
# TransAlta Centralia

# Boiler Emissions Modeling Study

Project Number: 146702.0030

## Final Report

## Sep 2007

BLACK & VEATCH

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## Introduction

TransAlta retained Black & Veatch to determine the expected emissions for Centralia Unit 1 and Unit 2 plant following boiler optimization projects recommended by ALSTOM. The proposed boiler projects addressed by this study include:

- Steam reheater replacement. The reheater will be replaced with a design providing increased transverse spacing and platenized surfaces to minimize ash deposition on tube surfaces and maximize sootblower cleaning effectiveness on the tube assembly surface areas.
- Low Temperature Superheater (LTSH) Replacement. The LTSH will be replaced by a design with longer tubes, which will improve heat transfer and result in a lower flue gas exit temperature. Erosion shields will be installed on the LTSH tubing in areas where sootblowers are located in order to provide sootblower erosion protection.
- Economizer Replacement. The economizer replacement in Unit 1 will be replaced for maintenance. The Unit 2 economizer will not be replaced.
- Unit 1 and Unit 2 will both receive an additional economizer bank of bare tubing in the hopper area below the existing economizer. The additional lower economizer bank increases the heat transfer surface area and will further reduce the flue gas exit temperature. Erosion shields will be installed on the new upper economizer and lower economizers where required to provide sootblower erosion protection.

This analysis makes use of EPRI's (Electric Power Research Institute) Vista software, developed and maintained by Black & Veatch. The scope of the study includes the following:

- Calibrate Vista model to reflect unit performance following implementation of projects. Performance results include emissions for $NO_x$, CO, and $SO_2$, boiler efficiency, and expected heat rates.
- Determine the expected emissions at max potential sustainable load and for annual operation based on the production plan provided by TransAlta. B&V has also provided estimates for the annual emissions assuming 100 capacity factor or "max potential sustainable load" conditions.
- Additional information such as fuel consumption, boiler efficiency, heat rates, and other consumables are also provided.
- The following coals were evaluated in this study: Buckskin, Caballo 8500, Cordero Rojo, Jacobs Ranch Upper Wyodak, Rawhide, Special K Fuel, Belle Ayr and Eagle Butte.

## Model Re-Calibration and Assumptions

The existing Vista model was recalibrated to reflect the unit performance (post-projects) provided by ALSTOM, with the assumption that both Unit 1 and Unit 2 would have the same boiler performance. Table 1 shows the main steam flow case and Table 2 shows the expected boiler performance for Buckskin coal for each main steam flow case.

| Table 1: Main Steam Flow Case (post-projects) by ALSTOM | | |
|---|---|---|
| Control Load | Klbm/hr | 2,944 |
| Starting Load | Klbm/hr | 3,744 |
| Sustainable Load | Klbm/hr | 4,800 |
| Max. Potential Sustainable Load | Klbm/hr | 5,230 |

**Table 2: Expected Boiler Performance (post-projects) by ALSTOM**

| | | | | | |
|---|---|---|---|---|---|
| Main Steam Flow | Klbm/hr | 5230 | 4800 | 3744 | 2944 |
| Fuel Burn Rate | lbm/hr | 838907 | 775144 | 614017 | 488492 |
| Boiler Efficiency | % | 84.36 | 84.59 | 85.14 | 85.54 |
| Boiler Exit Gas Flow Rate | lbm/hr | 7191278 | 6644693 | 5263476 | 4187448 |
| Air Heater Gas Out Temperature | °F | 312 | 302 | 277 | 259 |
| Excess Air | % | 20 | 20 | 20 | 20 |
| NOx | lbm/mmBtu | 0.222 | 0.196 | 0.175 | 0.152 |
| NOx | lbm/hr | 1,564 | 1,276 | 900 | 624 |
| CO | lbm/mmBtu | 0.083 | 0.062 | 0.041 | 0.041 |
| CO | lbm/hr | 585 | 404 | 211 | 168 |
| SO2 | lbm/mmBtu | 0.832 | 0.832 | 0.832 | 0.832 |
| SO2 | lbm/hr | 5,863 | 5,417 | 4,291 | 3,414 |

TransAlta noted that 5230 klbm/hr steam flow case is comparable to 715 Gross MW and 669 Net MW, and B&V estimated a net unit heat rate of 10,533 Btu/KWhr based on the fuel burn rate of 838907 lbm/hr provided by ALSTOM. The net unit heat rate is comparable to the 10,500 Btu/KWhr heat rate assumed in the Thermal Production Plan for TransAlta. Based on the information available, the Vista model is calibrated to the 5230 Klbm/hr steam flow load with an expected 669 Net MW. Below is a list of assumptions/estimates used for calibrating the model and Table 3 shows the differentials between Vista calibration results and the predicted unit performance Max Potential Sustainable Load provided by ALSTOM and TransAlta.

- The turbine cycle heat rate is calculated to be 8,314 Btu/KWh based on the boiler efficiency, net unit heat rate and expected net load.
- The split between fly ash and bottom ash is assumed to be 80/20.

