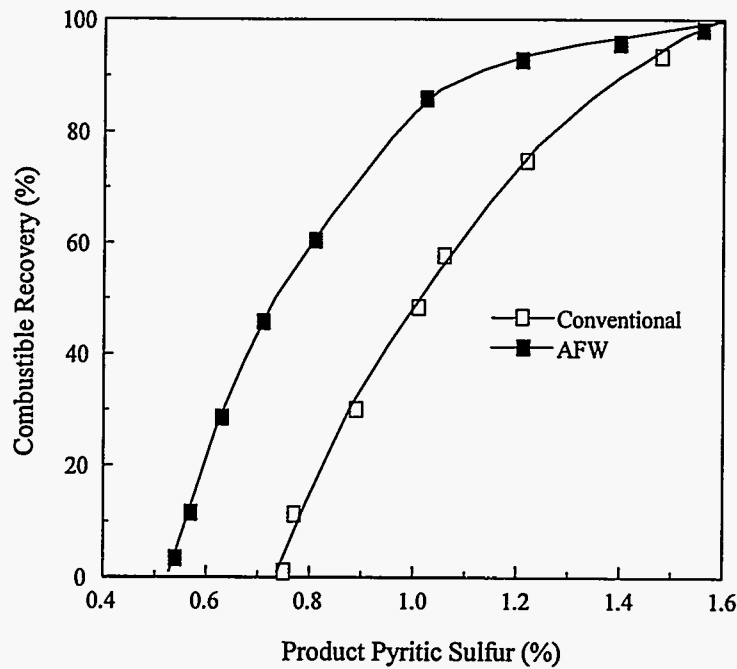


Figure 8. A comparison of the best flotation response curve generated from the conventional release and AFW procedures on the basis of a) total sulfur and b) pyritic sulfur results obtained from the treatment of an -100 mesh Illinois No.5 coal sample; feed total sulfur and pyritic sulfur contents are 2.75% and 1.55%, respectively.

the advanced flotation mechanisms provided by the AFW device. While treating an Illinois No. 5 coal having an ash, total sulfur and pyritic sulfur contents of about 20%, 2.7% and 1.55%, the AFW procedure produced a product of 4.8% ash, 1.75% total sulfur and 0.97% pyritic sulfur at a combustible recovery value of 80%. On the other hand, the best performance obtained so far from the traditional procedures at the same combustible recovery is 5.6% ash, 2.05% total sulfur and 1.28% pyritic sulfur. While the AFW procedure demonstrates its clear superiority, it must be realized that several possible means of improving the process is still on-going and it is believed that the performance can be enhanced. These possible improvements will be investigated during the next reporting period.

CONCLUSIONS AND RECOMMENDATIONS

Conclusions

Based on the analysis of the test results obtained during this reporting period, the following conclusions were derived:

1. The Advanced Flotation Washability (AFW) procedure developed in this investigation provides a superior separation performance when compared to the conventional and modified release analysis procedures. The largest difference in separation performance was obtained on the basis of product pyritic sulfur content which is most likely due to the apparent natural floatability of the coal pyrite particles. At 80% combustible recovery, a 19% improvement in the reduction of pyritic sulfur was obtained from the AFW technique when compared to the optimum result achieved using the release analysis procedure. In addition, the product ash content was reduced from the 5.6% content obtained from release analysis to 4.8% using the AFW method.
2. The results obtained to date using the tree analysis procedure are significantly inferior in the high recovery region of the performance curve. This finding has been obtained from several experiments using the tree procedure. Since this finding was not expected, work will continue during the next reporting period to ensure that the optimum curve is obtained from the tree procedure.
3. The feed solids content used in the AFW and conventional procedures was found to significantly affect the separation performance curve. The optimum results achieved in this study were obtained at a relatively high solids content of 20% by weight. The performance curves generated at a 10% feed solids content were substantially inferior to those achieved at 20% solids content. This is believed to be due to an enhancement in the competitive environment in the flotation process which improves the separation results as discussed in a previous quarterly report.
4. An additional step involving the filtration of the froth concentrate from the first phase of separation (i.e., separation of hydrophobic from hydrophilic material) was found to

improve the separation performance curve of the AFW and release analysis methods, especially in the low recovery region of the curve. This is likely due to the elimination of the pre-existing bubble-particle attachment. Also, the filtration step removes the excess chemical added to float the hydrophobic particles during the flotation steps in the first phase.

Recommendations

The followings represent recommendations or future work plans for the upcoming reporting period which are based on the findings presented in this report:

1. The repeatability of the AFW procedure will be statistically evaluated by conducting several tests using the same optimum process parameter values once the most appropriate values and procedure are determined.
2. An ANOVA analysis will be conducted to determine the statistical significance of the differences between the separation performance results obtained from the AFW and conventional techniques.
3. The results obtained to date from the Tree procedure have been significantly inferior to those achieved from the release analysis. Thus, additional tests must be performed to ensure that the optimum curve is obtained for the tree analysis.
4. Washability and scanning electron microscope analyses of the various products from the AFW and conventional methods need to be conducted to fully explain the improved performance achieved from the AFW procedure.
5. Multiple stage cleaning tests using a continuous Packed-Column will be conducted to determine if the performance curve obtained from the AFW technique represents the "optimum" performance that can be achieved from any froth flotation process.

