Low NOx/SOx Burner Retrofit for Utility Cyclone Boilers

Quarterly Technical Progress Report
April - June, 1991

Reference Cooperative Agreement
DE-FC22-90PC89661

Patents Cleared by Chicago
on September 24, 1991

Transure Technologies, Inc.
Marion, IL

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1.0 INTRODUCTION

This report is the fourth 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 April 1, 1991 to June 30, 1991.

Work on process design was deferred pending a restart of the mainstream project activities.

LNS Burner design effort during this period was focussed mainly on the continued development of the slag screen model. Documentation of the LNS Burner thermal model also continued.

Balance of plant engineering continued on the P&ID's for the fuel preparation building HVAC system, lighter oil, limestone/fuel additive handling system, instrument and service air and fire protection systems. Work began on the preparation of system and sub-system descriptions. Schematic connection and wiring drawings and diagrams for the fuel handling system, flame scanner/igniter system and DCS control modification for the lighter oil pumps and Unit 1 circulating water pumps were completed. Preparation of the modified wiring diagram for the main control panel is in progress. Detailed instrumentation criteria and cost estimates were developed for an acoustic furnace temperature measuring system. Instrument installation drawings have been finalized and work on the Instrument Index database is proceeding.

Site construction activity is still on hold and, with the exception of maintenance staff, the site is demobilized. At the end of May, the project schedule for Budget Period 1 was delayed for a further three months to October 1, 1991. Resumption of construction, fabrication and installation activities is scheduled for late September, 1991 and the Demonstration Test program is now scheduled for the period from March 1, 1992 through December 31, 1992.
2.0 PROGRESS REVIEW MEETING NO. 2

Project Progress Review No. 2 was held at Pittsburgh, Pennsylvania, on April 3, 1991. The meeting was opened by W.L. Fraser, President, TransAlta Technologies, who emphasized the progress made on the Cyclone Retrofit Project, both in engineering and in meeting DOE reporting requirements. He also commented on the excellent emissions results achieved by the LNS Burner at the Canadian Heavy Oil Recovery Plant at Cold Lake which met the project goals with excellent margins.

Dr. G. Elia of DOE reported that official NEPA approval was received on March 21, 1991 and formal notification would shortly be sent to TTI.

A proprietary technical review was held in the morning, at which K. Moore of TTI gave a review of LNS Burner theory and L. Martin discussed the Marion design and development work.

A non-proprietary project management review was given in the afternoon. An overview of the project was presented by D.E. Larson of TTI with emphasis on project milestones, schedule, costs and key issues. The status of environmental approvals and the Marion Unit 1 retrofit were reviewed by J. Smith of Bechtel. The non-proprietary presentations are summarized in the briefing notes which were circulated at the meeting. A general discussion followed the presentations.

The preliminary results of the Baseline Test and the status of the Baseline Test report were reviewed by J. Smith of Bechtel and a discussion followed.

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.
3.0 PROCESS DESIGN

Work has been deferred in this area pending a restart of the mainstream project activities.
4.0 LNS BURNER DESIGN

Higher priority work on other programs has suspended work on most of the ongoing tasks. Slag screen modelling is the only major task on which work has proceeded. These design and analysis tasks are discussed in the following sections.

4.1 LNS BURNER THERMAL ANALYSIS

A 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 documentation of the model continues.

Evaluation of thermal impacts have been delayed pending completion of higher priority work on other programs.

4.2 MECHANICAL DESIGN

Effort in finalizing the LNS Burner fabrication drawings has been delayed until the restart of mainstream project activities.

Fabrication of the LNS Burner is on hold until the release of the final fabrication drawings.

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\textsubscript{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\textsubscript{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 was 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\textsubscript{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. 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. 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 FLUENT model does not accurately represent the boiler heat transfer surfaces. The results obtained from the FLUENT model should predict higher temperatures than would be estimated by a boiler heat transfer model which incorporates a more accurate representation of the wall boundary conditions and the presence of ash particulate to scatter thermal radiation throughout the boiler.

The start of this task has been delayed pending completion of higher priority work on other programs.

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 reconfigured cyclone furnace barrel and impacts the slag screen at the boiler water wall. The slag screen is composed of two rows of vertical, refractory-covered water wall tubes. 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.

