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QUARTERLY TECHNICAL PROGRESS REPORT 15
APRIL - JUNE, 1996

# ENGINEERING DEVELOPMENT OF ADVANCED PHYSICAL FINE COAL CLEANING FOR PREMIUM FUEL APPLICATIONS

Prepared for
U. S. Department of Energy
Pittsburgh Energy Technology Center
Pittsburgh, Pennsylvania 15236

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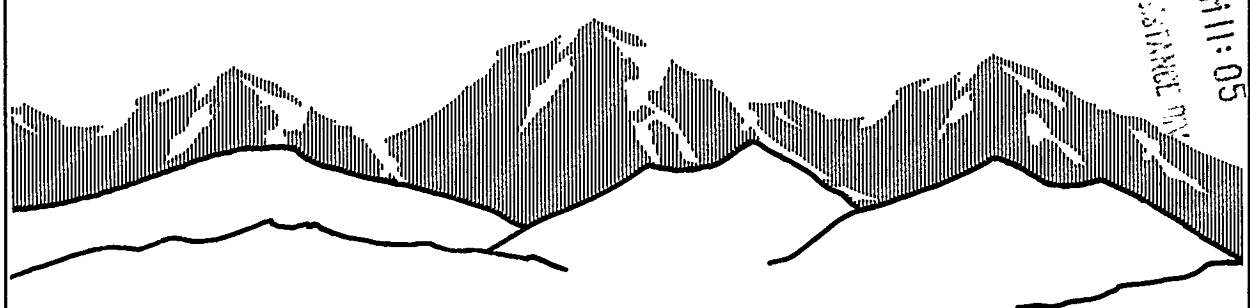

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# ABSTRACT

The primary goal of this project is the engineering development of two advanced physical fine coal cleaning processes, column flotation and selective agglomeration, for premium fuel applications. The project scope includes laboratory research and bench-scale testing on six coals to optimize these processes, followed by the design, construction, and operation of a 2-t/hr process development unit (PDU). The project began in October, 1992, and is scheduled for completion by September 1997.

During Quarter 15 (April - June 1996), parametric testing of the 30-inch Microcel™ flotation column at the Lady Dunn Plant under Subtask 3.2 was completed and clean coal samples submitted for briquetting tests. A paper describing the work at Lady Dunn was presented at the Coal Prep '96 Conference. Subtask 3.3 testing, investigating a novel Hydrophobic Dewatering process, continued at Virginia Tech with emphasis on the determination of butane losses due to absorption onto the coal surface.

Under Subtask 6.4, the benefits of slurry PSD (particle size distribution) modification and pH adjustment were evaluated for the Taggart and Hiawatha coals. Results indicate that only small improvements in loading can be obtained by further PSD modifications and that the adjustment of slurry pH had little effect on the slurry loading/viscosity relationship

Subtask 6.5 agglomeration bench-scale testing results confirmed that with the new sample of Taggart coal, the 1 lb/MBtu product ash specification can be achieved at a grind with a $d_{80}$ of approximately 33 microns. Similarly, it was also determined that a grind with a $d_{80}$ of approximately 65 microns of the Hiawatha coal meets the 2 lb/MBtu product ash specification.

Under Subtask 8.4, the PDU Flotation Module operations continued. During this quarter, optimization of the Taggart coal was completed, as well as the development of associated regression equations. Work was also performed with the Taggart coal to better determine scale-up similitude between the 12-inch and 6-foot Microcel™ columns. Testing of the Indiana VII coal also commenced.

Construction of the PDU selective agglomeration module continued under Subtask 9.1, with construction approximately 55 percent complete. All required equipment, with the exception of some instruments, have been purchased.

Under Task 11, work on the project final report began with the development of design criteria for the conceptual plants to be used as the basis for the economic assessment of both the advanced flotation and selective agglomeration technologies.

# EXECUTIVE SUMMARY

This project is a major step in the Department of Energy's (DOE) program to show that ultra-clean coal-water slurry fuel (CWF) can be produced from selected coals and that this premium fuel will be a cost-effective replacement for oil and natural gas now fueling some of the industrial and utility boilers in the United States, as well as for advanced combustors currently under development. The replacement of oil and gas with CWF can only be realized if retrofit costs are kept to a minimum and retrofit boiler emissions meet national goals for clean air. These concerns establish the specifications for maximum ash and sulfur levels and combustion properties of the CWF.

This multi-year cost-share contract started on October 1, 1992, and is scheduled for completion by September 1997. This report discusses the progress made during the 15th quarter of the project from April 1 to June 30, 1996.

## SPECIFIC OBJECTIVES OF PROJECT

The project has three major objectives:

- The primary objective is to develop the design base for prototype commercial advanced fine coal cleaning facilities capable of producing ultra-clean coals suitable for conversion to coal-water slurry fuel for premium fuel applications. The fine coal cleaning technologies are advanced column flotation and selective agglomeration.
- A secondary objective is to develop the design base for near-term application of these advanced fine coal cleaning technologies in new or existing coal preparation plants to efficiently process minus 28-mesh coal fines and convert them to marketable products in current market economics.
- A third objective is to determine the removal of toxic trace elements from coal by advance column flotation and selective agglomeration technologies.

## APPROACH

The project team consists of Cyprus Amax Minerals Company through its subsidiaries Amax Research & Development Center (Amax R&D) and Cyprus Amax Coal Company (Midwest and Cannelton Divisions), Arcanum Corporation, Bechtel Corporation, Center for Applied Energy Research (CAER) of the University of Kentucky, and the Center for Coal and Mineral Processing (CCMP) of the Virginia Polytechnic Institute and State University. Entech Global manages the project for Amax R&D and provides research and development services. Dr. Douglas Keller of Syracuse University and Dr. John Dooher of Adelphi University are both consultants to the project. Mech EL Contracting, Inc. of Aurora, Colorado, is constructing the Process Development Unit (PDU) Selective Agglomeration Module.

The project effort has been divided into four phases which are further divided into eleven tasks including coal selection, laboratory and bench-scale process optimization research and testing, along with design, construction, and operation of a 2 ton/hr PDU. Tonnage quantities of the ultra-clean coals will be produced in the PDU for combustion testing. Near-term applications of advanced cleaning technologies to existing coal preparation plants is also being studied.

## ACCOMPLISHMENTS DURING QUARTER

Activity continued during April - June 1996 on Phases I, II, and III of the project. Work was carried out under Tasks 3, 6, 8, 9, and 11 as described below.

## Task 3 Development of Near-Term Applications

A 1993 Bechtel engineering analysis evaluating potential column flotation and selective agglomeration applications found a column flotation application at the Lady Dunn Preparation Plant particularly attractive since the plant was being considered for a major capacity expansion. Because of the potential advantages of installing column flotation rather than mechanical flotation cells in the expanded fine coal cleaning circuit, Lady Dunn management was pleased to offer their plant as the study site for a near-term application of column flotation. The Microcel™ flotation column was selected for this study and the Center for Coal and Mineral Processing (CCMP) at Virginia Tech was assigned the responsibility for the on-site test work. Subtask 3.3, investigating a novel dewatering process for advanced flotation products is also being performed by CCMP.

### *Subtask 3.2 Engineering Development*

As described in previous Quarterly Reports, an existing 30-inch diameter Microcel™ flotation column was refurbished and installed in the Lady Dunn Plant. A high-quality product of about 8 to 10% ash was produced at approximately 80 to 85% combustible matter recovery. Based on these results, Cannelton included column flotation in its 1996 plant expansion. In the meantime, parametric testing continued to quantify the flotation characteristics of coarse coal particles (0.75 x 0.15 mm) in the feed to the column.

Parametric testing was completed this reporting quarter. The test matrix was of a Box-Behnkin design and utilized a low, medium, and high setting for each of feed rate, air volume, and frother dosage. Feed, product, and tails samples were collected for each of the 15 test points. Each sample was then screened at six sizes and each size fraction analyzed for ash.

Preliminary results indicate some interesting relationships for the variables tested (feed rate, frother dosage, and air volume). It is generally considered that recovery increases with a decrease in feed rate, increase in frother, and increase in air volume. Turbulence, however, plays a significant role with coarse coal recovery and this appears to be the case for this test work. At the higher feed rate, the recovery remained relatively high until the frother dosage or air volume was increased above some optimal point, in which case the recovery dropped off. It is believed that the higher turbulence resulting from bubbles rising against a higher downward flow may have caused the lower recoveries.

A portion of the clean coal from this parametric testing was submitted to Tra-Det Inc., of Triadelphia, West Virginia, for binderless briquetting tests. Good quality specimens of the briquette production were returned by Tra-Det who will be issuing a test report describing the briquetting work in the near future.

The near-term advanced flotation testing at the Lady Dunn Plant was described in a presentation at the Coal Prep '96 Conference on April 30. The title of the presentation was "The Evaluation of Column Flotation for Fine Coal Cleaning at the Lady Dunn Preparation Plant," and co-authors were Mahesh C. Jha, Frank J. Smit, Leslie R. Fish, T. Anthony Toney, Dennis L. Phillips, and Thomas J. Feeley, III.

***Subtask 3.3 Dewatering Studies***

This work, being performed by Virginia Tech, is aimed at developing a novel hydrophobic dewatering (HD) process for clean coal fines. This HD process will be capable of efficiently removing moisture from fine coal without the expense and other related drawbacks associated with mechanical dewatering or thermal drying. In this process a hydrophobic substance (butane) is added to a coal-water slurry to displace water from the coal surface. The butane is then recovered for recycle to the process. For this process to have commercialization potential, the amount of butane lost during the process must be small.

Previous testing revealed the ability of the HD process to reduce the moisture content of fine coal to a very low level. The work conducted during this reporting period focused on Subtask 3.3.3.4 and covered determination of potential butane losses due to the adsorption of butane onto the coal surface.

**Subtask 3.3.3.4 Hydrophobic Substance Recovery and Regeneration** - The following method was developed to best determine the amount of butane absorbed by the coal. Small bottles containing a known weight of dried coal were filled initially with liquid butane in a pressurized chamber. After one hour of pressurization, the chamber was de-pressurized and the weight of the coal sample was monitored as a function of time. If the weight of a coal sample reached its original weight, the butane loss to coal would be zero, or the butane recovery is 100%.

Results indicate that at room temperature the kinetics were slow, taking 80 minutes to reach a value of 99.9% butane recovery. At 50° C, however, the kinetics improved significantly reaching 99.9% recovery after only 10 minutes.

## Task 6 Engineering Development of Selective Agglomeration

Task 6 is divided into six subtasks. Subtasks 6.1 Agglomerating Agent Selection, 6.2 Grinding Studies, 6.3 Process Optimization Research, and 6.6 Conceptual Design of the Selective Agglomeration PDU Module have been completed and were reported during previous quarters. There was activity on the two remaining subtasks, 6.4 and 6.5, during this quarter.

### *Subtask 6.4 CWF Formulation Studies*

The primary objective of Subtask 6.4 is to evaluate the formulation of coal-water-fuel (CWF) slurries from selective agglomeration products. The slurry feedstock, i.e., selective agglomeration products, used for this work are generated during Subtask 6.5, Selective Agglomeration Bench-scale Testing and Process Scale-up.

While much of this test work is evaluating the effect of various parameters on slurry quality, there are two other objectives for the Subtask 6.4 work. First, this test work is providing a comparison between similar slurries formulated from flotation and agglomeration products. Second, the Subtask 6.4 work is attempting to determine slurry quality guidelines for commercial production. To this end, determinations of required slurry coal loadings, stabilities, and viscosities are being carried out.

During this reporting quarter, the benefits of slurry PSD (particle size distribution) modification and of pH adjustment were determined for Taggart and Hiawatha clean coal slurries. The PSD modifications were accomplished by additional grinding of varying proportions of each slurry in an attritor mill, and by regrinding of the entire slurry in a ball mill. The pH adjustment was done with ammonia to raise the slurry pH to 10 from the normal pH of approximately 7. The blended slurry formulations were prepared to be pourable mixtures, but wall slip frequently prevented meaningful direct measurements of their viscosities. For this reason, the effects of the parametric tests were evaluated from viscosity versus loading plots after small successive dilutions of each slurry. Loadings were compared by extrapolating the plotted points to a common 500 cp slurry viscosity.

Results indicate that only small improvements in loading could be obtained for the Taggart coal by PSD modifications. It was also noted that the as-blended sample loadings were usually higher than the projected loadings at 500 cp, indicating that the viscosities of most of the "pourable" slurries had true viscosities that were greater than 500 cp before they were diluted sufficiently to provide a good viscosity measurement free of wall slip.

Similar tests were carried out with the Hiawatha coal except that instead of ball milling the entire sample, selective grinding tests were conducted in which the minus 325-mesh fraction screened from the clean coal was ground for 30 minutes in the Attritor mill and reblended at two different proportions with the original plus 325 mesh fraction. The projected coal loadings for these Hiawatha coal slurries were not as high as for the Taggart coal due to the higher inherent moisture content of Hiawatha coal. Again, only minor improvements in loading could be obtained by modification of the PSD. Selective grinding of only the finest portion of the original coal particles appears to be the most effective procedure for improving the loading of the Hiawatha coal slurries.

The adjustment of slurry pH with ammonia had little effect upon projected loadings of Taggart and Hiawatha coal slurries.

A sample of Winifrede coal cleaned by selective agglomeration was also slurried. Only one test was carried out, however, since the coal was already very fine, providing little opportunity to change the PSD by additional grinding. The slurry was formulated at 48.8% coal, with indicated viscosities being shear-time dependent.

***Subtask 6.5 Bench-Scale Testing and Process Scale-up***

**Previous Work -** During previous testing with the 25 lb/hr bench-scale unit, evaluation of the Taggart, Sunnyside, Elkhorn No. 3, and Winifrede coals were completed. It should be noted that the Sunnyside coal has since been replaced with the Hiawatha coal.

Other previous and continuing work has focused on the three project coals of primary interest - Indiana VII, Hiawatha (Sunnyside replacement), and Taggart (new sample). This work has indicated that for the Indiana VII coal, the 2 lb/MBtu product ash specifications could be met at the selected 325-mesh topsize grind. More testing with the Indiana VII coal will be carried out utilizing coal ground in the PDU under Subtask 8.4 operations, providing valuable information to be used during Subtask 9.3 PDU operations.

Work with the new Taggart coal sample (from the Steer Branch mine) has utilized ground product from PDU operations. Using this feedstock, the 1 lb/MBtu product ash specification for this coal was met. Using Hiawatha coal feedstock closed-circuit ground to a 150-mesh topsize, the 2 lb ash/MBtu product specification was also met.

**Taggart Coal Continuous Testing -** During previous testing, two grinds of the Taggart coal ($d_{80}$ of 75 and 33 microns respectively) generated in the PDU grinding circuit under Subtask 8.4 operations were used. Results from this work indicated that the 80% passing 33 micron grind provided sufficient liberation to achieve the desired 1 lb/MBtu product ash specification.

Bench-scale (25 lb/hr) agglomeration testing continued this quarter with the completion of five tests utilizing the PDU generated feedstock with a $d_{80}$ of 33 microns. Four of these five new tests were carried out at 7% solids utilizing from 2.5 to 5 minutes of low-shear residence time. The other test was carried out at 10% solids and a low-shear residence time of 7 minutes. The bench-scale agglomeration unit operated well for all of these tests, with the production of well formed agglomerates, that screened easily. Btu recoveries were high (greater than 97%) for all of these tests, with tailings ash values all greater than 53%.

Three of the five Taggart coal agglomeration tests carried out this quarter met the target product ash specification of 1 lb/MBtu. For the other two tests, smaller agglomerates were formed, i.e., less than 1.5 mm in size. These results confirm previous data indicating that the formation of larger better formed agglomerates results in lower product ash values. With the completion of this test work, continuous bench-scale testing with the Taggart coal is complete.

**Hiawatha Coal Continuous Testing -** During previous testing, agglomeration of the Hiawatha coal with a $d_{80}$ of 47 microns was evaluated. Results from these tests indicated that this grind was sufficiently fine to achieve the desired 2 lb/MBtu product ash specification. To further evaluate agglomeration of the Hiawatha coal, four tests were carried out at a coarser grind ($d_{80}$ of 65 microns). All four of these tests were completed at a 25 lb/hr dry coal feed rate, two at 10% feed solids concentration and two at 7%.

Results indicate that the grind with a $d_{80}$ of 65 microns was sufficiently fine to achieve the product ash specification of 2 lb/MBtu. As expected, lower product ash values were achieved with the 7% solids feed than with the 10% solids feed. Heptane dosages utilized were in the 24-26% range on a dry coal basis.

Additional test work utilizing this coarser grind ($d_{80}$ = 65 microns) will be carried out to evaluate the effect of other process variables. Continuous heptane steam stripping tests will also be completed.

**Toxic Trace Elements Removal-** A study was completed comparing the residual amounts of twelve toxic trace elements in the five test coals cleaned by bench-scale column flotation with the residual amounts in the same coals cleaned by bench-scale selective agglomeration. The reductions in concentration of these same trace elements on a heating value basis from their concentrations in the run of mine (ROM) and as-received coals were also determined.

The residual amounts of the elements in the clean coals were found to be dependent upon the source coal. For example, there was about four times as much antimony in Indiana VII clean coal as found in the other four clean coals and a third as much or less arsenic in the Sunnyside clean coal as in the other clean coals. On the other hand, and with a few exceptions, advanced flotation clean coals and agglomeration clean coals both contained about the same amounts of the individual trace elements. The exceptions were lead in Elkhorn No. 3 coal, arsenic and nickel in Sunnyside coal, selenium in Taggart coal, and chromium and selenium in the Winifrede coal.

There were substantial reductions (25 to 75%), on a heating value basis, in the concentrations of arsenic, chromium, manganese, and nickel from the amounts in the as-received test coals. On the other hand, there was little or no reduction (<25%) in the amounts of antimony, beryllium, cobalt, selenium, and chlorine on the same basis. The reduction in the concentrations of lead and mercury varied from coal to coal. Nickel reduction in Indiana VII and arsenic reduction in Sunnyside and Taggart were exceptions.

Reductions from the concentrations found in the ROM parent coals were generally greater than the reductions from the concentrations found in the as-received test coals on a heating value basis. There were substantial reductions (25 to 90%) in the concentrations of arsenic, beryllium, chromium, cobalt, lead, manganese, mercury, and selenium from the amounts in the ROM coals. On the other hand, there was little or no reduction (<25%) in the amount of antimony on the same basis. The reduction of nickel and chlorine varied from coal to coal. Nickel reduction in the Elkhorn No. 3 coal, beryllium and chromium in the Sunnyside coal, and chromium and selenium in the Winifrede coal were exceptions.

## Task 8 PDU and Advanced Column Flotation Module

Work continued during this reporting quarter on Subtask 8.1 Coal Selection and Procurement and Subtask 8.4 PDU Flotation Module Operation and Production as discussed below.

### *Subtask 8.1 Coal Selection and Procurement*

Eight hundred tons of Hiawatha seam coal were ordered from the Genwal Crandall Creek Mine in Utah for delivery during July 1996. The Hiawatha coal will contain about 9 percent ash since the mine does not wash the coal before market. In most other respects, though, the Hiawatha coal resembles the Sunnyside coal used for Tasks 4 and 6 testing. The 800 tons will be sufficient for both the column flotation and the selective agglomeration PDU operations.

### *Subtask 8.4 PDU Flotation Module Operation and Production*

Operation of the PDU Flotation Module continued during the second quarter of 1996. Optimization of the Taggart coal was completed, as well as the development of associated regression equations. Work was also performed with the Taggart coal to better determine scale-up similitude between the 12-inch and 6-foot Microcel™ columns.

In addition to the work completed on the Taggart coal, testing of the Indiana VII coal also commenced during the quarter. The fine grinding requirements of the Indiana VII coal led to several unexpected operating problems in the PDU grinding circuit. As a result, most efforts during the quarter were directed to troubleshooting and correcting these problems. Specifically, degradation and loss of grinding media from the ball mills resulted in screen blinding, cyclone plugging, and unexpected downtime. Consultations with Mineral Resource Development, Inc., a firm specializing in grinding and size reduction, revealed that the speed of each mill was too fast, the ball size distribution was too coarse, the ball charge was too heavy, and the mill solids concentration was too dilute. New setpoints were established and the grinding circuit modified accordingly.

**Optimization of PDU Flotation Module (Taggart Coal)** - Optimization of Taggart coal in the PDU Flotation Module was completed during the quarter. A total of seven tests were performed to determine the optimum Microcel™ setpoints needed to achieve the process development goals of 1 lb/MBtu of ash and over 80% energy recovery.

Equations were first developed to estimate the effects of tested input variables on Microcel™ outputs such as yield and quality. The equations were developed by evaluating the input and output variables of parametric tests T21 through T39 by multiple linear regression. The resulting equations were then used to determine optimum Microcel™ test setpoints.