**Table 3: Comparison between Vista Calibration Results and Expected Boiler Performance**

| Parameter | Unit | ALSTOM Max Potential Sustainable Load | Vista Calibration | % Difference |
|---|---|---|---|---|
| Gross Generation | MW | 715.00 | 715.00 | 0.00 |
| Net Generations | MW | 669.00 | 669.00 | 0.00 |
| Aux Power | MW | 46.00 | 46.00 | 0.00 |
| Net Unit Heat Rate | Btu/KWhr | 10,533 | 10,534 | 0.01 |
| Turbine Cycle Heat Rate | Btu/KWhr | 8,314 | 8,314 | 0.00 |
| Main Steam Load | Klbm/hr | 5,230 | 5,230 | 0.00 |
| Fuel Burn Rate | lbm/hr | 838907 | 838952 | 0.01 |
| Boiler Efficiency | % | 84.36 | 84.36 | 0.00 |
| Boiler Exit Gas Flow Rate | lbm/hr | 7191278 | 7141310 | -0.69 |
| Air Heater Gas Outlet Temperature | °F | 312 | 312 | 0.00 |
| Excess Air | % | 20 | 20 | 0.00 |
| NOx | lbm/mmBtu | 0.222 | 0.222 | 0.00 |
| NOx | lbm/hr | 1,564 | 1,564 | 0.00 |
| CO | lbm/mmBtu | 0.083 | 0.083 | 0.00 |
| CO | lbm/hr | 585 | 585 | 0.00 |
| SO2 | lbm/mmBtu | 0.832 | 0.832 | 0.00 |
| SO2 | lbm/hr | 5,863 | 5,864 | 0.01 |

TransAlta recommended using the design scrubber removal efficiency of 91 percent for low sulfur coal. For Jacobs Ranch Upper Wyodak coal with $SO_2$ loading of 2.0 lbm/mmBtu, the modeling assumes that the plant would operate the scrubber at higher removal efficiency of 95 percent to stay within the applicable emission limits. B&V assumed no fly ash is removed by the scrubber although there could be up to 10 percent in real operation depending on the scrubber design and operations.

## Coal Quality

The coal quality data to be used in this study is provided by TransAlta and Table 4 below shows the respective quality for each mine. The "Special K Fuel" is a blend of Spring Creek with 12 percent Kaolin and the coal quality data is based on averages of the plant samples collected in April 2007.

**Table 4: Coal Quality Data**

| | Units | Buckskin | Caballo 8500 | Cordero Rojo | Jacobs Ranch Upper Wyodak |
|---|---|---|---|---|---|
| **Proximate Analysis (As-Received Basis)** | | | | | |
| Higher Heating Value | Btu/lbm | 8400.00 | 8500.00 | 8456.00 | 8800.00 |
| Moisture | % | 29.95 | 29.90 | 29.61 | 26.45 |
| Volatile Matter | % | 30.25 | 31.40 | 30.71 | 32.50 |
| Fixed Carbon | % | 34.65 | 33.80 | 34.22 | 34.35 |
| Ash | % | 5.15 | 4.90 | 5.46 | 6.70 |
| FC/VM Ratio | | 1.15 | 1.08 | 1.11 | 1.06 |
| **Ultimate Analysis (As-Received Basis)** | | | | | |
| Carbon | % | 49.00 | 49.91 | 49.16 | 51.26 |
| Hydrogen | % | 3.24 | 3.56 | 3.43 | 3.89 |
| Nitrogen | % | 0.63 | 0.71 | 0.71 | 0.80 |
| Sulfur | % | 0.35 | 0.36 | 0.32 | 0.88 |
| Ash | % | 5.15 | 4.90 | 5.46 | 6.70 |
| Moisture | % | 29.95 | 29.90 | 29.61 | 26.45 |
| Chlorine | % | 0.00 | 0.00 | 0.00 | 0.01 |
| Oxygen | % | 11.68 | 10.66 | 11.31 | 10.01 |
| **Ash Analysis** | | | | | |
| Silica ($SiO_2$) | % | 31.27 | 32.10 | 35.01 | 27.74 |
| Alumina ($Al_2O_3$) | % | 13.15 | 16.80 | 18.03 | 15.90 |
| Iron Oxide ($Fe_2O_3$) | % | 7.08 | 5.50 | 4.92 | 9.28 |
| Titania ($TiO_2$) | % | 1.11 | 1.40 | 1.35 | 1.13 |
| Phosphorous ($P_2O_5$) | % | 0.90 | 0.90 | 1.00 | 0.89 |
| Lime (CaO) | % | 25.75 | 23.90 | 21.06 | 18.83 |
| Magnesia (MgO) | % | 5.86 | 4.50 | 3.98 | 3.35 |
| Sodium ($Na_2O$) | % | 1.70 | 1.70 | 1.28 | 1.19 |
| Potassium ($K_2O$) | % | 0.19 | 0.30 | 0.50 | 0.31 |
| Sulfur Trioxide ($SO_3$) | % | 10.98 | 11.80 | 11.45 | 17.85 |
| Undetermined | % | 2.01 | 1.10 | 1.42 | 3.53 |
| **Miscellaneous Properties** | | | | | |
| Initial Deformation Temperature | °F | 2207.00 | 2125.00 | 2098.00 | 2128.00 |
| Softening Temperature | °F | 2226.00 | 2135.00 | 2121.00 | 2170.00 |
| Hemispherical Temperature | °F | 2236.00 | 2145.00 | 2136.00 | 2263.00 |
| $SO_2$ Production | lbm/mmBtu | 0.83 | 0.85 | 0.76 | 2.00 |

