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QUARTERLY TECHNICAL PROGRESS REPORT NO. 8

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**ENGINEERING DESIGN AND ANALYSIS OF ADVANCED PHYSICAL
FINE COAL CLEANING TECHNOLOGIES**

for

**U.S. DEPARTMENT OF ENERGY
PITTSBURGH ENERGY TECHNOLOGY CENTER
PITTSBURGH, PA**

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SUBMITTED BY

**P.W. GALLIER
PROJECT MANAGER**

**ASPEN TECHNOLOGY, INC.
251 VASSAR STREET
CAMBRIDGE, MA 02139**

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1.0 INTRODUCTION

This project is sponsored by the United States Department of Energy (DOE) for the "Engineering Design and Analysis of Advanced Physical Fine Coal Cleaning Technologies:. The major goal is to provide the simulation tools for modeling both conventional and advanced coal cleaning technologies. This DOE project is part of a major research initiative by the Pittsburgh Energy Technology Center (PETC) aimed at advancing three advanced coal cleaning technologies- heavy-liquid cycloning, selective agglomeration, and advanced froth flotation through the proof-of-concept (POC) level.

The commercially available ASPEN PLUS process simulation package will be extended to handle coal cleaning applications. Algorithms for predicting the process performance, equipment size, and flowsheet economics of commercial coal cleaning devices and related ancillary equipment will be incorporated into the coal cleaning simulator.

This report is submitted to document the progress of Aspen Technology, Inc. (AspenTech), its contractor, ICF Kaiser Engineers, Inc., (ICF KE) and CQ Inc., a subcontractor to ICF KE, for the seventh quarterly reporting period, April through June 1991. ICF KE is providing coal preparation consulting and processing engineering services in this work and they are responsible for recommending the design of models to represent conventional coal cleaning equipment and costing of these models.

2.0 ADMINISTRATIVE ITEMS

AspenTech delivered the Coal Cleaning Simulator (with ASPEN PLUS™ version 8.4) to ICF KE and CQ Inc. in the month of July. The version delivered was installed on July 10th at ICF KE and on July 30th at CQ Inc. AspenTech held a training session for personnel of both locations at the Pittsburgh offices of ICF KE. The training session covered a range of items required to run the simulator (coal washability input and/or databank retrieval, flowsheet definition, unit operation and streams specification, design specifications and sensitivity studies).

ICF KE met with Dr. Peter Luckie and Dr. Mark Klima, both of Penn State University, on August 6 to discuss the general status of models for conventional coal cleaning and the problems encountered in the coal washability interpolation routine. ICF KE submitted a formal request to Dr. Paul Gallier of AspenTech on July 25 for Dr. Mark Klima to be approved as a project consultant.

AspenTech and ICF KE met on September 6 to review the results of testing conducted on the Coal Cleaning Simulator version delivered in July. A number of required changes were discussed and implemented at the meeting.

On September 20, AspenTech approved the modifications to contract DE-AC22-89PC89908 for the addition of Task 6, supplied by Ms Cynthia Mitchell of DOE.

3.0 TASK 1.2 - Engineering Analysis of Conventional Coarse Coal Cleaning

3.1 Planned Scope of Work

The work plan for the eight quarter of the project called for the completion of all models required for Task 2. Model documentation (topical reports) and validation procedures were also scheduled to be completed.

3.2 Technical Status

The technical status of the interpolation routine, the various categories of models worked on during this quarter, the model testing, and other relevant items are discussed in the following sections.

3.2.1 Interpolation Routine

ICF KE met with Dr. Peter Luckie and Dr. Mark Klima of Penn State University to discuss the problems encountered in the coal washability interpolation routine. The original interpolation program developed at PSU by Klima and Luckie employing Akima's algorithm, did not guarantee monotonicity but rather was designed to function interactively in cases when non-monotonic cumulative weight data were generated. Furthermore, because of the methodology used in the interpolation of the attributes in a given size interval, i.e., cumulative attribute versus relative density, non-monotonic direct (interval) ash values were generated at times, contrary to what is observed in actual washability data. Consequently, the initial modifications to the program were designed to correct this problem by incorporating the Mayer curve approach for attribute interpolation in a given size interval, i.e cumulative attributes versus cumulative weight. Although this approach provided a better behaved function that reduced interpolation problems, non-monotonic weight and attribute values were still generated.

Because most of the problems were centered on data in the lower and upper intervals, several techniques were used to estimate additional "ghost" points beyond the end points. The final solution involved modifying Akima's estimate of the slope beyond these intervals. This approach seemed to eliminate non-monotonic values whenever the cumulative weight was interpolated on a log

basis but not when it was interpolated on a linear basis, as was necessary in many cases. At this point it was concluded that the effort would be spent better in pursuing a new interpolation algorithm that guaranteed monotonicity, especially in the calculation of the direct ash values, rather than to attempt additional modifications to Akima's algorithm.

