Quarterly Technical Progress Report
for the period ending June 30, 2002

METHANE de-NOX® for Utility PC Boilers

Covering Period: April 1, 2002 to June 30, 2002

Principal Authors: Joseph Rabovitser
Bruce Bryan
Serguei Nester
Stan Wohadlo

Date of Report: July 30, 2002

Award Number: DE-FC26-00NT40752

DOE Project Officer:

Bruce Lani
U.S. Department of Energy
National Energy Technology Laboratory
P.O. Box 10940, MS 922-273C
Pittsburgh, PA 15236-0940

Submitting Organization:

Institute of Gas Technology (IGT)
1700 Mount Prospect Road
Des Plaines, IL 60018-1804

IGT Technical Contacts:

Joseph Rabovitser
(847) 768-0548
Joseph.Rabovitser@gastechnology.org

Bruce Bryan
(847) 768-0591
bruce.bryan@gastechnology.org

Subcontractors: Babcock Borsig Power (BBP) [formerly DB Riley, Inc. (DBR)]
All-Russian Thermal Engineering Institute (VTI)

DISCLAIMER

ABSTRACT

The project seeks to develop and validate a new pulverized coal combustion system to reduce utility PC boiler NO_x emissions to 0.15 lb/million Btu or less without post-combustion flue gas cleaning. Work during previous reporting periods completed the design, installation, shakedown and initial PRB coal testing of a 3-million Btu/h pilot system at BBP's Pilot-Scale Combustion Facility (PSCF) in Worcester, MA. Based on these results, modifications to the gas-fired preheat combustor and PC burner were defined, along with a modified testing plan and schedule.

During the current reporting period, a revised subcontract was executed with BBP to reflect changes in the pilot testing program. Modeling activities were continued to develop and verify revised design approaches for both the Preheat gas combustor and PC burner. Reactivation of the pilot test system was begun with BBP personnel. A presentation on the project results to date was given at the NETL-sponsored 2002 Conference on SCR and SNCR for NOx Control on May 15-16, 2002 in Pittsburgh PA.

EXECUTIVE SUMMARY

Project Objectives: The overall project objective is the development and validation of an innovative combustion system, based on a novel coal preheating concept prior to combustion, that can reduce NO_x emissions to 0.15 lb/million Btu or less on utility pulverized coal (PC) boilers. This NO_x reduction should be achieved without loss of boiler efficiency or operating stability, and at more than 25% lower levelized cost than state-of-the-art SCR technology. A further objective is to make this technology ready for full-scale commercial deployment in order to meet an anticipated market demand for NO_x reduction technologies resulting from the EPA's NO_x SIP call.

Background: Conventional measures for NO_x reduction in PC combustion processes primarily rely on combustion modifications and post combustion controls. In general, combustion modification technologies try to reduce the formation of NO_x precursors while destroying already-formed NO_x. A variety of NO_x reduction technologies are in use today, including Low-NO_x Burners (LNB's), flue gas recirculation (FGR), and gas or other fuel reburning. Selective Non-Catalytic Reduction (SNCR) and Selective Catalytic Reduction (SCR) are post combustion techniques. NO_x reduction efficiencies from these technologies vary from 30 to 60%, with up to 90% for SCR.

A novel pulverized coal-preheating approach for NO_x reduction has been developed by the All Russian Thermal Engineering Institute (VTI), in Russia, for use on PC utility boilers. The technology consists of a burner modification that preheats pulverized coal to elevated temperatures (up to 1500°F) prior to coal combustion. This releases coal volatiles, including fuel-bound nitrogen compounds, into a reducing environment, which converts the coal-derived nitrogen compounds to molecular N_2. The quantity of natural gas fuel required for PC preheating is in the range of 3 to 5% of the total burner heat input. Basic combustion research and development of the preheat PC burner was conducted by VTI in the early 1980's. Following these promising laboratory results, commercial-scale coal preheat burners of 30 and 60 MW_t capacity were developed and demonstrated in field tests conducted in several Russian power stations.

