Project Status Report for: August 2000

Project Title: Ultra Low NOx Integrated System for Coal-Fired Power Plants

Project Number: 91890460 **Project Manager:** John Marion

Customer Name: U.S. DOE / Performance Projects **Project Leader:** Charles Maney

GOALS AND OBJECTIVES:

Develop low cost, retrofit NO_x control technologies to address current and anticipated, near term emissions control legislation for existing coal fired utility boilers. Specific goals include:

- Achieve < 0.15 lb/MMBtu NO_x for eastern bituminous coals
- Achieve < 0.10 lb/MMBtu NO_x for western sub-bituminous or lignitic coals
- Achieve economics at least 25% less than SCR-only technology
- Validate NOx control technology through large (15 MWt) pilot scale demonstration
- Evaluate the engineering feasibility and economics for representative plant cases
- Provide input to develop commercial guidelines for specified equipment
- Provide input to develop a commercialization plan for the resultant technologies

WORK PLANNED FROM PREVIOUS REPORT:

Task 2.1 – Test Fuels Characterization

- Obtain a second 5 gallon sample of the low reactivity coal and perform ASTM analyses.
- Determine high temperature volatile matter yield from a 200x400-mesh size cut in the DTFS-1 in nitrogen gas at 2650 ºF and ~ 0.5 sec. residence time
- Determine fuel nitrogen evolution from three size cuts -- 200x400-mesh, 270x400-mesh, and -400 mesh -- in the DTFS-1 in argon gas at 2650 ºF and ~ 0.5 sec. residence time.
- Send out a representative coal sample to an independent lab for petrographic analysis.

Task 2.3 – Global Mixing Process Improvement

- Continue post-processing of the CFD cases to examine the impact of SOFA mixing on predicted CO and carbon in ash levels.
- Continue CHEMKIN modeling of high temperature SNCR process.

Task 2.4 – Advanced Control System Design

- Install and check-out Coal Flow sensors
- Obtain field data set and begin NOx-heat rate and carbon in ash neural net modeling.

Task 3.1 – Test Planning & Facility Preparation

Plumbing / Mechanical

- Repair ignitor horns.
- Mark & install SOFA assemblies
- Begin installation of main windbox coal and air nozzles

Electrical

- Calibrate BSF O2 sensor
- Calibrate U-tube heat flux probe flow meters
- Check-out audio and video system
- Loop RTD sent out for calibration
- Install flue gas heat exchanger level control
- Confirm the BSF DCS system operability

Task 4 – Carbon Burnout System Evaluation

- Complete CBO™ feasibility study

Task 8 – Project Management

- Hold internal project status review meeting; make go / no go decision for Combustion Test Period #1 (Note: this activity may be delayed into September to correspond with the postponement of the first combustion test period).

ACCOMPLISHMENTS FOR REPORTING PERIOD:

Task 2.1 – Test Fuels Characterization

- *Obtain a second 5 gallon sample of the low reactivity coal and perform ASTM analyses.*

A second five (5) gallon sample of the medium volatile, low reactivity, bituminous coal was obtained and analyzed for ASTM properties in August. As shown in Table 1, the low reactivity coal sample has 26.8% VM on a dry ash free basis, consistent with the program objectives, and the previously reported fuel analysis. The sulfur (1.5%) and ash contents (13.0%) of the 2nd coal sample are now also within the specified fuel composition.

- *Determine high temperature volatile matter yield from a 200x400-mesh size cut in the DTFS-1 in nitrogen gas at 2650 ºF and ~ 0.5 sec. residence time.*
- *Determine fuel nitrogen evolution from three size cuts -- 200x400-mesh, 270x400-mesh, and -400 mesh -- in the DTFS-1 in argon gas at 2650 ºF and ~ 0.5 sec. residence time.*

Three size cuts (200x400-mesh, X_{mean} ~ 55 µm; 270x400-mesh, X_{mean}~ 40 µm; and 100% -400-mesh, X_{mean} ~ 20 µm) were prepared from the above noted medium volatile coal sample. Each size fraction will be tested in the Drop Tube Furnace System-1 (DTFS-1) for high temperature volatile matter yields, fuel nitrogen evolutions, and TGA char reactivities in September.

