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Low NO_x/SO_x Burner Retrofit for Utility Cyclone Boilers

Quarterly Technical Progress Report
January - March, 1991

Reference Cooperative Agreement
DE-FC22-90PC89661

*Trans Alta Technologies,
Marion, IL*

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**Patents Cleared by Chicago
on July 11, 1991**

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1.0 INTRODUCTION

This report is the third in the series of quarterly technical progress reports to be issued to the U.S. Department of Energy and other Funding Parties in accordance with the requirements of the Cooperative Agreement for this project, (DOE Instrument Number DE-FC22-90PC89661). It covers the period from January 1, 1991 to March 31, 1991.

LNS Burner design effort during this period focussed on the analysis of LNS Burner heat transfer, review and approval of fabrication drawings, completion of LNS Burner boiler flow modelling and the continued development of the slag screen model.

Balance of plant engineering included the finalization of roof and wall details for the Fuel Preparation Building, structural checks associated with installation of equipment in the existing plant, the design of the fire fighting and ventilation systems for the Fuel Preparation Building and the preparation of P&ID's for the materials handling facilities. Work continued on the preparation of P&ID's for the fuel oil system and the instrument air and service air systems, the preparation of equipment lists and system descriptions, detailed design documentation for powering and control of major electrical components and preparation of the instrument index. Work on electrical design details for the instrumentation and minor control devices has been started.

Site construction activity was significantly less during the current reporting period and was progressively reduced throughout the period in accordance with project requirements for control of cash flow in Budget Period I. At the end of March, the project schedule for Budget Period 1 was delayed for a further three months to July 1, 1991. Construction work was put on hold and, with the exception of maintenance staff, the site was demobilized. Resumption of construction, fabrication and installation activities is scheduled for late June, 1991 and the Demonstration Test program is now scheduled for the period from November 1, 1991 through April 30, 1992.

2.0 PROGRESS REVIEW MEETING NO. 1

Project Progress Review No. 1 meeting was held in Marion, Illinois, on January 31, 1991. The meeting was opened by W.L. Fraser, President, TransAlta Technologies, who emphasized TransAlta's continuing commitment to the LNS Burner Technology. An overview of the project was then given by D.E. Larson of TransAlta Technologies, who also reviewed the management and organization of the project, its objectives, milestones achieved, key issues and project costs and schedule.

J.H. Smith of Bechtel reviewed the environmental aspects of the Marion project and described the permitting process and application for NEPA approval. DOE explained the NEPA approval process and advised that signing by DOE headquarters was planned for the end of February, but might slip to March.

A status report on the HOR demonstration project for the LNS Burner at Cold Lake, Alberta was provided by K. Weston of TTI. He described the HOR design basis, test summary and schedule and the lessons learned from HOR and made a comparison of the HOR and Cyclone Retrofit projects. This was followed by a presentation by K. Weston on the technical aspects of the Marion project which included the design basis, process flow diagram, boiler modifications, fuel preparation design, operational status, plant betterment and status of the retrofit.

J.H. Smith of Bechtel reviewed the Baseline Testing and described the test matrix and preliminary test results. He also discussed the schedule for the Demonstration Test.

3.0 PROCESS DESIGN

Work has started on updating the material and energy balances to reflect performance characteristics learned from the Baseline Test of existing plant equipment, such as the air heater, etc. The results of this effort will be incorporated into the Startup Plan.

4.0 LNS BURNER DESIGN

4.1 LNS BURNER THERMAL ANALYSIS

An LNS Burner thermal model which uses conventional finite-difference methodology has been prepared to evaluate thermal profiles and startup requirements. The model uses a commercially available thermal analyzer program to solve the finite difference equations and to determine the temperature distribution. The thermal model has been applied to the current mechanical design to estimate temperature profiles across the refractory and metal shell. The model has been used to assess typical startup conditions and evaluate their subsequent thermal impacts on the design.

