Technical Progress Report No. 6

Development of a Coal Quality Expert

U.S. Department of Energy
Pittsburgh Energy Technology Center
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This is the sixth 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 Combustion Engineering, Inc. This report covers the period from July 1 through September 30, 1991. Four companies and seven host utilities have teamed with CQ Inc. and C-E to perform the work on this project. The work falls under DOE's Clean Coal Technology Program category of "Advanced Coal Cleaning." The 45-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, and 5 were active. Coal samples were collected from several mines located in the Powder River Basin for characterization studies in support of the Northern States Power (NSP) King test site. Pilot-scale combustion tests with the Mississippi Power Company's (MPC) Plant Watson coals were completed. Field combustion tests with the baseline coal were conducted at Alabama Power Company's (APC) Gaston Unit 5; data reduction, interpretation, and documentation continued for the PSO Northeastern and MPC Watson field tests. Task 5 activities were directed at overall CQE program definition, development of the CQE software specification, development and refinement of the Acid Rain Advisor (ARA), and continued formulation of CQE algorithms and submodels.

Task 2 - Coal Cleanability Characterization

A test report for the coal cleanability characterization studies performed on the Croweburg Seam coal - burned as part of the alternate coal blends during the PSO Northeastern field tests - was completed and distributed in July. These results were summarized in a paper presented at the Eighth Annual International Pittsburgh Coal Conference, entitled "Cleaning of Croweburg Seam Coal to Improve Boiler Performance." The paper was authored by R.L. Dospoy and presented by C.D. Harrison, both of CQ Inc. A report of the coal cleanability characterizations performed with the Watson baseline and alternate coals is in preparation, and will be distributed in the fourth quarter of 1991.

Coal samples for raw-coal characterization studies were collected from five mines located in the Powder River Basin as part of the NSP King test program; a sixth mine will be sampled in Spring 1992. Characterizations of these coals will greatly enhance the Western coal database of CQIS. Participating coal suppliers for this study are identified below:

- WestMoreland Resources, Inc.  
  Absaloka Mine  
  Bighorn County, MT  
  Seam: Rosebud-McKay

- Powder River Coal Co.  
  Rochelle Mine  
  Campbell County, WY  
  Seam: Wyodak

- Western Energy Co.  
  Rosebud Mine  
  Rosebud County, MT  
  Seam: Rosebud

- NERCO Coal Corp.  
  Antelope Mine  
  Converse County, WY  
  Seam: Anderson; "D"
The Antelope, Rochelle, and Absoloka Mines are all current suppliers of coal to NSP's King Station. During the past quarter, a representative sample of approximately 15 tons was obtained from each mine, except for the Eagle Butte Mine to be sampled in 1992. All samples were collected from a split of either a primary or secondary sampler stream as coal was being loaded to a unit train or storage area. Raw-coal characterizations are being performed on each coal, including proximate and ultimate analyses, sulfur forms, Hardgrove Grindability Index, ash fusion temperatures, ash composition, trace elements, size distribution, and float/sink washability analysis. In addition, the as-received coal will be crushed to certain topsizes to evaluate size/quality correlations and impurity liberation potential. Quality of the two Montana raw coals are summarized in Table 1.

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.

During the past quarter, bench-scale testing of the PSO Northeastern and MPC Watson coals continued at ABB/CE and the University of North Dakota’s Energy and Environmental Research Center (UNDEERC). Pilot-scale combustion testing of the Watson baseline and alternate coals were completed at CE’s Fireside Performance Test Facility (FPTF). Coal erosiveness tests were performed by Babcock and Wilcox (B&W) to provide predictive information about the erosive wear rate of the test coals on coal preparation and transport equipment.

The UNDEERC completed characterization analyses of the initial coals and ash products generated at CE’s FPTF during pilot-scale test burns of the four PSO coals:
# Table 1. Montana Raw Coal Quality Summary. *(NSP King CCC)*

<table>
<thead>
<tr>
<th></th>
<th>Westmoreland Absaloka Mine</th>
<th>Western Energy Rosebud Mine</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>As-Received</td>
<td>Dry Basis</td>
</tr>
<tr>
<td>Total Moisture (%)</td>
<td>25.67</td>
<td>22.73</td>
</tr>
<tr>
<td>Fixed Carbon (%)</td>
<td>37.42</td>
<td>35.49</td>
</tr>
<tr>
<td>Volatile Matter (%)</td>
<td>29.39</td>
<td>34.69</td>
</tr>
<tr>
<td>Ash (%)</td>
<td>7.43</td>
<td>7.09</td>
</tr>
<tr>
<td>Heating Value (Btu/lb)</td>
<td>8537</td>
<td>8940</td>
</tr>
<tr>
<td>Total Sulfur (%)</td>
<td>0.56</td>
<td>0.62</td>
</tr>
<tr>
<td>Pyritic Sulfur (%)</td>
<td>0.17</td>
<td>0.19</td>
</tr>
<tr>
<td>Organic Sulfur (%)</td>
<td>0.39</td>
<td>0.42</td>
</tr>
<tr>
<td>Lbs SO₂/MBtu</td>
<td>1.32</td>
<td>1.38</td>
</tr>
<tr>
<td>Carbon (%)</td>
<td>55.64</td>
<td>51.45</td>
</tr>
<tr>
<td>Hydrogen (%)</td>
<td>1.10</td>
<td>3.85</td>
</tr>
<tr>
<td>Nitrogen (%)</td>
<td>0.64</td>
<td>0.77</td>
</tr>
<tr>
<td>Oxygen (%)</td>
<td>8.87</td>
<td>13.49</td>
</tr>
<tr>
<td>Chlorine (%)</td>
<td>0.03</td>
<td>0.04</td>
</tr>
<tr>
<td>Hardgrove Grindability</td>
<td>49</td>
<td>50</td>
</tr>
<tr>
<td></td>
<td>Index</td>
<td>Index</td>
</tr>
</tbody>
</table>

Ash analyses reported on a SO₂-free basis.
• 100% Wyoming Wyodak Seam Coal (100 WY)
• 90% Wyoming Wyodak/10% Oklahoma Croweburg Blend (90 WY/10 OK)
• 70% Wyoming Wyodak/30% Oklahoma Croweburg Blend (70 WY/30 OK)
• 70% Wyoming Wyodak/30% Oklahoma Croweburg Cleaned Blend (70 WY/30 OKcl)

In-flame particulates, waterwall deposits, convection tube deposits, and fly ash samples were collected and sent to the UNDEERC for analyses. Scanning electron microscopy, Mossbauer, X-ray diffraction, and X-ray fluorescence were used to determine the distribution of amorphous and crystalline phases, chemical composition and surface chemistry of the ash components. These data are then related to performance characteristics of the test coals.

During FPTF testing, slag deposits were collected on sacrificial probes inserted in the lower furnace sections. If only the viscosity of these deposits is considered, the ranking of deposit severity was as follows (worst to best): 90 WY/10 OK, 100 WY, 70 WY/30 OKcl, and 70 WY/30 OK. The ranking of the coals is in agreement somewhat with the CE comparison of heat flux for the same coals. The heat flux ranking was as follows (lowest to highest): 100 WY, 90 WY/10 OK, 70 WY/30 OK, and 70 WY/30 OKcl.

Viscosities affect deposit crushing strength, adhesion strength, and, consequently, the ability of the deposit to resist soot blowing action, but will not necessarily give information on expected heat flux temperatures. In reference to heat flux recovery after soot blowing, it was determined that the 100 WY and 70 WY/30 OK performed the poorest, followed by the 90 WY/10 OK and 70 WY/30 OKcl. FPTF testing and ash deposit characterizations for the PSO coals are described further in a paper presented at the Eighth Annual International Pittsburgh Coal Conference, entitled "Developing a Coal Quality Expert: The Prediction of Ash Deposit Effects on Boiler Performance." The paper was co-authored by D.E. Thornock and R.W. Borio of ABB/CE, and A.K. Mehta of the Electric Power Research Institute, and is included here as Appendix B.
ASTM standard and specialty tests (flammability index, weak acid leaching, TGA char reactivities, and BET char surface areas), chemical fractionation, and CCSEM evaluations were performed on the Watson baseline and alternate coals. Drop Tube Furnace System-1 (DTFS-1) testing was completed on the same two coals. Characterization of fly ash, entrained solids, and deposits formed from these coals in the FPTF were initiated during the past quarter.