Optimization testing revealed that the overall quality goal of 1 lb/MBtu of ash can be attained. At a $d_{80}$ of 50 microns, an optimum clean coal ash, yield, and energy recovery of 0.99 lb/MBtu, 94.36%, and 96.90% respectively was achieved.

**Development of PDU Flotation Module Regression Equations (Taggart Coal) -** Data from PDU Flotation Module parametric testing was compiled and multiple regression models (equations) were generated. Forward stepwise regression produced equations which link output variables such as yield and clean coal quality to input variables such as feed rate, wash water rate, air rate, collector addition, and frother addition.

The equations indicate that the most important variable that affects yield, energy recovery, and clean coal ash is the frother dosage. In all cases, the frother dosage is directly proportional to the output variable. It is important to note that though yield, energy recovery, and clean coal ash are dependent on the feed coal ash content, the ash content itself is not a controllable variable and should be considered a covariate.

**Scale-up of Microcel™ Flotation Column (Taggart Coal) -** Because the Taggart coal that was used in the PDU Flotation Module has a higher ash content than that used during the Fall, 1994, parametric testing of the 12-inch column (4% versus 2%), the similitude for scale-up would be inaccurate. As a result, six tests were performed on the new Taggart coal sample in the 12-inch Microcel™ unit. The parameters of the six tests correspond directly to those used in optimization tests TO-2 through TO-7.

Overall, the clean coal ash goal of 1 lb/MBtu was achieved during all 12-inch Microcel™ tests. However, when compared to the identical tests conducted in the

6-foot Microcel™, different results were obtained. Though both units produce results that fall on the same grade-yield curve, the 6-foot Microcel™ unit produces clean coal at a higher yield and ash than the 12-inch unit. Discussions with Mr. Dennis Phillips of Virginia Tech reveal that the discrepancy is most likely attributable to the frother addition point.

The addition of frother into the suction side of the Microcel™ recirculation pump (6-foot column) is typically more efficient than adding frother in the slurry feed mixing tank (1-foot column). Specifically, when frother is added to the pump suction it is closest to the point where it is needed most - the air injection point. The result is a smaller bubble size for a constant frother addition rate. The smaller bubbles, which have greater surface area than larger bubbles, are now capable of carrying more clean coal particles to the overflow. In addition, smaller bubbles have a greater surface tension which facilitates the floating of middlings particles with lower hydrophobicity.

As a result, the discrepancy in performance between the two columns is not unexpected. The addition of frother to the 12-inch column slurry mix tank resulted in large bubbles (about 2 mm) with low carrying capacity and high selectivity. The result was a low-yield, high-quality product. However, the addition of frother to the recirculation suction line of 6-foot column resulted in smaller bubbles (1 mm) with high carrying capacity and low selectivity. The result was a high-yield, low-quality product

**Delivery of Taggart Filter Cake to The Pennsylvania State University -** Approximately 200 tons of clean coal filter cake produced during the Taggart extended production run is slated for transport to Penn State's Coal Utilization Laboratory. Previously scheduled for delivery during April, 1996, the delivery date has been postponed until PSU's slurry grinding circuit is operational. Currently, management at Penn State is searching for a warehouse storage location for shipment within the next month.

**Shakedown of PDU Flotation Module (Indiana VII Coal) -** Shakedown of the PDU Flotation Module with the Indiana VII coal was completed during the quarter. Unlike the Taggart coal, the Indiana VII coal required two distinct circuit changes in order to achieve adequate liberation:

- Sizetec screen cloths were changed from 140 mesh (105 microns) to 270 mesh (53 microns)
- Oversize material from the classification circuit to be ground in the Netzsch Fine Grinding Mill instead of the Secondary Ball Mill

Previous laboratory testing of the Indiana VII coal has indicated that adequate mineral liberation is achieved when the coal is ground to 80% passing 22 to 24 microns ($d_{80}$ = 22 to 24 microns). This size distribution goal, for all intents and purposes, was achieved during the second shakedown run with a $d_{80}$ of 24.9 microns.

**Evaluation and Modification of Area 100 Grinding Circuit** - The fine liberation requirements of the Indiana VII coal lead to several unexpected operating problems in the PDU grinding circuit. Specifically, degradation and loss of grinding media from the ball mills resulted in screen blinding, cyclone plugging, increased $d_{80}$ values, and unexpected downtime. As a result, parametric testing of the Indiana VII coal was temporarily discontinued and efforts redirected to troubleshooting and correcting these problems. Consultations with Mineral Resource Development Inc., a firm specializing in grinding and size reduction made the following recommendations:

- Reduce Mill Speed
- Reduce Ball Size Distribution
- Reduce Overall Ball Charge
- Increase Ball Mill Solids Concentration
- Remove Fines from Mill Feed

All recommendations, except for the last, have been implemented. The improvements have eliminated all operational problems previously encountered in the grinding circuit. Not only have screen blinding and cyclone plugging problems been eliminated, the $d_{80}$ of the Microcel™ feed is now consistently ranging from 20 to 23 microns.

**Laboratory Release Analysis (Indiana VII Coal)** - To better define the theoretical grade-yield curves associated with different feed size distributions, release analysis test work was performed on the Indiana VII coal during the quarter. Two Microcel™ feed slurries, one having a size distribution with 80% passing 22 microns and a second with 80% passing 19 microns, were evaluated.

The release analysis revealed that the product ash goal of 2 lb/MBtu can be achieved at yields of 74% and 83% for feed slurries having a $d_{80}$ of 22 and 19 microns, respectively. The increase in yield at the finer grind can be attributed to enhanced liberation of carbon and mineral matter.

It is important to note that though the additional yield associated with a $d_{80}$ grind of 19 microns may be desirable, the production of this size consist in the PDU flotation module would result in a dramatic reduction in filtering capacity as well as an increase in product moisture. As a result, all PDU test work will be performed at a $d_{80}$ of 22 microns.

**Parametric Testing of PDU Flotation Module (Indiana VII Coal)** - Parametric testing of Indiana VII coal in the PDU Flotation Module (6 foot Microcel™) commenced during this quarter. A test matrix was established to determine the effects of independent variables such as air rate, % solids, feed rate, wash water, and reagent dosage on response variables such as product ash and yield. Sixteen tests were conducted during the period.

The fine liberation requirements of the Indiana VII coal lead to several unexpected operating problems during the quarter. Degradation and loss of grinding media from the ball mills resulted in screen blinding, cyclone plugging, increased d80 values, and unexpected downtime. As a result, the parametric testing of the Indiana VII coal was temporarily suspended after 13 tests. Testing resumed in late June after all problems associated with the grinding circuit were corrected.

To date, the quality goal of 2 lb/MBtu of ash was met or exceeded on five occasions. The clean coal yield varied from 12.0% to 90.8% while the energy recovery and product ash varied from 13.2% to 97.4% and 1.81 lb/MBtu to 3.40 lb/MBtu respectively. Because tests 1-6 and 8-13 had inconsistent size distributions, the resulting difference in mineral liberation ($d_{80}$) renders these tests invalid. As a result, data from tests 7 and 14-16 only are considered valid.

The remaining parametric and optimization test work is expected to conclude during the month of July as well as the production run.

**Evaluation of Microcel™ Performance by Virginia Tech** - Mr. Dennis Phillips of Virginia Tech visited the Amax R&D Center on June 24 and 25, 1996 to observe the operation of the 6-foot and 12-inch Microcel™ units. Mr. Phillips reviewed the startup, operation, and shutdown of the entire PDU flotation module. Mr. Phillips recommended the following:

- Try using less wash water. Larger Microcel™ columns typically require less wash water than smaller units. This is primarily due to the added froth drainage obtained with larger diameter units.
- Frother should always be added at the suction side of the recirculation pump. Make adjustments to 12-inch column.
- Try to maintain a bubble size of 1 mm. The maximum carrying capacity of a column is achieved when the bubble size approaches 1 mm.

Overall, Mr. Phillips was very pleased with the operation of the PDU and Microcel™ unit.

**Evaluation of Proprietary Dewatering Aid on Indiana VII Clean Coal** - A five gallon sample of Microcel™ clean coal was sent to Virginia Tech for evaluation of a proprietary dewatering aid. Typically, the dewatering aid significantly reduces the moisture of vacuum filter cake (depending on size distribution). Unfortunately, the test work on the Indiana VII was not successful. The best results obtained with the dewatering aid was approximately 45% moisture. The fine particle size of the Indiana VII clean coal is the most likely cause of the high moisture. No further testing is planned.

**Evaluation of PDU Clean Coal Dewatering Circuit** - During PDU operations to date, it has been found that existing clean coal dewatering capacity was marginal, hindering operation at some desired conditions, particularly at coal feed rates approaching 2 t/hr.

As such, the dewatering circuit was evaluated to determine the costs and benefits associated with a capacity expansion. This economic evaluation indicated that due to the high capital cost, expansion of the existing PDU dewatering circuit was not justified. It was determined that, when required, the PDU would be operated at a lower feed rate to reduce demands on the dewatering circuit. This mode of operation, combined with the use of additional temporary labor on an as needed basis, will allow the project goals to be met in a cost effective manner.

## Task 9 Selective Agglomeration Module

### *Subtask 9.1 PDU Selective Agglomeration Module Construction*

During the previous reporting quarter, Mech El Contracting, Inc. (MEI) of Aurora, Colorado, was selected to carry out the construction of the PDU Selective Agglomeration (SA) module. Construction began on March 11, 1996. MEI is constructing the SA Module based on the detailed design prepared by Bechtel. MEI is providing all the labor and materials for the construction except the major pieces of equipment which are provided by Amax R&D.

**Equipment Purchasing** - Orders were placed and Purchase Orders issued for a number of equipment items as well as other miscellaneous electrical, instrumentation, and Distributive Control System (DCS) items during this quarter.

With the purchase of this equipment, all required non-electrical/instrumentation items have been ordered. Several instrumentation items, primarily hydrocarbon and oxygen detectors, remain to be purchased.

**Construction** - Construction of the PDU SA module by MEI continued. Work completed this quarter included:

- Fabrication and installation of new structural steel in Area 300
- Removal of existing siding in Area 300
- Installation of new siding on all four interior walls of Area 300
- Installation of MCC5
- Excavation of outdoor areas for pouring of required concrete pads
- Pouring of outside concrete pads for the Nitrogen tank, gas holder, water chiller, knock-out drum, flare, heptane storage tank, and heptane feed pump
- Completion of virtually all of the remaining structural steel work including installation of required cross bracing and additional equipment support members

- Installation of virtually all of the indoor equipment including all vessels, pumps, and agitators: only one heat exchanger and several other small pieces of equipment remain to be installed within the building
- Installation of ventilation system input air duct work
- Continuation of piping fabrication and installation for the process, water, relief, and gas blanket systems
- Continuation of the running of various feeder conduits and wiring from MCC5 and DCS locations to various equipment locations
- Completion of a portion of the required sheeting and painting work

The following summarizes the progress of the work completed as of the end of June 1996:

- Mobilization, excavation, concrete, and foundation work - 100% complete
- Structural steel & platework - 99% complete
- Equipment installation - 83% complete
- Piping Installation - 41% complete
- Electrical & instrumentation installation - 35% complete
- Ventilation and fire protection - 38% complete
- Sheeting and painting - 76% complete
- Overall construction effort - 55% complete

## Task 11 Project Final Report

The final project report will include an economic assessment of producing premium fuel from coal. The assessment will be based on the results of the Tasks 4 and 6 laboratory and bench-scale testing, as well as Tasks 8 and 9 PDU operation of the Advanced Flotation and Selective Agglomeration modules.

Capital and operating costs for the economic assessment will be based on conceptual plants tentatively located in the Ohio Valley Region producing 1.5 million short tons per year (dry basis) of clean coal to be marketed as a coal-water fuel. Two plants will be costed. One will utilize advanced column flotation for cleaning finely ground coal and the other will utilize selective agglomeration with recycled heptane as the bridging liquid. The two plants will be similar in other respects. Bechtel has initiated the design of the process flowsheet for the flotation plant and the collecting of data needed for selection and costing of the plant equipment.

# INTRODUCTION AND BACKGROUND

The main purpose of this project is the engineering development of advanced column flotation and selective agglomeration technologies for premium fuel applications. Development of these technologies is an important step in the Department of Energy program to show that an ultra-clean coal-water slurry fuel (CWF) can be produced from selected United States coals and that this fuel will be a cost-effective replacement for a portion of the oil and natural gas burned by electric utility and industrial boilers in this country, as well as for advanced combustors currently under development. Capturing even a relatively small fraction of the total utility and industrial oil-fired boiler fuel market would have a significant impact on domestic coal production and reduce national dependence on petroleum fuels. Significant potential export markets also exist in Europe and the Pacific Rim for cost-effective premium fuels prepared from ultra-clean coal.

The replacement of oil and natural gas with CWF can only be realized if retrofit costs and boiler derating are kept to a minimum. Also, retrofit boiler emissions must be compatible with national clean air goals. These concerns establish the specifications for the ash and sulfur levels and combustion properties of ultra-clean coal as discussed below.

This multi-year cost-shared contract effort began on October 1, 1992, and is scheduled for completion by September 30, 1997. This report discusses the technical progress made during the fifteenth quarter of the project, April 1 to June 30, 1996. Fourteen quarterly reports have been issued previously [1-14].

## SPECIFIC OBJECTIVES OF THE PROJECT

The three main objectives of this project are discussed below.

The primary objective is to develop the design base for commercial prototype advanced fine coal cleaning facilities capable of producing ultra-clean coals suitable for conversion to stable, highly loaded coal-water slurry fuels. These slurry fuels should contain less than 2 lb ash/MBtu HHV (860 grams ash/gigajoule) and preferably less than 1 lb ash/MBtu HHV (430 grams ash/gigajoule), and less than 0.6 lb sulfur/MBtu HHV (258 grams sulfur/gigajoule). The advanced fine coal cleaning technologies to be employed are advanced column froth flotation and selective agglomeration. Operating conditions during the advanced cleaning processes should recover at least 80 percent of the heating value in run-of-mine source coals at an annualized cost of less than $2.50/MBtu ($2.37/gigajoule), including the cost of the raw coal.

A secondary objective of the work is to develop a design base for near-term commercial applications of these advanced fine coal cleaning technologies. These applications should be suitable for integration into new or existing coal preparation plants for the purpose of economically and efficiently processing minus 28-mesh coal fines. The design base will also include the auxiliary systems required to yield a shippable, marketable product such as a dry clean coal product.

A third objective of the work is to determine the distribution of toxic trace elements between clean coal product and refuse during the cleaning of various coals by advanced froth flotation and selective agglomeration technologies. Eleven toxic trace elements have been targeted. They are antimony, arsenic, beryllium, cadmium, chromium, cobalt, lead, manganese, mercury, nickel, and selenium. The results will show the potential for removing these toxic trace elements from coal by advanced physical cleaning.

## APPROACH

A team headed by Amax Research & Development Center (Amax R&D) was formed to accomplish the project objectives. Figure 1 shows the project organization chart. Entech Global, Inc. is managing the project for Amax R&D and also performing laboratory research and bench-scale testing. Entech Global is also responsible for the operation and evaluation of the 2 t/hr process development unit (PDU). Cyprus Amax Coal Company is providing operating and business perspective, the site for the near-term testing, and some of the coals being used in the program. Bechtel Corporation is providing engineering and design capabilities, and the operating experience it gained while managing similar proof-of-concept projects for DOE. The Center for Applied Energy Research (CAER) at the University of Kentucky and the Center for Coal and Mineral Processing (CCMP) at the Virginia Polytechnic Institute and State University are providing research and operating experience in the column flotation area. Arcanum Corporation is providing similar experience in the selective agglomeration area. Dr. Douglas Keller of Syracuse University is serving as a consultant in the area of selective agglomeration and Dr. John Dooher of Adelphi University is serving as a consultant in the area of coal-water slurry formulation. Robert Reynouard was retained as a consultant to help with electrical and instrumentation systems in the PDU. Mech EL Contracting, Inc. is constructing the Selective Agglomeration Module of the PDU.

The overall engineering development effort has been divided into four phases with specific activities as discussed below. As shown in Table 1, Work Breakdown Structure, the four phases of the project have been further divided into tasks and subtasks, with specific objectives which may be inferred from their titles. Figure 2 shows the project schedule.

### Phase I

Phase I encompassed preparation of a detailed Project Work Plan, selection and acquisition of the test coals, and laboratory and bench-scale testing. The laboratory and bench-scale work determined the cleaning potential of the selected coals and established design parameters and operating guidelines for a 2 t/hr PDU containing both advanced column flotation and selective agglomeration modules. A conceptual engineering design was prepared for a fully integrated and instrumented 2 t/hr PDU incorporating the features determined from the laboratory and bench-scale studies.

Additional activities during Phase I included:

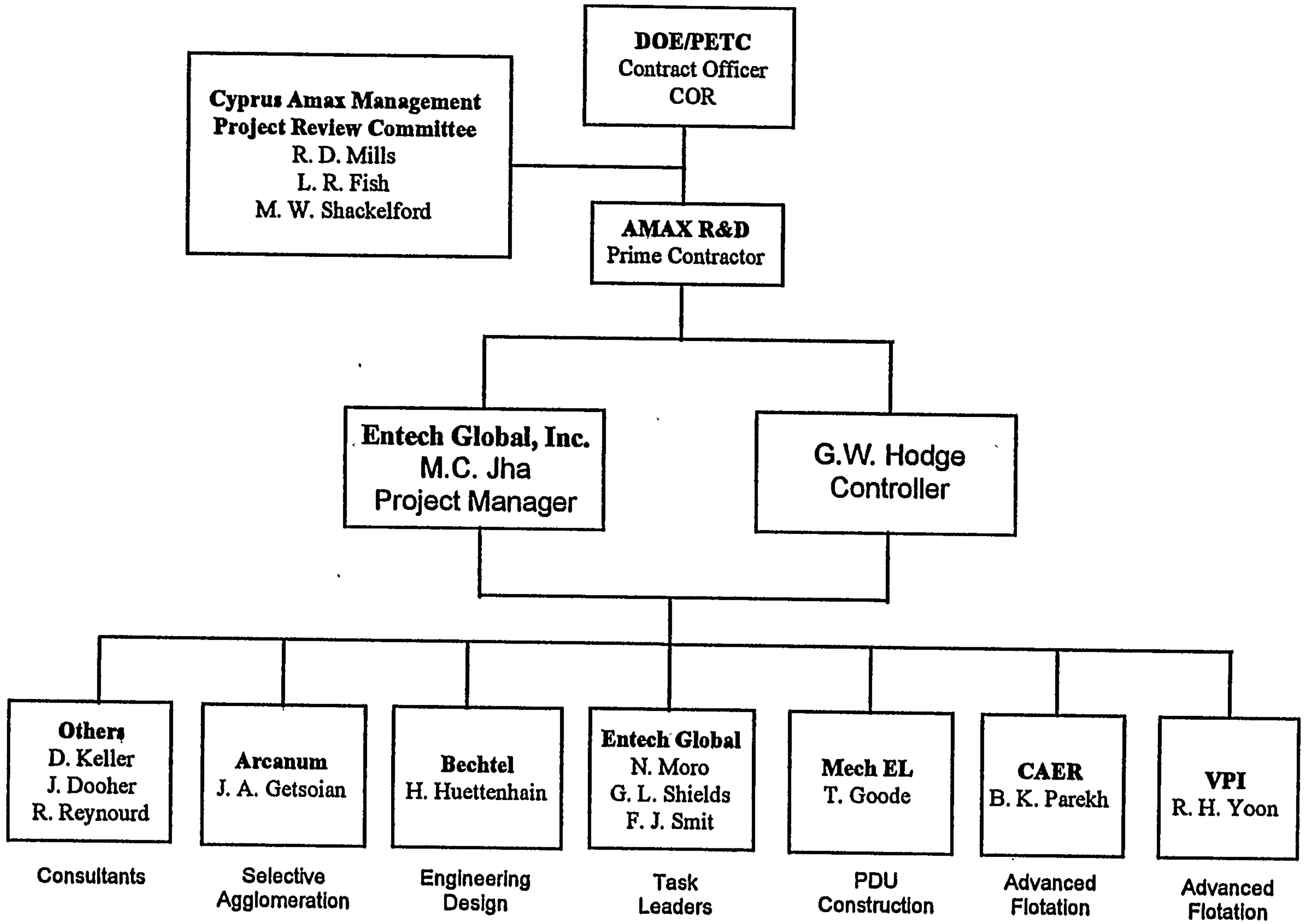
- Production of ultra-clean coal test lots by bench-scale column flotation and selective agglomeration for end-use testing
- Determination of toxic trace element distribution during production of these test lots
- Evaluation of the rheological properties of slurry fuels prepared from ultra-clean coals
- Evaluation of methods for applying these advanced cleaning technologies to existing coal preparation plants in the near term

<u>Phases II and III</u>

Phases II and III cover the construction and operation of the 2 t/hr PDU. Phase II is for advanced column flotation while Phase III is for selective agglomeration. Process performance is to be optimized at the PDU-scale, and 100 ton lots of ultra-clean coal is to be produced by each process for each of the three test coals. Toxic trace element distributions will also be determined during the production runs. The ultra-clean coals will be delivered to DOE or a designated contractor for end-use testing.