- *Send out a representative coal sample to an independent lab for petrographic analysis.*

A coal sample was sent to an independent lab for petrographic analysis. Results of this analysis will be reported along with completed bench scale evaluations in the September month end.

Table 1 – Medium Volatile Bituminous Coal Sample Analysis

	Med Vol Bit Spec.	Med Vol Bit Initial	Med Vol Bit Final
Proximate			
VM	24.3%	22.1%	22.1%
FC	57.9%	58.2%	60.4%
FC/VM	2.38	2.63	2.73
VM, DAF	28.1%	27.5%	26.8%
Ultimate			
Moisture	-	3.6%	4.5%
Hydrogen	4.6%	3.8%	4.1%
Carbon	71.8%	69.8%	72.5%
Sulfur	1.5%	1.9%	1.5%
Nitrogen	1.3%	1.2%	1.1%
Oxygen	7.2%	3.6%	3.3%
Ash	13.7%	16.1%	13.0%
Total	100.0%	100.0%	100.0%
HHV, BTU/lb	12,689	12,292	12,729
HGI	79		78
Ash Fusion T. (^oF)	Reducing Atm.	Reducing Atm.	Reducing Atm.
I.T.	2,600		2,620
S.T.	2,620		2,645
H.T.	2,670		2,670
F.T.	2,720		2,690

Task 2.3 – Global Mixing Process Improvement

- *Continue post-processing of the CFD cases to examine the impact of SOFA mixing on predicted CO and carbon in ash levels.*

Additional post processing was performed on the previously executed suite of CFD cases to examine the impact of SOFA mixing on the CO and carbon in ash (CIA) levels. Figure 1 shows the predicted improvement in SOFA mixing, along with changes in CIA and CO levels for variations to SOFA injection velocity for the BSF equip with a TFS 2000™ low NOx firing system.

As previously shown, the degree of SOFA mixing increases with increasing velocity (decreasing nozzle free area) suggesting a significant improvement in mixing can be made through the use of higher injection velocities for current T-fired SOFA designs. However, as illustrated in the figures, the modeling results indicate that an increase in mixedness (as defined in this study) does not always result in lower carbon in the ash and CO.

As shown in Figure 1, there was an initial decrease in CO and CIA as the SOFA velocity increased for the modeled 2 SOFA system. However, the CFD modeling predicted that further increases in SOFA velocity resulted in no additional improvement, or slightly degraded performance, suggesting an optimum range of velocity for a given boiler design. Validation of this effect is planned to be made during the up-coming BSF combustion testing.