Modelling effort on the slag screen has focussed on determining which of the many variables that effect performance are significant.
One such variable is presented in Figure 1, the curve of estimated slag viscosity as a function of temperature and slag composition. The different correlations shown on this figure have been taken from the open literature. Slag screen performance is dependent upon the apparent viscosity. Typical viscosities for most coal slags are highly non-linear with respect to temperature, as can be seen in Figure 1. The two correlations show good agreement at the design slag/tube surface temperature of 2265°F. While the model is dependent upon a prediction of slag velocity, a small change in operating conditions, such as temperature, can easily correct for any differences in viscosity prediction.

Figure 2 shows the effect caused by either a buildup or loss of surface slag material on the estimated slag screen pressure drop at 100% MCR. The normal design point is a pressure drop of 2.5 inches of water across the slag screen. The model shows that the buildup of a 0.125 inch thick layer would increase the pressure drop to 3.5 inches of water. Figure 3 shows the corresponding change in slag screen performance as a function of tube diameter.

Additional work will be done during the next reporting period and will be discussed at that time.
5.0 BALANCE OF PLANT ENGINEERING

5.1 MECHANICAL DESIGN

The following Piping and Instrumentation Drawings (P&ID's) were issued during the current reporting period and are shown in Figures 6 through 10:

- M74-GL01 Revision 0 Fuel Preparation Building HVAC
- M74-JD01 Revision 0 Lighter Oil System
- M74-JL01 Revision 1 Limestone/Fuel Additive Handling System
- M74-KA01 Revision 1 Instrument and Service Air System
- M74-KC01 Revision 0 Fire Protection System

Various types of carbon monoxide monitors were investigated to determine if suitable units are available for monitoring CO in enclosed spaces around the boiler during the demonstration test. It was found that several types are available ranging from expensive electronic devices with alarms to inexpensive indicator cards that change color. A final selection of the type of device has not yet been made.

Information on the existing precipitator and multiclone was assembled for use in evaluating the effects of the existing dust collection system with the LNS Burner.

Checking of the final submittal of Riley Stoker drawings for incorporation of all comments and issue as "Status 1" drawings continued. It is estimated that about forty drawings still require final approval and this work is expected to be completed in July 1991.

Bechtel began work on system descriptions for systems and sub-systems which they had designed or modified. The system description for the main fuel system will be completed by Riley Stoker. This work will continue through the next reporting period.
5.2 ELECTRICAL DESIGN

Schematic and connection drawings for the Fuel Handling System, (including the pulverizer, fuel transport blower, rotary valve, screw conveyor, diverter gate, bucket elevator, silo level indicator, limestone and additive feeders, coal feeder and coal conveyor), were finalized and drafted and will be issued after final review and approval. These drawings illustrate diagrammatically the control scheme of each of the above components and also reflect external cable pulls between components and wiring connections at each component. All reference drawings used to develop the control schemes and connections are listed and any pertinent notes related to the operation and installation of the components have been included.

Because the design philosophy used by J.B. Webb Co. for control of their equipment, (screw conveyor, diverter, gate and bucket elevator), is not compatible with the Siemens Motor Control Centre used to power these components, minor modifications to the control panel wiring and MCC motor starter wiring will be required. These wiring changes are minimal, however, and amount to little more than the disconnection of a few wires and the addition of jumper wires on some of the terminal blocks. These changes will be made at the site by field personnel during final installation.

Control design of the air cannons for the coal bunker and the limestone and additive silos was finalized and the corresponding wiring/connection diagram was developed and drafted. This drawing will be issued after final review and approval. Each bunker and silo will have up to three microprocessor-controlled air cannons which, when fired in their predetermined sequence, will clear any blockages. Each bunker and silo will have its own microprocessor control panel to control its air cannons. Operation of each set of cannons will be possible either locally from the control panel or remotely via a push-button switch located on the Unit 1 control console.

Schematic connection and wiring diagrams for the flame scanner/igniter system and DCS control modification for the lighter oil...
pumps and Unit 1 circulating water pump were completed and will be issued after final review and approval.