The chart presented in Figure 1 shows a normalized thermal gradient across the LNS Burner front-end wall. This chart represents a slice taken through the LNS Burner sidewall near the head-end region. Similar charts have been developed along the LNS Burner flow path in axial and radian directions. These charts are then used to establish refractory requirements and process conditions and to evaluate thermal loads that occur on the LNS Burner during startup transients.

An evaluation of a typical startup condition has been made in which refractory hotface, metal wall and slagscreen temperatures were determined. Figure 2 shows these profiles for the selected conditions. Key events in this startup are the initial warm-up on oil using the 30 MBtu/h oil ignitors, a switchover to coal and the ramp up to full load on coal. The illustrated cold startup takes about eight hours to complete. In the case presented in Figure 2, the boiler and turbine requirements were included in the startup ramp rate as follows:

1. The boiler was brought up about 75% operating pressure and turbine roll was established using oil.

2. Coal firing was established to complete startup after the turbine stabilized and was held at about 15% load for one hour.

More of these typical startup, shutdown and other transient cases are being run and will be reported on in subsequent reporting periods.

4.2 MECHANICAL DESIGN

Effort continued in finalizing the LNS Burner fabrication drawings. An independent structural assessment of the LNS Burner fabrication drawings has been done. Some issues in areas of welding requirements and overall requirements for mechanical attachments will need to be resolved by Riley Stoker before fabrication is started. None of these issues is expected to have major impact on the current design or its scheduled start of fabrication in early summer, 1991.

4.3 BURNER-BOILER FLOW MODELLING

Cyclone furnaces operate with high excess air and at high temperature. The heat release during combustion is very high and, as a result, the boiler volume is very much smaller than would be found in a conventional pulverized coal fired system. The LNS Burner's operation differs fundamentally from that of a cyclone furnace. As a result, sulphur is captured and significant NO_x reduction is achieved. Because of the smaller boiler volume, flow modelling is necessary to ensure that adequate mixing of LNS Burner combustion products with air can be accomplished to achieve NO_x emission goals.

Design requirements for the air injection system for the Marion furnace were developed using a commercially available computational fluid

dynamics (CFD) code called FLUENT*. A series of cases were evaluated to obtain the final air injection design that met the process design goals as closely as possible.

The primary design goal for the air system is to reduce gas temperatures to about 2200°F at the boiler superheat region. Constraints on this goal took two forms, one geometric and the other process. The geometric constraint was a small boiler cross section, (about five feet in depth and twenty feet in width), which offers a limited volume for mixing air into the gases exiting from the LNS Burner. Air addition within the boiler is carefully controlled in order to limit the formation of thermal NO_x until the flue gas reaches the superheat region. Additionally, as the design matured, a concern developed over gas temperatures in the lower furnace relative to slag fusion points and so a new design goal requirement was added. The air system must also raise the temperatures of gases below the slag screens above slag fusion points to guarantee that slag from the combustors will flow properly to and through the slag tap in the furnace floor.

The modelling has been completed and a final report is being prepared by Riley Stoker. Results have indicated that the design requirements have been met. The model indicates that there are some small channels of hot gas near the walls at 2500°F which is higher than desired. Figure 3 is an elevation profile in the overfire region showing the effect of adding air to complete combustion. Figure 4 is a plan section at the same elevation. The presence of these small zones of higher than desired temperatures should not impact superheater conditions. These temperature zones will be re-examined next using a boiler heat transfer model which has the capability to better determine the actual temperature domain.

* FLUENT is a finite difference code for solving the Navier-Stokes equations within a computational domain. It can treat three-dimensional, steady, turbulent flows with chemically reacting components and convective/radiation heat transfer at boundaries. This combination of physical modelling abilities corresponds to the requirements for designing the Marion air injection system.

The work on the mixing model has been completed. All the overfire air injection requirements have been identified and located. The next effort is to start the boiler heat transfer modelling which will take calculated gas flow field data from the FLUENT model and incorporate the effect of boiler heat transfer. The capabilities of the FLUENT model to represent the boiler heat transfer surfaces is limited. The results obtained from the FLUENT model should predict slightly higher temperature than would be estimated by a boiler heat transfer model. A more accurate representation of the wall boundary conditions and the presence of ash particulate to scatter thermal radiation throughout the boiler should produce a lower temperature than estimated by the FLUENT model.