| Table 4: Coal Quality Data (Continue) | | | | | |
|---|---|---|---|---|---|
| | **Units** | **Rawhide** | **Special K Fuel** | **Belle Ayr** | **Eagle Butte** |
| **Proximate Analysis (As-Received Basis)** | | | | | |
| Higher Heating Value | Btu/lbm | 8300.00 | 7907.00 | 8550.00 | 8400.00 |
| Moisture | % | 30.50 | 25.74 | 30.50 | 30.50 |
| Volatile Matter | % | 30.40 | 28.76 | 30.40 | 31.92 |
| Fixed Carbon | % | 34.20 | 32.46 | 34.20 | 32.93 |
| Ash | % | 4.90 | 13.04 | 4.90 | 4.65 |
| FC/VM Ratio | | 1.13 | 1.13 | 1.12 | 1.03 |
| **Ultimate Analysis (As-Received Basis)** | | | | | |
| Carbon | % | 48.58 | 45.82 | 50.01 | 49.17 |
| Hydrogen | % | 3.34 | 3.07 | 3.43 | 3.42 |
| Nitrogen | % | 0.63 | 0.56 | 0.67 | 0.67 |
| Sulfur | % | 0.37 | 0.28 | 0.26 | 0.38 |
| Ash | % | 4.90 | 13.04 | 4.90 | 4.65 |
| Moisture | % | 30.50 | 25.74 | 30.50 | 30.50 |
| Chlorine | % | 0.01 | 0.00 | 0.01 | 0.01 |
| Oxygen | % | 11.68 | 11.49 | 11.12 | 11.20 |
| **Ash Analysis** | | | | | |
| Silica ($SiO_2$) | % | 31.20 | 59.18 | 32.63 | 29.59 |
| Alumina ($Al_2O_3$) | % | 13.90 | 14.42 | 16.09 | 16.73 |
| Iron Oxide ($Fe_2O_3$) | % | 6.30 | 5.39 | 4.98 | 5.16 |
| Titania ($TiO_2$) | % | 1.10 | 0.81 | 1.41 | 1.21 |
| Phosphorous ($P_2O_5$) | % | 0.50 | 0.20 | 0.92 | 0.71 |
| Lime (CaO) | % | 24.30 | 7.52 | 26.09 | 24.51 |
| Magnesia (MgO) | % | 6.10 | 2.59 | 4.73 | 6.21 |
| Sodium ($Na_2O$) | % | 1.70 | 2.86 | 1.73 | 1.90 |
| Potassium ($K_2O$) | % | 0.20 | 2.10 | 0.27 | 0.29 |
| Sulfur Trioxide ($SO_3$) | % | 13.60 | 4.18 | 10.13 | 12.63 |
| Undetermined | % | 1.10 | 0.75 | 1.02 | 1.06 |
| **Miscellaneous Properties** | | | | | |
| Initial Deformation Temperature | °F | 2170.00 | 2143.00 | 2141.00 | 2209.00 |
| Softening Temperature | °F | 2180.00 | 2192.00 | 2148.00 | 2215.00 |
| Hemispherical Temperature | °F | 2230.00 | 2362.00 | 2215.00 | 2259.00 |
| $SO_2$ Production | lbm/mmBtu | 0.89 | 0.71 | 0.61 | 0.90 |

## Load Curve Assumptions for Annual Emission Analysis

Based on TransAlta's Thermal Production Plan from Year 2008 to 2025, TransAlta had requested B&V to estimate the annual emissions for the "maintenance" and "non-maintenance" year with highest generation (max potential sustainable load). Unit 1 boiler is scheduled on a three year boiler outage interval and Unit 2 is scheduled for a two year outage interval. Table 5 below shows the year, operating hours, outage hours, available hours for the "maintenance" and "non-maintenance" year selected for Unit 1 and Unit 2. Both Unit 1 and Unit 2 are assumed to be operating at 663 Net MW during the available hours. The annual emissions results in this study would reflect the "worst case" or highest projected emissions for Unit 1 and Unit 2.

**Table 5: Load Curve and Thermal Production Plan**

| | Units | Unit 1 (Maintenance Year) | Unit 1 (Non - Maintenance Year) | Unit 2 (Maintenance Year) | Unit 2 (Non - Maintenance Year) |
|---|---|---|---|---|---|
| Net Capacity | MW | 663.00 | 663.00 | 663.00 | 663.00 |
| Total Outage Hours | hr | 1361 | 602 | 1146 | 601 |
| Available Hours | hr | 7399 | 8182 | 7614 | 8159 |
| Total Hours in Year | hr | 8760 | 8784 | 8760 | 8760 |
| Equivalent Availability | % | 84.46 | 93.15 | 86.92 | 93.14 |

## Vista Predictions for Max Potential Sustainable Load Emissions

The Vista model which as initially calibrated to expected performance for Buckskin coal was used to evaluate the other alternate coals. Table 6 below shows the expected unit performance predicted by Vista for all the coal cases at the max potential sustainable load of 663 Net MW. Vista predictions are based on the coal quality from the mine specifications and plant samples. Actual coal quality received by the plant may vary from the coal quality used in the study and Vista result may not reflect the actual performance seen by the plant with off-spec quality.