B&W has developed a method to characterize pulverized coal (PC) erosiveness and provide predictive information about the erosive wear rate on coal preparation and transport equipment. Tests were performed on the four PSO Northeastern coals and two MPC Watson coals; the coal samples were shipped to B&W as pulverized coal with the minus 200 mesh size fraction ranging from 77.3 to 84.4 percent. The test method is based on impingement of PC entrained in a gas stream on a target plate composed of low carbon steel. A PC erosiveness index, equivalent to the metal loss as measured before and after weighings of the target plate, was determined for each coal. Past B&W correlations with actual field data indicate that a coal having an erosiveness index value greater than 36 is characterized as a highly erosive coal. Very low erosiveness was indicated for all coals (Table 2) except for the 70 WY/30 OK blend which, with an index value of 27.45, is considered to be an erosive coal, although not to a great extent.

Table 2. Erosiveness Values of PSO and MPC Test Coals

<table>
<thead>
<tr>
<th>Test Coal</th>
<th>Erosion Index (mg/15 lb. coal)</th>
</tr>
</thead>
<tbody>
<tr>
<td>PSO 100 WY</td>
<td>9.60</td>
</tr>
<tr>
<td>PSO 90 WY/10 OK</td>
<td>14.55</td>
</tr>
<tr>
<td>PSO 70 WY/30 OK</td>
<td>27.45</td>
</tr>
<tr>
<td>PSO 70 WY/30 OKalt</td>
<td>11.70</td>
</tr>
<tr>
<td>MPC Jader (baseline)</td>
<td>11.85</td>
</tr>
<tr>
<td>MPC Island Creek (alternate)</td>
<td>10.20</td>
</tr>
</tbody>
</table>

CE's FPTF is being used to evaluate the effects of coal properties on pulverization, ash deposition, combustion, erosion, and emissions. Testing of the MPC Watson coals
was completed, and data reduction and interpretation is underway. Test conditions are summarized in Table 3; both coals were evaluated under regular and low excess air conditions.

Preliminary results show that the baseline coal had better slagging performance than the alternate coal, and that fouling performances were similar. Low excess air decreased slagging performance in both coals. There appears to be good correlation with the Watson field test results.

A first draft of the PSO Northeastern pilot-scale test report is in preparation, and will be completed during the last quarter of 1991. The report will document the results of bench-scale, FPTF, and pilot-scale ESP testing, as well as commercial applications.

During the past quarter, full-scale combustion testing of the baseline coal was conducted at Alabama Power Company’s (APC) Gaston Unit No. 5. Data reduction, interpretation, and documentation continued for the tests performed at PSO’s Northeastern Unit 4, MPC’s Watson Unit 4, and NSP’s King Unit 1 (only baseline coal tests). A technical briefing was held at the Watson Plant in which the CQE test contractors presented preliminary findings of the field combustion tests and CQIM results to MPC personnel.

APC’s Gaston 5 is the fourth of six test sites selected for utility boiler field testing under this program. It is located in Wilsonville, Alabama, and consists of a pressurized Combustion Engineering (CE) 880-MW, twin-furnace, tangentially fired boiler which was commissioned in 1974. The boiler nameplate rating is 6.351 x 10^6 lb/hr of steam flow at 1000°F superheat temperature and 3,500 psig throttle pressure. The unit is a once through design with a total of 56 burners for the two furnaces; each furnace section has seven burner elevations. The unit is equipped with a hotside electrostatic precipitator with a design specific collection area of 287 ft²/1000 acfm.

Burn tests are being conducted to assess the coal quality impacts on boiler performance and emissions resulting from the burning of the typical, or baseline, coal and an alternate coal. The baseline coal for the test burn is a 2% sulfur Alabama coal from the North River Mine. The alternate
Table 3. FPTF Operating Conditions for Pilot-Scale Testing of MPC Watson Coals

<table>
<thead>
<tr>
<th>Test #</th>
<th>Duration (hrs)</th>
<th>Firing Rate (MBtu)</th>
<th>Avg Oper Temp (°F)</th>
<th>%Excess Air</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Baseline (Jader)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>12</td>
<td>3.6</td>
<td>2896</td>
<td>20</td>
</tr>
<tr>
<td>2</td>
<td>12</td>
<td>3.8</td>
<td>2949</td>
<td>20</td>
</tr>
<tr>
<td>3</td>
<td>12</td>
<td>4.0</td>
<td>3013</td>
<td>20</td>
</tr>
<tr>
<td>4</td>
<td>12</td>
<td>4.0</td>
<td>3013</td>
<td>20</td>
</tr>
<tr>
<td>5</td>
<td>12</td>
<td>4.0</td>
<td>2983</td>
<td>10</td>
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<td>6</td>
<td>12</td>
<td>4.0</td>
<td>2989</td>
<td>10</td>
</tr>
<tr>
<td>7</td>
<td>12</td>
<td>3.8</td>
<td>2978</td>
<td>10</td>
</tr>
<tr>
<td>8</td>
<td>12</td>
<td>3.6</td>
<td>2912</td>
<td>10</td>
</tr>
<tr>
<td><strong>Alternate (Island Creek)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>12</td>
<td>3.6</td>
<td>2905</td>
<td>20</td>
</tr>
<tr>
<td>2</td>
<td>12</td>
<td>3.8</td>
<td>2946</td>
<td>20</td>
</tr>
<tr>
<td>3</td>
<td>12</td>
<td>3.5</td>
<td>2870</td>
<td>20</td>
</tr>
<tr>
<td>4</td>
<td>12</td>
<td>3.6</td>
<td>2969</td>
<td>20</td>
</tr>
<tr>
<td>5</td>
<td>12</td>
<td>3.6</td>
<td>2917</td>
<td>10</td>
</tr>
<tr>
<td>6</td>
<td>12</td>
<td>3.4</td>
<td>2888</td>
<td>10</td>
</tr>
<tr>
<td>7</td>
<td>12</td>
<td>3.2</td>
<td>2833</td>
<td>10</td>
</tr>
<tr>
<td>8</td>
<td>12</td>
<td>3.6</td>
<td>2915</td>
<td>30</td>
</tr>
</tbody>
</table>
coal will be a 0.9% sulfur West Virginia coal from the Hartland Mine (to be opened in early 1992). Typical properties of the base coal are presented in Table 1. The properties of the alternate coal are actually those for a mine located adjacent to the Hartland Mine; both are located in the same seam, and the properties of each are expected to be similar. The reduced sulfur emission potential and lower grindability of the alternate coal will be important. Also, during the test from a boiler operating standpoint, burning of this coal may result in reduced ESP collection efficiency, higher opacity levels, and aggravated fouling and/or slagging.

The test burns at Gaston are being conducted in two phases. Testing of the baseline coal occurred over the period September 16 through October 11, 1991. The alternate coal test series is scheduled for April/May 1992. The following sections summarize the equipment modifications and test conditions for the baseline test series.

**Equipment Modifications.** A number of equipment modifications were required at APC Gaston to accommodate the field-testing effort. Labor and materials required to do the work were contracted by the Appalachian Power company, Southern Company Services, in support of the CQE program. The following are the equipment modifications and maintenance required at APC Gaston follows:

- Repaired and cleaned all existing aspirator/doors.
- Installed four 6" ID ports on each air heater outlet duct (total of 8).
- Modified 12 existing ports to 4" ID aspirator ports on economizer outlet ducts.
- Installed 2" standard pipe ports with ball valves at each pulverized coal/air pipe (total 56) leading to the burners.
- Provided new 6" x 12" opening and installed port on the side of each economizer outlet duct for on-line LOI sampling equipment.
Table 4. Raw Coal Analyses for APC Gaston Baseline and Alternate Test Coals. (As-received Basis)