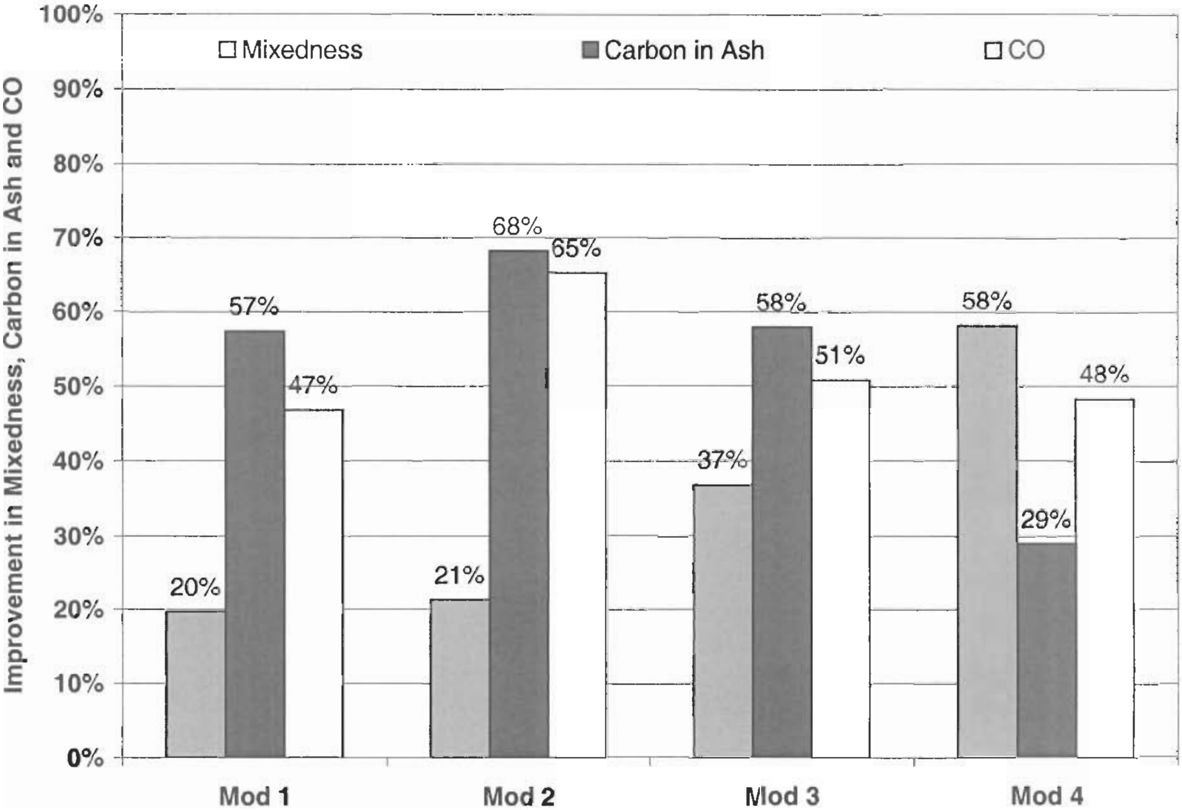

Figure 1 – Mixedness, %CIA, CO vs. Velocity for T-Fired OFA Systems

- *Continue CHEMKIN modeling of high temperature SNCR process.*

Additional CHEMKIN modeling was performed to examine the impact of oxygen concentration on the high temperature SNCR process. At typical boiler temperature and residence times, predicted NOx reduction in the absence of oxygen was found to be ~65% as reported in the July month end. As oxygen concentration is increased, however, Chemkin modeling results suggest that NH3 is preferentially oxidized to form NO, negating the value of this approach for NOx reduction.

As shown in Figure 2, at 1% O2, Chemkin results suggest that NO will increase by 11% at NH3 to NO molar ratios of 2:1. At 2% O2, the Chemkin results suggest that NO will increase by 39%, a significant change over the baseline NO levels. Thus, as indicated by the modeling results, for high temperature SNCR to be effective the NH3 must be injected in the absence of oxygen / away from combustion air sources.

This information will be used along with in-furnace species concentration data from previously performed BSF testing to identify appropriate locations for ammonia injection in the BSF for resultant evaluation during the up-coming combustion test campaign.