<u>Phase IV</u>

Phase IV activities will include decommissioning of the PDU, restoration of the host site, and preparation of the final project report.



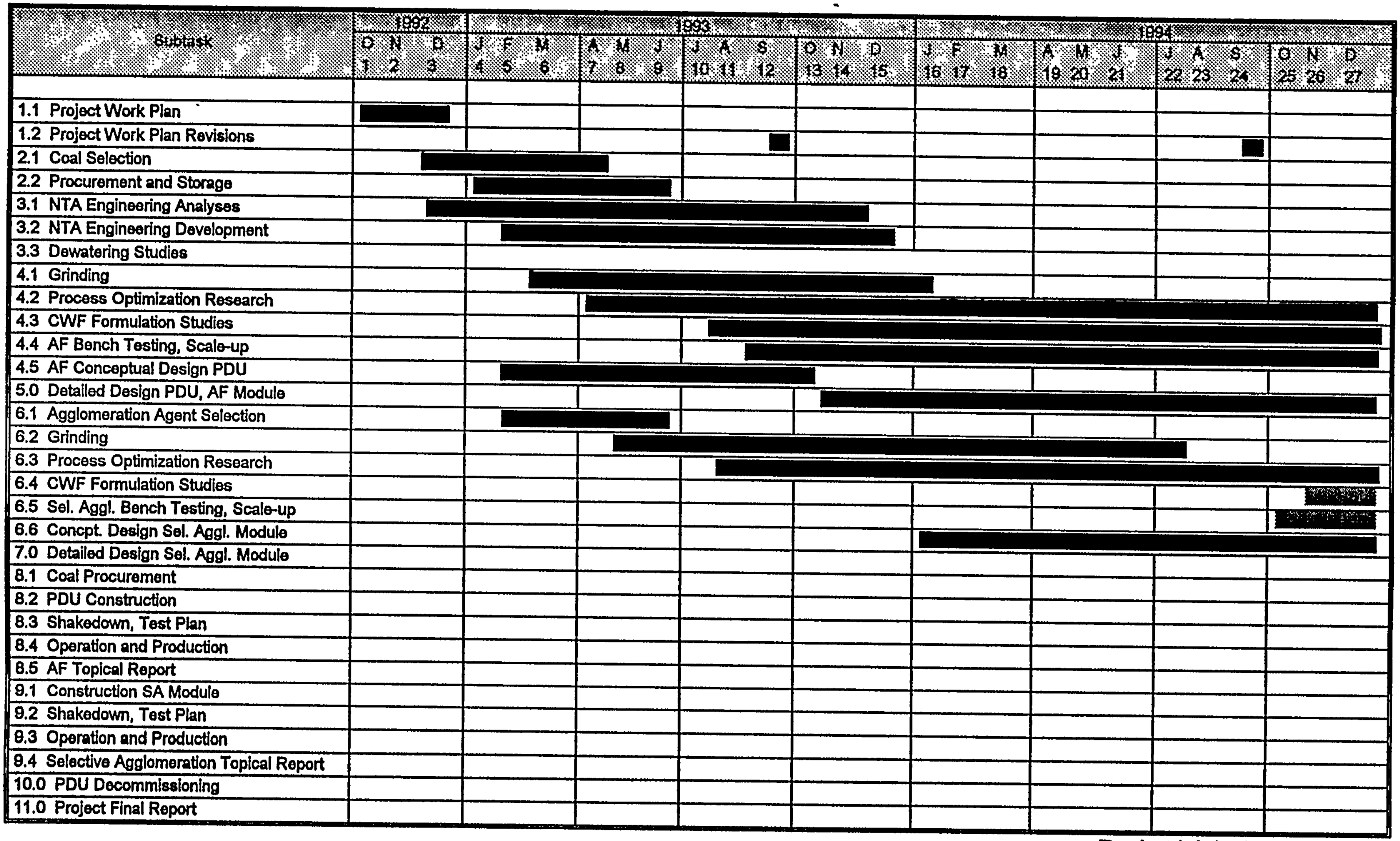

Revised July 25, 1996

**Figure 1. Project Management Organization Chart**

## Table 1. Outline of Work Breakdown Structure

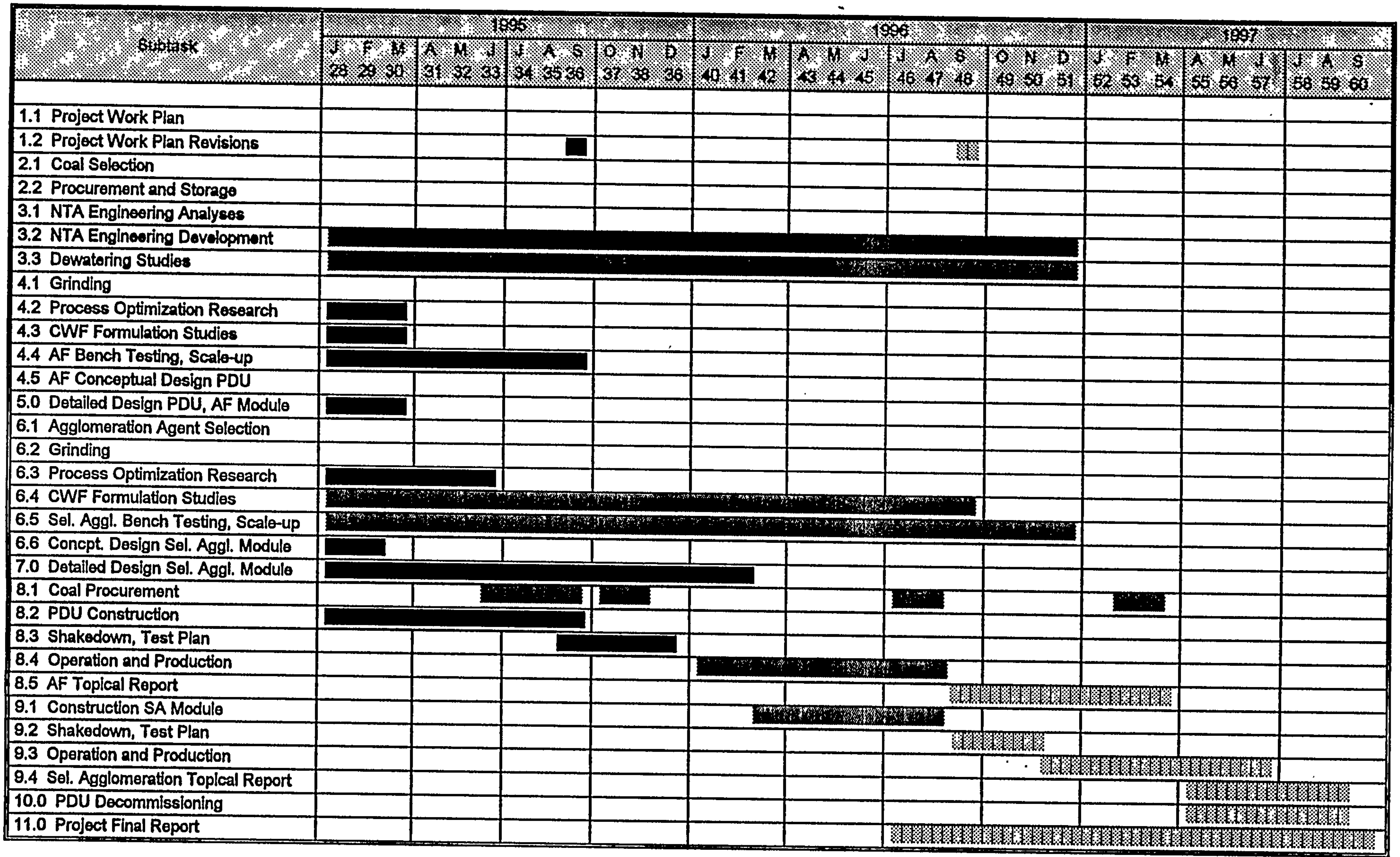
| | |
|---|---|
| | **Phase I. Engineering Analysis and Laboratory and Bench-Scale R&D** |
| Task 1. | Project Planning |
| Subtask 1.1. | Project Work Plan |
| Subtask 1.2. | Project Work Plan Revisions |
| Task 2. | Coal Selection and Procurement |
| Subtask 2.1. | Coal Selection |
| Subtask 2.2. | Coal Procurement, Precleaning and Storage |
| Task 3. | Development of Near-Term Applications |
| Subtask 3.1. | Engineering Analyses |
| Subtask 3.2. | Engineering Development |
| Subtask 3.3 | Dewatering Studies |
| Task 4. | Engineering Development of Advanced Froth Flotation for Premium Fuels |
| Subtask 4.1. | Grinding |
| Subtask 4.2. | Process Optimization Research |
| Subtask 4.3. | CWF Formulation Studies |
| Subtask 4.4. | Bench-Scale Testing and Process Scale-up |
| Subtask 4.5. | Conceptual Design of the PDU and Advanced Froth Flotation Module |
| Task 5. | Detailed Engineering Design of the PDU and Advanced Flotation Module |
| Task 6. | Selective Agglomeration Laboratory Research and Engineering Development for Premium Fuels |
| Subtask 6.1. | Agglomeration Agent Selection |
| Subtask 6.2. | Grinding |
| Subtask 6.3. | Process Optimization Research |
| Subtask 6.4. | CWF Formulation Studies |
| Subtask 6.5. | Bench-Scale Testing and Process Scale-up |
| Subtask 6.6. | Conceptual Design of the Selective Agglomeration Module |
| Task 7. | Detailed Engineering Design of the Selective Agglomeration Module |
| | **Phase II. PDU and Advanced Column Flotation Module Testing and Evaluation** |
| Task 8. | PDU and Advanced Column Froth Flotation Module |
| Subtask 8.1. | Coal Selection and Procurement |
| Subtask 8.2. | Construction |
| Subtask 8.3. | PDU and Advanced Coal Cleaning Module Shakedown and Test Plan |
| Subtask 8.4. | PDU Operation and Clean Coal Production |
| Subtask 8.5. | Froth Flotation Topical Report |
| | **Phase III. Selective Agglomeration Module Testing and Evaluation** |
| Task 9. | Selective Agglomeration Module |
| Subtask 9.1. | Construction |
| Subtask 9.2. | Selective Agglomeration Module Shakedown and Test Plan |
| Subtask 9.3. | Selective Agglomeration Module Operation and Clean Coal Production |
| Subtask 9.4. | Selective Agglomeration Topical Report |
| | **Phase IV. PDU Final Disposition** |
| Task 10. | Disposition of the PDU |
| Task 11. | Project Final Report |

Revised April 25, 1995




Revised July 15, 1996

**Figure 2. Project Schedule**




Revised July 15, 1996

**Figure 2. Project Schedule (Cont'd)**

# ACCOMPLISHMENTS DURING QUARTER

Work was carried out on Tasks 3, 6, 8, 9, and 11 during the fifteenth quarter (April 1 to June 30, 1996) reporting period. Good progress was made on these tasks as discussed below.

## TASK 3 DEVELOPMENT OF NEAR-TERM APPLICATIONS

During 1993, Bechtel performed an engineering analysis evaluating potential applications for column flotation and selective agglomeration at three coal preparation plants operated by what is now Cyprus Amax Coal Company [15]. Economic projections favored column flotation over selective agglomeration and an application at the Lady Dunn Preparation Plant (Cannelton Coal Company) in West Virginia was found to be particularly attractive since the plant was being considered for a major capacity expansion. Because of the potential advantages of installing column flotation rather than mechanical flotation cells in the expanded fine coal cleaning circuit, Lady Dunn management was pleased to offer their plant as the study site for a near-term application of column flotation. The Microcel™ flotation column was selected for this study and the Center for Coal and Mineral Processing (CCMP) at Virginia Tech was assigned the responsibility for the on-site column testing under Subtask 3.2 "Engineering Development." Subtask, 3.3 "Dewatering Studies", investigating a novel dewatering process for advanced flotation products is also being performed by CCMP.

### Subtask 3.2 Engineering Development

As described during previous Quarterly Progress Reports [11, 12, 13, 14], an existing 30-inch diameter Microcel™ flotation column was refurbished and installed in the Lady Dunn Plant for this engineering development work. A high-quality product, containing about 8 to 10% ash was produced at approximately 80 to 85% combustible matter recovery during preliminary testing [13]. Based on these results, Cannelton included column flotation in its 1996 plant expansion. In the meantime, parametric testing continued to quantify the flotation characteristics of the coarse coal particles (0.75 x 0.15 mm) in the feed to the column.

Parametric testing of the 30-inch Microcel™ column at the Lady Dunn Preparation Plant was completed this reporting quarter. The parametric test matrix was of a Box-Behnkin design and utilized a low, medium, and high setting for each of the main process variables: feed rate, air volume, and frother dosage. Feed, product, and tails samples were collected for each of the 15 test points. Each sample was then screened at six sizes and each size fraction analyzed for ash. Recovery by size plots of this data will be presented in the Topical Report.

Preliminary results indicate some interesting relationships for the variables tested (feed rate, frother dosage, and air volume). It is generally considered that recovery increases with a decrease in feed rate, increase in frother, and increase in air volume. Turbulence, however, plays a significant role with coarse coal recovery and this appears to be the case for this test work. At the higher feed rate, the recovery remained relatively high until the frother dosage or air volume was increased beyond an optimum point, in which case the recovery dropped off. It is believed that the higher turbulence resulting from bubbles rising against a higher downward flow may have caused the lower recoveries.

Due to the construction work involved with a major plant expansion, the column has been removed from the plant and will be returned to Blacksburg. Complete results will be included in the Topical Report after further evaluation of the data.

A portion of the clean coal from this parametric testing was submitted to Tra-Det, Inc., of Triadelphia, West Virginia, for binderless briquetting tests. Good quality briquettes were produced by Tra-Det who will be issuing a test report describing the briquetting work in the near future.

The near-term advanced flotation testing at the Lady Dunn Plant was described during a presentation at the Coal Prep '96 Conference on April 30. The title of the presentation was "The Evaluation of Column Flotation for Fine Coal Cleaning at the Lady Dunn Preparation Plant," and co-authors were Mahesh C. Jha, Frank J. Smit, Leslie R. Fish, T. Anthony Toney, Dennis L. Phillips, and Thomas J. Feeley, III.

## Subtask 3.3 Dewatering Studies

This work, being performed by Virginia Tech, is aimed at developing a novel hydrophobic dewatering (HD) process for clean coal fines. This HD process will be capable of efficiently removing moisture from fine coal without the expense and other related drawbacks associated with mechanical dewatering or thermal drying. In this process a hydrophobic substance (butane) is added to a coal-water slurry to displace water from the coal surface. The butane is then recovered for recycle to the process. For this process to have commercialization potential, the amount of butane lost during the process must be small.

Previous testing revealed the ability of the HD process to reduce the moisture content of fine coal to a very low level. The work conducted during this reporting period focused on Subtask 3.3.3.4 and covered determination of potential butane losses by the adsorption of butane onto the coal surface.

### *Subtask 3.3.3 Process Development*

During previous reporting quarters [12, 13, 14], a batch dewatering unit was designed, constructed, and tested to evaluate the HD process under Subtasks 3.3.3.1, 3.3.3.2, and 3.3.3.3, respectively.

**Subtask 3.3.3.4 Hydrophobic Substance Recovery and Regeneration** - Several methods were discussed or investigated in an attempt to determine butane loss during the HD process. The following method was developed to best determine the amount of butane absorbed by the coal. Small bottles containing a known weight of dried coal were filled initially with liquid butane in a pressurized chamber. After one hour of pressurization, the chamber was de-pressurized and the weight of the coal sample was monitored as a function of time. A laboratory balance capable of measuring weights down to four decimal points was used. Three duplicate tests were conducted and averaged. If the weight of a coal sample reached its original weight, the butane loss to coal would be zero, or the butane recovery is 100%.

To address the concern that all the attached butane may not evaporate at room temperature, some of the samples were subjected to heating at 50° C. The changes in the weight of coal were monitored as a function of time.

Results indicate that at room temperature the kinetics were slow, taking 80 minutes to reach a value of 99.9% butane recovery. At 50° C, however, the kinetics improved significantly reaching 99.9% recovery after only 10 minutes. Future work will involve the preliminary design of a continuous bench-scale unit and a review of the economics of the system.

## TASK 6 ENGINEERING DEVELOPMENT OF SELECTIVE AGGLOMERATION

Task 6 activity during this reporting quarter focused on Subtask 6.4 CWF Formulation Studies, and Subtask 6.5 Bench-scale Testing and Process Scale-up.

### Subtask 6.4 Coal-Water-Fuel Formulation Studies

The primary objective of Subtask 6.4 is to evaluate the formulation of coal-water-fuel (CWF) slurries from selective agglomeration products. The slurry feedstock, i.e., selective agglomeration products, used for this work are produced during Subtask 6.5, Selective Agglomeration Bench-scale Testing and Process Scale-up.

While much of this test work is evaluating the effect of various parameters on slurry quality, there are two other objectives for the Subtask 6.4 work. First, this test work is providing a comparison between similar slurries formulated from flotation and agglomeration products. Second, the Subtask 6.4 work is attempting to determine slurry quality guidelines for commercial production. To this end, determinations of required slurry coal loadings, stabilities, and viscosities are being carried out.

During this reporting quarter, the benefits of slurry PSD (particle size distribution) modification and of pH adjustment were determined for Taggart and Hiawatha clean coal slurries. The PSD modifications were accomplished by additional grinding of varying proportions of each slurry, and the pH adjustment was done with ammonia to raise the slurry pH to 10 from the normal pH of approximately 7. The blended slurry formulations were prepared to be pourable mixtures, but wall slip frequently prevented meaningful direct measurements of their viscosities. For this reason, the effects of the parametric tests were evaluated from viscosity versus loading plots after small successive dilutions of each slurry. Loadings were compared by extrapolating the plotted points to a common 500-cp slurry viscosity.

Three methods were used to modify the PSD of the Taggart slurries:

- Grind 10, 20, or 30% of original slurry for 7.5 minutes in an Attritor mill
- Grind 10, 20, or 30% of original slurry for 30 minutes in an Attritor mill
- Grind all of the original slurry for 15 minutes in a ball mill.

The additional grinding of a portion of the slurry increases the "bimodality" of the slurry by adding more very fine material while retaining a large portion of the original coarse size fraction. The extra ball milling was intended to increase the overall fineness of the slurry to match the finer mass mean diameter of the blended slurries, but little, if any, additional grinding was actually accomplished.

As shown by the projected loadings for Taggart coal in Table 2, only small improvements in loading (about 1% at best) can be attributed to the modifications made to the PSD. Also, the as-blended sample loadings were usually higher than the projected loadings at 500 cp. This indicates that the viscosities of most of the "pourable" slurries had true viscosities that were greater than 500 cp before they were diluted sufficiently to provide a good viscosity measurement free of wall slip.

**Table 2. Modified PSD Taggart Slurry Loadings at 500 cp**

| Unground Portion, % | Attritor Grind, min | Attritor Grind, % | Mass Mean Diameter, µm | As-Blended Loading, % | 500 cp Projected Loading, % |
|---|---|---|---|---|---|
| 100 | | | 21.0 | 62.2 | 61.8 |
| 90 | 7.5 | 10 | 20.1 | 62.7 | 62.1 |
| 80 | 7.5 | 20 | 19.1 | 62.0 | 62.5 |
| 70 | 7.5 | 30 | 18.2 | 62.7 | 62.9 |
| 90 | 30 | 10 | 19.5 | 63.0 | 63.0 |
| 80 | 30 | 20 | 18.0 | 63.5 | 62.8 |
| 70 | 30 | 30 | 16.5 | 63.3 | 62.5 |
| 0 | 15-min Ball Mill Grind | | 21.4 | 62.2 | 64.7 |

Interestingly, ball milling the entire slurry sample seems to have been more beneficial than fine grinding a portion of the slurry. This phenomenon could have been due to re-agglomeration of some Taggart coal particles during the ball milling.

Similar tests were carried out with the Hiawatha coal after cleaning by selective agglomeration except that the ball milling test was omitted. Instead, selective grinding tests were conducted in which the minus 325-mesh fraction screened from the clean coal was ground for 30 minutes in the Attritor mill and reblended at two different proportions with the original plus 325 mesh fraction. These data are presented in Table 3. The projected coal loadings are not as high as for Taggart coal because of the higher inherent moisture content of Hiawatha coal. Again, only minor improvements in loading can be attributed to modification of the PSD. Selective grinding of only the finest portion of the original coal particles appears to be the most effective procedure for improving the loading of the Hiawatha coal slurries.