<table>
<thead>
<tr>
<th>PROXIMATE ANALYSIS (Wt%)</th>
<th>Baseline</th>
<th>Alternate</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Alabama</td>
<td>West Virginia</td>
</tr>
<tr>
<td></td>
<td>North River</td>
<td>Hartland</td>
</tr>
<tr>
<td>Total Moisture</td>
<td>8.00</td>
<td>6.25</td>
</tr>
<tr>
<td>Ash</td>
<td>12.15</td>
<td>11.72</td>
</tr>
<tr>
<td>Volatile Matter</td>
<td>34.30</td>
<td>33.75</td>
</tr>
<tr>
<td>Fixed Carbon</td>
<td>45.55</td>
<td>48.28</td>
</tr>
<tr>
<td>Heating Value (Btu/lb)</td>
<td>11,986</td>
<td>12,141</td>
</tr>
<tr>
<td>Sulfur</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total (Wt%)</td>
<td>2.30</td>
<td>0.90</td>
</tr>
<tr>
<td>SO$_2$ (lb/Mbtu)</td>
<td>3.84</td>
<td>1.48</td>
</tr>
<tr>
<td>Ash (lb/MBtu)</td>
<td>10.13</td>
<td>9.65</td>
</tr>
<tr>
<td>Hardgrove Grind (HGI)</td>
<td>47</td>
<td>42</td>
</tr>
<tr>
<td>Chlorine (Wt%)</td>
<td>NA</td>
<td>0.09</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>ULTIMATE ANALYSIS (Wt%)</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Carbon</td>
<td>66.85</td>
<td>69.38</td>
</tr>
<tr>
<td>Hydrogen</td>
<td>4.55</td>
<td>4.59</td>
</tr>
<tr>
<td>Nitrogen</td>
<td>1.59</td>
<td>1.31</td>
</tr>
<tr>
<td>Sulfur</td>
<td>2.30</td>
<td>0.90</td>
</tr>
<tr>
<td>Ash</td>
<td>12.15</td>
<td>11.72</td>
</tr>
<tr>
<td>Oxygen</td>
<td>4.56</td>
<td>5.85</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>ASH FUSIBILITY (°F)</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>(Reducing/Oxidizing)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Initial Deformation</td>
<td>2129/NA</td>
<td>2700/2800</td>
</tr>
<tr>
<td>Softening</td>
<td>2248/NA</td>
<td>2800/NA</td>
</tr>
<tr>
<td>Hemispherical</td>
<td>2265/NA</td>
<td>NA/NA</td>
</tr>
<tr>
<td>Fluid</td>
<td>2391/NA</td>
<td>NA/NA</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>ASH COMPOSITION (Wt%)</th>
<th></th>
<th></th>
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</thead>
<tbody>
<tr>
<td>SiO$_2$</td>
<td>40.62</td>
<td>58.20</td>
</tr>
<tr>
<td>Al$_2$O$_3$</td>
<td>25.86</td>
<td>28.90</td>
</tr>
<tr>
<td>Fe$_2$O$_3$</td>
<td>17.47</td>
<td>6.54</td>
</tr>
<tr>
<td>CaO</td>
<td>6.48</td>
<td>0.60</td>
</tr>
<tr>
<td>MgO</td>
<td>1.36</td>
<td>1.50</td>
</tr>
<tr>
<td>Na$_2$O</td>
<td>0.51</td>
<td>0.46</td>
</tr>
<tr>
<td>K$_2$O</td>
<td>2.26</td>
<td>2.10</td>
</tr>
<tr>
<td>TiO$_2$</td>
<td>1.14</td>
<td>1.02</td>
</tr>
<tr>
<td>P$_2$O$_5$</td>
<td>NA</td>
<td>0.08</td>
</tr>
<tr>
<td>SO$_2$</td>
<td>NA</td>
<td>0.30</td>
</tr>
</tbody>
</table>
• Provided scaffolding on the eleventh floor for HVT traverses.

• Opened existing wall boxes @ 534' elevation and provided 2-1/2" standard diameter pipe with threaded cap on each side of the boiler furnace for large HVT traverses.

• Modified existing 2" ports at the windbox to facilitate secondary air flow traverses (total 56).

• Repaired fuel-air and auxiliary air dampers.

• Cleaned ash taps at economizer and air preheater hoppers.

• Calibrated key plant instrumentation.

• Provided new penetrations at furnace side walls to accommodate view ports (total 12).

• Repaired site glasses.

• Cleaned refractory from inside boiler for furnace penetrations.

• Enlarged existing furnace wall O₂ taps, and added additional taps at two elevations.

• Provided 12 chordal thermocouples at selected locations.

• Installed a flop gate and chute from the primary coal sampler to the ground, and provided a stone base around the sampler to accommodate raw-coal sampling during the test burns.

**Test Conditions.** Following a brief series of diagnostic tests, the baseline coal test burn was conducted according to the matrix shown as Table 5. In addition to a detailed emissions and performance characterization at full load, tests were performed at varying levels of load and excess air. Tests of specific interest to APC were performed to examine in more detail the slagging and carbon burnout.
Table 5. APC Gaston Unit 5 Test Matrix - Baseline Coal

<table>
<thead>
<tr>
<th>Test</th>
<th>Load (MWg)</th>
<th>O₂</th>
<th>Test Objective</th>
<th>Tests</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Baseline Coal (Alabama North River)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>D</td>
<td>880</td>
<td>Norm</td>
<td>Full Load Operation</td>
<td>B,C,F</td>
</tr>
<tr>
<td>E</td>
<td>880</td>
<td>Low</td>
<td>Full Load Operation with Low O₂</td>
<td>B,C,F</td>
</tr>
<tr>
<td>F'</td>
<td>880</td>
<td>Norm</td>
<td>Burner Tilt Characterization</td>
<td>B,C,F</td>
</tr>
<tr>
<td>G</td>
<td>450</td>
<td>Norm</td>
<td>1/2 Load Operation</td>
<td>B,C,F</td>
</tr>
<tr>
<td>H</td>
<td>450</td>
<td>Low</td>
<td>1/2 Load Operation with Low O₂</td>
<td>B,C,F</td>
</tr>
<tr>
<td>I</td>
<td>880</td>
<td>Norm</td>
<td>Detailed Full Load Characterization</td>
<td>B,C,F,E,M</td>
</tr>
<tr>
<td>J</td>
<td>920</td>
<td>Norm</td>
<td>Maximum Load Test</td>
<td>B,C,F</td>
</tr>
<tr>
<td>K'</td>
<td>880</td>
<td>Norm</td>
<td>Boiler Performance Optimization</td>
<td>B,C,F</td>
</tr>
<tr>
<td>L'</td>
<td>880</td>
<td>Norm</td>
<td>Special Tests</td>
<td>B,C,F</td>
</tr>
<tr>
<td>M'</td>
<td>660</td>
<td>Norm</td>
<td>3/4 Load Operation</td>
<td>B,C,F</td>
</tr>
<tr>
<td>N'</td>
<td>660</td>
<td>Low</td>
<td>3/4 Load Operation with Low O₂</td>
<td>B,C,F</td>
</tr>
</tbody>
</table>

Notes:
- Optional
  B - Boiler monitoring (control room, gaseous, opacity, etc.)
  C - Combustion performance (LOI or gas traverse)
  M - Mill monitoring - one mill only (fineness, vibration, rejects, etc.)
  F - Furnace measurements (exit gas temp or slagging/fouling)
  E - ESP measurements (V/I, loading, size distribution, resistivity, SO₃)
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.

During the past quarter, work continued on development of the object diagrams for the CQE program, revisions of the CQE application descriptions, initial guidelines and approaches for developing the CQE software specification, revisions to the Acid Rain Advisor (ARA), and ongoing CQIM enhancements and algorithm development.

Work continued on development of the object diagrams for the CQE program. Minor enhancements were made to the diagramming tool to improve modeling capabilities, drawing/redrawing capabilities, and graphical representation. Various object databases and expert systems were further explored.

Further improvements were made to the ARA to resolve problems found during testing of the initial Beta version. An update of the program was sent to the seven participating utilities of the Beta Test Committee on September 24. Program modifications will continue throughout the next quarter based on comments received from the test team and further in-house review.
Tentative plans were made to conduct an ARA Workshop in early December to demonstrate and market the program. A draft copy of the preliminary documentation for the ARA will be available for the Workshop.

Work continued on enhancing current CQIM models and the development of essential algorithms for the CQE, including the Boiler Expert, Slagging/Fouling Expert, precipitator model, ball tube mill model, and the Coal Purchase and Transport submodels.

