DOE/F

DOE/PC/89663--T9

DE93 012267

Technical Progress Report No. 10

Development of a Coal Quality Expert

to

**U.S. Department of Energy
Pittsburgh Energy Technology
Center
Pittsburgh, Pennsylvania**

DE-FC22-90PC89663

DISCLAIMER

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

MASTER

DISTRIBUTION OF THIS DOCUMENT IS UNLIMITED

**Technical Progress Report No. 10
FINAL**

Development of a Coal Quality Expert

U.S. Department of Energy
Pittsburgh Energy Technology Center
Pittsburgh, Pennsylvania

DE-FC22-90PC89663

December 21, 1992

CQ Inc.
One Quality Center
Post Office Box 280
Homer City, Pennsylvania 15748
(412) 479-3503

INTRODUCTION

This is the tenth Technical Progress Report, describing work performed under DOE Contract No. DE-FC22-90PC89663, "Development of a Coal Quality Expert." The contract is a Cooperative Agreement between the U.S. Department of Energy, CQ Inc., and ABB Combustion Engineering, Inc. This report covers the period from July 1 through September 30, 1992. Five companies and seven host utilities have teamed with CQ Inc. and ABB/CE to perform the work on this project. The work falls under DOE's Clean Coal Technology Program category of "Advanced Coal Cleaning." The 51-month project will provide the utility industry with a PC expert system to confidently and inexpensively evaluate the potential for coal cleaning, blending, and switching options to reduce emissions while producing lowest cost electricity. Specifically, this project will:

- Enhance the existing Coal Quality Information System (CQIS) database and Coal Quality Impact Model (CQIM) to allow confident assessment of the effects of cleaning on specific boiler cost and performance.
- Develop and validate a methodology, Coal Quality Expert (CQE) which allows accurate and detailed predictions of coal quality impacts on total power plant capital cost, operating cost, and performance based upon inputs from inexpensive bench-scale tests.

The project consists of the following seven tasks:

- Task 1 - Project Management
- Task 2 - Coal Cleanability Characterization
- Task 3 - Pilot-Scale Combustion Testing
- Task 4 - Utility Boiler Field Testing
- Task 5 - CQIM Completion and Development of CQE Specification
- Task 6 - Develop CQE
- Task 7 - CQE Workstation Testing and Validation

WORK PERFORMED

During the past quarter, Tasks 2, 3, 4, 5, and 6 were active. Under Task 2--Coal Cleanability Characterizations--final reports were completed and distributed for coal characterization studies performed in support of the following three full-scale combustion test sites:

- Mississippi Power Company's Watson Unit 4 (baseline coal)
- Alabama Power Company's Gaston Unit 5 (baseline coal)
- Northern States Power Company's King Unit 1 (five Powder River Basin subbituminous coals).

Task 3 Pilot Scale Combustion Testing activity included:

- Completion and distribution of the final test report for ABB/CE's pilot-scale testing of PSO's Northeastern Station test coals.
- Completion and distribution of the final test report for B&W's pilot-scale testing of the Northern States Power Allen S. King Station test coals.
- Characterizations of slagging and fouling ash deposits in support of the King pilot-scale combustion tests.
- Continued development of the slagging and fouling models.

No utility test burns (Task 4) were conducted during the past quarter. Test plans and schedules were finalized for the alternate coal test burn at APC's Gaston Unit 5, to occur in October 1992. In addition, the initial coordination meeting and site inspection occurred for the fifth utility combustion test site, the Homer City Station Unit 2 co-owned by the Pennsylvania Electric Company and the New York State Electric and Gas Corporation.

Tasks 5 & 6 activities were directed at overall CQE program definition, development of the CQE software specification, and continued formulation of CQE algorithms and submodels.

Task 2 - Coal Cleanability Characterization

Topical reports were completed and submitted to DOE for the Coal Cleanability Characterizations performed in support of the full-scale test burns conducted at MPC's Watson Unit 4, NSP's King Unit 1, and APC's Gaston Unit 5.