**Table 3. Modified PSD Hiawatha Slurry Loadings at 500 cp**

| Unground Portion, % | Attritor Grind, min | Attritor Grind, % | Mass Mean Diameter, µm | As-Blended Loading, % | 500-cp Projected Loading, % |
|---|---|---|---|---|---|
| 100 | | | 30.3 | 59.7 | 59.5 |
| 80 | 7 1/2 | 20 | 26.9 | 61.0 | 59.3 |
| 70 | 7 1/2 | 30 | 25.1 | 61.4 | 60.5 |
| 80 | 30 | 20 | 25.8 | 62.1 | 60.6 |
| 70 | 30 | 30 | 23.6 | 62.5 | 61.5 |
| Selective Grind 2 | | 20 | 27.9 | 64.0 | 63.0 |
| Selective Grind 3 | | 30 | 26.4 | 64.2 | 62.4 |

The adjustment of slurry pH with ammonia had little effect upon projected loadings of Taggart and Hiawatha 70/30 (coarse/fine) coal blends at 500 cp viscosity as shown in Table 4.

**Table 4. Effect of pH on Projected Coal Loadings**

| 70/30 Blends | Mass Mean Diameter, µm | Projected Loading at 500 cp, % Coal | |
|---|---|---|---|
| | | pH ~7 | pH 10 |
| Taggart | 16.5 | 62.5 | 61.7 |
| Hiawatha | 23.6 | 61.5 | 61.9 |

A sample of Winifrede coal cleaned by selective agglomeration was also slurried. Only one test was carried out, however, since the coal was already minus 30 µm (D80=7.4 µm) after cleaning, providing little opportunity to change the PSD by additional grinding. The slurry was formulated at 48.8% coal with 1.5% A-23 dispersant. The indicated viscosities were shear-time dependent, that is, they were 300 cp at 100/s and over 1700 cp at 500/s on the up cycle and fell to 10 cp at 100/s on the down cycle. Such a wide range of values made it impractical to project a loading at 500 cp. No further slurry formulation work is planned with the Winifrede coal.

## Subtask 6.5 Bench-Scale Testing and Process Scale-up

During previous testing with the 25 lb/hr bench-scale unit, evaluation of the Taggart, Sunnyside, Elkhorn No. 3, and Winifrede coals were completed. It should be noted that the Sunnyside coal has since been replaced with the Hiawatha coal.

Other previous and continuing work has focused on the three project coals of primary interest - Indiana VII, Hiawatha (Sunnyside replacement), and Taggart (new sample). This work has indicated that for the Indiana VII coal, the 2 lb/MBtu product ash specifications could be met at the selected 325-mesh topsize grind. More testing with the Indiana VII coal will be carried out utilizing coal ground in the PDU under Subtask 8.4 operations, providing valuable information to be used during Subtask 9.3 PDU operations.

Work with the new Taggart coal sample (from the Steer Branch mine) has utilized ground product from PDU operations. Using this feedstock, the 1 lb/MBtu product ash specification for this coal was met. Using Hiawatha coal feedstock closed-circuit ground to a 150-mesh topsize, the 2 lb ash/MBtu product specification was also met.

### *Taggart Coal*

During previous testing, a sample of the new Taggart coal was closed-circuit ground to both 62- and 100-mesh top sizes for evaluation, with results indicating that a product ash content of 1.3 - 1.5 lb ash/MBtu was achieved at both sizes. Two additional grinds of the Taggart coal were also evaluated in continuous agglomeration testing. Both of these feedstocks (with 80% passing values of 75 and 33 microns respectively) were generated in the PDU grinding circuit under Subtask 8.4 operations. Results from this work determined that a $d_{80}$ of 33 microns provided sufficient liberation to achieve the desired 1 lb/MBtu product ash specification.

Bench-scale (25 lb/hr) agglomeration testing continued this quarter with the completion of five tests utilizing the PDU generated feedstock with a $d_{80}$ of 33 microns. This grind was obtained by operating the PDU grinding circuit in closed-circuit with cyclones and a 70-mesh screen, with the oversize material recycled to the Netzsch fine-grinding mill. Results for these five tests (T5A8-T5A12) are shown in Appendix A along with the results for other previously completed tests that utilized the same feedstock material, i.e., the same grind size.

Four of these five new tests were carried out at 7% solids and utilized from 2.5 to 5 minutes of low-shear residence time depending on the solids feed rate. The other test was carried out at 10% solids and a low-shear residence time of approximately 7 minutes. For these five tests, high-shear tip speeds ranged from 7.7 to 15 m/s with the low-shear tip speed fixed at 4.8 m/s. The bench-scale agglomeration unit operated well for all of these tests, with the production of well formed agglomerates that screened easily.

Results for these tests are presented in Figure 3 which shows Btu Recovery vs product ash content in lb ash/MBtu. Also shown in Figure 3 are the results of seven previously agglomeration tests carried out at 5, 10, and 13% solids utilizing the same feedstock.

As can be seen from the data in Figure 3, Btu recoveries were high (greater than 97%) for all of the tests carried out. Corresponding tailings ash values for the five new tests were all greater than 53%.

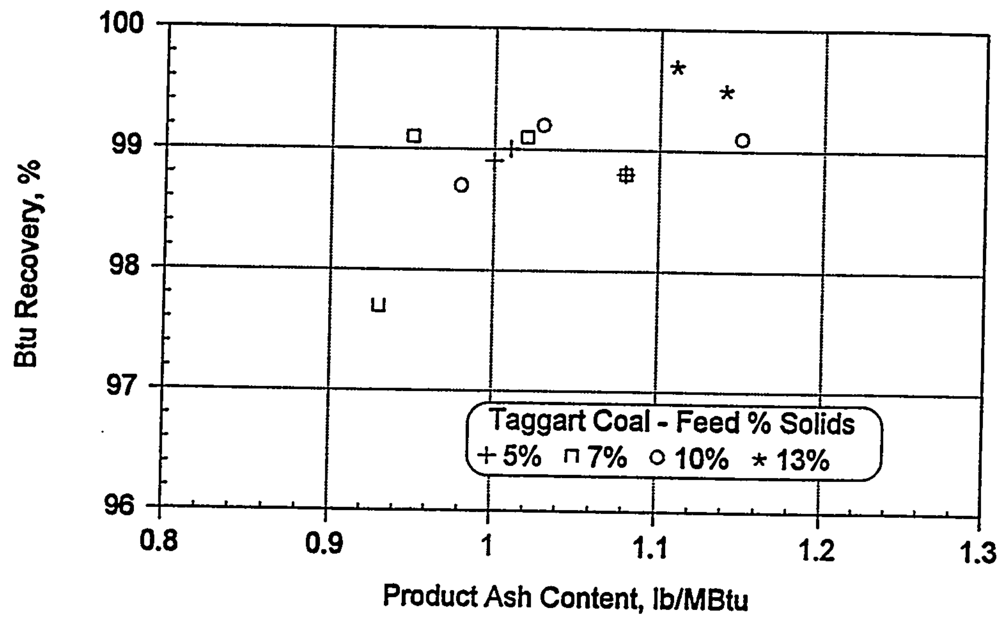



**Figure 3. Taggart Coal Continuous Agglomeration Results**

It should be noted that three of the five agglomeration tests carried out this reporting period met the target product ash specification of 1 lb/MBtu. For the two tests that didn't meet the product specification, smaller agglomerates were formed, i.e., less than 1.5 mm in size. These results confirm previous data indicating that the formation of larger better formed agglomerates results in lower product ash values. With the completion of this test work, continuous bench-scale testing with the Taggart coal is complete.

***Hiawatha Coal***

During previous testing, agglomeration of the Hiawatha coal at a 150-mesh topsize ($d_{80}$ of 47 microns) was evaluated. Results from these tests, shown in Figure 4 and also in Appendix B, indicate that this grind size was sufficiently fine to achieve the desired 2 lb/MBtu product ash specification.

To further evaluate agglomeration of the Hiawatha coal, additional testing was carried out during June at a coarser (100 mesh) topsize grind with a $d_{80}$ of 65 microns. Four such tests were completed, the results of which are shown in Figure 4, as well as presented in Appendix B along with the previous 150-mesh topsize results.

All four of these tests were completed at a 25 lb/hr dry coal feed rate, two at 10% feed solids concentration and two at 7%.

As can be seen from the data in Figure 4, the 100-mesh topsize grind was sufficiently fine to achieve the product ash specification of 2 lb/MBtu. As expected, lower product ash values were achieved with the 7% solids feed than with the 10% solids feed. Heptane dosages utilized for these four tests were in the 24-26% range on a dry coal basis.

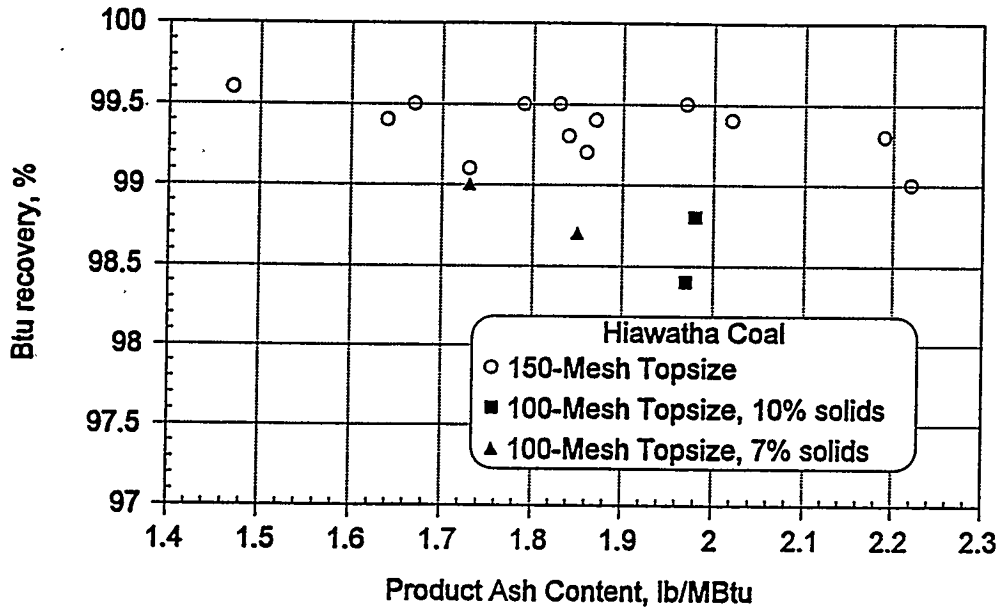



**Figure 4. Hiawatha Coal Continuous Agglomeration Results**

Additional test work utilizing this coarser 100-mesh topsize ($d_{80}$ of 65 microns) grind will be carried out to evaluate the effect of other process variables. Continuous heptane steam stripping tests will also be completed.

***Continuous Steam Stripper Testing***

No structured steam-stripping tests for heptane recovery were carried out during November. Steam stripping of agglomerated coal continued on a regular basis, however, to allow for coal disposal. Random analysis of steam stripper products confirmed that heptane concentrations in the 5000 ppm (dry coal basis) range were produced.

***Toxic Trace Elements Removal***

A study was completed to compare the residual amounts of twelve toxic trace elements in the five test coals cleaned by bench-scale column flotation with the residual amounts in the same coals cleaned by bench-scale selective agglomeration. The reduction in the concentration of these trace elements on a heating value basis was also determined.

The residual amounts of the elements in the clean coals were found to be dependent upon the source coal. For example, there was about four times as much antimony in the Indiana VII clean coal as found in the other four clean coals and a third as much or less arsenic in the Sunnyside clean coal as in the other clean coals.

On the other hand, and with a few exceptions, advanced flotation clean coals and the agglomeration clean coals prepared from the same test coals contained about the same amounts of the trace elements. The exceptions were lead in the Elkhorn No. 3 coal, arsenic and nickel in the Sunnyside coal, selenium in the Taggart coal, and chromium and selenium in the Winifrede coal.

There were substantial reductions, 25 to 75% on a heating value basis, in the concentrations of arsenic, chromium, manganese, and nickel from the concentrations in the as-received test coals. On the other hand, there was little or no reduction on a heating value basis, less than 25 percent, in the amounts of antimony, beryllium, cobalt, selenium, and chlorine in the test coals. The reduction of lead and mercury varied from coal to coal. Nickel reduction in Indiana VII and arsenic in Sunnyside and Taggart coals were exceptions.

Reductions from the concentrations found in the ROM parent coals were generally greater than the reductions from the as-received test coals on a heating value basis. There were substantial reductions, 25 to 90%, in the concentrations of arsenic, beryllium, chromium, cobalt, lead, manganese, mercury, and selenium from the amounts in the ROM coals. On the other hand, there was little or no reduction, less than 25%, in the amount of antimony. The reduction of nickel and chlorine varied from coal to coal. Nickel reduction in Elkhorn No. 3, beryllium and chromium in Sunnyside, and chromium and selenium in Winifrede were exceptions.

The tabulated data are presented in Table 5 below, and the comparisons will be the subject of a poster presentation at the Pittsburgh Coal Conference in September.

**Table 5. Impurities in Clean Coals**

| | Clean Coal Analysis | | Reduction on Heating Value Basis, % From Test Coal | | Reduction on Heating Value Basis, % From ROM Coal | |
|---|---|---|---|---|---|---|
| | Flotation | Agglomeration | Flotation | Agglomeration | Flotation | Agglomeration |
| **Taggart Coal** | | | | | | |
| Ash, % | 1.52 | 1.58 | 29 | 23 | 97 | 97 |
| S(tot), % | 0.63 | 0.65 | 2 | 2 | 19 | 17 |
| S(pyr), % | 0.12 | 0.14 | neg | neg | neg | neg |
| Sb, ppm | 0.42 | 0.3 | neg | 1 | neg | neg |
| As, ppm | 1.7 | 1.7 | 11 | 15 | 79 | 79 |
| Be, ppm | 1.8 | 1.3 | neg | 8 | 41 | 58 |
| Cd, ppm | < 0.1 | < 0.1 | | | | |
| Cr, ppm | 4.2 | 6 | 35 | 57 | 87 | 81 |
| Co, ppm | 8.0 | 6.8 | neg | 1 | 37 | 46 |
| Pb, ppm | 2 | 2 | 1 | 1 | 54 | 54 |
| Mn, ppm | 4 | 4.0 | 43 | 45 | 98 | 98 |
| Hg, ppm | 0.01 | < 0.01 | 1 | | 66 | > 66 |
| Ni, ppm | 10 | 16 | 24 | 24 | neg | neg |
| Se, ppm | 3.1 | 1.7 | neg | 1 | 52 | 74 |
| Cl, ppm | 68 | 58 | neg | neg | neg | 10 |
| **Winifrede Coal** | | | | | | |
| Ash, % | 2.96 | 2.76 | 68 | 69 | 92 | 93 |
| S(tot), % | 0.89 | 0.94 | 14 | 10 | 28 | 24 |
| S(pyr), % | 0.19 | 0.13 | 15 | 39 | 57 | 70 |
| Sb, ppm | 0.55 | 0.5 | neg | neg | neg | neg |
| As, ppm | 1.5 | 1.7 | 46 | 45 | 78 | 75 |
| Be, ppm | 2.9 | 2.5 | 18 | 16 | 33 | 42 |
| Cd, ppm | < 0.1 | < 0.1 | | | | |
| Cr, ppm | 28 | 56 | 53 | 48 | 20 | neg |
| Co, ppm | 7.6 | 7.9 | 22 | 3 | 37 | 34 |
| Pb, ppm | 5 | 4 | 6 | 47 | 59 | 67 |
| Mn, ppm | 4 | 5.3 | 77 | 55 | 89 | 86 |
| Hg, ppm | 0.03 | 0.02 | 6 | 38 | 45 | 63 |
| Ni, ppm | 15 | 19 | 44 | 41 | neg | neg |
| Se, ppm | 5.2 | 2.3 | 18 | 14 | 35 | 71 |
| Cl, ppm | 940 | 651 | 0 | 15 | 34 | 54 |
| **Elkhorn No. 3 Coal** | | | | | | |
| Ash, % | 2.63 | 2.57 | 55 | 56 | 97 | 97 |
| S(tot), % | 0.92 | 0.93 | 13 | 6 | 42 | 42 |
| S(pyr), % | 0.24 | 0.12 | 11 | neg | 69 | 84 |
| Sb, ppm | 0.48 | 0.3 | neg | 3 | neg | 16 |
| As, ppm | 2.5 | 2.4 | 35 | 51 | 82 | 83 |
| Be, ppm | 1.9 | 1.6 | 3 | 3 | 56 | 63 |
| Cd, ppm | < 0.1 | < 0.1 | | | > 47 | > 47 |
| Cr, ppm | 9.6 | 12 | 38 | 54 | 82 | 78 |
| Co, ppm | 5.6 | 4.9 | 11 | 12 | 73 | 76 |
| Pb, ppm | 2 | 7 | 36 | 3 | 73 | 7 |
| Mn, ppm | 10 | 6.8 | 61 | 61 | 97 | 98 |
| Hg, ppm | 0.02 | 0.01 | 36 | 3 | 65 | 82 |
| Ni, ppm | 14 | 15 | 25 | 28 | 33 | 28 |
| Se, ppm | 2.1 | 2.1 | 12 | 19 | 76 | 76 |
| Cl, ppm | 1240 | 1080 | 0 | 5 | 24 | 33 |

neg = negative number

**Table 5 (Cont'd). IMPURITIES IN CLEAN COALS**

| | Clean Coal Analysis | | Reduction on Heating Value Basis, % From Test Coal | | Reduction on Heating Value Basis, % From ROM Coal | |
|---|---|---|---|---|---|---|
| | Flotation | Agglomeration | Flotation | Agglomeration | Flotation | Agglomeration |
| **Indiana VII coal** | | | | | | |
| Ash, % | 2.86 | 2.74 | 73 | 74 | 96 | 96 |
| S(tot), % | 0.57 | 0.63 | 21 | 20 | 56 | 52 |
| S(pyr), % | 0.19 | 0.14 | 43 | 56 | 78 | 83 |
| Sb, ppm | 2.3 | 1.9 | neg | neg | neg | 6 |
| As, ppm | 1.7 | 1.7 | 76 | 46 | 75 | 75 |
| Be, ppm | 2.7 | 2.2 | 4 | 8 | 30 | 43 |
| Cd, ppm | < 0.1 | < 0.1 | | | > 40 | > 41 |
| Cr, ppm | 14 | 15 | 50 | 55 | 62 | 59 |
| Co, ppm | 9.2 | 9.0 | 8 | 2 | 50 | 51 |
| Pb, ppm | 5 | 7 | 34 | 28 | 79 | 70 |
| Mn, ppm | 14 | 17 | 61 | 55 | 94 | 93 |
| Hg, ppm | 0.02 | < 0.01 | 38 | > 8 | 40 | > 70 |
| Ni, ppm | 36 | 33 | 12 | 34 | 29 | 35 |
| Se, ppm | 0.78 | 0.5 | 20 | 23 | 40 | 62 |
| Cl, ppm | 76 | 101 | neg | neg | neg | neg |
| **Winifrede Coal** | | | | | | |
| Ash, % | 2.69 | 2.54 | 49 | 53 | 83 | 84 |
| S(tot), % | 0.65 | 0.65 | 4 | 5 | 4 | 4 |
| S(pyr), % | 0.13 | 0.14 | neg | neg | 6 | 0 |
| Sb, ppm | 0.10 | 0.1 | neg | 3 | neg | neg |
| As, ppm | 0.15 | 0.6 | 54 | 17 | 84 | 37 |
| Be, ppm | 0.8 | 0.5 | 3 | 3 | 13 | 46 |
| Cd, ppm | < 0.1 | < 0.1 | | | | |
| Cr, ppm | 5.9 | 10 | 41 | 69 | 44 | 6 |
| Co, ppm | 1.3 | 0.6 | 10 | 17 | 49 | 76 |
| Pb, ppm | 2 | 3 | 3 | 3 | 57 | 35 |
| Mn, ppm | 12 | 15 | 62 | 67 | 75 | 69 |
| Hg, ppm | < 0.01 | < 0.01 | > 51 | | > 57 | > 57 |
| Ni, ppm | 3.3 | 13 | 58 | 68 | neg | neg |
| Se, ppm | 0.71 | 0.7 | neg | 3 | 31 | 32 |
| Cl, ppm | 1120 | 982 | 1 | 1 | 17 | 28 |

neg = negative number

## TASK 8 PDU AND ADVANCED COLUMN FLOTATION MODULE

The Task 8 work completed this reporting quarter focused on Subtask 8.1 Coal Selection and Procurement and Subtask 8.4 PDU Operation and Clean Coal Production as discussed in the next sections of this report.

### Subtask 8.1 Coal Selection and Procurement

Eight hundred tons of Hiawatha seam coal were ordered from the Genwal Crandall Creek Mine in Utah. Because of a shortage of freight cars, delivery to the American Coal Company yard in Denver was delayed until July 19, 1996. The Hiawatha coal will contain about 9 percent ash since the mine does not wash the coal before market. In most other respects, though, the Hiawatha coal resembles the Sunnyside coal used for the Tasks 4 and 6 testing. The 800 tons will be sufficient for both the column flotation and the selective agglomeration PDU operations.