**Boiler (Slagging/Fouling) Expert.** A boiler expert is being developed as a means of integrating the technical advancements to be made in the areas of slagging and fouling for the CQE project. A methodology for the Slagging/Fouling (S/F) Model was developed based on information provided by B&V, EPT, UNDEERC, and PSIT. Slagging/fouling, sootblower recovery, and load shedding recovery relationships that characterize deposition and recovery of slag/foul buildup will be established in each of ten defined regions within the boiler. These relationships will be governed by many factors, as grouped into the following three related areas:

- **Coal Properties - Deposition characterization** (stickiness, growth, transport, adhesion, expansion/contraction, conductivity, reflectivity, emissivity), initial deposition, excess oxygen (chemical effect), ash loading and particle distribution.

- **Boiler Design -** Design heat input per plan area, design FEGT, burner type and firing arrangement, overall geometry and dimensions.

- **Operating Conditions -** Temperature, boiler/duty cycle, firing (burner position), and excess oxygen (thermal effect).

Each of these factors will be treated as separate objects within CQE; these objects will be used to build three baseline relationships utilizing data and correlations from EPT, UNDEERC, and PSIT. The objects will include information and correlations capable of adjusting the
baseline relationships to account for variations between actual unit configuration and operating strategy and the assumptions used in developing the baseline relationships. The adjustments may use user input and/or correlations based on test burn information, written documentation, or additional analyses performed by PSIT and UNDEERC.

**Precipitator Model.** Preliminary research and design for the precipitator model were initiated. The current precipitator model for the CQIM considers coal characteristics and past operating history, but does not consider in detail the physical characteristics of the precipitator. The capabilities of this model were compared to those of the Southern Research Institute's (SoRI) ESPert precipitator model. ESPert considers fly ash particle size and distribution, electrical operating conditions, wire-plate arrangements, sectionalization, rapping re-entrainment, and nonuniform gas distribution. It is anticipated that ESPert will be used to some extent in CQE as a basis for estimating ESP performance.

Several different opacity models were investigated and found to use very similar approaches and methodology. Also, the possibility of using EPRI's ESPM model was explored.

**Ball Tube Mill Model.** Information and data were gathered from the field and equipment manufacturers in support of this model, which will use inputs and default capabilities to determine capacity corrections for coal grindability, fineness, moisture, and inlet size. Modeling efforts to date have included preliminary heat balance and mill capacity correction routines. Information required to develop and validate this model was obtained at MPC Plant Watson (additional data will be collected at other test sites using ball tube mills); information required to model ball tube mills includes:

- Coal moisture at crusher dryer inlet.
- Coal moisture between crusher dryer and mill.
- Coal moisture at classifier outlet.
- Crusher dryer air/fuel ratio.
- Mill air/fuel ratio.
- Bypass damper position.
- Crusher dryer inlet temperature.
- Temperature between crusher dryer and mill.
- Temperature at crusher dryer outlet.
- Crusher dryer power requirements (kWh/ton).
- Mill power requirements.

**Coal Purchase & Transport.** Decision Focus Incorporated (DFI) continued the object oriented design for coal cleaning, blending, handling, and transportation. The original algorithms in this set were modified and integrated to arrive at the current set: the Coal Quality Information System (CQIS), the Cleaning Option Optimizer (COO), the Coal Blending Model (CBM), and the Coal Transportation Model (CTM). DFI estimates that algorithm design is 80% complete for CQIS, 60% complete for COO and CBM, and 75% complete for CTM. It is expected that the preliminary Object Oriented Design for this set will be completed in the next quarter, and efforts to integrate this model into the overall CQE design will begin early in 1992.

**PROJECT MEETINGS**

The following major project meetings were held over the past quarter:

A technical briefing was presented at MPC's Watson Station in Gulfport, Mississippi on August 6, 1991. Preliminary results were presented for the test burns conducted at Watson Unit 4 in October/November 1991, including findings for boiler/combustion and precipitator tests. CQIM results, pilot combustion test results, and coal cleanability characterizations of the test coals were also presented.

The first software design meeting was held August 19 and 20, attended by representatives of each of the CQE software developers. Meeting topics included project schedule; 1991 schedule for activities and meetings; general concepts to be used within CQE; overview of CQE applications; role of each developer; and requirements for base level objects and tools.

The first boiler expert meeting was held August 27 and 28 in Kansas City, attended by all CQE team members involved with development of the boiler and slagging/fouling models. Topics discussed included overall capabilities of the Boiler Expert; integration of slagging/fouling, operations, and heat transfer analysis;
general framework of the Boiler Expert; treatment of slagging and fouling; object identification/interactions; and modeling concerns and responsibilities.

Appendix A; Appendix B
removed (recycled)
APPENDIX C

Coal Quality Expert
Program Applications and Tools
THE
COAL
QUALITY
EXPERT
APPLICATIONS
PLANT-LEVEL FUEL EVALUATOR

DESCRIPTION: This application evaluates utilization of alternative coals with an existing power station, including consideration of transportation, clean/blending, historical experience, etc., in conjunction with CQIM™ technical/economic analysis.

INTENDED USE: Fuel Purchasing Department, Coal Companies, Engineering Department, Plant Engineers/Personnel

CQE NEEDS MET: Document fuel procurement decisions, assist in finding coal sources, bridge to existing fuel planning and comparison tools, consider/include handleability factor, evaluate alternative fuel sources by cost and/or benefit, assess ash pond/landfill capacity and economics, estimate total fuel related costs, break-even analysis, evaluate performance emissions, provide communication tool (need for new fuel, plant betterment, load recovery & NOx equipment), provide advice for test burn, consider handleability, include CQIS and user defined database, evaluate transportation costs and assist user in identifying new sources of fuel.


LOGICAL FLOW DESCRIPTION: The user will first select a plant, using the Select Plant subapplication, that he/she would like to evaluate. The plant (and units) can be selected from plants/units that have been developed before or can be specified at this time. After the plants/units have been selected, the user will select the coals that are to be evaluated using the Select Fuel subapplication. The Select Fuel subapplication will assist the user in selecting the appropriate fuels by providing access to the fuel database through the Fuel Supply Expert and by applying certain selection criteria. The user will also develop a network (transportation, blending, cleaning, etc.) which will be attached to the Fuel Source to make up a Fuel. The user will then establish expected generation based on historical generation from system analysis. CQE will now calculate unit and plant performance and economics. The Plant and Unit Performance/Economic Results IOUs can be used to evaluate performance and economic results for each unit and the overall plant with assistance provided by the performance and economic results experts. If the user so desires, sensitivity analyses on coal quality parameters and economic parameters can be performed. A flow diagram illustrating the operational steps is attached.
NEW PLANT DESIGNER

DESCRIPTION: This application evaluates power plant costs on a conceptual level as a function of technology and potential envelope(s) of design coals, including consideration of utility-specific design philosophy, market conditions, and fuel sourcing issues.

INTENDED USE: Utility Engineering Department, Consulting Engineering Firms, Independent Power Producers, Equipment Manufacturers, Coal Companies

CQE NEEDS MET: Provide conceptual estimates of coal fired power plants, assist in finding coal sources, evaluate capital cost vs. fuel flexibility for new unit, evaluate alternative fuel sources by cost and/or benefit, estimate total fuel related costs, provide communication tool (need for new fuel, plant betterment, load recovery and NOx equipment), design and cost new plant, include CQIS and user defined data base, evaluate transportation costs, and assist user in identifying new sources of fuel.