**Table 6: Max Potential Sustainable Load Performance Summary Results (663 MW)**

| Description | Units | Buckskin | Caballo 8500 | Cordero Rojo | Jacobs Ranch Upper Wyodak | Rawhide | Special K Fuel | Belle Ayr | Eagle Butte |
|---|---|---|---|---|---|---|---|---|---|
| **Max Potential Sustainable Load Unit Operation** | | | | | | | | | |
| Gross Power | MW | 708.59 | 710.28 | 709.15 | 710.40 | 708.94 | 709.63 | 709.35 | 709.98 |
| Net Power | MW | 663.00 | 663.00 | 663.00 | 663.00 | 663.00 | 663.00 | 663.00 | 663.00 |
| Aux Power | MW | 45.59 | 47.28 | 46.15 | 47.40 | 45.94 | 46.63 | 46.35 | 46.98 |
| Net Unit Heat Rate | Btu/kWh | 10,542 | 10,673 | 10,611 | 10,639 | 10,634 | 10,564 | 10,611 | 10,656 |
| Coal Burn Rate | ton/hr | 416.02 | 415.94 | 415.68 | 400.49 | 424.41 | 442.60 | 411.10 | 420.16 |
| Coal Burn Rate | lbm/hr | 832,038 | 831,872 | 831,360 | 800,980 | 848,814 | 885,208 | 822,190 | 840,318 |
| Coal Burn Rate | mmBtu/hr | 6,989 | 7,071 | 7,030 | 7,049 | 7,045 | 6,999 | 7,030 | 7,059 |
| Boiler Efficiency | % | 84.36 | 83.44 | 83.76 | 83.70 | 83.58 | 84.36 | 83.80 | 83.52 |
| **Stack Emission** | | | | | | | | | |
| $SO_2$ Emissions | lbm/mmBtu | 0.075 | 0.076 | 0.068 | 0.100 | 0.080 | 0.064 | 0.055 | 0.081 |
| $SO_2$ Emissions | lbm/hr | 523 | 538 | 478 | 704 | 564 | 445 | 384 | 574 |
| $NO_x$ Emissions | lbm/mmBtu | 0.222 | 0.247 | 0.240 | 0.264 | 0.225 | 0.213 | 0.233 | 0.237 |
| $NO_x$ Emissions | lbm/hr | 1,552 | 1,743 | 1,690 | 1,859 | 1,584 | 1,488 | 1,637 | 1,675 |
| CO Emission | lbm/mmBtu | 0.083 | 0.087 | 0.085 | 0.088 | 0.086 | 0.076 | 0.086 | 0.083 |
| CO Emission | lbm/hr | 580 | 615 | 595 | 621 | 604 | 531 | 604 | 588 |

*$SO_2$*

The scrubber is predicted to be able to operate at 95 percent removal efficiency for Jacobs Ranch Upper Wyodak and at 91 percent removal efficiency for the other lower sulfur coals without any limitations. Jacobs Ranch Upper Wyodak has the highest $SO_2$ loading of 2.0 lbm/mmBtu with expected $SO_2$ emission of 0.10 lbm/mmBtu. The rest of the coals have $SO_2$ loading of between 0.7 to 0.9 lbm/mmBtu. Vista predicts $SO_2$ emissions of between 0.05 to 0.08 lbm/mmBtu with 91 percent scrubber efficiency.

*$NO_x$*

At max potential sustainable load conditions, Vista did not predict significant differences in furnace temperature across the coals that would result in significant change in thermal NOx production. The boiler stoichiometry also remains unchanged as Vista assumed an excess air of 20 percent across the coals. Thus, Black Thunder having the lowest nitrogen content is predicted to have lowest $NO_x$ emission of 0.205 lbm/mmBtu and Jacobs Ranch Upper Wyodak is predicted to have the highest NOx emission of 0.266 lbm/mmBtu due to its high nitrogen content.

*CO*

Besides the coal qualities, the CO emission is highly dependent on the stoichiometry at the burners and boilers, and changes in operation set point would greatly affect the CO emissions. The CO value which is predicted by Vista is applicable to full-load operation only, and is scaled by the excess air level, the burner zone primary stoichiometry, and by the level of unburned carbon produced by the unit. The burner zone primary stoichiomery and excess air level is held relatively constant across the coals, and the major driver would be the unburned carbon produced by the unit.

Antelope having the highest fixed carbon to volatile matter ratio and high gas velocity at the boiler, resulted in less complete burnout and highest CO emissions. Although Jacobs Ranch Upper Wyodak has a significantly lower fixed carbon to volatile ratio, the CO emissions is estimated to be slightly below Antelope mine due to high flue gas velocity which resulted in incomplete burnout. Jacobs Ranch Upper Wyodak having the lowest oxygen content requires more combustion air which resulted in higher flue gas flow.

Buckskin, Special K Fuel, and Rawhide has comparable fixed carbon to volatile matter ratio (1.15 for Buckskin and 1.13 for Special K Fuel and Rawhide). Vista predicted that Special K Fuel has a lower CO emission because it has lower gas velocity at the boiler resulting in better complete char combustion. Although Special K Fuel has lower oxygen content and requires a higher fuel burn rate, the amount of combustion air and flue gas produced is still less due to the coal stoichiometry. Note that Special K Fuel has a high amount of ash, which reduces the combustion air requirement and thus the resulting flue gas as well.