The Watson report summarizes the characterization results for a blend of the Illinois No. 2, 3, and 5 Seam coals; this blend was tested as the baseline coal during full-scale combustion tests at the Watson Plant. A topical report for the cleanability characterization of the alternate coal (Kentucky No. 11 Seam) was submitted previously.

A topical report was submitted in August for the coal cleanability characterization studies performed in support of the baseline coal field test conducted at Alabama Power's Gaston Plant. It contains the results of a complete cleanability characterization--including raw coal characterization, impurities liberation investigations, and coal-cleaning evaluations--performed on the Pratt and Utley Seam coals burned at Gaston.

Another topical report was submitted in September, documenting the coal characterization tests that were conducted in support of the field test at Northern States Power's King Station. It includes the results of a detailed laboratory cleanability characterization program conducted on five Powder River Basin subbituminous coals. This report will eventually be revised and re-issued upon the completion of trace element data analysis.

Task 3 - Pilot-Scale Combustion Testing

Task 3 provides detailed characterization of fuel properties of the test coals and in-depth evaluation of their performance characteristics under controlled pilot-scale combustion testing. Results from this task provide fundamental information required to develop the improved algorithms for the CQE. Both bench-scale fuel characterization and test furnace performance evaluations are being performed under this task.

Bench-Scale Testing

Bench-scale testing and data analyses continued during the quarter in support of the development of the slagging and fouling models. Data obtained from the analysis of deposits, inflame solids, fly ash, and coal from pilot-scale and drop tube combustion tests performed with coals from the first three utility test sites--PSO Northeastern, MPC

Watson, and NSP King--were evaluated for use in devising and verifying the slagging and fouling algorithms.

Adhesion strength measurements were completed on all CQE test coals, with the exception of those used for the Gaston baseline test.

Pilot-Scale Testing

A final topical report of the bench- and pilot-scale combustion test results for the PSO Northeastern test coals was issued in July by ABB Combustion Engineering. In general, the correspondence of data from the pilot-scale and field testing was very good. Selected conclusions from that report are summarized below:

- The blend of 70% Wyoming (WY) and 30% Oklahoma cleaned (OK CLN) coal resulted in lower furnace deposits which remained cleanable at temperatures up to 2975 to 3000 °F. Deposits in the lower furnace from the 90% WY/10% OK blend were cleanable up to temperatures only slightly below the 70% WY/30% OK CLN blend. The 100% WY and 70% WY/30% OK fuels, by contrast, produced lower furnace deposits which were cleanable only up to 2800 to 2850 °F.
- Of the three coals that were field tested, the 90% WY/10% OK blend resulted in the lowest furnace outlet temperature, implying that resistance to heat transfer (due to deposits) was less in that case. This finding was supported by thermal conductance ($k/\Delta x$) measurements made in ABB/CE's Fireside Performance Test Furnace, which were significantly higher for the 90% WY/10% OK blend as compared to the 100% WY and 70% WY/30% OK coals.
- Low excess air was shown to have a more significant effect on the nature of lower furnace deposits in the 100% WY case; this was corroborated by field test data. Specifically, low excess air reduced the critical temperature for adequate deposit cleanability to a greater extent in the 100% WY case than for the other fuel blends tested.
- Bonding strength of deposits in the convective pass generally increased with increasing amounts of the OK

coal. However, only with the 70% WY/30% OK blends did the deposit bonding strength clearly begin to exceed the ability of conventional soot blowers to remove deposits; such conditions generally occurred at gas temperatures of 2250 °F or higher.

- Though erosion rates of fly ashes from the 90% WY/10% OK blend were three times that of the 70% WY/30% OK CLN blend, both blends showed very low erosion relative to most other U.S. coals.