SUBAPPLICATIONS USED: Select Plant, Select Fuels, Establish Expected Generation/Demand, Perform Design Calculations, Review and Approve Design, Unit and Plant Economics, Save Plant Design, Plant-Level Fuel Evaluator


10/22/91
LOGICAL FLOW DESCRIPTION: The user will first define some general design configurations such as unit size, balanced draft vs. pressurized, subcritical vs. supercritical, hot ESP vs. cold ESP, etc. The plant can be a new unit or an existing unit for which the user would like to add a unit. After basic information for the plants/units have been defined, the user will select the coals for which the unit design and cost should be based on. The user can select a single fuel or may elect to have the unit designed to burn several coals with varying coal quality. CQE will then perform the appropriate design calculations for each unit and each coal (or combination of coals) that were selected. The user will then approve the design that was predicted and make changes as are appropriate. The user will be given the opportunity to gradually design the entire unit by allowing the user to keep track of portions of design data via a approval checklist. This approval checklist does not prevent the user from evaluating economics for alternative designs but rather the user as to what designs have been reviewed and approved. Economics are calculated for each unit/fuel combination scenario and presented to the user in side-by-side comparative fashion so that the user can conveniently evaluate each scenario. Upon approval of each unit design and the overall plant design, the user can save the entire design within the CQE data base. This plant can then be treated by other analysts as if it really exists. That is, system analysts can evaluate the impacts this plant has on the entire system. Likewise, the Environmental Strategic Planner could determine how this new plant will affect system wide SO₂ reduction strategies.
New Plant Designer

1. Select/Specify New Plant Design
   - Derive Fuel/Unit Combinations
   - Perform Design Calculations for Fuel/Unit Combinations
     - Review and Approve Design
       - User Approves Design Data
         - Perform Economics
           - Examine Costs for Fuel/Unit Scenarios
             - Save Plant Design Data
               - Yes
                 - Evaluate Alternate Fuels
                   - Yes
                     - Plant-Level Fuel Evaluator
                   - No
                     - Exit
               - No
                 - Save Plant Design Data

2. Exit
   - Yes
   - No
SYSTEM-LEVEL FUEL EVALUATOR

APPLICATIONS

DESCRIPTION: This application builds on capabilities of the plant-level fuel evaluator. It would allow the utility to compare broad fuel-switching strategies, including multiplant coal blending/cleaning facilities.

INTENDED USE: System Planning Department, Fuel Purchasing Department, Coal Companies, Utility Engineering Department

CQE NEEDS MET: Provide better data for General Planning bridge to Engineering, document fuel procurement decisions, assist in finding coal sources, bridge to existing fuel planning and comparison tools, evaluate scenarios in terms of cost and emissions of SO₂ and NOx (subsets: sensitivities and SO₂, NOx allowances), credit due to SO₂ allowance (selling), evaluate alternative fuel sources by cost and/or benefit, assess ash pond/landfill capacity and economics, estimate total fuel related costs, break-even analysis, consider emissions of SO₂ and NOx, provide communication tool (need for new fuel, plant betterment, load recovery, NOx equipment), include CQIS and user defined data base, evaluate transportation costs, and assist user in identifying new sources of fuel.

SUBAPPLICATIONS USED: Select Plant, Select Fuels, Establish Expected Generation, Evaluate Unit/Equipment Performance, Plant Performance, Unit Economics, Plant Level Economics, Create System Scenario, Evaluate System Scenario, Economic Results IOU, Economic Results Expert

Consumables, Maintenance, Capital, Fixed O&M Costs, Waste Disposal Cost, Replacement Power. (Only major objects are listed.)

**LOGICAL FLOW DESCRIPTION:** The user will first define the utility system to be considered by selecting the plants and units in the utility system and by specifying system-level economic information. Plants and units may be selected from plants and units that currently reside in the CQE or may be specified at this time. Next, fuels to be used in the system level evaluation must be selected. The Select Fuel subapplication will assist the user in selecting the appropriate fuels by providing access to the fuel database through the Fuel Supply Expert and by applying selection criteria. If a transportation network does not exist, the user will be requested to develop a network (transportation, blending, cleaning, etc.) which will be attached to the Fuel Source to make up a Fuel. Next, the user will use the Create System Scenario subapplication to establish a specific set of fuel and plant/unit combinations that she/he wishes to evaluate. The user will have the option of developing several unique scenarios or may elect to evaluate a single scenario. After the scenario(s) have been defined, the program will automatically evaluates performance and costs impacts for each fuel and plant/unit combination defined within the utility system by each scenario. Finally, the user will be able to review each system scenario that is created by the Create System Scenario subapplication via the System Economic Results IOU with assistance from the Economic Results Expert. If after reviewing results additional scenarios are needed, the user can easily return to the Create System Scenario subapplication and repeat the process.
System-Level Fuel Evaluator

Economic Criteria → Define Utility System → Select Plant

Select Fuels to be Evaluated → Create System Scenario

Establish Expected Generation/Demand → Evaluate Unit/Equipment Performance

Plant Performance → Unit Economics → Plant Level Economics

Evaluate System Scenario → System Economic Results IOU

sensitivity

Economic Results Expert
ENVIRONMENTAL STRATEGIC PLANNER

APPLICATIONS

DESCRIPTION: Based on the Acid Rain Advisor (ARA), this application provides utilities with the capability to evaluate costs and risks, as well as with provisions to consider market conditions, load demand forecasts, and system expansion plans.

INTENDED USE: Environmental Department, System Planning Department, Fuel Purchasing Department

CQE NEEDS MET: Provide better data for General Planning bridge to Engineering, provide a visual strategic planning tool, bridge to existing fuel planning and comparison tools, evaluate scenarios in terms of cost and emissions of SO₂ and NOx (subsets: sensitivities, allowances for SO₂, NOx), credit due to SO₂ allowances (selling), estimate total fuel related costs, consider emissions of SO₂ and NOx, provide communication tool (need for new fuel, plant betterment, load recovery and NOx equipment), include CQIS and user defined data base, and assist user in identifying new sources of fuel.

SUBAPPLICATIONS USED: Determine Baseline Allowances, Establish Allowance Market, Select Plant, Establish Expected Generation/Demand, Create System Scenario, Evaluate System Scenario, Economic Results IOU, Economic Results Expert

LOGICAL FLOW DESCRIPTION: The user will first define the utility system to be considered by selecting the plants and units in the utility system and by specifying system-level economic information. Plants and units may be selected from plants and units that currently reside in the CQE or may be specified at this time. After the plants and units have been selected, the user will be lead through a series of steps to establish expected generation/demand curves, determine baseline allowances, and establish the allowance market. Next, compliance options and economic criteria will be established for each unit. Allowances and the allowance market will be utility specific and will have to be defined by someone within the utility. The user will be able to evaluate and review the system scenario that is created via the System Economic Results IOU with assistance from the Economic Results Expert.
Environmental Strategic Planner

Economic Criteria ─────────── Define Utility System ─────────── Select Plant

Establish Expected Generation/Demand ─ 1 2 3 ─ Determine Baseline Allowances ─ Establish Allowance Market ─ Establish Unit Compliance Options/Economic Criteria ─ 1 2 3 ─ Create System Scenario ─ 1 2 3 ─ Evaluate System Scenario ─ 1 2 3 ─ System Economic Results IOU ─ 1 2 3 ─ Economic Results Expert

sensitivity
FUEL PURCHASE MANAGER

DESCRIPTION: This application focuses on day-to-day management/reporting of coal purchase decisions. It includes provisions to construct historical coal quality/cost data as a function of coals.

INTENDED USE: Fuel Purchase Manager, Plant Coal Receipt Personnel

CQE NEEDS MET: Document fuel procurement decisions, document what has been bought and where, the quality of what was bought, provide communication tool (need for new fuel, plant betterment, load recovery and NOx equipment), assist in establishing supplier reputation and reliability, include CQIS and user defined data base, and assist user in identifying new sources of fuel.

SUBAPPLICATIONS USED: Select Plant, Fuel Selection, Record Coal Purchases, Record Coal Received, Review Coal Purchases, Review Coal Received

OBJECTS USED: Plant, Unit, Fuel Supply Expert, Fuel Source, Record Coal, Review Coal

LOGICAL FLOW DESCRIPTION: The user will first select the plant for which the Fuel Purchase Manager is to record or review fuel purchases or fuel shipments. If a purchase or shipment is to be recorded, the user will be led through a series of steps to record (and store for later retrieval) the information pertinent to the purchase or shipment. If a user wishes to review purchases and/or shipments, he/she may review any parameters individually for a purchase or shipment or may compare parameters individually for a shipment and its corresponding purchase. Parameters that may be stored/reviewed will include supplier, cost information and trends, quality information and trends, quantity information and trends, and composite analysis.
**Fuel Purchase Manager**

1. **Select Plant**
   - **Record**
     - **Record Coal Purchases**
       - **Store/Retrieve Supplier, Costs, Quality, Quantity**
       - **Record Coal Received**
   - **Review**
     - **Review Coal Purchases**
     - **Suppliers**
       - **Cost Information & Trends**
       - **Quality Information & Trends**
       - **Quantity Information & Trends** *
       - **Composite Analysis**
       - **Purchased vs. received**
     - **Review Coal Received**

* Quantity by CQ (HHV, Sulfur, Ash, Moisture)
COAL BID EVALUATOR

**DESCRIPTION:** This application streamlines the process for entering and evaluating a large number of coals in a short timeframe. It includes provisions for historical performance, special handling needs, and price comparisons of alternative coals.