## Vista Predictions for Annual Emissions

For the annual "max potential sustainable load" conditions, the units are assumed to be operating at 100% capacity factor without any outages for the entire year. Hence, we assumed the same unit performance for both Unit 1 and Unit 2, the annual emissions for both units would be the same for the annual "max potential sustainable load" conditions. Table 7 shows the annual emissions assuming 100 percent capacity factor for normal year (8760 hours) and leap year (8784 hours).

Based on the available operation hours as shown in Table 5, the projected annual emissions are calculated for the "maintenance" and "non-maintenance" year. Table 8 and Table 9 show the projected annual emissions, net generation, and coal consumption for Unit 1 and Unit 2.

**Table 7: Projected Annual Emissions (100 Percent Capacity Factor)**

| Description | Units | Buckskin | Caballo 8500 | Cordero Rojo | Jacobs Ranch Upper Wyodak | Rawhide | Special K Fuel | Belle Ayr | Eagle Butte |
|---|---|---|---|---|---|---|---|---|---|
| **Normal Year** | | | | | | | | | |
| Total Hours in Year | hr | 8760 | 8760 | 8760 | 8760 | 8760 | 8760 | 8760 | 8760 |
| Operating Hours | hr | 8760 | 8760 | 8760 | 8760 | 8760 | 8760 | 8760 | 8760 |
| Annual Net Generation | GWh/yr | 5,808 | 5,808 | 5,808 | 5,808 | 5,808 | 5,808 | 5,808 | 5,808 |
| Annual Fuel Burn Rate | kton/yr | 3,644 | 3,644 | 3,641 | 3,508 | 3,718 | 3,877 | 3,601 | 3,681 |
| Annual SO2 Emitted | ton/yr | 2,292 | 2,357 | 2,094 | 3,083 | 2,472 | 1,949 | 1,683 | 2,514 |
| Annual NOx Emitted | ton/yr | 6,796 | 7,635 | 7,404 | 8,144 | 6,937 | 6,518 | 7,171 | 7,335 |
| Annual CO | ton/yr | 2,541 | 2,695 | 2,605 | 2,721 | 2,647 | 2,327 | 2,646 | 2,576 |
| **Leap Year** | | | | | | | | | |
| Total Hours in Year | hr | 8784 | 8784 | 8784 | 8784 | 8784 | 8784 | 8784 | 8784 |
| Operating Hours | hr | 8784 | 8784 | 8784 | 8784 | 8784 | 8784 | 8784 | 8784 |
| Annual Net Generation | GWh/yr | 5,824 | 5,824 | 5,824 | 5,824 | 5,824 | 5,824 | 5,824 | 5,824 |
| Annual Fuel Burn Rate | kton/yr | 3,654 | 3,654 | 3,651 | 3,518 | 3,728 | 3,888 | 3,611 | 3,691 |
| Annual SO2 Emitted | ton/yr | 2,299 | 2,364 | 2,100 | 3091 | 2,479 | 1,954 | 1,687 | 2,521 |
| Annual NOx Emitted | ton/yr | 6,815 | 7,656 | 7,424 | 8,167 | 6,956 | 6,536 | 7,191 | 7,355 |
| Annual CO Emitted | ton/yr | 2,548 | 2,702 | 2,612 | 2,728 | 2,654 | 2,333 | 2,653 | 2,583 |

**Table 8: Projected Annual Emissions for Unit 1**

| Description | Units | Buckskin | Caballo 8500 | Cordero Rojo | Jacobs Ranch Upper Wyodak | Rawhide | Special K Fuel | Belle Ayr | Eagle Butte |
|---|---|---|---|---|---|---|---|---|---|
| **Maintenance Year** | | | | | | | | | |
| Total Hours in Year | hr | 8760 | 8760 | 8760 | 8760 | 8760 | 8760 | 8760 | 8760 |
| Operating Hours | hr | 7399 | 7399 | 7399 | 7399 | 7399 | 7399 | 7399 | 7399 |
| Annual Net Generation | GWh/yr | 4,906 | 4,906 | 4,906 | 4,906 | 4,906 | 4,906 | 4,906 | 4,906 |
| Annual Fuel Burn Rate | kton/yr | 3,078 | 3,078 | 3,076 | 2,963 | 3,140 | 3,275 | 3,042 | 3,109 |
| Annual SO2 Emitted | ton/yr | 1,936 | 1,991 | 1,769 | 2604 | 2,088 | 1,646 | 1,421 | 2,123 |
| Annual NOx Emitted | ton/yr | 5,740 | 6,449 | 6,253 | 6,879 | 5,860 | 5,506 | 6,057 | 6,195 |
| Annual CO | ton/yr | 2,146 | 2,276 | 2,200 | 2,298 | 2,236 | 1,965 | 2,235 | 2,176 |
| **Non-Maintenance Year** | | | | | | | | | |
| Total Hours in Year | hr | 8784 | 8784 | 8784 | 8784 | 8784 | 8784 | 8784 | 8784 |
| Operating Hours | hr | 8182 | 8182 | 8182 | 8182 | 8182 | 8182 | 8182 | 8182 |
| Annual Net Generation | GWh/yr | 5,425 | 5,425 | 5,425 | 5,425 | 5,425 | 5,425 | 5,425 | 5,425 |
| Annual Fuel Burn Rate | kton/yr | 3,404 | 3,403 | 3,401 | 3,277 | 3,472 | 3,621 | 3,364 | 3,438 |
| Annual SO2 Emitted | ton/yr | 2,141 | 2,202 | 1,956 | 2879 | 2,309 | 1,820 | 1,572 | 2,348 |
| Annual NOx Emitted | ton/yr | 6,348 | 7,131 | 6,915 | 7,607 | 6,480 | 6,088 | 6,698 | 6,851 |
| Annual CO Emitted | ton/yr | 2,373 | 2,517 | 2,433 | 2,541 | 2,472 | 2,173 | 2,471 | 2,406 |