The results of bench- and pilot-scale combustion and deposition testing of the NSP King test coal blends were documented in a topical report issued by B&W in September. Combustion and deposition tests were performed in their small boiler simulator with both the baseline coal blend--70% Wyoming (WY), 20% Montana (MT), and 10% petroleum coke (PC)--and the alternate coal blend--93% WY and 7% PC; bench-scale tests were only conducted on the baseline coal. The following conclusions were made:

- The baseline coal blend showed low abrasiveness (wear caused by the rubbing action of the coal against pulverizer internals) and low erosiveness (sandblasting type wear that occurs in burner lines and diffusers when coal particles are pneumatically transported).
- The ignition temperature as measured by the Inflammability Temperature test was low, indicating good ignitability.
- The measured slag viscosity results showed that the baseline coal blend more than meets B&W's slag viscosity requirements for cyclone furnace firing (T_{250} less than 2450 °F).
- The sintered strength of the baseline coal blend was very low compared to other low rank coals, indicating low fouling deposit strength.
- The NO_x emissions were found to be about 50 ppm higher for the alternate coal blend than the baseline coal blend.

- The SO₂ emissions of the baseline coal were 100 ppm higher than the alternate coal.
- The average ash carbon levels were below 0.5% for both blends.
- The deposits that formed on the secondary superheater probe were easily removed, and the heat recovery of the superheater probe was good after sootblowing for both coals.

Task 4 - Utility Boiler Field Testing

No full-scale utility combustion tests were performed during the past quarter; efforts were devoted to planning, data reduction, and report preparation.

Final plans were completed for the APC Gaston alternate coal test scheduled to begin the week of October 5, 1992. To ensure a continuous supply of alternate coal to Gaston's Unit 5 throughout the test period, APC's Plant and Fuels Department personnel made special arrangements, including excavation of soil around a trussel to accommodate 100,000 to 150,000 tons of coal. Tests are scheduled to be performed at full load (884 MW), maximum load (920 MW), and half load (450 MW), as well as at different levels of excess air.

The Duquesne Light Company cancelled the field test that was scheduled for September at the Cheswick Station; the field test may be rescheduled for the Spring of 1993. The initial site inspection and preliminary planning meeting for the Penelec/NYSEG Homer City field test was held in August; preparation of the preliminary test plan for that site was started.

Electric Power Technologies and its field-testing contractors held a technical briefing at NSP's King Station in July to review preliminary field test results with NSP personnel.

Task 5 - CQIM Completion and Development of CQE Specification

The primary objectives of this task are to:

- Improve and enhance the Coal Quality Impact Model (CQIM)
- Identify and assemble all models and data bases to be incorporated into the CQE

- Develop the specification for the CQE.

Primary efforts during the past quarter were focused on development of the boiler, slagging (SLAGGO), and fouling (FOULER) models. Meetings and teleconferences were held periodically during the quarter to monitor the development of the CQE algorithms and submodels, and to ensure that the approach being taken by the various developers was consistent with the overall objective.

Efforts continued on defining classes to encompass the framework and functionality of the CQE's Plant Performance calculations, including network, performance, equipment and equipment system classes. Functionality needed to support the CQE graphical user interface (GUI) classes was evaluated; eventually, a GUI class library suitable for the needs of CQE will be provided.

Work continued in the development of the following CQE algorithms and models:

- **Tube Erosion Model**--based on empirical correlations, primarily a function of the ash mass flux, velocity, and the quartz in the ash. The relationship would focus only on the economizer, although the possibility of extending the correlations to superheat and reheat predictions have been discussed. Documentation of this model is expected to be completed during the fourth quarter of 1992.
- **Mill Abrasion Model**--based on empirical correlations and is a function of ash loading, ash composition, higher heating value, and CCSEM data. The output of the model will be mill material worn per 1000 tons throughput. It is also scheduled for delivery during the fourth quarter of 1992.
- **Pulverizer Capacity**--it was decided that the mill capacity algorithm currently used within CQIM will be acceptable for CQE's needs. However, a need to accurately predict mill outlet moisture content for various coals was identified and will be further investigated.