**INTENDED USE:** Fuel Purchasing Department, Coal Company, Engineering Department, Plant Engineering/Personnel

**CQE NEEDS MET:** Document fuel procurement decisions, consider/include handleability factor, evaluate alternative fuel sources by cost and/or benefit, break-even analysis, provide communication tool (need for new fuel, plant betterment, load recovery and NOx equipment), include CQIS and user defined data base and assist user in identifying new sources of fuel.

**SUBAPPLICATIONS USED:** Select Plant, Select Fuels, Establish Unit/Equipment Performance, Plant Performance, Unit Economics, Plant Level Economics, Economics Results IOU, Economics Results Expert


**LOGICAL FLOW DESCRIPTION:** The user will first select the plant for which a coal bid shall be evaluated. Next, the Select Fuel subapplication will assist the user in
expediting the selection of fuels to be evaluated. The user may select a fuel source list or bidder list that already exists or proceed through a streamlined process of entering fuel quality data. After the selection of fuels, further assistance is provided to assure that the fuel quality parameters are complete and that each fuel falls within the fuel specification for the plant. Next the fuels will be screened for cost, allowing the user to choose a smaller list of fuels to be evaluated for performance and economics. After a final fuels list has been designated, CQE will evaluate equipment, unit, and plant performance and unit and plant economics. Next, the Plant and Unit Economic Results IOUs with assistance from the Economic Results Expert will present the user with economic aspects of each fuel. Finally, the user may request a reiteration of the evaluation process or complete the evaluation by requesting a ranked bidders list showing key performance issues and generation/breakeven fuel costs.
COAL CONTRACTS ASSISTANT

DESCRIPTION: This application assists in developing coal contract provisions, including coal contract costs/adders for deviations in coal quality parameters and historical performance.

INTENDED USE: Fuel Purchase Department, Coal Company, Engineering Department

CQE NEEDS MET: Assist in finding coal sources, price contract adjustments, assist in coal contract negotiations, assist in defining worth of contract provisions, provide communication tool (need for new fuel, plant betterment, load recovery and NOx equipment), include CQIS and user defined data base and assist user in identifying new coal sources.

SUBAPPLICATIONS USED: Select Plant, Select Fuel, Evaluate Unit/Equipment Performance, Plant Performance, Unit Economics, Plant Level Economics, Perform Fuel Quality Sensitivity, Fuel Purchase Manager


LOGICAL FLOW DESCRIPTION: The user will first select a plant, using the Select Plant subapplication, that he/she would like to evaluate. The plant (and units) can be selected from plants/units that have been developed before or can be specified at this time. After the plants/units have been selected, the user will select the coals that are to
be evaluated using the Select Fuel subapplication. The Select Fuel subapplication will assist the user in selecting the appropriate fuels by providing access to the fuel database through the Fuel Supply Expert and by applying certain selection criteria. If a transportation network does not exist, the user will also develop a network (transportation, blending, cleaning, etc.) which will be attached to the Fuel Source to make up a Fuel. After the plant and fuels have been selected, the user will define specific contract parameters such as higher heating value, ash, moisture, sulfur, sodium content, and hardgrove grindability or other parameters from the proximate, ultimate, or ash analyses. CQE will then evaluate the level of performance and economics for each plant/fuel combination based on the selected contract parameters. Next, the fuel quality will be compared to the fuel specification. If the fuel quality is within the specification, CQE will generate cost vs. variation in contract parameter graphs. If the fuel quality is not within the specification, CQE will alert the user of other considerations and warnings. At this point, the user may decide to adjust the specification or continue to the generation of cost vs. variation in contract parameter graphs. Next, CQE will provide premium/penalty cost data on the contract parameter and historical supplier performance/reliability information as recorded by the Fuel Purchase Manager. This information can be used by the user to establish specific contract provisions for each parameter of interest. Finally, the user can document the premium/penalty cost adjustment that was established by generating a coal quality cost adjustment report.
COAL CLEANING EXPERT

APPLICATIONS

DESCRIPTION: This application focuses on establishing the feasibility of cleaning, determining appropriate cleaning process design, and predicting associated capital costs.

INTENDED USE: Fuel Purchasing Department, Coal Company, Coal Brokers, Utility Engineering Department

CQE NEEDS MET: Assist in evaluating feasibility of cleaning processes, assist in quantifying benefits of cleaned coals, provide communication tool (need for new fuel, plant betterment, load recovery and NOx equipment), include CQIS and user defined database and assist user in identifying new sources of fuel.

SUBAPPLICATIONS USED: Select Fuel, Determine Feasibility of Cleaning, Determine Appropriate Cleaning Process Design


LOGICAL FLOW DESCRIPTION: The user may start either by selecting the fuel to be cleaned or by selecting an existing cleaning facility to be modified. If the user selects a cleaning facility first, the application drops directly into the design phase after the facility is selected. If the user chooses to select a fuel to be cleaned first, the Select Fuel subapplication assists the user in determining the fuel that is to be cleaned. Next, the user must specify the target coal quality parameters, the target coal quality values, and the required quantity of coal. With the targets specified, the Cleaning Feasibility Analyst will determine the feasibility of cleaning the coal. If the feasibility of cleaning is reasonable, CQE will begin the design phase by determining an appropriate cleaning process design. Next a detailed design report may be generated and reviewed by
engineering. If the design is not accepted, the design phase is reiterated to modify the design. Upon acceptance of the design, the Cleaning Plant Designer assists in predicting capital and operating costs for the cleaning facility. When finished, the cleaning facility data can be stored for future reference by other applications.
COAL SPECIFICATION ANALYST

DESCRIPTION: This application helps a utility establish appropriate specification limits by considering total fuel-related costs as a function of coal quality ranges, specification limits, and price/availability of coals as a function of defined specifications.

INTENDED USE: Fuel Purchasing Department, Utility Engineering Department, Plant Engineering/Personnel, Coal Company

CQE NEEDS MET: Assist in defining appropriate coal sources, evaluate existing specs and assist in defining coal contract specs (analysis, implementation and optimization), provide communication tool (need for new fuel, plant betterment, load recovery and NOx equipment), include CQIS and user defined data base, and assist user in identifying new fuel markets.

SUBAPPLICATIONS USED: Select Plant, Evaluate Unit/Equipment Performance, Plant Performance, Unit Economics, Plant Level Economics, Perform Fuel Quality Sensitivity, Evaluate Coal Availability/Pricing


LOGICAL FLOW DESCRIPTION: The user will first specify the plants and units to be considered. Plants and units may be selected from plants and units that currently reside in the CQE or may be specified at this time. CQE will then determine if a coal
specification exists. If the specification exists, CQE will begin the coal specification analysis. If the specification does not exist, the user will be requested to identify the design coal or to select coals with acceptable prior burn knowledge. These coals will be used to establish baseline performance and equipment design. From these steps, CQE will begin the coal specification analysis by identifying the coal specification quality and checking the completeness of the coal specification. Next, the user must define the specification criteria that is to be used in the analysis. CQE will then evaluate each level of performance and economics for the plant based on the selected specification parameters and will generate cost vs. variation graphs for each spec parameter. Based on this information and performance limitations, a preliminary specification will be developed. To ensure the spec is reasonable and acceptable, the preliminary specification coal should encapsulate additional issues such as availability/pricing, previous plant experience, and prior test burn experience. Availability of low priced coal may alone alter specification limits, depending on equipment design and generation demand. After these issues are considered, the user may approve the specification or may request reiteration of the analysis. Approval of the specification will update coal quality specification limits or ranges which are needed by other applications to establish buying guidelines.
Coal Specification Analyst

Select Plant

Identify Design Coal

Identify Spec. Coal Quality

Does Not Exist

Determines if there is an Existing Spec.

Select Coals with Acceptable Prior Burn Knowledge

Fuel Supply Expert

Check Spec. Coal for Completeness


Evaluate Selected Spec. Parameters

Generate Cost versus Variation in Spec. Parameters

Develop Preliminary Spec.