## Table 9: Projected Annual Emissions for Unit 2

| Description | Units | Buckskin | Caballo 8500 | Cordero Rojo | Jacobs Ranch Upper Wyodak | Rawhide | Special K Fuel | Belle Ayr | Eagle Butte |
|---|---|---|---|---|---|---|---|---|---|
| **Maintenance Year** | | | | | | | | | |
| Total Hours in Year | hr | 8760 | 8760 | 8760 | 8760 | 8760 | 8760 | 8760 | 8760 |
| Operating Hours | hr | 7614 | 7614 | 7614 | 7614 | 7614 | 7614 | 7614 | 7614 |
| Annual Net Generation | GWh/yr | 5,048 | 5,048 | 5,048 | 5,048 | 5,048 | 5,048 | 5,048 | 5,048 |
| Annual Fuel Burn Rate | kton/yr | 3,168 | 3,167 | 3,165 | 3,049 | 3,231 | 3,370 | 3,130 | 3,199 |
| Annual SO2 Emitted | ton/yr | 1,993 | 2,049 | 1,820 | 2679 | 2,149 | 1,694 | 1,463 | 2,185 |
| Annual NOx Emitted | ton/yr | 5,907 | 6,636 | 6,435 | 7,079 | 6,030 | 5,665 | 6,233 | 6,375 |
| Annual CO | ton/yr | 2,208 | 2,342 | 2,264 | 2,365 | 2,301 | 2,022 | 2,300 | 2,239 |
| **Non-Maintenance Year** | | | | | | | | | |
| Total Hours in Year | hr | 8784 | 8784 | 8784 | 8784 | 8784 | 8784 | 8784 | 8784 |
| Operating Hours | hr | 8159 | 8159 | 8159 | 8159 | 8159 | 8159 | 8159 | 8159 |
| Annual Net Generation | GWh/yr | 5,409 | 5,409 | 5,409 | 5,409 | 5,409 | 5,409 | 5,409 | 5,409 |
| Annual Fuel Burn Rate | kton/yr | 3,394 | 3,394 | 3,392 | 3,268 | 3,463 | 3,611 | 3,354 | 3,428 |
| Annual SO2 Emitted | ton/yr | 2,135 | 2,196 | 1,951 | 2871 | 2,303 | 1,815 | 1,567 | 2,341 |
| Annual NOx Emitted | ton/yr | 6,330 | 7,111 | 6,896 | 7,586 | 6,462 | 6,071 | 6,679 | 6,832 |
| Annual CO Emitted | ton/yr | 2,366 | 2,510 | 2,426 | 2,534 | 2,465 | 2,167 | 2,464 | 2,399 |

DATA BOOK KEY

# PACIFIC POWER & LIGHT COMPANY

AND

# THE WASHINGTON WATER POWER COMPANY

## CENTRALIA POWER PLANT PROJECT

# PLANT DATA



JOB NO. 6442

ENGINEERS  CONSTRUCTORS

TO

TAB 15 A

# CONTRACT DATA SHEET

January 9, 1970

File alphabetically. PAC
Destroy sheet dated

CONTRACT NO. 13167 - 5168

DISTRICT OFFICE CREDITED WITH SALE 50% Denver 50% San Francisco

CONTRACT DATE 10-10-67

**PURCHASER** Pacific Power & Light Co., Portland, Oregon & Washington Water Power Co., Spokane, Washington

**USER** Pacific Power & Light Co. Centralia, Washington

PLANT NAME Centralia

CONS. ENGR. Bechtel Corp. San Francisco, Cal.

INDUSTRY P. U.

**BOILER** # 1 & # 2

SQ. FT. H.S. PER UNIT 41,500

DESIGNATION 90' - 0" / 42' - 8 & 1/2" 431 - 2" O.D. / 205 - 2" O.D. CCRRD

**PRESS**
DESIGN 2990
OPER. S.O. 2655
TURBINE THROTTLE 2540

**FURNACE** VOLUME CU. FT. TOTAL 527,000

TYPE OF BOTTOM Basket

WIDTH 90' - 0"

FRONT TO REAR 42' - 8 & 1/2"

**SUPERHEATER** TYPE 2 Stage with platen and panel

**REHEATER** TYPE 2 Stage with radiant wall

**ECONOMIZER** NO. 1 TYPE Plain tube

**AIR HEATER** NO. 2 TYPE 32 - VI - 73 & 1/2 (T) MAKE Ljungstrom

**FUEL BURNING EQUIPMENT** 8-# 1003 RP Mills & TT Burners

| FUEL | | ASH FUSION TEMP. F | GRIND-ABILITY | HHV |
|---|---|---|---|---|
| Sub. Bit. | | | | |
| Moist. 20% Vol. Matter 34.4% | | initial 2190<br>soft 2290 | 40 | 8100 |
| Fixed Carb. 29.6% Ash 16% | | | | |