- **Twin Furnace Model**--review of twin furnace historical operating data indicated that each half of the furnace behaves in basically the same manner, suggesting that the CQE model could be a simplified model that would run two units in "parallel" and combine the results.
- **Unburned Carbon Model**--work continued on the development of a database that links ASTM coal analysis to reactivity parameters that are used in CQIM's unburned carbon model.
- **Ball Tube Mill Model**--work continued on the integration of ball tube mills within the fuel preparation and firing system objects. Additional ball tube mill performance data from the Watson field test were obtained to facilitate the development of heat transfer correlations for the model.
- **Slagging Model (SLAGGO)**--ABB/CE and PSI Technologies continued the development of the ash deposition model (ADM) and the thermal properties model (TPM). ABB/CE is preparing a database from tests performed at their FPTF to be used in developing and validating the ADM and TPM. The ADM will predict the change of the cleanliness factor with time at six different regions of a furnace. The cleanliness factor is defined as the ratio of the heat transmitted across the clean waterwall tubes to the heat transmitted across the waterwall tubes with deposit. The cleanliness factor increases with time until it reaches an equilibrium value and reflects the effect of slagging on boiler performance; it can be used to estimate the optimal sootblowing frequencies for economical operations.

The ADM was refined to reflect a change in the calculation of the ash particle temperature. Originally, this temperature was assumed to be the temperature of the gas stream; however, further investigation indicated that the temperature of the ash particle arriving at the deposit surface is closer to the wall temperature than to the gas temperature.

- **Fouling Model (FOULER)**--the FOULER algorithm shell was completed, and verification of the submodels was started. Data from the bench-, pilot-, and full-scale

testing of the PSO Northeastern, MPC Watson, and NSP King coals were evaluated for use in developing the fouling algorithm.

Also, final modifications were made to the Acid Rain Advisor (ARA). The ARA program and documentation were completed and shipped to the EPRI Software Center for commercial release.

TECHNOLOGY TRANSFER

Seven technical papers were presented at major conferences during the past quarter, documenting some of the activities which have occurred under the CQE project. Six of these papers were presented at the EPRI Conference, "The Effects of Coal Quality on Power Plants," held in La Jolla, California, August 25-27, 1992:

- "Evaluating Impacts of Clean Air Act Compliance Strategies" co-authored by C. Harrison (CQ Inc.), B. Evans (DOE-PETC), D. Shirer (Duquesne Light), and D. Kehoe (CQ Inc.), and presented by C. Harrison.
- "Application of Developmental Techniques to Solve Combustion Related Problems in Power Plants" authored and presented by Z. Frompovicz (Energy and Environmental Research Corporation).
- "Assessment and Validation of Coal Quality Impact Model at Mississippi Power Company's Unit 4" co-authored by S. Lowe and P. Vitta of Southern Company Services and R. Cromwell and M. Matson of Mississippi Power Company, and presented by S. Lowe.
- "A Comparison of Ash Deposition Behavior in Field, Pilot, and Bench-Scale Testing" co-authored by S. Benson, S. Allen, and C. Zygarlicke of UND's Energy and Environmental Research Center, R. Borio of ABB/CE, and A. Mehta of EPRI, and presented by C. Zygarlicke.
- "Measuring the Impact of Coal Quality on Boiler Operation and Performance" co-authored by R. Thompson (Fossil Energy Research Company), Z. Frompovicz (EER), E. Landham (Southern Research Institute), P. Vitta (Southern Companies Services), and

D. Giovanni (Electric Power Technologies), and presented by R. Thompson.

- "Coal Quality Field Test at Mississippi Power Company's Watson Unit 4" co-authored by P. Vitta (SCS), Z. Frompovicz (EER), R. Cromwell (MPC), and M. Matson (MPC), and presented by P. Vitta.

In addition, C. Harrison presented the paper "Coal Quality Expert: Status and Software Specifications" at the First Annual Clean Coal Technology Conference held in Cleveland, Ohio, September 22-24, 1992; the paper was co-authored by R. Evans, the DOE Project Manager.

END

**DATE
FILMED
5/13/93**