DISCLAIMER STATEMENTS

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REFERENCES

- Adel, G. T., 1994. Personal communications.
- Ahmed, N. and Jameson, G. J., 1989. "Flotation Kinetics," *Mineral Proc. & Extract. Metal.*, Vol. 5, pp. 77 - 99.
- Arnold, B. J., and Aplan, F. F., 1989. "The Hydrophobicity of Coal Macerals," *Fuel*, Vol. 68, pp. 651 - 657.
- Crelling, J., 1995. Personal communications.
- Dell, C. C., 1957. "Determination of Froth-Flotation-Washability Data," *J. Inst. Fuel*, Vol. 30, pp. 523 - 526.
- Dell, C. C., 1964. "Procedure for Determining Coal Washability," *J. Inst. Fuel*, pp. 149 - 150.
- Dell, C. C., Bunyard, M. J., Rickelton, W. A., and Young, P. A., 1972. "Release Analysis: A Comparison of Techniques," *Transactions, Mining and Metallurgy*, C89 - C96.
- Forrest, W. R., Adel, G. T., and Yoon, R.-H., 1994. "Characterizing Coal Flotation Performance Using Release Analysis," *Coal Preparation*, Vol. 14, pp. 13 - 27.
- Killmeyer, R. P., Hucko, R. E., and Jacobson, P. S., 1989. "Interlaboratory Comparison of Advanced Froth Flotation Processes," *Proceedings, Society of Mining Engineers Annual Meeting, Las Vegas, Nevada, February 27 - March 4.*

Mohanty M.K. and Honaker R.Q., 1994: unpublished data.

Nicol, S.K., Bennisley, C.N., The, K.C. and Firth, B.A., 1983. "The estimation of coal flotation response. In: W. Membrey (Editor), Proc. Congr. Improving Froth Flotation of Coal. Australian Coal Industry Research Laboratories, pp. 116-134.

Parekh, B. K., 1994. Pittsburgh Coal Conference, presentation.

Pratten, S. J., Bensley, C. N., and Nicol, S. K., 1989. "An Evaluation of the Flotation Response of Coals," *Inter. J. Mineral Proc.*, Vol. 27, pp. 243 - 262.

Speight, J. G., 1994. The Chemistry and Technology of Coal (Marcel and Dekker, New York, New York) pp. 83 - 101.

Yoon, R.-H., and Luttrell, G. H., 1989. "The Effect of Bubble Size on Fine Particle Flotation," *Mineral Proc. & Extract. Metal.*, pp. 101 - 122.

PROJECT MANAGEMENT REPORT
March 1 1996, through May 31, 1996

Project Title: **A MODIFIED RELEASE ANALYSIS PROCEDURE USING
ADVANCED FROTH FLOTATION MECHANISMS**

DOE Cooperative Agreement Number:	DE-FC22-92PC92521 (Year 4)
ICCI Project Number:	95-1/1.2B-1P
Principal Investigator:	R. Q. Honaker Department of Mining Engineering Southern Illinois University at Carbondale
Other Investigator:	M. K. Mohanty Department of Mining Engineering Southern Illinois University at Carbondale
Project Manager:	K. Ho, ICCI

COMMENTS

None.