The modification drawing for the Unit 1 main control panel layout was completed. This drawing reflects the deletion of control and instrumentation devices which have been consolidated into the DCS and the addition of the bunker and silo air cannon remote control switches, DCS system CRT's and keyboard. It will be issued after final review and approval.

The modified wiring diagram for the main control panel has been started and is in progress. This drawing will identify existing panel wiring which must be disconnected and removed with the control and instrumentation devices that require removal. The electrical terminals which become available will be reused to wire up and connect the new devices, such as the air cannon remote switches, which will be installed in the panel.

Input into the modified existing circuit schedule and new circuit schedules continues as the detailed design of the various systems and components and their locations are finalized. Input into these schedules will be an ongoing activity until detailed design has been completed.

The electrical drawings for the 2400 kV switchgear required for the retrofit were not approved and were returned to the supplier because the physical configuration of the equipment did not meet the technical specifications for compatibility with existing plant equipment. As a result of this, the bus bar configuration would not be capable of mating with adjacent switchgear on the same electrical bus. The switchgear had been fabricated and delivered to site by the supplier prior to drawing approval. After revision and resubmittal of the drawing for approval, the switchgear will require modification prior to installation and operation in the retrofit program.
5.3 INSTRUMENTATION AND CONTROLS

Detailed instrumentation criteria and estimated costs were developed for an acoustic temperature measurement system, as discussed below. This system will be installed prior to the demonstration phase of the project in order to monitor the furnace internal temperature. The equipment will include electronic readout purchased on a rental basis and permanent boiler-mounted temperature sensors. The system is required to provide a seven-path graphics temperature profile map at elevation 550, one single path temperature measurement down the furnace centreline at elevation 566 and one single path temperature measurement down the furnace centreline at elevation 540.

Gas temperature measurement is important in many production processes which involved furnace or boiler units such as electric utility steam units, refuse fired boilers or chemical process recovery boilers. Gas temperatures have been difficult to measure in these systems because of the hostile environment created by the combustion processes. Intrusive measurements using water-cooled thermocouple probes are difficult, costly, yield questionable results and have generally been limited to short term test applications.

An extensive market study was completed and it was concluded that cyclone retrofit requires advanced technologies in acoustics and signal processing to provide continuous, accurate, real-time measurement of combustion gas temperatures on a fully automatic basis. The system must be configured to handle measurements over one to eight independent path volumes or in a transceiver mode at up to eight locations on a single plane for isothermal mapping. Temperatures can be presented numerically in the control room using the digital display unit or as graphic isothermal contours and three-dimensional surface plots using the optional SEI-3G colour graphics display unit.

The velocity with which acoustic waves propagate through a gas mixture is a primary function of absolute temperature and, to a lesser extent, a function of the gas composition. For most applications, the gas
constituents and their relative quantities are well known or fall within a small range of values. The average gas temperatures along a path between a sound source and a receiver can therefore be determined by measuring the flight time of the acoustic wave along the known distance between the source and receiver, as shown in Figure 11.

A short audio tone burst with a specific frequency range and duration is launched from an electrodynamic source transducer at one side of the boiler and its arrival detected at the opposite side by a receiver transducer. The time interval, (flight time), is divided by the distance to give the acoustic velocity.

The system must overcome sootblower noise interference by monitoring the background noise before any measurement attempts are made. The system waits until the sootblower has completed its cycle, at which time the background noise signal drops. At this time, measurements are made at a rate of five paths per second before the next sootblower cycle begins.

The system must regularly monitor background noise at each channel's receiver transducer. If the background noise (sootblower noise plus combustion noise) is below a user-defined threshold level, the system will initiate an acoustic transmission on that channel. The received signal is processed and the corresponding temperature is calculated and displayed.

Installation must be straightforward and, in many cases, can be done while the boiler or furnace is on-line. Acoustic source and receiver transducer/waveguide assemblies are mounted on opposite sides of the furnace or cavity through which temperature measurements are required. These transducer assemblies are mounted on specially modified observation port doors, which may be quickly and easily detached at any time. The presence of a transducer assembly, however, in no way interferes with the ability of the port to be opened for visual observation.
A number of waveguide geometries are available to accommodate rectangular or circular port openings. Each waveguide assembly is equipped with an electrically operated solenoid valve which allows plant compressed air to be periodically injected into the waveguide. This purge valve is controlled and operated in a pulse mode to inject bursts of compressed air to clear flyash or prevent other loose material from accumulating in the waveguide assembly.