AspenTech assisted ICF KE in providing a reference to an article that described a new interpolation algorithm, which could be used as a substitute for Akima's. This particular article was available in PSU's Math library. After reviewing this article by Fritsch and Carlson and comparing their approach to Akima's, it was decided to incorporate their algorithm into the interpolation program.

AspenTech provided a series of fortran subroutines containing the Fritsch and Carlson interpolation algorithm to ICF KE. These subroutines were incorporated into the original program after the necessary modifications were made. This program was tested successfully on several data sets.

During the validation testing, it was found that the attribute values for the first relative density interval were incorrect. This problem was traced to the attribute estimates that were inputted at zero weight percent and was corrected by providing a new estimation technique. This involved determining the slope from the first two data points and then extrapolating to obtain the cumulative attribute value at zero weight percent. This program is now being tested at ICF KE on over 20 coal data sets.

Most of the discussion in this section was provided in a report of completed work tasks submitted by Dr. Mark Klima.

3.2.2 Size Reduction Models

ICF KE completed and submitted a model for the roll crushing process to AspenTech on July 1. The model algorithm was developed by L.G. Austin of Penn State in the late 1970s and is the same algorithm utilized in the current version of the DOE Coal Cleaning Simulator. The algorithm is based on the primary breakage distribution function to describe the fracture pattern for coal and a selection function to describe the probability of a given size particle to be broken at a user-input crusher setting size (commonly called gap size). These two

functions, along with a description of the secondary crusher selectivity values (or how often a particle is re-broken before passing through the roll gap), are combined into a matrix of transfer values to determine the crusher product size distribution.

The capacity of a roll crusher depends on the roll tire speed, the roll width, and diameter, and the roll gap (set) size. The roll crusher is sized (diameter by length) by an equation utilizing these factors to calculate the theoretical limit of coal to pass a given crusher setting size.

Two enhancements to the roll crushing model are currently being studied and will be included in the model as information becomes available. The first involves the description of the parameters characterizing the primary breakage distribution function. Currently, one set of parameters for a typical coal are contained in the simulator. However, it is known that the primary breakage distribution is dependent upon the type or grindability (HGI) of the coal being crushed. Hence, it is desirable to describe the change of these parameters with a user-supplied HGI value.

The second enhancement involves the description of liberation. Professor Austin has submitted his first report on the subject during the work period. ICF KE and Professor Luckie are currently evaluating his algorithm for predicting liberation during size reduction process and will report on its usefulness in the simulator in future reports. It has been suggested that some laboratory work be completed to define and validate some of the assumptions utilized by Professor Austin in his algorithm. A statement of work will be forthcoming within Task 6 for funding this effort.

A rotary breaker model was also programmed during the work period, but to date is not yet completed. The algorithm was developed by Luckie and Austin at Penn State and also is the same algorithm utilized in the current DOE Coal Preparation Simulator. Several enhancements to this model have also been made and will be discussed when the model is completed and tested.

Block reports for the roll crusher and rotary breaker have been completed.

3.2.3 Blending and Splitting

ICF KE completed and delivered a coal stream blender (mixer) subroutine to AspenTech on July 11. The blender

is capable of mixing any number of coal streams into one and should prove to be very useful and handy in the simulation of large complex flowsheets. A block report for the mixer was also developed and delivered.

The stream splitter resident in ASPEN PLUS™ was found adequate for splitting coal streams.

3.2.4 Model Testing and Validation

This work period for the most part was spent testing all the models currently installed in the Coal Cleaning Simulator. Each model was being tested for mathematical completeness, block report content and clarity, and connectivity with other models. The testing was carried out by AspenTech, ICF KE and CQ Inc. The following summarizes the work completed at each site.

AspenTech carried out tests on two large coal cleaning flowsheets. These flowsheets were obtained from actual plants by a consultant on the project, Mr. William Halvorsen, who provided his assistance for the flowsheet testing.

The first flowsheet consists of forty seven unit operation models and utilizes models from all the categories available in the coal cleaning simulator. The major unit operation models in this plant are two heavy media cyclones, a heavy media vessel, and a froth flotation model. In order to simplify the testing process the flowsheet was divided into five sections. Each section was tested in a separate ASPEN PLUS™ simulation. Problems were encountered in some sections. These problems were recorded for future revisions to the models.

The second flowsheet consists of forty five unit operations and includes a selection of models different from that of the first flowsheet. The major unit operation models in this flowsheet are two heavy media vessels, two roll crushers, a fine coal jig, and a froth flotation model. This flowsheet was also tested in sections. These were fewer problems encountered, but all errors were also recorded.