**Subtask 8.4 PDU Operation and Clean Coal Production**

Operation of the PDU Flotation Module continued during the second quarter of 1996. Optimization of the Taggart coal was completed as well as the development of associated regression equations. Work was also performed with the Taggart coal to better determine scale-up similitude between the 12-inch and 6-foot Microcel™ columns.

In addition to the work completed on the Taggart coal, shakedown testing of the PDU using Indiana VII coal also commenced during the quarter. The fine liberation requirements of the Indiana VII coal led to several unexpected operating problems in the PDU grinding circuit. As a result, most efforts during the quarter were directed to troubleshooting and correcting these problems. Specifically, degradation and loss of grinding media from the ball mills resulted in screen blinding, cyclone plugging, and unexpected downtime. Consultations with Mineral Resource Development Inc., a firm specializing in grinding and size reduction, revealed that the speed of each mill was too fast, the ball size distribution was too coarse, the ball charge was too heavy, and the mill solids concentration was too dilute. New setpoints were established and the grinding circuit modified accordingly.

***Optimization of PDU Flotation Module - Taggart Coal***

Optimization of Taggart coal in the PDU Flotation Module was completed during the quarter. A total of seven tests were performed to determine the optimum Microcel™ setpoints needed to achieve the process development goals of 1 lb/MBtu of ash and over 80% energy recovery.

Equations were first developed to estimate the effects of tested input variables on Microcel™ outputs such as yield and quality. The equations were developed by evaluating the input and output variables of parametric tests T21 through T39 by multiple linear regression. The resulting equations were then used to determine optimum Microcel™ setpoints. A unique function found in the Microsoft Excel software package called "Solver" was used to determine the proposed optimal setpoints for test work. The results of the optimization test work are shown in Table 6.

Observation of the data shows that the overall quality goal of 1 lb/MBtu of ash was achieved on two occasions during optimization (tests TO-6 and TO-7). The clean coal yield varied from 87.5% to 88.3% while the product ash varied from 0.88 lb/MBtu to 0.97 lb/MBtu. It is important, however, to note that the aforementioned results correspond to a $d_{80}$ of approximately 60 microns. Parametric testing, on the other hand, indicated improved yield and energy recovery when the $d_{80}$ approached 50 microns. As a result, the yield and product ash values of 94.4% and 0.99 lb/MBtu achieved during parametric test T-25 should be considered optimum.

**Table 6. PDU Flotation Optimization Testing - Taggart Coal**

| Test | Fuel Oil lb/ton | Frother lb/ton | % Sol | Air CFM | Wash GPM | Recirc GPM | Feed lb / hr | Column d80 | PDU Yield | Energy Recov | Sulfur lb/MBtu | Ash lb/MBtu |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| TO-1 | 0.26 | 0.42 | 6.51 | 75 | 77 | 852 | 4,200 | 58 | 95.53 | 97.43 | 0.45 | 1.18 |
| TO-2 | 0.26 | 0.42 | 5.58 | 75 | 77 | 852 | 4,200 | 58 | 95.26 | 97.31 | 0.46 | 1.16 |
| TO-3 | 0.26 | 0.31 | 6.16 | 55 | 77 | 800 | 4,200 | 52 | 92.69 | 95.21 | 0.46 | 1.05 |
| TO-4 | 0.26 | 0.25 | 7.72 | 75 | 77 | 990 | 4,200 | 66 | 92.34 | 95.23 | 0.47 | 1.24 |
| TO-5 | 0.53 | 0.25 | 6.24 | 75 | 77 | 990 | 4,200 | 66 | 95.39 | 97.71 | 0.47 | 1.32 |
| TO-6 | 0.26 | 0.20 | 7.14 | 55 | 77 | 800 | 4,200 | 59 | 86.63 | 88.26 | N/R | 0.88 |
| TO-7 | 0.26 | 0.25 | 7.70 | 55 | 77 | 800 | 4,200 | 60 | 85.46 | 87.53 | N/R | 0.97 |
| T-25 | 0.50 | 0.50 | 6.63 | 55 | 71 | 800 | 4,200 | 51 | 94.36 | 96.90 | 0.44 | 0.99 |
| MAX | 0.53 | 0.50 | 7.72 | 75 | 77 | 990 | 4,200 | 66 | 95.53 | 97.71 | 0.47 | 1.32 |
| MIN | 0.26 | 0.20 | 5.58 | 55 | 77 | 800 | 4,200 | 51 | 85.46 | 87.53 | 0.45 | 0.88 |

***Development of PDU Flotation Regression Equations - Taggart Coal***

Data from PDU Flotation Module parametric testing was compiled and multiple regression models (equations) were generated. Forward stepwise regression produced equations which link output variables such as yield and clean coal quality to input variables such as feed rate, wash water rate, air rate, collector addition, and frother addition. The equation term coefficients for the two main response variables are shown in the Tables 7 and 8.

**Table 7. Regression Analysis of Taggart Yield (%)**

| Input Variable | Equation Coefficient | t-Statistic |
|---|---|---|
| Intercept | 130.66143 | 27.10 |
| % Solids | -1.66891 | -2.14 |
| $(\text{Feed Ash})^2$ | -0.45968 | -15.95 |
| $(\text{\% Solids})^2$ | 0.16377 | 3.05 |
| $(\text{Frother lb/ton})^{1/2}$ | -28.15453 | -9.16 |
| 1 / (Frother lb/ton) | -5.97012 | -34.14 |
| 1 / Recirculation Rate (gpm) | -3503.73683 | -3.67 |
| ln (Air Rate CFM) | 2.55721 | 3.59 |
| Coefficient of Determination ($R^2$) | 0.999 | |
| Adjusted $R^2$ | 0.997 | |

The Coefficient of Determination ($R^2$) and Adjusted Coefficient of Determination (Adjusted $R^2$) both show that the each equation fits the data quite well. In addition, observation of the t-statistic, which indicates the relative importance of each independent variable to the response equation, shows that the most important variable that affects yield and clean coal ash is the frother dosage. In both cases, the frother dosage is directly proportional. It is important to note that though the yield and clean coal ash are dependent on the feed coal ash content, the ash content itself is not a controllable variable but considered a covariate.

**Table 8. Regression Analysis of Taggart Product Ash (lb/MBtu)**

| Input Variable | Equation Coefficient | t-Statistic |
|---|---|---|
| Intercept | 173.13462 | 2.51 |
| % Solids | 0.16140 | 3.73 |
| d80 | -1.18726 | -2.82 |
| $(\text{Feed Ash})^2$ | -0.06340 | -1.57 |
| $(\text{Frother lb/ton})^2$ | 0.92194 | 7.07 |
| $(\text{Wash Water GPM})^2$ | 2.91293 E-05 | 1.59 |
| $(\text{Recirculation GPM})^2$ | 6.67988 E-07 | 1.30 |
| $(\text{d80})^2$ | 0.01114 | 2.84 |
| 1 / (Feed Ash %) | -8.20673 | -1.52 |
| 1 / (Collector lb/ton) | -0.09205 | -2.95 |
| 1 / (% Solids) | 5.52978 | 3.10 |
| 1 / (Air Rate CFM) | -111.34457 | -1.43 |
| 1 / (Wash Water GPM) | 26.86557 | 1.35 |
| 1 / (Feed Rate lb/hr) | -47,416.95503 | -2.24 |
| ln (Air Rate CFM) | -2.67400 | -1.74 |
| ln (Recirculation GPM) | -0.64466 | -1.03 |
| ln (Feed Rate lb/hr) | -13.42548 | -2.34 |
| Coefficient of Determination ($R^2$) | 0.978 | |
| Adjusted $R^2$ | 0.861 | |

***Scale-up of Microcel™ Flotation Column - Taggart Coal***

Because the Taggart coal that was used in the PDU Flotation Module has a higher ash content than that used during the Fall, 1994, parametric testing of the 12-inch column (4% versus 2%), the similitude for scale-up would be inaccurate. As a result, six tests were performed on the Taggart coal in the 12-inch Microcel™ unit. The parameters of the six tests correspond directly to those used in optimization tests TO-2 through TO-7. The results are provided in Tables 9 and 10.

Observation of the data shows that the clean coal ash goal of 1 lb/MBtu was achieved during all 12-inch Microcel™ tests. However, when compared to the identical tests conducted in the 6-foot Microcel™, different results were obtained. This difference is depicted more clearly in Figure 5.

**Table 9. Scale Up Testing of Microcel™ Column - Taggart Coal**

| Test | Fuel Oil lb / ton | Frother lb / ton | % Solids | Air CFM | Wash GPM | Feed lb / hr | % Yield | Energy Recov (%) | Ash lb/MBtu |
|---|---|---|---|---|---|---|---|---|---|
| T12-01 | 0.26 | 0.40 | 6.93 | 2.08 | 2.44 | 120 | 91.15 | 94.18 | 1.00 |
| T12-02 | 0.26 | 0.33 | 6.89 | 1.53 | 2.35 | 120 | 72.29 | 74.76 | 0.82 |
| T12-03 | 0.26 | 0.24 | 6.73 | 2.08 | 2.10 | 117 | 84.78 | 87.78 | 0.98 |
| T12-04 | 0.48 | 0.23 | 7.00 | 2.08 | 2.10 | 122 | 90.96 | 93.89 | 0.99 |
| T12-05 | 0.20 | 0.17 | 7.83 | 1.53 | 2.16 | 137 | 74.43 | 76.68 | 0.85 |
| T12-06 | 0.23 | 0.22 | 7.55 | 1.53 | 2.16 | 132 | 76.76 | 78.98 | 0.84 |
| MAX | 0.48 | 0.40 | 7.83 | 2.08 | 2.44 | 137 | 91.15 | 94.18 | 1.00 |
| MIN | 0.20 | 0.17 | 6.73 | 1.53 | 2.10 | 117 | 72.29 | 74.76 | 0.82 |

**Table 10. Performance of 1-foot and 6-foot Microcel™ - Taggart Coal**

| Parameter | Series #1 | | Series #2 | | Series #3 | | Series #4 | | Series #5 | | Series #6 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 12 in | 6 ft | 12 in | 6 ft | 12 in | 6 ft | 12 in | 6 ft | 12 in | 6 ft | 12 in | 6 ft |
| Feed, lb/hr | 120 | 4,200 | 120 | 4,200 | 117 | 4,200 | 122 | 4,200 | 137 | 4,200 | 132 | 4,200 |
| Solids Conc., % | 6.93 | 5.81 | 6.89 | 6.16 | 6.73 | 7.72 | 7.00 | 6.24 | 7.83 | 7.14 | 7.55 | 7.70 |
| Fuel Oil, lb/ton | 0.26 | 0.26 | 0.26 | 0.26 | 0.26 | 0.26 | 0.48 | 0.53 | 0.20 | 0.26 | 0.23 | 0.26 |
| Frother, lb/ton | 0.40 | 0.41 | 0.33 | 0.30 | 0.24 | 0.25 | 0.23 | 0.25 | 0.17 | 0.20 | 0.22 | 0.25 |
| Yield, % | 91.15 | 95.26 | 72.29 | 92.69 | 84.78 | 92.34 | 90.96 | 95.39 | 74.43 | 86.63 | 76.76 | 85.46 |
| Feed Ash, % | 4.45 | 4.27 | 4.26 | 4.27 | 4.60 | 5.26 | 4.35 | 4.73 | 3.97 | 3.63 | 3.84 | 3.86 |
| CC Ash, % | 1.51 | 1.74 | 1.24 | 1.59 | 1.48 | 1.86 | 1.50 | 1.98 | 1.28 | 1.33 | 1.27 | 1.46 |
| CC Ash, lb/MBtu | 1.00 | 1.16 | 0.82 | 1.05 | 0.98 | 1.24 | 0.99 | 1.32 | 0.85 | 0.88 | 0.84 | 0.97 |
| Tails Ash, % | 34.73 | 42.23 | 12.14 | 34.68 | 21.98 | 37.89 | 33.03 | 48.82 | 11.80 | 13.97 | 12.33 | 16.38 |
| Product, lb/hr/ft$^2$ | 139 | 142 | 111 | 138 | 127 | 137 | 141 | 142 | 130 | 129 | 129 | 127 |
| Air Vel, ft/min | 2.65 | 2.65 | 1.95 | 1.95 | 2.65 | 2.65 | 2.65 | 2.65 | 1.95 | 1.95 | 1.95 | 1.95 |
| $H_2O$ Vel, ft/min | 0.42 | 0.36 | 0.40 | 0.36 | 0.36 | 0.36 | 0.36 | 0.36 | 0.37 | 0.36 | 0.37 | 0.36 |

Though both units produce results that fall on the same grade-yield curve, Figure 5 clearly illustrates that the 6-foot Microcel™ produces clean coal at a higher yield and ash than the 12-inch unit. Discussions with Mr. Dennis Phillips of Virginia Tech revealed that the discrepancy is most likely attributable to the frother addition point.

The addition of frother into the suction side of the Microcel™ recirculation pump (6-foot column) is typically more efficient than adding frother in the slurry feed mixing tank (1-foot column). Specifically, when frother is added to the pump suction it is closest to the point where it is needed most - the air injection point. The result is a smaller bubble size for a constant frother addition rate. The smaller bubbles, which have greater surface area than larger bubbles, are now capable of carrying more clean coal particles to the overflow. In addition, smaller bubbles have a greater surface tension which facilitates the floating of middlings particles with lower hydrophobicity.

As a result, the discrepancy in performance between the two columns is not unexpected. The addition of frother to the 12-inch column slurry mix tank resulted in large bubbles (about 2 mm) with low carrying capacity and high selectivity. The result was a low-yield, high-quality product. However, the addition of frother to the recirculation suction line of 6-foot column resulted in smaller bubbles (1 mm) with high carrying capacity and low selectivity. The result was a high-yield, low-quality product.

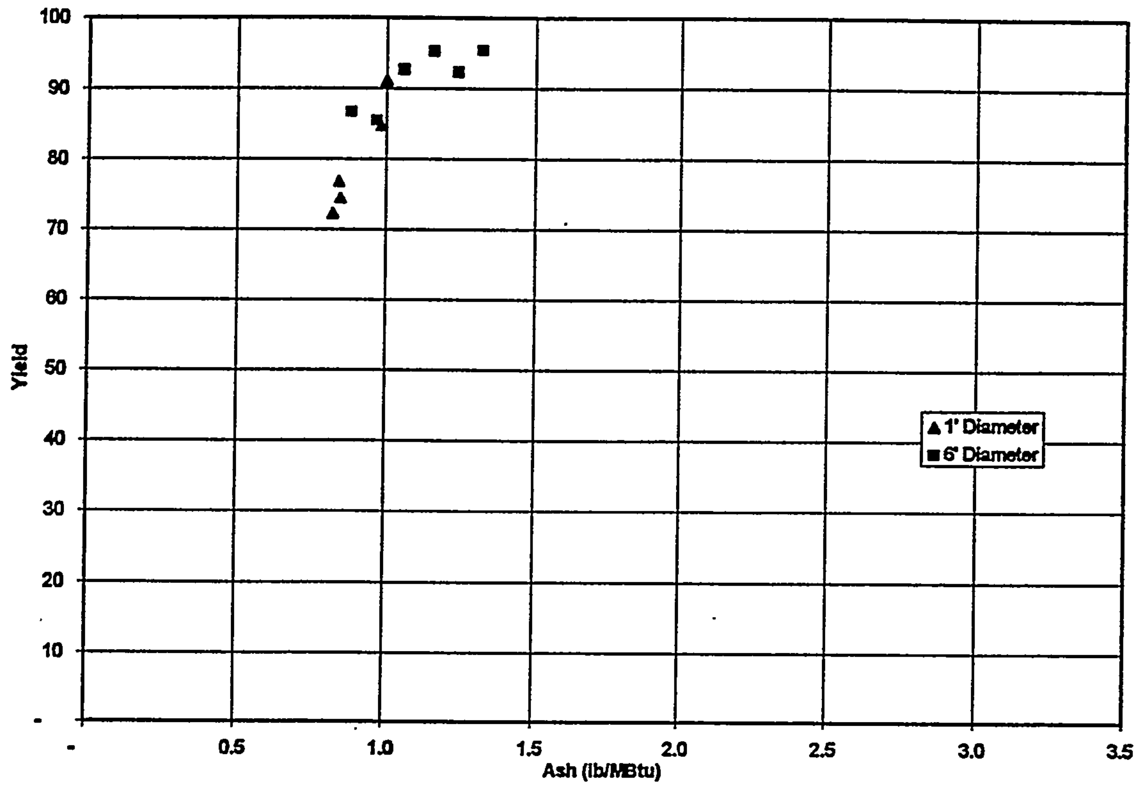



**Figure 5. Comparison of 1-Foot and 6-Foot Microcel™ Columns - Taggart Coal**

***Delivery of Taggart Filter Cake to The Pennsylvania State University***

Approximately 200 tons of clean coal filter cake produced during the Taggart extended production run is slated for transport to Penn State's Coal Utilization Laboratory. Previously scheduled for delivery during April, 1996, the delivery date has been postponed until PSU's slurry grinding circuit is operational. Unfortunately, PSU has made very little progress in this area. Currently, management at Penn State is searching for a warehouse storage location for shipment within the next month.

***Shakedown of PDU Flotation Module - Indiana VII Coal***

Shakedown of the PDU Flotation Module using Indiana VII coal was completed during the quarter. Unlike the Taggart coal, the Indiana VII coal required two distinct circuit changes in order to achieve adequate liberation:

- Sizetec screen cloths were changed from 140 mesh (105 microns) to 270 mesh (53 microns)

- Oversize material from the classification circuit was ground in the Netzsch Fine Grinding Mill instead of the Secondary Ball Mill

Previous laboratory testing of the Indiana VII coal indicated that adequate mineral liberation is achieved when the coal is crushed to 80% passing 22 to 24 microns ($d_{80}$ = 22 to 24 microns). This size distribution goal, for all intents and purposes, was achieved during the second shakedown run with a $d_{80}$ of 24.9 microns.

## *Evaluation and Modification of Area 100 Grinding Circuit*

The fine liberation requirements of the Indiana VII coal led to several unexpected operating problems in the PDU grinding circuit. Specifically, degradation and loss of grinding media from the ball mills resulted in screen blinding, cyclone plugging, increased $d_{80}$ values, and unexpected downtime. As a result, parametric testing of the Indiana VII coal was temporarily suspended and efforts redirected to troubleshooting and correcting these problems. Consultations with Mineral Resource Development Inc., a firm specializing in grinding and size reduction, revealed that the speed of each mill was too fast, the ball size distribution was too coarse, the ball charge was too heavy, and the mill solids concentration was too dilute. Their recommendations, which were implemented by Entech Global personnel, are listed as follows:

- **Reduce Mill Speed** - The critical speed of each mill was calculated to be approximately 35 RPM. The actual speed of each mill, however, was measured at 85% of critical or 30 RPM. Because optimum grinding efficiency occurs at a mill speed of 65% of critical, the speed of each mill was reduced to 24 RPM.
- **Reduce Ball Size Distribution** - The size distribution of balls in each mill was found to be too large for the 1/2 inch coal being fed to the circuit. As a result, the ball topsize in the primary mill was reduced from 3 inches to 2 inches while that of the secondary mill was reduced from 2-1/2 inches to 1-1/2 inches. The new overall distribution of balls in each mill is as shown in Table 11.

**Table 11. Distribution of Balls in Primary and Secondary Mills**

| Ball Size | Primary Mill Distribution | Secondary Mill Distribution |
|---|---|---|
| 2 inch | 33.3 % | — |
| 1.5 inch | 33.3 % | 33.3 % |
| 1 inch | 33.3 % | 33.3 % |
| 0.5 inch | | 33.3 % |
| Total | 100.0 % | 100.0 % |

- **Reduce Overall Ball Charge** - The total weight of balls in each mill was too great for the amount of coal processed. As such, balls were impacting each other, contributing to media degradation. The total ball weight of each mill was reduced from 13,600 and 14,000 pounds in the primary and secondary mills, respectively, to 8,100 pounds in each mill.

- **Increase Solids Concentration** - Previous test work performed in the PDU on the Taggart coal revealed that the concentration of coal solids in each mill was typically around 20%. The low solids concentration is the result of excess push water being used at the primary mill inlet. Ideally, the solids concentration in each mill should be somewhere between 40% and 50%. Entech operating personnel have found that the mill solids concentration can be increased by slowly reducing the primary mill push water to its operating minimum quantity. Currently, the ratio of push water to coal feed tonnage has been reduced from over 7 GPM per t/hr of coal to 5 GPM per t/hr of coal. This reduction in push water has increased the mill solids concentration to over 38%.
- **Remove Fines From Mill Feed** - One of the common principles of comminution states that only oversize material should be presented to the size reduction unit operation. As a result, the undersize material should be removed from the coal stream prior to grinding. Because space limitations prohibit the removal of fines from the primary mill feed stream, efforts were directed to the removal of fines from the secondary mill feed. Currently, the most economical method of fines removal for this application is a single classifying cyclone. The cyclone, capable of removing 80% of the minus 270 mesh (53 micron) material from the secondary mill feed stream, is scheduled for delivery during the last week of July.