Evaluate Coal Availability/ Pricing

Solicit Plant Experience

Solicit Prior Test Burn Experience

Approve Spec.

Evaluate Unit/ Equipment Performance

Plant Performance

Unit Economics

Plant Level Economics

Perform Fuel Quality Sensitivity

* Spec. Criteria may include Derate Limits, availability, heat rate, differential cost, etc.
ENVIRONMENTAL EXPERT

APPLICATIONS

DESCRIPTION: This application focuses on compliance issues by troubleshooting (or evaluating) potential corrective action for ESPs, FGD systems, and boilers on a unit level (or by system via Environmental Strategic Planner). Also provides a means of recording/tracking emission levels and trending as a function of load, coal, unit operating characteristics, and time.

INTENDED USE: Environmental Engineers, Environmental Managers

CQE NEEDS MET: Consider and project emissions of CO₂, consider emissions of SO₂ and NOx, evaluate performance emissions, provide communication tool (need for new fuel, plant betterment, load recovery and NOx equipment), provide engineering analysis, include CQIS and user defined data base, and assist user in identifying new sources of fuel.

SUBAPPLICATIONS USED: Environmental Strategic Planner, Select Plant, Select Fuel, Evaluate Unit/Equipment Performance, Plant Performance, Define/Edit Plant Configuration/Characteristics, Define/Edit Unit Configuration/Characteristics


LOGICAL FLOW DESCRIPTION: The user will first specify the plants and units to be considered. Plants and units may be selected from plants and units that currently

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reside in the CQE, may be specified at this time, or may have been specified during a prior Environmental Strategic Planner application. Next, the user determines whether to record/review emission levels or to begin an emissions performance analysis. If the user chooses to record/review emission levels, he/she may record emission data, review emission data, or evaluate emission level trading. Emission data may be recorded as a function of load, fuel, time, and operating characteristics, as excursion events, or possibly as continuous emissions monitoring (CEM) data.

If the user chooses to begin an emissions performance analysis, he/she must start by identifying fuels to analyze with assistance from the Select Fuels subapplication. If emission limits cannot be retrieved from plant/unit data, the user is asked to establish emission limits for the plant/unit to be analyzed. CQE will then evaluate performance to identify limiting systems from an emission standpoint. If some limiting systems are present, equipment experts are queried for possible corrective actions. Corrective actions may include operational changes as well as equipment modifications. If some corrective actions are identified, appropriate operational modifications are performed and the unit/equipment performance is reevaluated. If operational changes do not correct the situation alone, the user can suggest specific equipment modifications or equipment design changes that will improve equipment removal efficiencies. This loop is iterated until no limiting systems are identified or until no corrective actions are known by the equipment experts or the user. As a final step, the user is provided with a list of potential performance improvements and/or corrective actions.
Environmental Expert

Select Plant/Unit to Analyze

Record/Review Emission Levels

Emission Level Trading

Record Emission Data as Function of load, fuel, time and operating char.

Review Emission Data

Select Fuel

CEM Data Record/Reduction (Future)

Identify Fuels to Analyze

Establish Emission Limits

Establish Plant/Unit/Equipment Performance

Identify Limiting Systems From Emission Stand Point

Plant Performance

Corrective Actions (Operational changes, Equip. mod. etc.)

Identify Potential Performance Improvements

Modify Equipment/Operations

Report on Potential Performance Improvements and/or Corrective Actions

Boiler Expert

ESP Expert

FGD Expert
**DESCRIPTION:** This application emphasizes the "engineering" side of CQE by providing in-depth analysis on the impacts of operational parameters on plant and unit performance and assists in identifying possible advantage/disadvantages of viable retrofit options.

**INTENDED USE:** Plant Engineering, Utility Engineering Department, Consulting Engineering Firms

**CQE NEEDS MET:** Consider/include handleability factor, assess ash pond/landfill capacity and economics, consider emissions of SO₂ and NOx, NERC-GADS data interface, evaluate equipment modifications, provide communication tool (need for new fuel, plant betterment, load recovery and NOx equipment), provide engineering analysis, provide advice for test burn, include CQIS and user defined data base, and assist user in identifying new fuel markets.

**SUBAPPLICATIONS USED:** Select Plant, Select Fuel, Establish Expected Generation/Demand, Evaluate Unit/Equipment Performance, Performance Results IOU, Performance Results Expert, Unit Economics, Economic Results IOU, Economic Results Expert, Plant Level Economics, Define/Edit Plant Configuration/Characteristics, Define/Edit Unit Configuration/Characteristics, Test Burn Planning/Procedures

Logical Flow Description: The user will first specify the plants and units to be considered. Plants and units may be selected from plants and units that currently reside in the CQE or may be specified at this time. Next, fuels to be used in the evaluation must be selected. The Select Fuel subapplication will assist the user in selecting the appropriate fuels by providing access to the fuel data base through the Fuel Supply Expert and by applying selection criteria. The user can also develop a network (transportation, blending, cleaning, etc.) which can be attached to the Fuel Source to make up a Fuel. After the plants, units, and fuels have been selected, the user modify equipment data or evaluate appropriate retrofit options for each unit selected. If desired, operational parameters can also be adjusted, as appropriate. The user will then be asked to establish expected generation/demand curves or use curves that already exist within CQE. CQE will then evaluate unit/equipment performance in preparation for presenting the user with unit performance and economic results. Unit performance will be presented by the Performance Results IOU with assistance from the Performance Results Expert. Unit economics will be presented by the Economic Results IOU with assistance from the Economic Results Expert. The user can also access the Test Burn Planning/Procedures subapplication to get more detailed information on suggested/recommended test burns.

CQE will evaluate plant performance and present the results through the Performance Results IOU with assistance from the Performance Results Expert. Then CQE will evaluate plant economics and present the results through the Economic Results IOU with assistance from the Economic Results Expert. Finally, the user may quit or reiterate the application.
Plant Engineer

Retrofit Cost

Change Appropriate Equipment Design

Select Plant/Unit

Select Fuels

Modify/Retrofit Equipment

Modify Operational Parameters

Establish Expected Generation/Demand

Evaluate Unit/Equipment Performance

Unit Performance Results IOU

Unit Economics Results IOU

Plant Performance

Plant Performance Results IOU

Plant Level Economics

Plant Economic Results IOU

Test Burn Planning/Procedures

Performance Results Expert

Economic Results Expert
CAPITAL VS. O&M TRADEOFF ANALYST

APPLICATIONS

DESCRIPTION: This application considers the issues of capital retrofit expenditure vs. O&M by identification of potential retrofit needs, costing estimate, O&M estimate (with/without), and remaining life/payback economic analysis.

CQE NEEDS MET: Equipment modification capital costs vs. fuel reliability, evaluate capital vs. fuel cost for modifications, evaluate payback O&M cost vs. capital costs, evaluate equipment modifications, provide communication tool (need for new fuel, plant betterment, load recovery and NOx equipment), include CQIS and user defined data base, and assist user in identifying new sources of fuel.

SUBAPPLICATIONS USED: Select Plant, Select Fuel, Establish Expected Generation/Demand, Evaluate Unit/Equipment Performance, Unit Economics, Plant Performance, Plant Level Economics, Define/Edit Plant Configuration/Characteristics, Define/Edit Unit Configuration/Characteristics


LOGICAL FLOW DESCRIPTION: The user will first specify the plants and units to be considered. Plants and units may be selected from plants and units that currently reside in the CQE or may be specified at this time. Next, fuels to be used in the
evaluation must be selected. The Select Fuel subapplication will assist the user in selecting the appropriate fuels by providing access to the fuel database through the Fuel Supply Expert and by applying selection criteria. The user can also develop a network (transportation, blending, cleaning, etc.) which will be attached to the Fuel Source to make up a Fuel. After the plants, units, and fuels have been selected, the user will establish expected generation/demand curves (or selects from already established curves) and will be assisted in establishing the baseline performance and costs. Next the CQE will determine possible retrofit needs depending on the units capabilities and the objectives/goals that are trying to be met. That is, improved heat rate, better availability, elimination of equipment limitations, meeting design or target operating conditions, etc. Depending on the goal/objectives, CQE will suggest making appropriate equipment design changes. Next, the Retrofit Estimator will estimate capital costs for each suggested retrofit. Retrofit costs will be estimated for a set number of unique retrofit options. Capital costs associated with retrofit options for which CQE does not consider can be factored into the analysis by a direct input from the user. The utility-specific retrofit cost estimator is an object which the user can develop for the utility and incorporate into CQE.