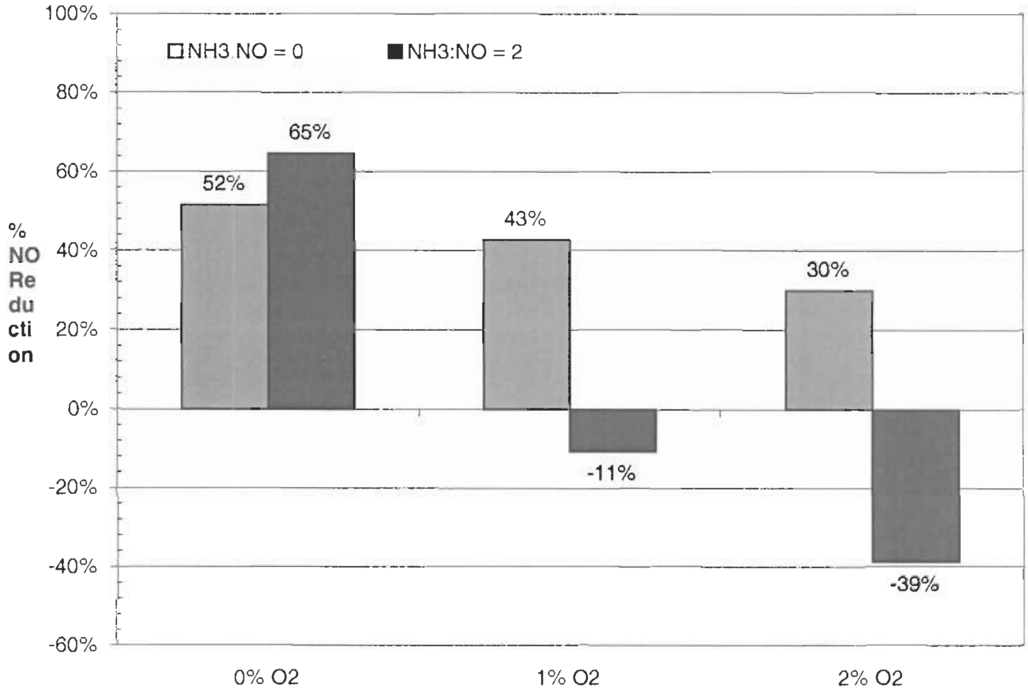

Figure 2 – Predicted NO reduction as a function of O_2 and NH_3 concentration.

Task 2.4 – Advanced Control System Design

- *Install and check-out Coal Flow sensors.*

Delivery of the ABB Instrumentation PC Flow meters has slipped to the week of September 18th due to delays in their manufacture. In anticipation of this, where possible, preparations have been made to facilitate the installation of the flow meters including: installing the mounting flanges, installing a box to house the electronics, and running conduit, etc. in advance of their receipt. In addition, the existing 2-way coal splitters were modified to add a mechanism to allow the coal mass flow splits to be adjusted online to support the evaluation of coal and air flow balancing under this project.

- *Obtain field data set and begin NOx-heat rate and carbon in ash neural net modeling.*

Three large Tangentially Fired Pulverized Coal Utility Boiler units having suitable data sets have been identified by Pavilion Technology and Reliant Energy. Final approval to use the data sets has not, however, been received.

Task 3.1 – Test Planning & Facility Preparation

- *The following work will be completed in August for Task 3.1:*

  Plumbing / Mechanical

  - *Repair ignitor horns*
  - *Mark & install corner SOFA assemblies*
  - *Begin installation of main windbox coal and air nozzles*

On the mechanical side, the ignitor horns were repaired and 7 of the 8 SOFA assemblies were installed. Installation of the last SOFA assembly was delayed to allow easy access to the furnace through its installation port. All main windbox coal and air nozzles have been installed with the exception of 2 CFS nozzles which are being fabricated to allow access for the flame scanner sight pipes.

A photo of the installed firing system components is given in Figure 3 below.