Though only four of the above five recommendations have been implemented to date, the improvements have eliminated all operational problems previously encountered in the grinding circuit. Not only have screen blinding and cyclone plugging problems been eliminated, the $d_{80}$ of the Microcel™ feed particle size distribution now consistently ranges from 20 to 23 microns.

***Laboratory Release Analysis - Indiana VII Coal***

To better define the theoretical grade-yield curves associated with different feed size distributions, release analysis test work was performed on the Indiana VII coal during the quarter. Two Microcel™ feed slurries, one having a size distribution with 80% passing 22 microns and a second with 80% passing 19 microns, were evaluated. The results of the flotation test work are shown in Figure 6.

Observation of the data shows that the product ash goal of 2 lb/MBtu can be achieved at yields of 74% and 83% for feed slurries having a $d_{80}$ of 22 and 19 microns respectively. The increase in yield can be attributed to enhanced liberation of carbon and mineral matter.

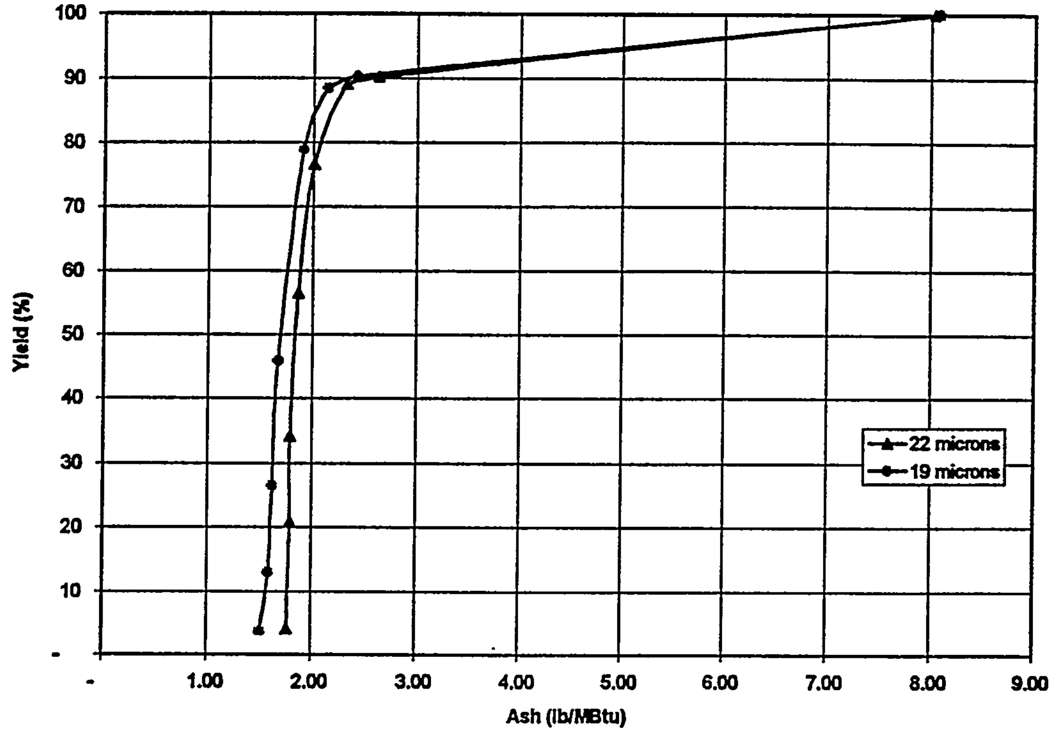



**Figure 6. Laboratory Release Analysis - Indiana VII Coal**

It is important to note that though the additional yield associated with a $d_{80}$ grind of 19 microns may be desirable, the production of a similar size consist in the PDU flotation module would result in a dramatic reduction in filtering capacity as well as an increase in product moisture. As a result, all PDU test work will be performed at a $d_{80}$ of 22 microns.

***Parametric Testing of PDU Flotation Module - Indiana VII Coal***

Parametric testing of the PDU Flotation Module (6 foot Microcel™) commenced during the second quarter of 1996. A test matrix was established to determine the effects of independent variables such as air rate, % solids, feed rate, wash water, and reagent dosage on response variables such as product ash and yield. The test matrix is shown in Table 12.

As mentioned earlier in this report, the fine liberation requirements of the Indiana VII coal led to several unexpected operating problems in the PDU grinding circuit. Degradation and loss of grinding media from the ball mills resulted in screen blinding, cyclone plugging, increased $d_{80}$ values, and unexpected downtime. As a result, the parametric testing of the Indiana VII coal was temporarily suspended after 13 tests. Testing resumed in late June after all problems associated with the grinding circuit was corrected. Unfortunately, due to inadequate liberation of mineral matter, only data from 1 of the 13 tests can be considered valid (Test I-7).

**Table 12. PDU Flotation Module Test Matrix - Indiana VII Coal**

| Test | Collector | Frother | % Solids | Air Rate | Wash Water | Recirculation | Feed Rate |
|---|---|---|---|---|---|---|---|
| I-1 | 5.0 lb/ton | 2.50 lb/ton | 7.50 | 55 | 142 | 800 | 3,200 |
| I-2 | 3.0 lb/ton | 2.50 lb/ton | 7.50 | 55 | 142 | 800 | 3,200 |
| I-3 | 7.0 lb/ton | 2.50 lb/ton | 7.50 | 55 | 142 | 800 | 3,200 |
| I-4 | 5.0 lb/ton | 3.50 lb/ton | 7.50 | 55 | 142 | 800 | 3,200 |
| I-5 | 5.0 lb/ton | 1.50 lb/ton | 7.50 | 55 | 142 | 800 | 3,200 |
| I-6 | 5.0 lb/ton | 2.50 lb/ton | 10.00 | 55 | 142 | 800 | 3,200 |
| I-7 | 5.0 lb/ton | 2.50 lb/ton | 5.00 | 55 | 142 | 800 | 3,200 |
| I-8 | 5.0 lb/ton | 2.50 lb/ton | 7.50 | 75 | 142 | 800 | 3,200 |
| I-9 | 5.0 lb/ton | 2.50 lb/ton | 7.50 | 35 | 142 | 800 | 3,200 |
| I-10 | 5.0 lb/ton | 2.50 lb/ton | 7.50 | 55 | 180 | 800 | 3,200 |
| I-11 | 5.0 lb/ton | 2.50 lb/ton | 7.50 | 55 | 100 | 800 | 3,200 |
| I-12 | 5.0 lb/ton | 2.50 lb/ton | 7.50 | 55 | 142 | 1000 | 3,200 |
| I-13 | 5.0 lb/ton | 2.50 lb/ton | 7.50 | 55 | 142 | 600 | 3,200 |
| I-14 | 5.0 lb/ton | 2.50 lb/ton | 7.50 | 55 | 142 | 800 | 2,500 |
| I-15 | 5.0 lb/ton | 2.50 lb/ton | 7.50 | 55 | 111 | 800 | 2,500 |
| I-16 | 5.0 lb/ton | 2.50 lb/ton | 7.50 | 35 | 142 | 800 | 3,900 |
| I-17 | 5.0 lb/ton | 2.50 lb/ton | 7.50 | 55 | 173 | 800 | 3,900 |
| I-18 | 5.0 lb/ton | 2.50 lb/ton | 7.50 | 55 | 142 | 800 | 3,200 |

The results of all parametric test work completed during the quarter are shown in Table 13.

**Table 13. Parametric Testing of PDU Flotation Module - Indiana VII Coal**

| Test | Fuel Oil lb / ton | Frother lb / ton | % Solids | Air Rate CFM | Wash GPM | Recirc GPM | Feed lb / hr | Microcel d80 | PDU Yield | Energy Recov | Ash lb / MBtu |
|---|---|---|---|---|---|---|---|---|---|---|---|
| I-1 | 4.97 | 2.53 | 7.66 | 55 | 142 | 800 | 3,200 | 25 | 87.46 | 94.59 | 2.69 |
| I-2 | 2.97 | 2.53 | 7.15 | 55 | 142 | 800 | 3,200 | 26 | 88.45 | 95.46 | 2.57 |
| I-3 | 6.97 | 2.53 | 6.98 | 55 | 142 | 800 | 3,200 | 24 | 88.87 | 95.24 | 2.82 |
| I-4 | 4.97 | 0.73 | 6.44 | 55 | 142 | 800 | 3,200 | 23 | 50.46 | 54.73 | 1.95 |
| I-5 | 4.97 | 1.53 | 6.36 | 55 | 142 | 800 | 3,200 | 23 | 85.40 | 93.33 | 2.47 |
| I-6 | 4.97 | 3.53 | 6.41 | 55 | 142 | 800 | 3,200 | 23 | 88.65 | 96.07 | 2.66 |
| I-7 | 4.97 | 2.53 | 8.99 | 55 | 142 | 800 | 3,200 | 22 | 87.83 | 94.67 | 3.04 |
| I-8 | 4.97 | 2.53 | 3.88 | 55 | 142 | 800 | 3,200 | 25 | 88.26 | 95.72 | 2.67 |
| I-9 | 4.97 | 0.73 | 6.29 | 55 | 142 | 800 | 3,200 | 27 | 44.55 | 48.72 | 1.96 |
| I-10 | 4.97 | 2.53 | 6.54 | 55 | 142 | 800 | 3,200 | 26 | 90.79 | 97.40 | 2.76 |
| I-11 | 4.97 | 2.53 | 4.31 | 55 | 142 | 800 | 3,200 | 25 | 85.30 | 91.57 | 2.94 |
| I-12 | 4.97 | 2.53 | 3.76 | 55 | 142 | 800 | 3,200 | 27 | 87.52 | 94.06 | 3.18 |
| I-13 | 4.97 | 2.53 | 3.94 | 55 | 142 | 800 | 3,200 | 27 | 89.48 | 95.45 | 3.40 |
| I-14 | 4.97 | 0.73 | 5.70 | 55 | 142 | 800 | 3,200 | 21 | 11.97 | 13.21 | 1.81 |
| I-15 | 4.97 | 1.13 | 6.29 | 35 | 142 | 800 | 3,200 | 22 | 57.17 | 62.32 | 1.95 |
| I-16 | 5.04 | 0.94 | 6.57 | 55 | 111 | 800 | 3,200 | 18 | 19.78 | 21.73 | 1.93 |
| MAX | 6.97 | 3.53 | 3.73 | 55 | 142 | 800 | | 27 | 90.79 | 97.40 | 3.40 |
| MIN | 2.97 | 0.73 | 8.99 | 55 | 111 | 800 | | 18 | 11.97 | 13.21 | 1.81 |

Observation of the data in Table 13 shows that the overall quality goal of 2 lb/MBtu of ash was met or exceeded on five occasions. The clean coal yield varied from 11.97 to 90.79% while the energy recovery and product ash varied from 13.21 to 97.40% and 1.81 to 3.40 lb/MBtu respectively. Because tests 1-6 and 8-13 had inconsistent size distributions, the resulting difference in mineral liberation ($d_{80}$) renders these tests invalid.

As a result, only valid data from tests 7, and 14-16 are shown in Figures 7 and 8. Observation of the data in these two figures shows that the target clean coal ash quality of 2 lb/MBtu should be optimally achieved at an approximate yield of 74% and an energy recovery of 82%. Future optimization test work will confirm this premise.

Both parametric and optimization test work is expected to conclude during the month of July as well as the production run.

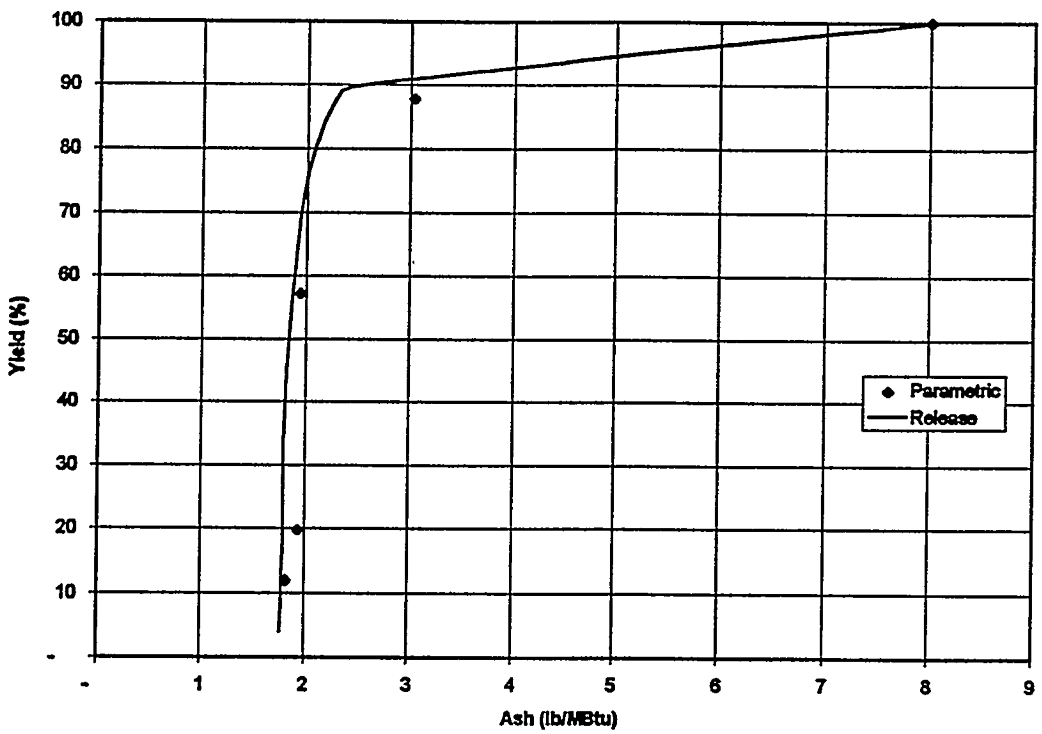



**Figure 7. Parametric Testing of Indiana VII Coal - Yield vs. Ash**

## *Evaluation of Microcel™ Performance by Virginia Tech*

Mr. Dennis Phillips of Virginia Tech visited the Amax R&D Center on June 24 and 25, 1996 to observe the operation of the 6-foot and 12-inch Microcel™ units. Mr. Phillips reviewed the startup, operation, and shutdown of the entire PDU flotation module and recommended the following:

- Try using less wash water. Larger Microcel™ columns typically require less wash water than smaller units. This is primarily due to the added froth drainage obtained with larger diameter units.
- Frother should always be added at the suction side of the recirculation pump. Make modifications to 12-inch column;
- Try to maintain a bubble size of 1 mm. The maximum carrying capacity of a column is achieved when the bubble size approaches 1 mm.

Overall, Mr. Phillips was very pleased with the operation of the PDU and Microcel™ unit.

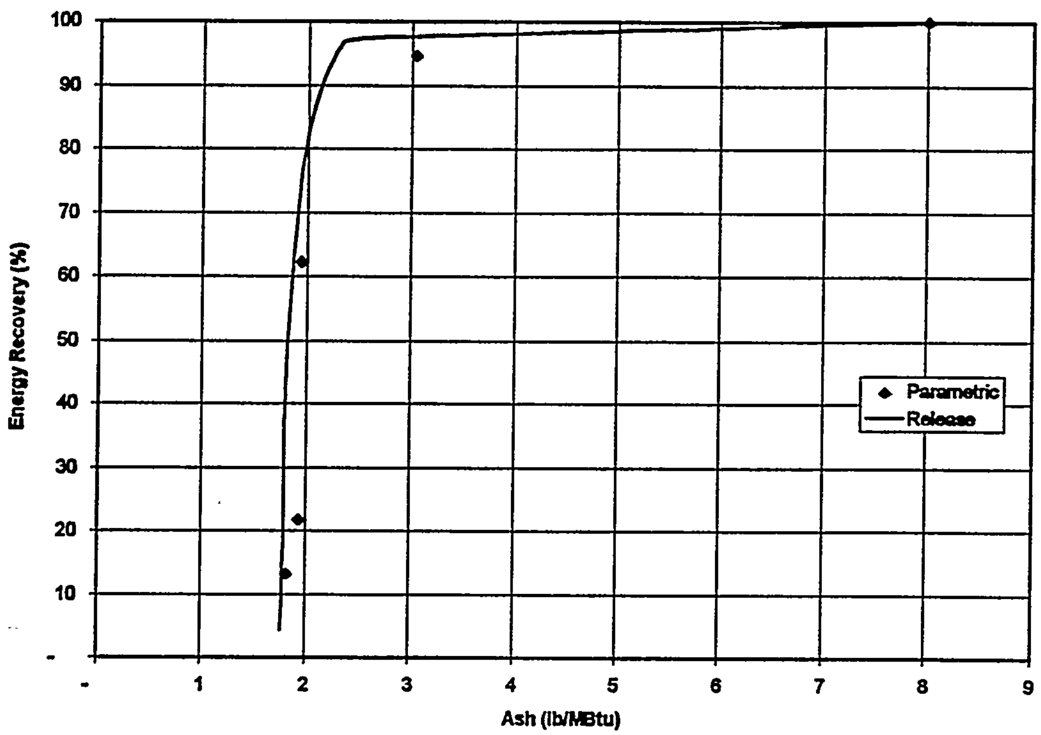



**Figure 8. Parametric Testing of Indiana VII Coal - Energy Recovery vs. Ash**

## *Evaluation of Proprietary Dewatering Aid on Indiana VII Clean Coal*

A five gallon sample of Microcel™ clean coal was sent to Virginia Tech for evaluation of a proprietary dewatering aid. Typically, the dewatering aid significantly reduces the moisture of vacuum filter cake (depending on size distribution). Unfortunately, the test work on the Indiana VII was not successful. The best results obtained with the dewatering aid was approximately 45% moisture. The fine particle size of the Indiana VII clean coal is the most likely cause of the high moisture. No further testing is planned.

***Evaluation of PDU Clean Coal Dewatering Circuit***

During PDU operations to date, it has been found that existing clean coal dewatering capacity was marginal, hindering operation at some desired conditions, particularly at coal feed rates approaching 2 t/hr. As such, the dewatering circuit was evaluated to determine the costs and benefits associated with a capacity expansion. This economic evaluation indicated that due to the high capital cost, expansion of the existing PDU dewatering circuit was not justified. It was determined that, when required, the PDU would be operated at a lower feed rate to reduce demands on the dewatering circuit. This mode of operation, combined with the use of additional temporary labor on an as needed basis, will allow the project goals to be met in a cost effective manner.