4.4 SLAG SCREEN DESIGN

The slag screen uses principles of inertial separation to remove slag droplets from hot LNS Burner gases exiting into the boiler volume. The hot gas with entrained molten slag flows through the configured cyclone furnace barrel and impacts the slag screen at the boiler water wall. The slag screen is composed of two rows of vertical, retractory-covered water wall tubes. Figure 5 shows a schematic arrangement of the LNS Burner, slag screen and furnace. The slag screen functions by forcing the combustion gas and entrained molten slag droplets to travel between tubes. As the gas flow changes direction, the slag droplets, with momentum too high to follow the gas flow, impact on the boiler side row of tubes. The slag then flows down the tubes and into the slag tap at the bottom of the boiler.

A thermal-hydraulic model has been developed to determine the slag screen design parameters. The model uses a thermal analyzer program to evaluate the temperature flow field by solving finite difference equations. The model predicts thermal performance of the slag screen by coupling the hot gas containing molten slag droplets to the slag screen by convection and radiation. Overall pressure drop and slag droplet collection efficiency are also calculated by the model.

The initial checkout of the model has been completed and parametric studies are being run. Key areas which will be explored are the effect of gas temperature on slag capture, buildup of material on the tube surface, erosion of the tube surface and different slag properties such as fusion temperatures and thermal conductivity.

Curves have been developed which show pressure drop and slag capture over the load range from 50% to 100% boiler maximum continuous rating (MCR). A sample of these preliminary curves is presented in Figure 6. This curve is normalized to 100% MCR and shows the effect of turndown on slag capture efficiency and overall pressure drop. Curves like Figure 6 are being developed to describe the slag screen operating envelope for operator training.

Further results will be provided in the next reporting period.

5.0 BALANCE OF PLANT ENGINEERING

5.1 ARCHITECTURAL WORK

Elevation drawings were revised to show access requirements for maintenance of the coal conveyor which transports coal from the silos to the Fuel Preparation Building. These changes had not been included in the preliminary drawings used for the bid package, so the appropriate modifications were made in the field, prior to demobilization of the siding contractor.

Similar revisions were made to the roof drawings to show all roof penetrations such as hatches and ventilation details. The revised roof drawings were issued to the roofing contractor prior to his site mobilization.

5.2 CIVIL AND STRUCTURAL DESIGN

The civil design drawings were updated to include site modifications that were made during construction of the Fuel Preparation Building. These modifications were necessary to resolve interference problems and were recorded at the time as Design Change Notices (DCN). Approximately ten DCN's were generated.

Contractors' billings for reinforced concrete work, structural steel and miscellaneous steelwork were reviewed and the final material quantities established.

Design and drafting work associated with the installation of equipment and raceways in the existing plant structures was completed. Evaluations of structural adequacy were performed and modifications designed for existing structural components which needed strengthening to accommodate the additional loads.

Design documents, calculations and drawings were finalized in preparation for microfilming and project design close-out procedures.

5.3 MECHANICAL DESIGN

Design of the firefighting and ventilation systems for the Fuel Preparation Building has been finalized and P&ID's are being prepared.

The ventilation system will draw fresh air in through manually adjustable louvers near the pulverizer and will exhaust warm air through roof ventilators, one at each roof level. Each ventilator will be operated automatically and will be equipped with an automatic shutoff damper and a manually adjustable thermostat.

The firefighting system will consist of a single dry-pipe riser in the Fuel Preparation Building which feeds two hose stations, each with 75 ft. of 1-1/2" hose. The hose stations will be located on the ground floor and the feeder floor. Manual alarm pull stations and alarm horns will be provided at each building exit. The supply valve for the dry-pipe system will be located in the Unit 1 turbine building.