## OPERATING CONDITIONS

| | | CONTROL POINT | 100% LOAD | MAX. CONT. LOAD | | |
|---|---|---|---|---|---|---|
| LB STEAM PER HOUR ACTUAL | PRIMARY | 2,944,000 | 4,907,000 | 5,168,000 | | |
| | REHEAT | 2,652,000 | 4,420,000 | 4,562,000 | | |
| STEAM TEMP. F LEAVING | SUPERHEATER | 1005 | 1005 | 1005 | | |
| | REHEATER | 1005 | 1005 | 1005 | | |
| REHEAT DATA | ENTERING TEMP. | 620 | 687 | 690 | | |
| | ENTERING PRESS. | 427 | 713 | 735 | | |
| FEEDWATER TEMP. F | | 452 | 504 | 509 | | |
| TEMP. AIR TO AIR HEATER | | 80 | 80 | 80 | | |
| TEMP. GAS FROM AIR HEATER | | 250 | 300 | 310 (uncorr) | | |
| OVERALL EFFICIENCY % *Guaranteed | | 86.82 | 85.50 * | 85.24 | | |

**SUPPLEMENTARY DATA** Setting & Insulation (R & I Products), S.B., Circulation system, F.D. & I.D. Fans T.V. Equip., Casing, Ductwork, Platforms & Stairways, Controls, Feeders, etc.

**GENERATOR KW** MFR. RATING 650

PLANT ELEV. 220 feet

CE 0010213 (11/69)

| Efficiency | % | 86.82 | 85.50 | 85.24 |
|---|---|---|---|---|

## SECTION 4.2

## STEAM GENERATOR - PERFORMANCE

## TECHNICAL DATA - 8100 Btu/lb.

| Rated Pressure | Temp. Control Load (60%) | Guar. Point Load (100%) | Max. Cont. Load |
|---|---|---|---|
| Superheater Outlet flow, M #/Hr. | 2944 | 4907 | 5168 |
| Total steam flow, M #/Hr. | 2944 | 4907 | 5168 |
| Temp. at superheater outlet, $^{o}F$ | 1005 | 1005 | 1005 |
| Max. spray for emerg. control, M #/Hr. | 213 | 270 | 295 |
| Spray water temperature, $^{o}F$ | 380 | 425 | 430 |
| Press. at superheater outlet, psig | 2443 | 2520 | 2655 |
| Superheater pressure drop, psi | 60 | 150 | 155 |
| Feedwater Temp. $^{o}F$ | 452 | 504 | 509 |
| Feedwater Temp. leaving Econ., $^{o}F$ | 536 | 592 | 608 |
| Econ. press. drop, friction only, psi | 10 | 25 | 27 |
| Reheat steam flow M #/Hr. | 2652 | 4420 | 4562 |
| Max. spray for emerg. control, M #/Hr. | -- | -- | 200 |
| Temp. at reheater outlet, $^{o}F$ | 1005 | 1005 | 1005 |
| Temp. at reheater inlet, $^{o}F$ | 620 | 687 | 690 |
| Press. at reheater inlet, psig | 427 | 713 | 735 |
| Reheater press, drop, psi | 21 | 35 | 37 |
| Ambient air temp., $^{o}F$ | 80 | 80 | 80 |
| Air temp. entering air heater, $^{o}F$ | 80 | 80 | 80 |
| Air temp. leaving air heater, $^{o}F$ | 565 | 700 | 733 |
| Gas temp. leaving furnace, $^{o}F$ | 1600 | 1875 | 1900 |
| Gas temp. leaving economizer, $^{o}F$ | 640 | 805 | 840 |
| Gas temp. leaving air heater, uncor., $^{o}F$ | 250 | 300 | 310 |
| Gas temp. leaving air heater, corrected, $^{o}F$ | 235 | 285 | 295 |

| Rated Pressure | Minimum Load (without Stabil. Firing) | Temp. Control Load (60%) | Guar. Point Load (100%) | Max. Cont. Load |
|---|---|---|---|---|
| $CO_2$ at econ. outlet, % | | 16.0 | 16.0 | 16.0 |
| Excess air leaving furnace, % | | 25 | 20 | 20 |
| Excess air leaving Economizer, % | | 25 | 20 | 20 |
| Gas entering air heater, Wet, M #/Hr. | | 4390 | 6550 | 6845 |
| Gas leaving air heater, Wet corrected, M #/Hr. | | 4774 | 7035 | 7360 |
| Air entering air heater M #/Hr. | | 4158 | 6189 | 6484 |
| Air leaving air heater, M #/Hr. | | 3774 | 5694 | 5969 |
| Air leakage across air heater, M #/Hr. | | 384 | 495 | 515 |
| Heat Loss: | | | | |
| Dry Gas % | | 3.77 | 4.90 | 5.12 |
| $H_2$ & $H_2O$ in fuel % | | 7.39 | 7.66 | 7.71 |
| $H_2O$ in air % | | .09 | .12 | .12 |
| Carbon % | | .15 | .15 | .15 |
| Radiation % | | .28 | .17 | .16 |
| Unacc & Mfg. Margin % | | 1.50 | 1.50 | 1.50 |
| Total heat loss % | | 13.18 | 14.50 | 14.76 |
| Overall boiler eff., % | | 86.82 | 85.50 | 85.24 |
| Fuel fired @ 8,100 Btu/lb lbs/hr | 92,400 | 517,000 | 802,000 | 835,000 |
| Heat release, furnace volume, Btu/hr/$ft^3$ | 1,470 | 7,820 | 12,300 | 12,800 |
| Heat release, projected furnace surface Btu/hr/$ft^2$ | 9,050 | 49,900 | 74,900 | 78,600 |
| Pressure Drop: | | | | |
| Windbox & burners "$H_2O$ | | 3.00 | 3.50 | 3.80 |
| Air heater, air side "$H_2O$ | | 1.30 | 3.15 | 3.45 |
| Air ducts "$H_2O$ | | 1.00 | 2.50 | 2.70 |
| Total press. drop "$H_2O$ | | 5.30 | 9.15 | 9.95 |