ICF KE personnel were primarily involved in testing large coal preparation flowsheets described by the cleaning unit operations as follows:

- (1) coarse coal jig/fine coal jig
- (2) heavy-media vessel/fine coal jig/froth flotation

- (3) heavy-media vessel/heavy-media cyclone/froth flot.
- (4) heavy-media vessel/heavy media cyclone/spiral

These flowsheets would include all ancillary operations such as raw coal screens, dewatering screens, drain and rinse screens, deslime screens, etc... and all required dewatering equipment such as centrifuges, belt presses, filters, and thickeners. Each flowsheet was programmed into an ASPEN PLUS input file and submitted for input translation and simulation. When problems were encountered, they were documented for correction by the appropriate personnel.

CQ Inc. personnel were primarily involved in testing the range of unit operation flowsheets described in the EPRI Coal Cleaning Cost Model. These unit operation flowsheets include the equipment for cleaning, sizing, and dewatering the coal and refuse products. Each flowsheet was made into an ASPEN PLUS input file and submitted for input translation followed by simulation. When problems were encountered, they were documented for correction by the appropriate personnel. CQ Inc. personnel were examining the unit operation models for mathematical completeness, material balance and report accuracy.

The problems found while testing at the three locations were compiled. AspenTech met with ICF KE to discuss and implement the required corrections to the models on September 6. During that meeting, corrections were made to the gravity separation models to aid in the convergence of user-supplied separating gravity upon the calculated composite separating gravity. It was also decided to add to each of the models zero-registering loops to clean stray data located in important model vectors and arrays.

3.2.5 ASPEN PLUS™ Implementations

The new washability mixer and roll crusher models were installed as system models in the Coal Cleaning Simulator. A cost model was also developed and installed for the roll crusher.

Aside from the incorporation of the new models into the simulator, the system work completed in this quarter consisted in making the necessary changes to ensure the correct handling of coal washability in the ASPEN PLUS™ flowsheet convergence system. A FORTRAN subroutine was written to assign convergence flags to the coal washability data in a stream. This will make sure the

data is initialized, normalized, and reported correctly in the ASPEN PLUS convergence history information.

Also, due to the growing number of models in the Coal Cleaning Simulator, some built in limits were being reached in the system definition file. The system subroutines where these limits are set were changed and incorporated into the new 8.4 version of ASPEN PLUS™.

3.2.6 ModelManager™ Implementations

ModelManager™ screens were developed for the stream washability mixer and the roll crusher.

3.2.7 Upcoming Coal Cleaning Simulator Deliveries

The latest PC version of the Coal Cleaning Simulator with ModelManager™ was to be delivered to DOE at the end of September. The delivery was delayed to allow the incorporation of recent changes to the coal cleaning models. Also, the delivery of a PC version to DOE was not explicitly stated in the project contract. The legal conditions attached to the use of this version may have to be worked out before the delivery is complete.

3.2.8 Miscellaneous Items

Equipment sizing algorithms are currently under development for non-process equipment utilized in a coal preparation plant. These equipment sizing models will primarily include coal handling and transporting equipment such as belt conveyors, pumps, raw and clean coal silos, raw and clean coal storage piles, feeders, refuse bins, etc...

An algorithm for sizing belt conveyors has been completed following procedures developed by the Conveyor Equipment Manufacturers Association (CEMA) and an abbreviated method summarized in the EPRI Coal Cleaning Cost Model. Stream inputs to the model will be the total stream flow rate (in tons per hour). The composite ash value will be utilized to designate the stream as either raw coal, clean coal or refuse and assign bulk density values of 55, 50, and 75 lbs/cubic ft., respectively. The algorithm then uses this information to select a belt width operating at an appropriate belt speed for the subsequent cost analysis. The user is required to input conveyor lengths and elevations.

- 4.0 TASK 1.3 - Engineering Analysis of Unit Operations for Processing Fine and Ultrafine Coals
- TASK 1.4 - Engineering Analysis of Advanced Technologies for Cleaning of Fine and Ultrafine Coals

The planning stages for model development within Tasks 3 and 4 have begun. A model listing, such as the one submitted for Task 2, is being developed from the items found in the DOE supplied Statement of Work. At completion of the listing, it is suggested that DOE review and agree to the type of models to be delivered under these tasks.

5.0 QUARTER NO. 9 - WORK PLAN

- Completion of Task 2 models
- Completion of model documentation
- Complete testing validation procedures for Task 2 models
- Beginning of Task 3 and 4 work
- Begin Task 6 at Penn State

END

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