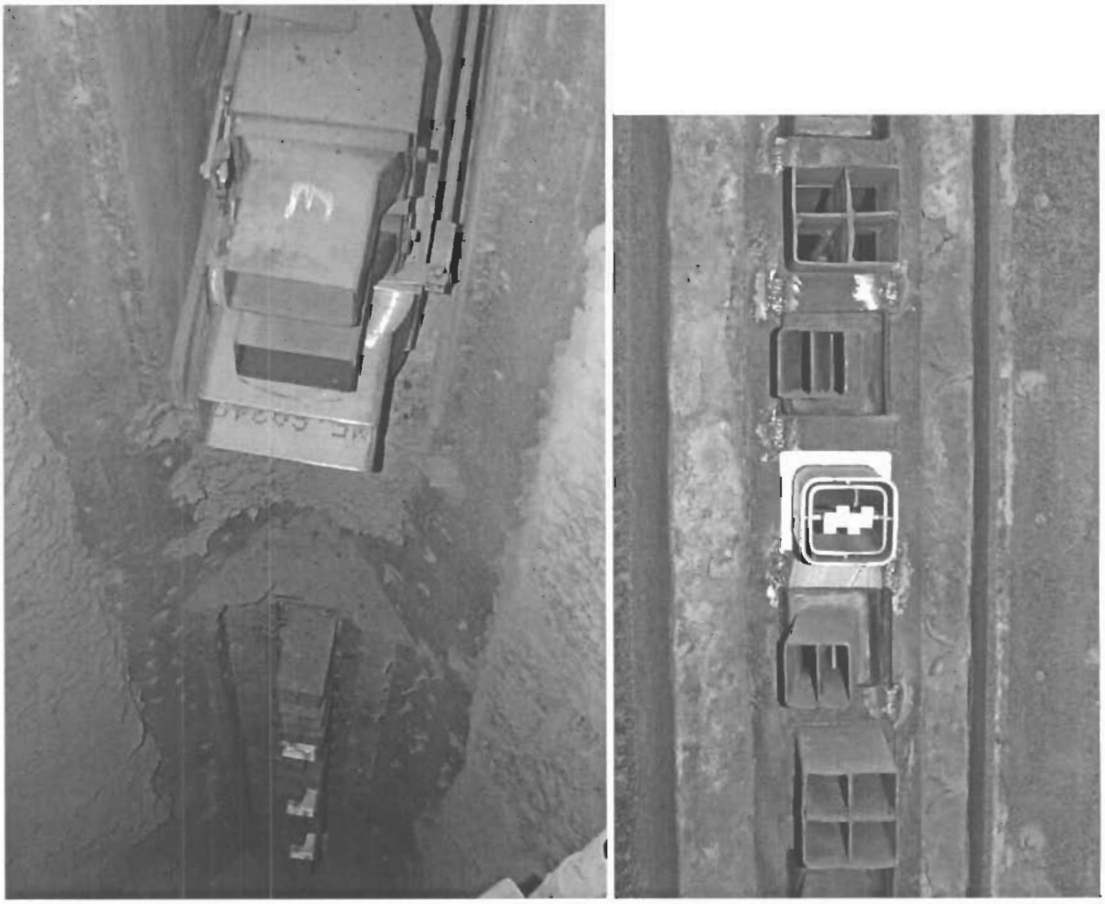

Figure 3 – Installed Firing System Components for Large Pilot Scale Testing

In addition, the coal piping was modified to mount the coal splitters (modified with the coal diverters) to adjust the coal mass flow distribution. The remaining SOFA feed ductwork was also installed and the ignitor fan was repaired and reinstalled.

All known leaks in the BSF water jacket have been repaired with the exception of a leak in the simulated economizer tubes. A flue gas path isolation plate must be removed before the extent of damage to the economizer tubes can be determined. Repair to these tubes will be performed in September after completion of testing in an associated combustion test facility.

Electrical

- *Calibrate BSF O2 sensor,*
- *Calibrate U-tube heat flux probe flow meters,*
- *Check-out audio and video system,*
- *Loop RTD sent out for calibration,*
- *Install flue gas heat exchanger level control,*
- *Confirm the BSF DCS system operability,*

On the electrical side, the in-furnace camera system was checked out and 4 of the loop RTD's were calibrated and reinstalled. One RTD has not yet been received from the vendor who was performing the calibration. The manometers were cleaned and installed and the lines were leak tested. Some parts of the DCS system have been checked out, although much of the system can not be tested until remaining mechanical preparation work is completed.

The water level control valve has been ordered, but not yet received. The calibration of the O_2 sensor and the U-tube heat flux probe flow meters was postponed. In addition, required soot blower components have been received but not yet installed.

Task 4 – Carbon Burnout System Evaluation

- *Complete CBO™ feasibility study*

A preliminary economic evaluation of seven low NOx control systems as applied to a hypothetical 500 MWe (Base) plant firing a medium to high volatile Eastern Bituminous coal was performed and reported on last month. Evaluated cases included:

#	Low NOx Control System Description
1	Base uncontrolled tangential firing unit
2	Modified with SCR
3	Modified with TFS2000™R
4	Modified with TFS2000™R plus SCR polishing system
5	Modified with TFS2000™R plus advanced control system
6	Modified with TFS2000™R plus advanced control system plus CFI
7	Modified with TFS2000™R plus advanced control system plus CFI plus SNCR
8	Modified with TFS2000™R plus advanced control system plus CFI plus SCR

In August, the economic evaluation was expanded to include several designs firing Eastern Bituminous coal containing low quantity of volatile matter. The analyses were limited to the low NOx emission system installed for Case 7 which includes a TFS 2000™R system combined with an advanced control system, coal fines injection (CFI) and SNCR. This was shown to be the most cost effective of the solutions currently evaluated to achieve less than 0.15 lb/MMBtu firing a bituminous coal.