***Miscellaneous Accomplishments***

The following miscellaneous accomplishments were made during the quarter:

- Replaced cracked air regulator on drum filter feed pump air line
- Repaired drum filter discharge chute
- Replaced bad circuit board on raw coal vibrating conveyor (100-T-02)
- Removed tramp material protection plate from primary ball mill discharge sump to facilitate ease in cleaning
- Moved excess fuel oil drums from pilot plant to warehouse
- Replaced Microcel™ in-line mixers
- Installed tarp / cover on coal storage pile
- Replaced spray water rotameter on west side of west Sizetec unit
- Repaired west Eimco filter discharge belt (400-Y-02)
- Installed new agitator (100-Y-05) in ground product sump
- Removed a metal nut from internal mechanism of 3-way valve (LV-201)
- Installed power to new ground product agitator (100-Y-05)
- Disconnected power from Netzsch mill feed sump agitator (100-Y-06)
- Installed raw coal bin discharge chute on the tail end of weigh belt feeder
- Installed new gasket on primary ball mill inlet
- Installed new retention screen on discharge of secondary ball mill
- Replaced collector pump calibration tube
- Replaced rotor and stator on cyclone feed pump (100-G-02)
- Installed splash guards on discharge ends of Sizetec screens
- Relocated clean coal filter cake super sacks from Taggart production run to WTP warehouse
- Cleaned Microcel™ wash water spray nozzles
- Added packing to Microcel™ recirculation pump (200-G-02)

- Repaired flat tire on forklift
- Installed Microtrac size analyzer in pilot plant laboratory
- Replaced worn Eimco filter cloth
- Installed Netzsch mill feed sump agitator (100-Y-06)
- Repaired primary ball mill trommel screen
- Installed power to ground product sump agitator
- Replaced 1-inch pipe to Sizetec screens with 2-inch PVC
- Disassembled and inspected clarified water pump (100-G-07)
- Disassembled pressure control valve (PCV-102) and removed a 6-inch piece of electrical tape obstructing the flow of water to Area 100
- Replaced rotor and stator on primary ball mill discharge pump (100-G-01)
- Replaced rotor and stator on fine grinding mill feed pump (100-G-03)
- Crushed Indiana VII coal at Ralston Development
- Installed ventilation pipes for MIBC and Fuel Oil storage cabinets
- Installed a new air pump for transferring Sizetec screen overflow back to the primary ball mill inlet. This dilute stream will be used for push water
- Fabricated and installed a sump for collection of all Sizetec overflow material
- installed 3-inch air pump from for use as 100-G-06
- Replaced VFD for east Eimco filter conveyor
- Disassembled and cleaned out Netzsch fine grinding mill. Removed 240 pounds of fine metallic powder
- Cleaned glass beads from Netzsch fine grinding mill on SWECO screen
- Charged Netzsch fine grinding mill with clean glass beads
- Installed lifting lugs on primary and secondary ball mill discharge end plates
- Removed balls from primary and secondary ball mills
- Sorted and weighed balls from primary and secondary ball mills
- Cleaned cyclone distributor
- Modified drum filter discharge chute and moved filtrate sump to accommodate super sack support structure
- Installed new filter cloth on drum filter
- Removed rubber strips from drum filter filtrate pump chamber
- Relocated CDAS computer to accommodate agglomeration I/O panel
- Re-routed cyclone underflow piping to allow magnet installation in the Netzsch mill feed sump
- Added lubricant to Microcel™ air compressor
- Performed general plant cleanup

- Installed exhaust fan for ventilation of MIBC storage cabinet
- Removed rubber skirtboard from west Eimco filter conveyor
- Installed magnets in discharge stream of primary and secondary mills
- Installed magnets in discharge stream of cyclone underflow
- Replaced master cylinder on front end loader
- Relocated non-essential operating items from PDU plant to rear of fabrication shop
- Repaired conveyor skirtboard rubber on west Eimco filter conveyor
- Replaced 200-K-01 oil filter. Cleaned air cooler fins and filter housing
- Removed 2-inch pipe anchor brace from Microcel™ feed pump
- Removed nylon wire tie as well as a 3-inch and 6-inch piece of heavy gauge wire from thickener underflow pump
- Repaired loose lead on the Microcel™ air compressor breaker
- Performed tape backup of CDAS
- Installed re-build kit on Tailings filter press charge pump (400-G-01)
- Performed plant preventive maintenance
- Reconfigured Microcel™ tailings flow transmitter (FIT-215)

## TASK 9 SELECTIVE AGGLOMERATION MODULE

Phase III of this project involves the construction and operation of a 2 t/hr selective agglomeration (SA) PDU module. This SA module will be integrated with the existing PDU facility constructed during Subtask 8.2 and currently being operated under Subtask 8.4.

During operation of the SA module, the existing coal handling and grinding circuits will be used to produce ground coal slurry feed for the selective agglomeration process. Similarly, the existing product and tailings dewatering circuits will also be used. As such, the SA module will essentially replace the Microcel™ flotation column, with the remainder of the plant remaining intact.

Just like the advanced flotation PDU, selective agglomeration process performance will be optimized at the 2 t/hr scale, and 100 ton lots of ultra-clean coal will be produced for each of the three test coals. Toxic trace element distributions will also be determined during the production runs. The ultra-clean coals will be delivered to DOE or some other user for end-use testing.

### Subtask 9.1 Selective Agglomeration Module Construction

During the previous reporting quarter, Mech El Contracting, Inc. (MEI) of Aurora, Colorado, was selected to carry out the construction of the PDU selective agglomeration module. Construction began on March 11, 1996. MEI is constructing the SA Module based on the detailed design prepared by Bechtel. MEI is providing all the labor and materials for the construction except the major pieces of equipment which are provided by Amax R&D.

The overall scope of work being performed by MEI includes:

- Excavation and concrete foundation work for equipment as required
- Structural steel installation and modifications
- Installation of equipment, piping, and valves
- Installation of MCC and electrical from existing switchgear to equipment
- Installation of various instruments and expanded process control system
- Sheeting and painting
- Assistance during plant shakedown testing

***Equipment Purchasing***

Orders were placed and Purchase Orders issued for a number of different equipment items as well as other miscellaneous electrical, instrumentation, and Distributive Control System (DCS) items during this quarter. A complete listing of all equipment purchased/rented to date for the selective agglomeration module construction, along with the status of delivery is presented in Appendix C. Items ordered during this quarter are as follows:

- One (1) gas holding tank with flexible membrane liner
- One (1) boiler (rental)
- Twelve (12) 55-gallon carbon drum filters
- One (1) diaphragm pump to feed the carbon filter
- One (1) hand pump for heptane transfer
- Three (3) sets of air regulators/filters/oilers
- One (1) drum mixer for asphalt emulsion
- Twenty-three (23) flow meters
- Thirteen (13) control valves
- Ten (10) pressure safety valves
- Ten (10) pressure gauges/switches
- Four (4) pressure transmitters
- Eight (8) level switches/gauges/transmitters
- Three (3) differential pressure level transmitters
- Four (4) sight glasses
- One (1) interface detector

- One (1) computer for DCS system
- DCS system hardware
- DCS system controller software package w/ Series 9000 upgrade
- Forty (40) Zener barriers for DCS panel construction
- Two (2) circuit breakers
- Twenty-six (26) hand/off/auto selector switches

With the purchase of this equipment, all required non-electrical/instrumentation items have been ordered. Several instrumentation items, primarily hydrocarbon and oxygen detectors, remain to be purchased.

***Construction***

Construction of the Selective Agglomeration PDU module by MEI continued during this reporting quarter. Work completed on the construction of Plant Area 300 was as follows:

- Fabrication and installation of new structural steel in Area 300
- Removal of existing siding in Area 300
- Installation of new siding on all four interior walls of Area 300
- Installation of MCC5
- Excavation of outdoor areas to prepare for pouring of required concrete pads
- Pouring of outside concrete pads for the Nitrogen tank, gas holder, water chiller, knock-out drum, flare, heptane storage tank, and heptane feed pump
- Completion of virtually all of the remaining structural steel work including installation of required cross bracing and additional equipment support members
- Installation of virtually all of the indoor equipment including all vessels, pumps, and agitators: only one heat exchanger and several other small pieces of equipment remain to be installed within the building
- Installation of ventilation system input air duct work
- Continuation of piping fabrication and installation for the process, water, relief, and gas blanket systems
- Continuation of the running of various feeder conduits and wiring from MCC5 and DCS locations to various equipment locations
- Completion of a portion of the required sheeting and painting work

Based on the work completed as of the end of this reporting period, Table 14 presents the percent completion of each construction milestone and the overall project.

Table 14. SA Module Construction Progress by Milestone

| Item | Milestone | Percent Complete |
|---|---|---|
| 1 | Mobilization, excavation, concrete, and foundation work | 100 |
| 2 | Structural Steel & Platework | 99 |
| 3 | Equipment Installation | 93 |
| 4 | Piping Installation | 41 |
| 5 | Electrical & instrumentation installation | 35 |
| 6 | Ventilation & fire protection installation | 38 |
| 7 | Sheeting & Painting | 76 |
| 8 | Shakedown testing, cleanup, & demobilization | -- |
| | **Total Contract** | **55** |

## TASK 11 PROJECT FINAL REPORT

The final project report will include an economic assessment of the production of premium fuel from coal. The assessment will be based upon the results of the Tasks 4 and 6 laboratory and bench-scale testing and upon the Tasks 8 and 9 PDU operation of the advanced flotation and selective agglomeration circuits.

Capital and operating costs for the economic assessment will be based on conceptual plants tentatively located in the Ohio Valley Region and producing 1.5 million short tons per year (dry basis) of clean coal to be marketed as a coal-water fuel. Two plants will be costed. One will utilize advanced column flotation for cleaning finely ground coal, and the other will utilize selective agglomeration with recycled heptane as the bridging liquid. The two plants will be similar in other respects. Bechtel has initiated design of the process flowsheet for the flotation plant and the collection of data needed for selecting and costing the equipment in the plant.

## PLANS FOR NEXT QUARTER

The following activities are planned for the sixteenth quarterly reporting period, July - September, 1996:

- Subtask 3.2 - Near Term Applications testing will continue as follows:
  - Work will begin on a draft of the Subtask 3.2 Topical Report. The report will combine the work done by Virginia Tech at Lady Dunn with the earlier laboratory studies and will also include the dewatering, briquetting, and slurry preparation studies on the clean coal produced by the column flotation. It is expected that the final report will be issued during October.
- Under Subtask 3.3 work will begin on the preliminary design of a continuous bench-scale unit and review of the economics of the system.
- Test work will continue on Subtask 6.4, Selective Agglomeration CWF Formulation Studies with the completion of six to eight slurry preparation tests with the most recent lot of Indiana VII coal cleaned in the bench-scale selective agglomeration circuit. After that, the complete set of data will be evaluated, and the results presented in the Subtask 6.4 Topical Report to be issued by December.
- Test work will continue on Subtask 6.5, Selective Agglomeration Bench-scale Testing. Work will also begin on the Subtask 6.5 report.
- Subtask 8.4 efforts will be directed toward the following:
  - Complete parametric testing of Indiana VII coal
  - Complete optimization testing of Indiana VII coal
  - Complete extended production run of Indiana VII coal
  - Complete parametric testing of Hiawatha coal
  - Complete optimization testing of Hiawatha coal
  - Complete extended production run of Hiawatha coal
- Under Subtask 9.1, the PDU Selective Agglomeration Module construction will be completed.
- Under Subtask 9.2, Selective Agglomeration Module shakedown and test plan development will begin.
- Work will continue on the economic evaluation of the conceptual advanced flotation and selective agglomeration commercial plants under Task 11.

# REFERENCES

1. Smit, F. J., and Jha, M. C., Quarterly Technical Progress Report 1, October - December, 1992, "Engineering Development of Advanced Physical Fine Coal Cleaning for Premium Fuel Applications", Amax R&D Report to the U. S. Department of Energy Contract DE-AC22-92PC92208, January 18, 1993.

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# *APPENDIX A*

## Taggart Coal Agglomeration Results

# Appendix A - Taggart Coal - 25 lb/hr Agglomeration Test Conditions and Results

| Run | Grind Top Size Mesh | System Configuration – High Shear Imp in | High Shear Tip m/s | High Shear RT min | Low Shear Imp in | Low Shear Tip m/s | Low Shear RT min | Scrn Incl deg | Feed Solids % | Feed Solids lb/hr | Feed % ash | Feed Hept %.daf | Screen Product % Sol | Screen Product Size mm | Without Froth Skimming Prod % ash | Without Froth Skimming Tails % ash | Agg Perform Yield % | Agg Perform Btu Rec.% | Agg Perform AR % | With Froth Skimming Product % ash | Product #ash/ MBtu | Tails % ash | Agg Perform Yield % | Agg Perform Btu Rec.% | Agg Perform AR % | ROM Perfrom Yield % | ROM Perfrom Btu Rec.% | ROM Perfrom AR % |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| T5A1 | 70 | 2.4 | 15.0 | 0.7 | 4.8 | 4.8 | 3.6 | 42 | 5.0 | 25.4 | 4.18 | 30.2 | 34.7 | <1 | 1.62 | 33.8 | 92.0 | 94.7 | 64.3 | 1.64 | 1.08 | 66.5 | 96.1 | 98.8 | 62.4 | 61.5 | 93.2 | 98.4 |
| T5A2 | 70 | 2.4 | 15.0 | 0.7 | 4.8 | 4.8 | 3.6 | 42 | 5.0 | 25.1 | 4.16 | 32.1 | 43.3 | <1.5 | 1.53 | 55.3 | 95.1 | 97.9 | 65.0 | 1.53 | 1.01 | 70.8 | 96.2 | 99.0 | 64.6 | 61.6 | 93.4 | 98.5 |
| T5A3 | 70 | 2.4 | 15.0 | 0.7 | 4.8 | 4.8 | 3.6 | 42 | 5.0 | 24.9 | 4.15 | 33.2 | 46.9 | <2.5 | 1.51 | 63.6 | 95.7 | 98.6 | 65.2 | 1.51 | 1.00 | 68.9 | 96.1 | 98.9 | 65.0 | 61.5 | 93.3 | 98.5 |
| T5A4 | 70 | 2.4 | 15.0 | 1.4 | 4.8 | 4.8 | 7.2 | 42 | 10.1 | 25.4 | 4.16 | 30.3 | 51.5 | <1.5 | 1.55 | 62.7 | 95.7 | 98.5 | 64.3 | 1.56 | 1.03 | 72.9 | 96.4 | 99.2 | 63.9 | 61.7 | 93.5 | 98.5 |
| T5A5 | 70 | 2.4 | 15.0 | 1.4 | 4.8 | 3.2 | 7.1 | 42 | 10.0 | 25.6 | 4.15 | 29.3 | 45.4 | <1 | 1.73 | 52.3 | 95.2 | 97.8 | 60.3 | 1.73 | 1.15 | 70.4 | 96.5 | 99.1 | 59.7 | 61.7 | 93.4 | 98.3 |
| T5A6 | 70 | 2.4 | 10.8 | 0.9 | 4.8 | 4.8 | 2.2 | 42 | 13.3 | 50.5 | 4.15 | 31.2 | 41.7 | <1 | 1.72 | 59.4 | 95.8 | 98.4 | 60.3 | 1.72 | 1.14 | 78.4 | 96.8 | 99.5 | 59.8 | 62.0 | 93.8 | 98.3 |
| T5A7 | 70 | 2.4 | 15.0 | 0.9 | 4.8 | 4.8 | 2.2 | 42 | 13.1 | 50.2 | 4.17 | 32.4 | 49.9 | <2 | 1.67 | 79.7 | 96.8 | 99.5 | 61.2 | 1.67 | 1.11 | 83.5 | 96.9 | 99.7 | 61.1 | 62.0 | 94.0 | 98.4 |
| T5A8 | 70 | 2.4 | 8.0 | 1.4 | 4.8 | 4.8 | 3.4 | 42 | 7.0 | 17.6 | 4.09 | 31.7 | 50.6 | <3.5 | 1.41 | 48.8 | 94.3 | 97.2 | 67.5 | 1.42 | 0.93 | 53.1 | 94.8 | 97.7 | 67.2 | 60.7 | 92.1 | 98.6 |
| T5A9 | 70 | 2.4 | 15.0 | 1.4 | 4.8 | 4.8 | 3.4 | 42 | 7.0 | 17.5 | 4.14 | 31.9 | 42.1 | <1.5 | 1.62 | 56.2 | 95.4 | 98.1 | 62.7 | 1.63 | 1.08 | 66.8 | 96.2 | 98.8 | 62.0 | 61.5 | 93.2 | 98.4 |
| T5A10 | 70 | 2.4 | 11.2 | 1 | 4.8 | 4.8 | 5 | 42 | 7.0 | 25.6 | 4.12 | 35.3 | 48.1 | <1.5 | 1.52 | 64.8 | 95.9 | 98.7 | 64.6 | 1.54 | 1.02 | 70.8 | 96.3 | 99.1 | 64.0 | 61.6 | 93.4 | 98.5 |
| T5A11 | 70 | 2.4 | 12.1 | 0.5 | 4.8 | 4.8 | 2.5 | 42 | 7.0 | 50.2 | 4.17 | 35.2 | 47.6 | <3 | 1.44 | 70.7 | 96.1 | 99.0 | 66.8 | 1.44 | 0.95 | 73.4 | 96.2 | 99.1 | 66.7 | 61.6 | 93.5 | 98.6 |
| T5A12 | 70 | 2.4 | 7.7 | 1.4 | 4.8 | 4.8 | 7.2 | 42 | 10.0 | 25.1 | 4.15 | 29.9 | 63.5 | 2 | 1.47 | 61.1 | 95.5 | 98.4 | 66.2 | 1.49 | 0.98 | 65.7 | 95.8 | 98.7 | 65.7 | 61.3 | 93.1 | 98.6 |

# APPENDIX B

## Hiawatha Coal Agglomeration Results

# Appendix B - Hiawatha Coal - 25 lb/hr Agglomeration Test Conditions and Results

**System Configuration and Feed**

| Run | Date | Top Size Mesh | High Shear Imp in | High Shear Tip m/s | High Shear RT min | Low Shear Imp in | Low Shear Tip m/s | Low Shear RT min | Vibrat. Screen Size Mesh | Vibrat. Screen Incl deg | Vibrat. Screen H20 lb/hr | Feed Solids % | Feed Solids lb/hr | Feed % ash | Feed Btu/lb | Feed Heptane %.db | Feed Heptane %.daf |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| H1A1 | 11/13 | 150 | 2.4 | 8.3 | 1.4 | 4.8 | 8.0 | 3.3 | 48 | 38 | 47.6 | 10.5 | 26.9 | 8.50 | 13472 | 22.3 | 24.4 |
| H1A2 | 11/14 | 150 | 2.4 | 18.0 | 1.4 | 4.8 | 8.0 | 3.4 | 48 | 38 | 47.6 | 10.3 | 26.1 | 8.21 | 13513 | 22.6 | 24.6 |
| H1A3 | 11/15 | 150 | 2.4 | 15.0 | 1.4 | 4.8 | 4.8 | 7.2 | 48 | 38 | 30 | 10.0 | 25.4 | 8.09 | 13530 | 22.8 | 24.9 |
| H1A4 | 11/16 | 150 | 2.4 | 15.0 | 0.7 | 4.8 | 4.8 | 3.7 | 48 | 38 | 47.6 | 10.0 | 50.1 | 8.13 | 13524 | 22.1 | 24.1 |
| H1A5 | 11/16 | 150 | 2.4 | 15.0 | 0.7 | 4.8 | 4.8 | 3.6 | 48 | 38 | 47.6 | 10.0 | 50.5 | 7.89 | 13559 | 22.6 | 24.6 |
| H1A6 | 11/28 | 150 | 2.4 | 15.0 | 1.4 | 4.8 | 4.8 | 7.1 | 48 | 38 | 47.6 | 9.9 | 25.3 | 7.96 | 13549 | 23.3 | 25.3 |
| H1A7 | 11/30 | 150 | 2.4 | 15.0 | 1.4 | 4.8 | 6.4 | 3.4 | 48 | 38 | 47.6 | 9.8 | 24.5 | 7.69 | 13588 | 26.3 | 28.5 |
| H1A8 | 11/30 | 150 | 2.4 | 15.0 | 1.4 | 4.8 | 6.4 | 3.3 | 48 | 38 | 47.6 | 10.0 | 25.6 | 7.47 | 13621 | 26.7 | 28.8 |
| H1A9 | 12/1 | 150 | 2.4 | 15.0 | 1.4 | 4.8 | 6.4 | 3.3 | 48 | 38 | 47.6 | 10.1 | 25.8 | 7.66 | 13593 | 26.0 | 28.2 |
| H1A10 | 12/4 | 150 | 2.4 | 15.0 | 1.4 | 4.8 | 4.8 | 3.4 | 48 | 38 | 47.6 | 9.9 | 25.3 | 7.68 | 13590 | 23.7 | 25.6 |
| | | | | | | | | | | 34 | | | | | | | |
| H1A10R | 12/5 | 150 | 2.4 | 15.0 | 1.4 | 4.8 | 4.8 | 3.4 | 48 | 38 | 40 | 10.0 | 25.3 | 7.45 | 13623 | 23.6 | 25.5 |
| H1A11 | 12/4 | 150 | 2.4 | 15.0 | 1.4 | 4.8 | 4.8 | 7.2 | 48 | 38 | 0 | 9.9 | 24.8 | 7.39 | 13632 | 24.2 | 26.1 |
| H1A12 | 12/5 | 150 | 2.4 | 15.0 | 1.4 | 4.8 | 4.8 | 3.4 | 48 | 38 | 47.6 | 10.0 | 25.5 | 7.40 | 13631 | 24.6 | 26.5 |
| H1A13 | 12/5 | 150 | 2.4 | 15.0 | 1.4 | 4.8 | 3.0 | 3.4 | 48 | 38 | 47.6 | 10.1 | 25.5 | 7.35 | 13638 | 24.6 | 26.5 |
| H2A1 | 6/14 | 100 | 2.4 | 15.0 | 1.4 | 4.8 | 4.8 | 3.4 | 48 | 42 | 52.3 | 9.9 | 25.0 | 7.97 | 13548 | 23.6 | 25.6 |
| H2A2 | 6/19 | 100 | 2.4 | 7.3 | 1.4 | 4.8 | 4.8 | 3.3 | 48 | 42 | 52.3 | 9.8 | 25.2 | 7.63 | 13597 | 21.9 | 23.7 |
| H2A3 | 6/19 | 100 | 2.4 | 15.0 | 1.0 | 4.8 | 4.8 | 2.4 | 48 | 42 | 52.3 | 6.9 | 25.0 | 7.65 | 13594 | 24.3 | 26.3 |
| H2A3R | 6/19 | 100 | 2.4 | 15.0 | 1.0 | 4.8 | 4.8 | 2.3 | 48 | 42 | 52.3 | 6.9 | 25.3 | 7.62 | 13598 | 24.0 | 26.0 |