The software must be designed to run unattended in ROM and generates modulated audio signals for use in measuring gas temperature.

The general functions to be performed by the software can be summarized as follows:

1. Perform gas-temperature measurement by measuring speed of sound on eight channels where a signal is transmitted and the delay of the received signal is times.

2. Allow for 24 additional transceiver path combinations using the right channels; example: transmit on channel 2 and receive on channel 7.

3. Allow rapid sampling during quiet intervals (such as sootblower pauses) while buffering the sampled data, for computation later.

4. Allow periodic activation of solenoid controlled air purge valves to remove debris from speaker horns. The duration and interval are programmable.

5. Allow for averaging temperature data using a variable length moving average.

6. Present averaged temperature data in analog voltage or current format using programmable scaling for chart recorder use.
7. Present averaged temperature data in digital format for display on a remote terminal using RS422 serial interface. Display data also on local keypad terminal display.

8. Accumulate data log array containing the most recent readings over a period of several hours.

9. Allow sensing of switch closure to disable transmission and purging on an individual channel or all channels, depending on which of ten possible switches are sensed.

10. Present menu of options through keypad terminal allowing examination or modification of system parameters stored in non-volatile memory.

11. Allow formatted dump parameters for printed record.

12. Allow formatted dump of data logged over several hours for subsequent analysis using, for example, a spreadsheet program.

System and hardware details were finalized in an engineering design review with TransAlta, Southern Illinois Power Co-op, Riley Stoker and Bechtel.

A design review of access to valve stations, instrumentation, and test connections on pipe and duct in the fuel preparation building was completed. All items were added to the general arrangement drawings. There were several valve stations and instruments where routine access would require the added expense to design and construct new platforms. None were identified as falling into a must category although additional access would be desirable. Temporary platforms will be required for erection and maintenance which will be put in place as necessary during the construction program.

Conceptual sketches were reviewed to determine optimum arrangements for the LNS Burner Platforms and layout of equipment
related to the burner oil ignitor system and instrumentation. The general area around the burner is extremely congested with operational and test instrumentation and required a detail study to assure proper installation. The valve rack for the control valves for each burner will be field fabricated. Auxiliary equipment and instrumentation for the oil ignition system and burner instruments (two racks each burner) will require field assembly. Detailed drawings will be completed for installation of this equipment.

Input to the Instrument Index database is continuing and near completion. Additional engineering time has been required to research Instrument Index data on most of the older original plant instruments which have often been replaced by equivalent instruments from various instrument suppliers. Input to this database will be required until all necessary data is incorporated from document submittals.

The Instrument Installation Detail drawings have been finalized and drafted. They will be issued upon final review and approval. These drawings provide standard tubing, valve and instrument installation details in an isometric format for all of the field mounted instruments. Also shown with these details are material lists itemizing all required materials needed to complete the installation and installation notes detailing any special installation requirements.

A completed configuration was developed of the Distributed Control System (DCS) inputs and outputs. This allowed for the identification of circuits to each field device. To minimize the amount and size of raceway required to house these circuits a study was undertaken to establish ways to group non-line mounted devices in a co-located manner. For example, on each burner there are approximately 10 temperature elements which are wired to temperature transmitters and from there to the DCS monitor cabinet. By locating a common rack for these transmitters near the burner, it allows the use of a multi-conductor cable between the transmitters and monitor cabinet instead of individual pair cable. This resulted in a savings of approximately 600' of cable. This approach was used in reviewing each area with a large concentration of instruments that have a common destination.
Conduit and circuit routing continued with the completed configuration of the DCS and receipt of remaining support documents from Riley Stoker.

Because of the high concentration of field devices located at each burner a scheme had to be developed to minimize the number of conduits and support them appropriately. A stand-off bracket was designed in conjunction with Riley Stoker that would allow for the mounting of instrument piping and conduits on each side of the burner (on centerline).