When firing low volatile coal it was assumed that the advanced firing system may result in an undesireable increase in carbon loss which could be mitigated through the use of the CBO™ Carbon Burnout system. For this analysis, two carbon loss levels were considered equivalent to 7.5% and 10% carbon in the fly ash. A preliminary financial analysis showing the impact of pre- and post CBO™ system application for these high carbon loss levels is summarized in Table 2. Cases 7A and 7B present pre-CBO™ system costs for the 7.5% and 10% carbon in ash cases while cases 7C and 7D present the respective post-CBO™ application results.

CBO™ plant performance for all cases was estimated based on existing commercial plant data. Increasing firing rate made up potential loss of load due to the increased carbon loss. Additionally, a differential cost of $8/ton ($5/ton disposal and $3/ton sale) was assumed between the cost to dispose of the high carbon fly ash absent the CBO™ system, and the value recovered from the sale of the expected low (<2%) carbon CBO™ fly ash product. Financial results were benchmarked against Case 2 which represents an uncontrolled tangentially fired unit using SCR to decrease the NOx loading from 0.7 lb/Mbtu to 0.15 lb/MBtu consistent with the overall objectives of the program.

Comparison of the cases with and without the Carbon Burnout system show that while application of CBO™ results in higher investment costs, the cost of generating power is slightly smaller or the same. These results are preliminary and more detail analyses are required to quantify the benefits of the CBO™ system. The use of the CBO™ system, however, will become more attractive when cost of ash disposal is high and when revenue can be created from selling the fly ash to cement industry or when carbon losses are significantly higher than used in the present analysis.

Table 2 Preliminary Economic Analysis with CBO™.

Case #	1	2	7A	7B	7C	7D
Case ID	Base	SCR	Case 7 7.5% CIA	Case 7 10% CIA	Case 7A + CBO	Case 7B + CBO
Capital Cost Constrution $K	$0	$18,520	$15,250	$15,250	$20,507	$21,796
Tons of NOx Removed/Yr	0	9,726	9,726	9,726	9,726	9,726
NPV (KUSD)	NA	$52,244	$45,711	$47,598	$47,593	$50,587
Increase in $/MWhr	NA	$0.80	$0.74	$0.77	$0.73	$0.77
K$/Ton NOx removed	NA	$5.4	$4.7	$4.9	$4.9	$5.2

Notes:
7A - no carbon burn out cell, 7.5% carbon loss in flyash
7B - no carbon burn out cell, 10% carbon loss in flyash
7C - with carbon burn out cell, 7.5% carbon loss in flyash
7D - with carbon burn out cell, 10% carbon loss in flyash

Task 8 – Project Management

- *Hold internal project status review meeting; make go / no go decision for Combustion Test Period #1 (Note: this activity may be delayed into September to correspond with the postponement of the first combustion test period).*

The internal project review meeting is currently scheduled for September 12.

WORK PLANNED FOR NEXT REPORTING PERIOD:

Task 2.1 – Test Fuels Characterization

- Determine high temperature volatile matter yield from a 200x400-mesh size cut in the DTFS-1 in nitrogen gas at 2650 ºF and ~ 0.5 sec. residence time
- Determine fuel nitrogen evolution from three size cuts -- 200x400-mesh, 270x400-mesh, and -400 mesh -- in the DTFS-1 in argon gas at 2650 ºF and ~ 0.5 sec. residence time.

Task 2.4 – Advanced Control System Design

- Install and check-out Coal Flow sensors
- Obtain field data set and begin NOx-heat rate and carbon in ash neural net modeling
- Initiate evaluation of the economic benefits of advanced control system

Task 3.1 – Test Planning & Facility Preparation

Plumbing / Mechanical

- Prepare coal transport and storage systems
- Install ignitor fan ducting
- Repair economizer tubes (as needed)
- Repair BSF refractory
- Seal the 5ft duct
- Insulate the BSF hopper
- Begin coal pulverization
- Service scrubber system

Electrical

- Calibrate BSF O2 sensor
- Calibrate U-tube heat flux probe flow meters
- Install flue gas heat exchanger level control
- Complete all other identified tasks to allow shakedown of DCS system
- Confirm the BSF DCS system operability

Task 8 – Project Management

- Hold internal project status review meeting; make go / no go decision for Combustion Test Period #1