**Screen Product and Results**

| Run | Screen Product % Sol | Screen Product Size mm | W/out Froth Skim Prod % ash | W/out Froth Skim Tails % ash | W/out Froth Skim Yield % | W/out Froth Skim Agg Perform Btu Rec.% | W/out Froth Skim Agg Perform AR % | With Froth Skim Prod % ash | With Froth Skim #ash/ MBtu | With Froth Skim Tails % ash | With Froth Skim Yield % | With Froth Skim Agg Perform Btu Rec.% | With Froth Skim Agg Perform AR % | ROM Perfrom Yield % | ROM Perfrom Btu Rec.% | ROM Perfrom AR % |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| H1A1 | 52.5 | .5-2 | 2.43 | 70.0 | 91.0 | 97.5 | 74.0 | 2.49 | 1.73 | 83.2 | 92.6 | 99.1 | 72.9 | 73.3 | 89.2 | 92.8 |
| H1A2 | 37.4 | 0-1 | 3.14 | 48.4 | 88.8 | 94.0 | 66.0 | 3.18 | 2.22 | 81.8 | 93.6 | 99.0 | 63.7 | 74.1 | 89.2 | 90.3 |
| H1A3 | 56.5 | .5-1 | 2.61 | 71.6 | 92.1 | 98.0 | 70.3 | 2.64 | 1.84 | 84.6 | 93.4 | 99.3 | 69.5 | 73.9 | 89.5 | 91.9 |
| H1A4 | 38.4 | 0-.5 | 3.12 | 53.9 | 90.1 | 95.4 | 65.4 | 3.14 | 2.19 | 84.4 | 93.9 | 99.3 | 63.8 | 74.3 | 89.5 | 90.4 |
| H1A5 | 42.9 | 0-1 | 2.83 | 69.2 | 92.4 | 97.8 | 66.9 | 2.83 | 1.97 | 86.5 | 94.0 | 99.5 | 66.3 | 74.4 | 89.6 | 91.0 |
| H1A6 | | | | | | | | Continuous growth, low shear plugged | | | | | | | | |
| H1A7 | 39.2 | 0-1 | 2.88 | 66.6 | 92.5 | 97.6 | 65.4 | 2.89 | 2.02 | 84.9 | 94.1 | 99.4 | 64.6 | 74.6 | 89.6 | 90.6 |
| H1A8 | 49.2 | 0-3 | 2.56 | 81.0 | 93.7 | 99.1 | 67.9 | 2.57 | 1.79 | 86.0 | 94.1 | 99.5 | 67.6 | 74.6 | 89.7 | 91.4 |
| H1A9 | 55.4 | 0-3 | 2.36 | 82.6 | 93.4 | 99.2 | 71.2 | 2.40 | 1.67 | 86.2 | 93.7 | 99.5 | 70.6 | 74.2 | 89.7 | 92.2 |
| H1A10 | 40.8 | .5-1.5 | 2.66 | 55.1 | 90.4 | 95.7 | 68.7 | 2.67 | 1.86 | 81.8 | 93.7 | 99.2 | 67.4 | 74.2 | 89.3 | 91.3 |
| | 40.6 | | 2.62 | | | | | | | | | | | | | |
| H1A10R | 42.9 | 0-1.5 | 2.62 | 77.7 | 93.6 | 98.9 | 67.1 | 2.63 | 1.83 | 85.1 | 94.2 | 99.5 | 66.7 | 74.6 | 89.6 | 91.1 |
| H1A11 | 71.4 | 3-6 | 2.06 | 81.3 | 93.3 | 99.2 | 74.0 | 2.13 | 1.47 | 86.9 | 93.8 | 99.6 | 72.9 | 74.3 | 89.8 | 92.8 |
| H1A12 | 49.1 | 0-3 | 2.34 | 76.1 | 93.1 | 98.7 | 70.5 | 2.36 | 1.64 | 84.2 | 93.8 | 99.4 | 70.0 | 74.3 | 89.6 | 92.0 |
| H1A13 | 42.7 | 0-3 | 2.68 | 72.4 | 93.3 | 98.4 | 66.0 | 2.69 | 1.87 | 84.3 | 94.3 | 99.4 | 65.5 | 74.7 | 89.6 | 90.8 |
| H2A1 | 49.5 | .5-1 | 2.8 | 61.3 | 91.2 | 96.7 | 68.0 | 2.84 | 1.98 | 78.9 | 93.3 | 98.8 | 66.8 | 73.9 | 89.0 | 91.2 |
| H2A2 | 46.1 | 1 | 2.81 | 53.4 | 90.5 | 95.6 | 66.7 | 2.83 | 1.97 | 73.1 | 93.2 | 98.4 | 65.5 | 73.8 | 88.7 | 90.8 |
| H2A3 | 53.9 | .5-3 | 2.44 | 69.1 | 92.2 | 97.8 | 70.6 | 2.50 | 1.73 | 80.4 | 93.4 | 99.0 | 69.5 | 74.0 | 89.2 | 91.9 |
| H2A3R | 46.3 | 1 | 2.63 | 58.3 | 91.0 | 96.4 | 68.6 | 2.66 | 1.85 | 76.6 | 93.3 | 98.7 | 67.5 | 73.9 | 88.9 | 91.3 |

# APPENDIX C

## PDU Selective Agglomeration Module Purchasing

# Appendix C - PDU Selective Agglomeration Module Purchasing

| Equip # | Description | Vendor | Status |
|---|---|---|---|
| | **NEW EQUIPMENT PURCHASES** | | |
| 300-C-02 | High shear reactor B | Process Fabricators, Inc. | Rcv'd |
| 300-C-03 | Low Shear Reactor | " | Rcv'd |
| 300-C-04 | Froth skimmer tank | " | Rcv'd |
| 300-C-05 | Steam stripper A | " | Rcv'd |
| 300-C-06 | Steam stripper B | " | Rcv'd |
| 300-C-07 | Heptane/water gravity separator | " | Rcv'd |
| 300-C-08 | Heptane storage tank | " | Rcv'd |
| 300-C-10 | Tailings surge drum | " | Rcv'd |
| 300-C-11 | Slurry sampling pot | " | Rcv'd |
| 300-C-12 | Emergency slop tank | " | Rcv'd |
| 300-C-13 | Steam stripper feed tank | " | Rcv'd |
| 300-C-15 | Relief knock-out drum | " | Rcv'd |
| 300-E-01 | Condensed vapor cooling heat exchanger | Fluid Technology, Inc. (ITT) | Rcv'd |
| 300-E-02 | Water preheater heat exchanger | " | Rcv'd |
| 300-E-03 | Product slurry cooler heat exchanger | " | Rcv'd |
| 300-E-04 | Blanket gas cooler heat exchanger | " | Rcv'd |
| 400-E-01 | Clarified water cooler heat exchanger | " | Rcv'd |
| 300-E-05 | Vapor condenser air cooler | CS Group | Rcv'd |
| 600-E-01 | Fine grinding mill cooling water air cooler | " | Rcv'd |
| 300-F-02 | Relief system flare stack | Flare Industries, Inc.. | Rcv'd |
| 300-G-01 | Agglomeration circuit feed pump | Quadna Pump Systems | Rcv'd |
| 300-G-02 | Steam stripper A feed pump | " | Rcv'd |
| 300-G-03 | Steam stripper B feed pump | " | Rcv'd |
| 300-G-04 | Clean coal slurry pump | " | Rcv'd |
| 300-G-07 | Tailings pump | " | Rcv'd |
| 600-G-02 | Cooling water pump | " | Rcv'd |
| 600-G-03 | Fine grinding mill cooling water pump | " | Rcv'd |
| 300-G-08 | Emergency slop tank discharge pump | " | Rcv'd |
| 300-G-05 | Heptane feed pump | Centennial Equipment | Rcv'd |
| 300-G-06 | Conditioner (asphalt emulsion) feed pump | " | Rcv'd |
| 300-G-12 | Floor sump pump | Canmac Enginnering Sales | Rcv'd |
| 300-Y-03 | High shear reactor A impellers | D.W. Daigler (Lightnin) | Rcv'd |
| 300-Y-04 | High shear reactor B agitator w/impellers | " | Rcv'd |
| 300-Y-05 | Low shear reactor agitator w/impellers | " | Rcv'd |
| 300-Y-07 | Froth skimmer paddle agitator w/impeller | " | Rcv'd |
| 300-Y-08 | Steam stripper feed agitator w/impellers | " | Rcv'd |
| 300-Y-09 | Steam stripper A agitator w/impeller | " | Rcv'd |
| 300-Y-06 | Vibrating screen | Sizetech, Inc. | Rcv'd |
| 600-V-01 | Cooling water refrigeration unit | York International Corp. | Rcv'd |
| 300-D-04 | Gas holding tank | Process Fabricators, Inc. | 7/22 |
| " | Gas holder flexible liner | Flexi-Liner Corporation | 7/25 |
| 300-C-14 | 12 Carbon filter drums | Fluid Technology, Inc. | 7/15 |
| 300-G-09 | Carbon drum feed pump | Denver Industrial Pumps | Rcv'd |
| 300-Y-10 | Asphalt emulsion tank agitator | Indco | Rcv'd |
| -- | Heptane hand pump | Grainger | Rcv'd |
| 300-Y-10 | Asphalt drum mixer | " | Rcv'd |

| Equip # | Description | Vendor | Status |
|---|---|---|---|
| -- | 3 air motor filters,oilers, & regulators | " | Rcv'd |
| | **USED/RECONDITIONED EQUIPMENT** | | |
| 300-Y-03 | High shear reactor A agitator | Ekato Corporation | Rcv'd |
| 600-G-01 | Cooling water refrigeration unit feed pump | DIP | Rcv'd |
| 600-D-02 | Fine grinding mill cooling water feed sump | -- | -- |
| 600-D-01A | Cooling water circuit feed sump | -- | -- |
| 600-D-01B | Cooling water circuit feed sump | -- | -- |
| | **ELECTRICAL EQUIPMENT** | | |
| -- | 600 amp circuit breaker | -- | Rcv'd |
| -- | Six section motor control center | Cons. Elect | Rcv'd |
| -- | Variable frequency drive - 30 hp | Reliance | Rcv'd |
| -- | Variable frequency drive - 7.5 hp | " | Rcv'd |
| -- | Variable frequency drive - 5 hp | " | Rcv'd |
| -- | Variable frequency drive - 5 hp | " | Rcv'd |
| -- | Variable frequency drive - 3 hp | " | Rcv'd |
| -- | Variable frequency drive - 1 hp | " | Rcv'd |
| -- | 250 A circuit breaker | CED | |
| -- | 100 A circuit breaker | " | |
| | **INSTRUMENTATION** | | |
| FT-6023 | 3" water flowmeter w/gpm digital indicator | PCI Sales, Inc. | Rcv'd |
| FT-3175 | 1" N2 flowmeter cfm digital indicator | " | Rcv'd |
| FIQ-6010 | 2" fuel gas flowmeter w/cfm digital indicator | " | Rcv'd |
| FE/FT-3090 | 6" steam flowmeter | " | Rcv'd |
| FE/FT-3013 | 1.5" magnetic flowmeter (HS recirc) | Meter and Valve Company | Rcv'd |
| FE/FT-3102 | 1.5" magnetic flowmeter (product) | " | Rcv'd |
| FE/FT-3014 | 2" magnetic flowmeter (HS feed) | " | Rcv'd |
| FE/FT-3055 | 2" magnetic flowmeter (tailings) | " | Rcv'd |
| FE/FT-3065 | 2" magnetic flowmeter (stripper feed) | " | Rcv'd |
| FI-3053 | 1" paddle water flowmeter (dilution water) | Integrity Controls, inc. | Rcv'd |
| FI-6024 | 1.5" paddle flowmeter (gas cooling water) | " | Rcv'd |
| FIT-3115 | 2" cooling water flowmeter (300-E-03) | Joy and Cox, Inc. | Rcv'd |
| FIQ-3119 | 3/4" water flowmeter (grav sep discharge) | " | Rcv'd |
| FIQ-3123 | 1/2" heptane flowmeter (grav sep discharge) | " | Rcv'd |
| FIQ-3144 | 1" water flowmeter (asphalt emulsion dilution) | " | Rcv'd |
| FIQ-6009 | 2" water flowmeter (plant feed) | " | Rcv'd |
| FIQ-6025 | 2" water flowmeter (sewer discharge) | " | Rcv'd |
| FI-3146 | 3/4" N2 flowmeter (froth skimmer gas) | " | Rcv'd |
| FIT-3037 | 1" water flowmeter (low shear dilution) | " | Rcv'd |
| FIT-3046 | 1" water flowmeter (screen spray water) | " | Rcv'd |
| FIT-3084 | 1" cooling water flowmeter (300-E-01) | " | Rcv'd |
| FIT-3108 | 1" cooling water flowmeter (300-E-03) | " | Rcv'd |
| LV-3149 | 2" tailings flow control valve (FCV) | Protech Sales, Inc. | Rcv'd |
| FV-3090 | 4" FCV, steam to stripper B | ICS Sales | Rcv'd |
| PV-3092 | 4" FCV, steam from stripper B | " | Rcv'd |
| FV-3108 | 1" FCV, cooling water to 300-E-02 | " | Rcv'd |
| TV-3110 | 2" FCV, cooling water to 300-E-03 | " | Rcv'd |
| LV-3121 | 1" FCV, water from gravity separator | " | Rcv'd |

| Equip # | Description | Vendor | Status |
|---|---|---|---|
| LV-3187 | 1" FCV, blanket gas relief | " | Rcv'd |
| LV-3188 | 1" FCV, N2 makeup | " | Rcv'd |
| PSV-3021 | 1.5 " x 2", HS A relief | Protech | Rcv'd |
| PSV-3029 | 1.5" x 2.5", HS B relief | " | Rcv'd |
| PSV-3039 | 2" x 3" low shear pressure safety valve relief | " | Rcv'd |
| PSV-3067 | 1.5" x 3" stripper A relief | " | Rcv'd |
| PSV-3095 | 1.5" x 2.5" Stripper B relief | " | Rcv'd |
| PSV-3103 | .75" x 1" 300-E-02 thermal relief | " | Rcv'd |
| PSV-3109 | .75" x 1" 300-E-03 thermal relief | " | Rcv'd |
| PSV-3122 | 1.5" x 2.5" gravity separator relief | " | Rcv'd |
| PSV-3127 | 3" x 4" heptane storage tank relief | " | Rcv'd |
| PSV-3154 | 3" x 4" emergency slop tank relief | " | Rcv'd |
| LV-3008 | 1.5" FCV, gas blanket to high shear | " | Rcv'd |
| FV-3074 | 2" FCV, feed to stripper B | " | Rcv'd |
| FV-3094 | 4", 3-way FCV | Winn-Marion, Inc. | Rcv'd |
| PI-3017 | Pressure indicator (PI) water to Area 300 | JMC Instruments, Inc. | 7/26 |
| PI-3133 | PI - Heptane to agglomeration circuit | " | Rcv'd |
| PI-6011 | PI - Fuel gas supply | " | Rcv'd |
| PI-6021 | PI - Chilled water to process | " | Rcv'd |
| PI-3136 | PI - Asphalt emulsion to agglom circuit | " | Rcv'd |
| PI-3153 | PI - Tailings pump discharge | " | 7/26 |
| PI-3176 | PI - Nitrogen supply | " | Rcv'd |
| PSL-3176 | Low pressure switch - Nitrogen supply | " | Rcv'd |
| PI-6020 | PI - Utility cooling water | " | Rcv'd |
| PI-6008 | PI - Utility water | " | Rcv'd |
| TE/TW-3016 | Temperature Indicator (TI) - agglom feed | " | Rcv'd |
| TE/TW-3022 | TI - high shear reactor A | " | Rcv'd |
| TE/TW-3077 | TI - steam stripper A vapor | " | Rcv'd |
| TE/TW-3080 | TI - Ambient air | " | Rcv'd |
| TE/TW-3082 | TI - 300-E-05 condensed vapor discharge | " | Rcv'd |
| TE/TW-3085 | TI - cooling water to sewer | " | Rcv'd |
| TE/TW-3088 | TI - vapor to gas blanket cooler | " | Rcv'd |
| TE/TW-3086 | TI - 300-E-01 cooled condensate discharge | " | Rcv'd |
| TE/TW-3090 | TI - Steam to stripper B | " | Rcv'd |
| TE/TW-3105 | TI - 300-E-02 slurry discharge | " | Rcv'd |
| TE/TW-3107 | TI - cooling water to 300-E-02 | " | Rcv'd |
| TE/TW-3110 | TI - 300-E-03 slurry discharge | " | Rcv'd |
| TE/TW-3111 | TI - cooling water from E-03 | " | Rcv'd |
| TE/TW-3112 | TI heated clarified water to skimmer | " | 7/26 |
| TE/TW-3030 | Ti - high shear reactor B | " | Rcv'd |
| TE/TW-3038 | TI - loe shear reactor | " | Rcv'd |
| TE/TW-3062 | Ti - stripping circuit feed | " | Rcv'd |
| TE/TW-3071 | TI - stripper A liquid | " | Rcv'd |
| TE/TW-3093 | TI - stripper B vapor | " | Rcv'd |
| TE/TW-3096 | Ti - stripper B liquid | " | Rcv'd |
| TE/TW-3156 | TI - slop tank liquid | " | 7/26 |
| TE/TW-4000 | TI - clarified water to 400-E-01 | " | Rcv'd |

## Appendix C - PDU Selective Agglomeration Module Purchasing

| Equip # | Description | Vendor | Status |
|---|---|---|---|
| TE/TW-4001 | TI - cooling water from 400-E-01 | " | Rcv'd |
| TE/TW-4002 | TI clarified water from 400-E-01 | " | Rcv'd |
| TE/TW-6013 | TI - utility water | " | Rcv'd |
| TE/TW-6022 | TI 0 chilled utility water | " | Rcv'd |
| TI/TW-3182 | TI - condensate from 300-E-04 | " | Rcv'd |
| TI/TW-3184 | TI - cooling water from 300-E-04 | " | Rcv'd |
| TI/TW-6008 | TI - cooling water to 600-E-01 | " | 7/26 |
| TI/TW-6009 | TI cooling water from 600-E-01 | " | 7/26 |
| TI/TW-3128 | TI - heptane storage | " | Rcv'd |
| TI/TW-3183 | TI - gas blamket to 300-E-04 | " | Rcv'd |
| LSH-3039 | Low shear | Frontier Industrial Controls | |
| LSH-3155 | Slop tank | " | Rcv'd |
| LG/LSH-3179 | High level switch, knock-out drum | " | Rcv'd |
| LG/LT-3124 | Level indicator, heptane storage | " | 7/26 |
| LG/LT-3149 | Level indicator, tailings tank | " | Rcv'd |
| LT-3001 | Level transmitter, slurry storage A | " | 7/26 |
| LT-3002 | Level transmitter, slurry storage B | " | 7/26 |
| LT-3186 | Level transmitter, gas holder position | " | 7/26 |
| LG-3054 | Sight glass, froth skimmer | PSI | Rcv'd |
| LG-3061 | Dight glass, stripper feed sump | " | Rcv'd |
| LG-3120 | Sight glass, gravity separator | " | Rcv'd |
| LG-3155 | Sight glass, emergency slop tank | " | Rcv'd |
| LT-3121 | Gravity separator | ICS Sales | Rcv'd |
| LT-3059 | Differential pressure level, stripper feed sump | Fisher-Rosemont | 7/22 |
| LT-3073 | Differential pressure level, stripper A | " | 7/22 |
| LT-3097 | Differential pressure level, stripper B | " | 7/22 |
| PV-3087 | 2" flow control valve, condensed vapor | ICS Sales | Rcv'd |
| PIT-3090 | Pressure transmitter, boiler steam | Joy and Cox, Inc. | 7/22 |
| PIT-3087 | Pressure transmitter, stripper A vapor out | " | 7/22 |
| PIT-3015 | Pressure transmitter, slurry to agglom circuit | " | 7/22 |
| PT-3092 | Pressure transmitter, stripper B | " | 7/22 |
| DT-3012 | Mass/density meter | ICS Sales | 8'12 |
| | **DCS COMPUTER SYSTEM** | | |
| – | DCS Pentium computer | Honeywell, Inc. | Rcv'd |
| – | Series 9000 upgrade | " | Rcv'd |
| | **DCS PANEL COMPONENTS** | | |
| – | Series 9000 software | Honeywell, Inc. | Rcv'd |
| – | Series 9000 hardware | " | Rcv'd |
| – | DCS Panel | Circle AW | Rcv'd |
| – | 30 Zener barriers | Rocky Mountain Coveyor | 7/15 |
| – | 10 Zener barriers | " | 7/15 |
| | **RENTAL EQUIPMENT** | | |
| 300-V-01 | Nitrogen tank | General Air | 7/16 |
| 30--F-01 | Boiler | T-M Service Company | 7/25 |