Mechanical and piping penetrations in the siding and roof of the Fuel Preparation Building were located from the preliminary routing of service systems piping to the equipment in the building. The final pipe routing will be constrained to use these penetrations, even if the remainder of the pipe route is changed from the preliminary layout. Field inspection showed that additional removable panels were also required in the north wall siding to give access to the coal feeder conveyor. This occurred because the vendor submitted drawings for a different model of coal feeder than the one supplied. Overall dimensions and connection requirements were correctly shown on these drawings but the access and pull space requirements were incorrect.

Details of the fuel oil system have been received and the P&ID is being prepared. The existing ignitor oil pumps and piping will be used up to and including the ring header at the boiler front.

Work continued on preparation of equipment, line and valve lists and piping class sheets. Numbering of all lines and valves uses the same system as the original design documents. Piping class sheets are as originally issued wherever possible, with updates where necessary to incorporate more modern materials and procedures. New plant equipment will be numbered in accordance with the Bechtel standard system, since no system exists at present. The plant equipment list is being continuously revised to incorporate vendor information as it is received. Detailed vendor information is also being obtained from equipment suppliers to support preparation of the instrument index and instrument installation details.

P&ID's for the Limestone and Additive Handling system and the Instrument and Service Air system have been issued for use. The Limestone and Additive Handling system incorporates all data from the vendor's drawings. A new centrifugal air compressor supplied by SIPC will supply air to a new 4-inch header. The existing instrument air dryer will be fed from the new header and will supply air to Unit No. 1, the new Fuel Preparation Building and the new fuel system.

Preparation of equipment system descriptions is under way for inclusion in the update to the Plant Data Book. All existing installation and operating instructions are currently being reviewed. Spare parts lists are being prepared and, where necessary, lists of recommended spares are being obtained from suppliers.

5.4 ELECTRICAL DESIGN

Detailed design documentation for the powering and control of major electrical components has been started. The schematic and wiring connection diagrams which are being prepared will be used for physical

termination of cabling and identification of the control scheme and interfaces.

Piping drawings for the new fuel preparation building were reviewed to establish physical locations of instruments. The locations of non line-mounted devices, such as transmitters, were examined relative to the routing of conduit and raceway. Grouping of devices was maximized to reduce raceway and cabling requirements.

Miscellaneous component vendor data was reviewed to ensure that adequate detail had been provided for the location and identification of electrical connections and requirements. In many cases, additional supporting data was requested.

Identification and tabulation of new electrical circuits was started. Scheduling of these circuits will include origin and destination points, cable types and sizes and the routing of the circuits. The grouping of circuits by service type and function has been established, together with standard nomenclature for identification of the circuits.

Electrical design details for instrumentation and minor control devices has been started, including cabling and wiring termination data required for field installation and checkout. The high concentration of instrumentation and peripheral devices associated with the new burner design necessitated considerable review to group the devices and minimize space requirements.

5.5 INSTRUMENTATION AND CONTROLS

Preparation of the Instrument Index continued with incorporation of additional data and information after review of DCS drawings and control equipment documentation. Continuing input into the Instrument Index database will be required until all necessary data from document submittals has been included.

Work continued on preparation of instrument installation details to provide connection details for field mounted instruments, lists of materials, accessory items and other installation information. Standard Bechtel drawings are being used for new instruments in the system and will be modified for existing installations to show the new instruments being added to existing connections.

Detailed design drawings for physical modifications to the control room are being continuously updated as client comments are incorporated into the proposed changes. The lack of space in the control room and the continued use of existing control functions on the Unit 1 console section prohibited replacement with a new DCS console. The control equipment in the existing console will be replaced, new CRT's will be added on the top of the console and a keyboard shelf will be mounted at the front edge to allow the operator to sit or stand for DCS operation.

The bunker and silo air cannon design was modified to suit the operation of the controller units supplied with the air cannons. Operation from the DCS was changed to pushbutton control on the Unit 1 console because DCS actuation would require additional components. The air cannon pushbutton operation from the console will be similar to other plant units for consistency of operation.