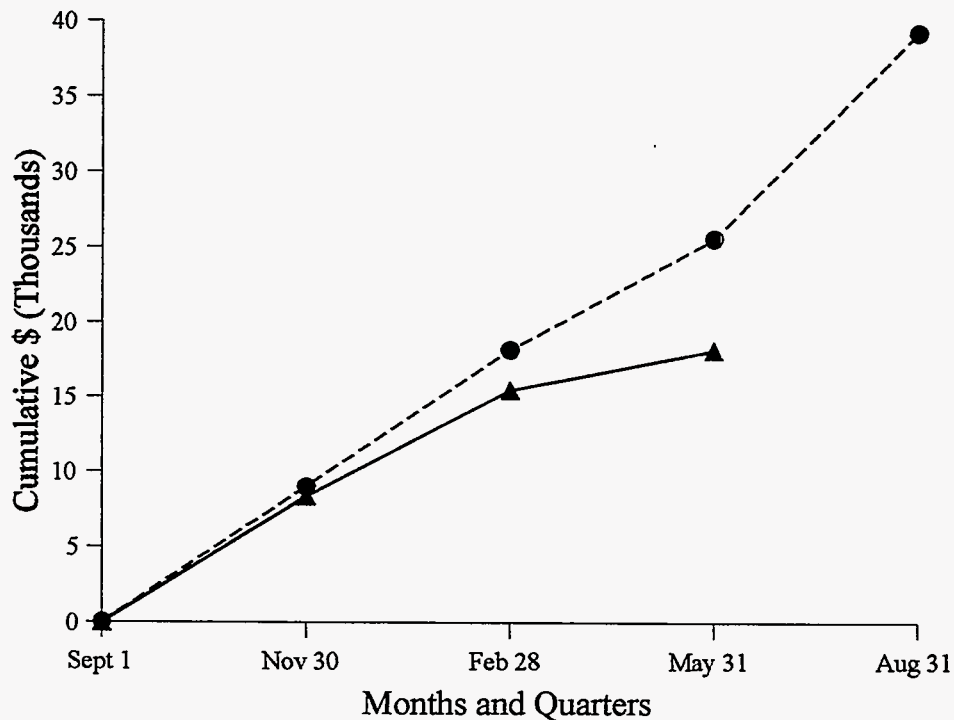
PROJECTED AND ESTIMATED EXPENDITURES BY QUARTER

Quarter*	Types of Cost	Direct Labor	Fringe Benefits	Materials and Supplies	Travel	Major Equipment	Other Direct Costs	Indirect Cost	Total
Sept. 1, 1995 to Nov. 30, 1995	Projected	2,925	1,111	700	0	1,500	2,000	824	9,060
	Estimated	5,577	1,340	738	0	0	0	766	8,421
Sept. 1, 1995 to Feb. 28, 1996	Projected	5,850	3,332	1,400	500	1,500	4,000	1,658	18,240
	Estimated	11,154	2,233	738	0	0	227	1,179	15,531
Sept. 1, 1995 to May 31, 1996	Projected	8,775	4,443	2,100	500	1,500	6,000	2,332	25,650
	Estimated	11,154	2,679	1,282	625	263	532	1,645	18,180
Sept. 1, 1995 to Aug. 31, 1996	Projected	16,866	5,543	2,800	1,000	1,500	8,000	3,571	39,280
	Estimated								

*Cumulative by Quarter

CUMULATIVE COSTS BY QUARTER

A Modified Release Analysis Procedure Using Advanced Froth Flotation Mechanisms

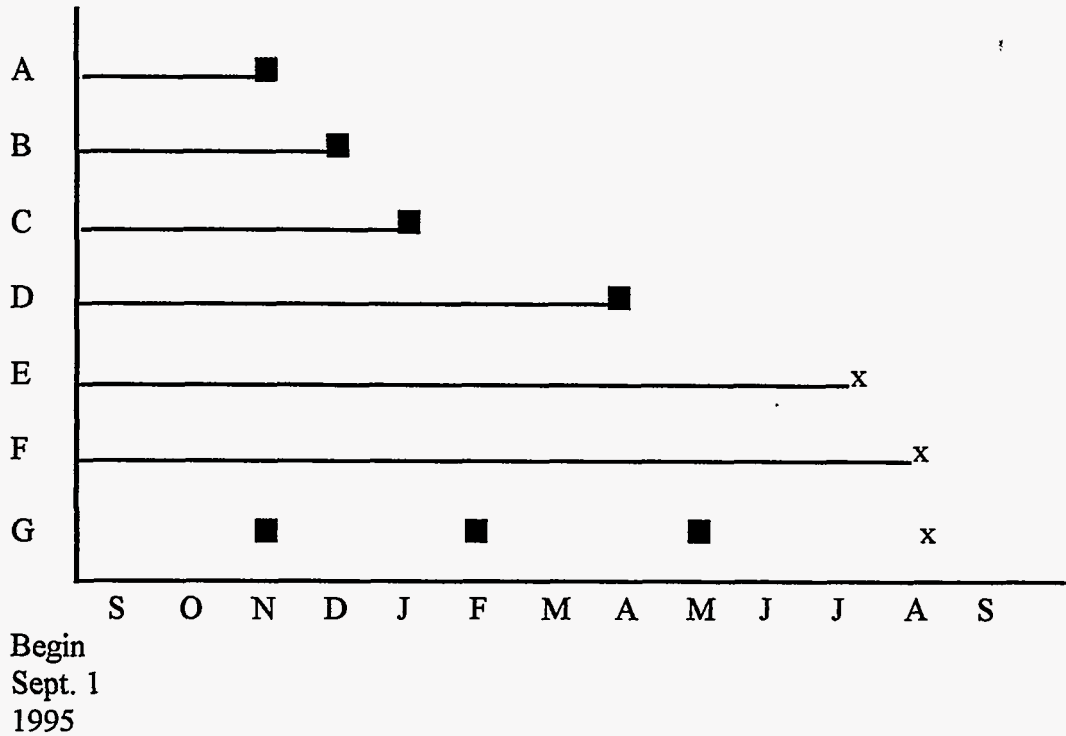


● = Projected Expenditures - - - - -

▲ = Actual Expenditures _____

Total Illinois Clean Coal Institute Award \$39,280

SCHEDULE OF PROJECT MILESTONES



Hypothetical Milestones:

- A: Equipment ordered and received
- B: Sample Acquisition and Characterization (Task 1)
- C: Construction of Release Analysis Apparatus (Task 2)
- D: Procedure Development for Modified Release Analysis (Task 3)
- E: Comparison with Traditional Methods (Task 4)
- F: Comparison with Advanced Flootation Technologies (Task 5)
- G: Reporting

Comments:

None.