As a final step in this application, CQE determines performance and costs for retrofits, performs a payback analysis, and generate a retrofit analysis report. Finally, the user will be allowed to review the retrofit analysis report and determine if any iteration of the process is necessary.
Capital vs. O&M Tradeoff Analyst

Evaluate Unit/Equipment Performance

Unit Economics

Plant Performance

Plant Level Economics

Select Plant/Unit

Select Fuels

Establish Expected Generation/Demand

Establish Baseline Performance/Costs

Determine Possible Retrofit Needs

Make Appropriate Equipment Design Changes

Estimate Capital Costs for Each Retrofit

Determine Performance/Costs for Retrofit

Perform Payback Analysis

Generate Retrofit Analysis Report (Capital Costs, Differential Performance and Operating Costs, Payback Period)

Check Emissions vs.: Heat Rate, Availability, Derate, and Operating Targets

Input by User

Retrofit Estimator

Equipment Design Modules

Utility Specific Retrofit Cost Estimator
THE

COAL

QUALITY

EXPERT

TOOLS
DESCRIPTION: This tool will assist the user in constructing complete CQE models. It will provide "guided" assistance given type of data available and "screen" as much as possible.

CQE NEEDS MET: Facilitates data entry and model set up, assists user in identifying essential or important data, provides user with ability to store system, plant, unit, economic, maintenance/availability, and coal data which can easily be retrieved and accessed.

SUBAPPLICATIONS USED: Select Plant, Define/Edit Plant Configuration/Characteristics, Define/Edit Unit Configuration/Characteristics, Select Unit, Define/Edit Equipment Design/Calibration Data, Edit M/A Data, Define/Edit Economic Data


LOGICAL FLOW DESCRIPTION: The user will first determine whether he/she wants to define/edit plant configuration characteristics, unit configuration characteristics, maintenance/availability data, or economics. If he/she chooses plant configuration characteristics, CQE will assist the user through the steps of defining or editing plant data. If he/she chooses unit configuration characteristics, CQE will assist the user through the steps of defining or editing unit data. Unit data also includes equipment design and calibration data as well as design coal data. If he/she chooses maintenance/availability data, CQE will issue a warning that plant and unit data should
be entered first and then assist the user through the steps of inputing maintenance/availability data. If he/she chooses economics, CQE will request the level of economics the user wishes to work with. Then, CQE will load the closest level of economics that exists within CQE for the system, plant, or unit. If no economics exist, the user will be requested to specify system economic data and then will be allowed to edit the economics data for the level selected. The assistance provided during each process of entering data will be sensitive to user profiles and will include features such as help, input checks, and screen selection.
CQE VALIDATION EXPERT

DESCRIPTION: This expert evaluates the consistency/accuracy of CQE predictions to historical results and suggests corrective action (and reasons) to improve model accuracy.

CQE NEEDS MET: Ensure data input is consistent, ensure CQE prediction match experimental data, build confidence in CQE predictions.


LOGICAL FLOW DESCRIPTION: The user will first specify the plants/units to be validated. Plants and units may be selected from plants and units that have been developed and currently reside in the CQE. After the plants/units have been selected, the user will select the coal(s) that are to be used to validate CQE predictions. The Select Fuel subapplication will assist the user in selecting the appropriate fuels by providing
access to the fuel data base through the Fuel Supply Expert and by applying certain selection criteria. CQE will then determine if unit performance data exists for the plant/unit selected. If performance data is not present, performance data will be established by executing certain subapplications within the Plant-Level Fuel Evaluator. Once performance data is available, CQE will analyze input data and predictions for consistency. Next, CQE will determine if historical performance data exists. If historical performance data does not exist CQE will ask appropriate question to assist validation and will analyze feedback vs. inputs and predictions. Once historical performance data is known, CQE will analyze and compare inputs and predictions to existing data. Next, CQE will identify and generate a list of discrepancies and suggest appropriate input changes, if any. Finally, the user will be allowed to change inputs and reiterate the validation process. if necessary.
COAL QUALITY IMPACT MODEL (CQIM™)

**DESCRIPTION:** This tool allows the user direct access to the CQIM program. In this mode, CQIM will operate as a stand alone program with its full capabilities and functionality available to the user.

**CQE NEEDS MET:** Allow CQE users to perform analyses on already familiar computer programs.

**SUBAPPLICATIONS USED:** Select Plant, Select Fuels, CQIM Interface


**LOGICAL FLOW DESCRIPTION:** The user will be allowed to build projects as in the stand alone version of CQIM. Models will be built using screens with familiar inputs. Output will consist of the existing IOUs and the same hardcopy output format.
Coal Quality Impact Model Diagram
FIRESIDE ADVISOR

DESCRIPTION: This tool allows the user direct access to the Fireside Advisor program. In this mode, the Fireside Advisor will operate as a stand alone program with its full capabilities and functionality available to the user.

CQE NEEDS MET: Allow CQE users to perform analyses on particular topics of interest.

SUBAPPLICATIONS USED: Select Plant, Select Fuels, FSA Interface


LOGICAL FLOW DESCRIPTION: The user will be queried to determine the type of performance problem that he/she wishes to address with a test burn. After narrowing the problem, the fireside advisor will provide knowledge on what parameters should be tested, suggest test to be performed, and how to reduce/document test results. This process might also be initiated due to a potential performance problem identified during a CQE application.
"WHAT-IF" EVALUATOR

DESCRIPTION: This tool specializes in developing calculational procedures to evaluate variations in parameters of interest to the user by employing knowledge of data sources, calculational requirements, specialized tools (e.g. IOU), and other applications.

CQE NEEDS MET: Provide sensitivity capability to identify areas of risk or parameters that exhibit great impact on performance/costs. Will assist General Planning and Engineering assess comfort bands and viability of alternative plans.

SUBAPPLICATIONS USED: Select Plant, Select Fuel, Economic Results IOU, Economic Results Expert


LOGICAL FLOW DESCRIPTION: The user will first determine what type of "what if" analysis is to be considered. The type of analysis may either be selected from a list of topics or existing applications or defined through a series of questions asked by CQE. After the analysis type has been determined, identify parameters, the scenario, the plants, and the fuels to be considered in the analysis. CQE will then recalculate performance and costs. Finally, the results will be presented in the Economic Results IOU with assistance from the Economic Results Expert.
"What-If" Evaluator

Select from list

Select Area of Interest*

*Select from a list of topics or existing applications

What type of "What If" Analysis is to be Considered

Select via Questions/Answers

Ask User Appropriate Questions to Define Type of "What if" Analysis

Identify Parameters

Select a Scenario

Select Plant

Select Fuel

Recalculate Performance and Costs

Economic Results EXPERT

Economic Results IOU

System

Plant

Unit
DESCRIPTION: This tool centralizes all program security as well as user and utility "preferences" to provide an appropriate level of data sharing, an appropriate level of data integrity, and "personalization" of the user interface.

CQE NEEDS MET: Provides overall program security, ensures data integrity, restricts data entry access, establishes user familiarity with program.

SUBAPPLICATIONS USED: User Maintenance

BASE OBJECTS USED: Default Discipline Profiles, Add/Edit/Delete Users, Database/Network Manager

LOGICAL FLOW DESCRIPTION: CQE will first check security administrator access privilege. The administrator will determine if he/she wants to establish default discipline profiles, perform user maintenance, or manage the database/network. Default discipline profiles will be adjustable by the administrator (only) to meet the needs of the users. User maintenance will allow the administrator to add/edit user names and select/edit a users profile. Database/network management consists of database backup, database archive retrieval, or network maintenance.
Security/System Administrator

Check Security Administrator Access Privilege

Establish Default Discipline Profiles

User Maintenance

Database/Network Manager

Add User

Edit User

Add/Edit Username and Password

Select Default User Profile

Modify User Profile

- Profiles include screen and application access.

Database Backup or Archive Retrieval

Network Maintenance
DATE
FILMED
9/9/93
END