| Rated Pressure | | Minimum Load (without Stabil. Firing) | Temp. Control Load (60%) | Guar. Point Load (100%) | Max. Cont. Load |
|---|---|---|---|---|---|
| Draft Loss: | | | | | |
| Furnace | "$H_2O$ | | .15 | .15 | .15 |
| Superhtd & rhtr | "$H_2O$ | | 1.25 | 3.00 | 3.25 |
| Economizer | "$H_2O$ | | .65 | 1.50 | 1.65 |
| Air Htr gas side | "$H_2O$ | | 2.65 | 6.25 | 6.75 |
| Gas ducts, etc. | "$H_2O$ | | 1.40 | 2.75 | 2.95 |
| Total draft loss | "$H_2O$ | | 5.10 | 13.65 | 14.75 |
| Pulverizer | | | | | |
| Number in use | | 2 (5) | 8 | 8 | 8 |
| Air temp to pulver. | $^oF$ | - | 590 | 725 | 765 |
| Mill power | kwh/ton | 12.45(9.4) | 10.80 | 9.45 | 9.30 |

ADDITIONAL PREDICTED PERFORMANCE

| | | | |
|---|---|---|---|
| Coal H.H.V. | Btu/lb | 8724 | 6681 |
| Superheater Outlet Flow | M #/Hr | 5168 | 5168 |
| Superheater Outlet Temperature | $^oF$ | 1005 | 1005 |
| Superheater Outlet Pressure | Psig | 2655 | 2655 |
| Feedwater Temperature | $^oF$ | 509 | 509 |
| Feedwater Temperature Lvg. Economizer | $^oF$ | 600 | 607 |
| Reheater Steam Flow | M #/Hr | 4562 | 4562 |
| Reheater Outlet Temperature | $^oF$ | 1005 | 1005 |
| Reheater Inlet Temperature | $^oF$ | 690 | 690 |
| Reheater Inlet Pressure | Psig | 735 | 735 |
| Ambient Air Temperature | $^oF$ | 80 | 80 |
| Air Temperature Entg. Air Heater | $^oF$ | 80 | 80 |
| Gas Temperature Lvg. Air Heater, Uncorr. | $^oF$ | 310 | 326 |
| Gas Temperature Lvg. Air Heater, Corr. | $^oF$ | 295 | 315 |
| Excess Air | % | 20 | 20 |
| Gas Entering Air Heater | M #/Hr | 6730 | 7080 |
| Gas Leaving Air Heater | M #/Hr | 7245 | 7600 |
| Air Entering Air Heater | M #/Hr | 6412 | 6580 |
| Air Leaving Air Heater | M #/Hr | 5897 | 6060 |
| Heat Loss: | | | |
| Dry Gas | % | 5.11 | 5.46 |
| $H_2$ & $H_2O$ in fuel | % | 7.17 | 9.38 |
| $H_2O$ in Air | % | .12 | .13 |
| Carbon | % | .15 | .15 |
| Radiation | % | .16 | .16 |
| Unacc. & Mfg. Margin | % | 1.50 | 1.50 |
| Total Heat Loss | % | 14.21 | 16.78 |
| Overall Boiler Efficiency | % | 85.79 | 83.22 |
| Fuel Fired | #/Hr | 780,000 | 1,040,000 |

| | | | |
|---|---|---|---|
| Pressure Drop: | | | |
| Windbox & Burners | "$H_2O$ | 3.80 | 3.80 |
| Air Heater, Air Side | "$H_2O$ | 3.40 | 4.15 |
| Air Duct | "$H_2O$ | 2.40 | 2.80 |
| Total Pressure Drop | "$H_2O$ | 9.60 | 10.75 |
| Draft Loss: | | | |
| Furnace | | .15 | .15 |
| Superheater & Reheater | | 3.15 | 3.45 |
| Economizer | | 1.60 | 1.75 |
| Air Heater Gas Side | | 6.65 | 7.30 |
| Gas Ducts & Dust Collector | | 2.85 | 3.15 |
| Total Draft Loss | | 14.40 | 15.80 |
| Pulverizer: | | | |
| Number in use | | 8 | 8 |
| Air Temp. to Pulverizer | $^oF$ | 755 | 768 |
| Mill Power | KWH/Ton | 10.1 | 7.6 |