Two main conduits were run on each side of the burner barrel length. Conduits from the field devices on the barrel tie into one of the two conduits acting as a main artery depending on whether the device is wired directly to the DCS or if it is connected to a transmitter mounted on the co-located instrument rack for each burner. By taking this approach we were able to minimize the number of conduits in this congested area.

To accommodate temperature measurement of the burner gas at the slag screen, a terminal point and junction box was designed for the connection of these three thermocouples per burner. They are housed inside the existing abandoned burner air duct. Because this is a welded closed and high temperature environment special high temperature armored cable was routed out through a sealed fitting to a junction box for connection to the transmitters.

The final configuration of the DCS inputs and outputs was completed. A comprehensive review of each signal was undertaken to assure that all changes and modifications requested by TransAlta, SIPC and Bechtel have been included.

5.4 CONSTRUCTION

Installation of roofing for the Fuel Preparation Building was completed by a roofing sub-contractor. Additional flashing was required to accommodate a roof opening that was added for access.
Construction forces at the Marion site were demobilized, rented construction equipment returned and all construction activities suspended in accordance with cash flow restraints. A maintenance program was put in place to ensure proper in-place storage of equipment.
6.0 BASELINE TEST

All outstanding comments to the Baseline Emissions Test Report by Clean Air Engineering (CAE) and the Baseline Performance Test Report by Riley Stoker were resolved and incorporated and the final issue of these reports was made in April.

The Baseline Test Report CDOE30601N, Issue A, was issued to all funding parties on May 29, 1991 after patent clearance had been received for this document release.

A summary of the test results for the 100% MCR test is as follows:

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Boiler efficiency</td>
<td>83.69%</td>
</tr>
<tr>
<td>Flyash/slag ratio</td>
<td>40% / 60%</td>
</tr>
<tr>
<td>Air heater leakage</td>
<td>32.1%</td>
</tr>
<tr>
<td>SO₂</td>
<td>5.93 lb/MBtu</td>
</tr>
<tr>
<td>NOₓ</td>
<td>0.831 lb/MBtu</td>
</tr>
<tr>
<td>Acid dewpoint</td>
<td>274°F</td>
</tr>
<tr>
<td>Precipitator efficiency</td>
<td>97.35%</td>
</tr>
</tbody>
</table>

Isokinetic flyash samples from the air heater inlet were analyzed for total percent carbon in order to substantiate the unusually high unburned carbon content reported in the composite flyash sample. The flyash leaving the boiler was found to have a carbon content of approximately 46% compared with 55% for the composite sample. Recalculating the boiler efficiency based on the lower carbon content resulted in an increase in boiler efficiency of approximately 1% to 83.7%.

Additional isokinetic probe samples taken from the stack during baseline testing were also sent for analysis for total percent carbon. The results of these tests are not yet available.
7.0 WORK PLANNED FOR NEXT PERIOD

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

- Continue LNS Burner thermal analysis for typical startup, shutdown and other transient conditions.

- Finalize report on Burner-Boiler flow modelling.

- Finalize LNS Burner Fabrication Drawings.

- Complete slag screen modelling and design.

- Complete preparation of P&ID's, equipment system descriptions, I and C drawings and wiring details.

- Complete electrical design and documentation.

- Continue preparation of operating manuals.

- Prepare startup plan.
Figure 1
Estimated Slag Velocity
Figure 4

Plan View of LNS Burner
Access Platform
Figure 5

Side View of LNS Burner
Access Platform
NOTES:

1. THERMOSTATS MUST BE MOUNTED ON WEST WALL AT ELEVATIONS SHOWN.
2. LOUVER LOCATED ON NORTH WALL BELOW FEEDER FLOOR.
NOTES:

1. PIPING IS CLASS PDT-4 AND INSULATION IS CLASS N.

2. THIS DRAWING SHOWS MODIFICATIONS TO EXISTING SIPC DRAWING 5P23 REV. 3.

REvised AREA

Figure 7

BECHTEL
GAI'THESBURG, MARYLAND

TRANSALTA TECHNOLOGIES CYCLONE RETROFIT PROJECT SOUTHERN ILLINOIS POWER COOP

MODIFICATION DRAWING LIGHTER OIL SYSTEM P & ID UNIT 1
Figure 11

Gas Temperature Measurement Using Acoustic Methods
END

DATE FILMED
10/22/92