A review of the DCS design documentation was performed to verify that all instruments have been incorporated into the control system and that the BMS logic and combustion control/BOP loops have been configured as shown. Instrument grouping within the system was reviewed to ensure that components with the same end destination were located in the same area to minimize system cabling and raceway.

A study to determine design and installation requirements for steam level instrumentation for Marion Unit 1 has been completed. Boiler requirements are for two independent direct level indications to be available to the operator. The pre-retrofit equipment comprised direct visual indication by mirror visible from the control room and a level gauge at the old boiler front panel which received an electrical signal from a transmitter

attached to the boiler drum and was also visible from the control room. Both signals are no longer available because the sources of indication have been displaced by the LNS Burner. Also, the level receiver that had been located at the boiler front was found to be defective. The study showed that a replacement transmitter and receiver must be purchased and installed. The direct reading visual system will be operable after installation of a new mirror. Adjustments will be made and operability verified during start-up.

Control equipment for the oil ignition system was purchased as loose components and an engineering evaluation is required to determine the most cost effective method for field installation. Additional requirements such as isolation valves, strainers, small pipe and fittings must be purchased and bills of material and field installation drawings will be prepared for these.

5.6 CONSTRUCTION AND INSTALLATION

The installation of miscellaneous steelwork for the Fuel Preparation Building was completed and siding and roofing have been installed. The installation of major equipment items has also been completed, with the exception of the LNS Burners.

Site construction activity was significantly less during the current reporting period and was progressively reduced throughout the period in accordance with project requirements for control of cash flow in Budget Period I. At the end of March, construction work was put on hold and, with the exception of maintenance staff, the site was demobilized. Resumption of construction, fabrication and installation activities is scheduled for late June, 1991.

6.0 BASELINE TEST

Preliminary boiler performance, air quality and waste monitoring results of the Baseline Test, which was carried out during the previous reporting period, are being reviewed. Initial results indicate a much higher carbon content in the ash than had been expected or would appear to be reasonable. Since the carbon content is a key factor in the calculation of boiler efficiency and coal consumption, reassessment is necessary.

Calculations of carbon content were based on data from composite samples taken at two points at the electrostatic precipitator hoppers and one at the mechanical multiclone outlet hopper. Independent samples were also taken at these locations during testing, but were not analyzed, and samples of flyash were taken at three points in the flue gas stream for other purposes. All of these samples are being analyzed independently for carbon content and the results will be compared with those from the samples taken at the hopper outlet. The Baseline Test Report will be completed and issued when these analyses have been completed.

7.0 MAINTENANCE

The host utility, SIPC, had the boiler steam drum inspected by the original equipment manufacturer to assess the operational reliability of the drum and internals during the demonstration period. Repairs were made as required.

Material requisitions have been prepared for valves, valve replacement parts, valve packing and instrumentation parts required for the demonstration program preventative maintenance program. These will be placed on order to ensure delivery at the site prior to initiation of the program.

8.0 WORK PLANNED FOR NEXT PERIOD

The following work is scheduled for execution during the next reporting period from April 1, 1991 to June 30, 1991:

- Prepare presentations for Project Review No. 2
- Continue LNS Burner thermal analysis for typical startup, shutdown and other transient conditions
- Finalize report on Burner-Boiler flow modelling
- Complete slag screen modelling and design
- Complete and issue Baseline Test Report
- Complete preparation of P&ID's, equipment system descriptions, I and C drawings and wiring details
- Complete electrical design and documentation
- Prepare operating manuals
- Prepare startup plan

FIGURE 1

Normalized Gradient Across Front - End Wall

FIGURE 2

Temperatures During Startup

FIGURE 3

Profile of Boiler Temperature at OFA Ports

FIGURE 4

Plan View, Three Feet Above OFA Ports

FIGURE 5

Slag Screen Schematic

FIGURE 6

Typical Curves of Slag Screen Performance

Figure 7

Fuel Preparation Building
With Siding Installed

Figure 8
Boiler Front
Indicator Panel

Figure 9
Existing Control Panel
Prior to Modification

END

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