The advanced pulverized coal (PC) preheat combustion system being developed in this project for direct-fired PC boilers combines the modified VTI preheat burner together with elements of IGT's successful METHANE de-NOX technology for NO_x reduction. METHANE de-NOX has been commercially demonstrated on coal, MSW and biomass-fired stoker boilers in the U.S. and Japan. Overall, the new PC preheat system combines several NO_x reduction strategies into an integrated, low-NO_x, PC combustion system, including a novel PC burner design using natural gas-fired coal preheating, and internal and external combustion staging in the primary and secondary combustion zones. This integrated system can achieve very low NO_x levels – down to 0.15 lb/million Btu – without the complications, limitations and expense of SCR or SNCR technology.

Work during previous reporting periods completed the design, installation, shakedown and initial PRB coal testing of a 3-million Btu/h pilot system at BBP's Pilot-Scale Combustion Facility (PSCF) in Worcester, MA. Analysis of test data demonstrated that the PC Preheat process has a significant effect on final NO_x formation in the coal burner and that the mechanism by which this is effected is not directly controlled by the final preheat temperature but rather by the residence time of the coal in the high temperature region within the gas-fired preheat combustor. A second significant determination from testing was that the PC burner design utilized was not optimally constructed for low-NO_x combustion of the preheated char and pyrolysis products generated in the preheat combustor. Modifications to the PC Preheat pilot system gas-fired combustor and PC burner were determined to be necessary in order to test the full potential of the PC Preheat process for NO_x reduction. A revised testing plan and schedule was also developed to complete the pilot-scale testing and development activities. BBP's subcontract was then modified to reflect changes in the pilot testing program, and the modifications to the gas-fired preheat combustor were completed. The Computational Fluid Dynamics (CFD) modeling approach was defined for the combined PC burner and 3-million Btu/h pilot system and modeling of the modified gas-fired preheat combustor was started.

During the current reporting period, a revised subcontract was executed with BBP to reflect changes in the pilot testing program. Modeling activities were continued to develop and verify revised design approaches for both the Preheat gas combustor and PC burner. Reactivation of the pilot test system was begun with BBP personnel. A presentation on the project results to date was given at the NETL-sponsored 2002 Conference on SCR and SNCR for NOx Control on May 15-16, 2002 in Pittsburgh PA.

Project Status:

EXPERIMENTAL

Task 1.1 *Pilot-Scale Design*

All work in this task is complete.

Task 1.2 *CFD Modeling*

Modeling studies for the modified PC Preheat gas combustor were continued using flow conditions from the previous pilot-scale tests with the computational mesh generated for the modified combustor during the previous quarter (Figure 1). Completed modifications to the pilot-scale combustor are shown in Figure 2. As discussed in the previous report, combustor modifications were required to increase the residence time of the pulverized coal in the high temperature region of the combustor. In addition to increasing the length of the combustion chamber, a set of secondary gas inlets was added partway down the chamber from the coal inlet to reheat the pyrolysis products after initial devolatilization. The effect of this modification can be seen in Figure 3, where a secondary flame front is seen to develop at the secondary gas inlet. The model indicates that the average residence time of coal particles in the high temperature chamber is increased from 0.11 seconds to 0.2 seconds.

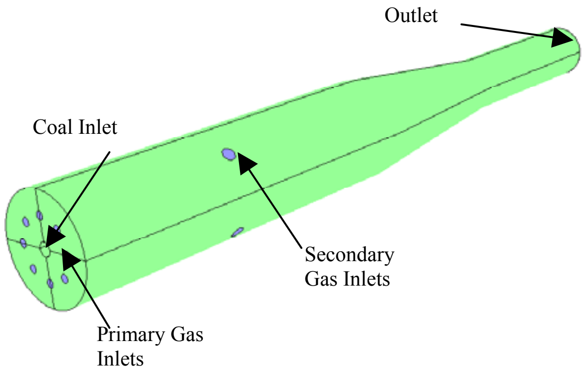

Figure 1. Modified gas-fired combustor design for the PC Preheat pilot-scale test

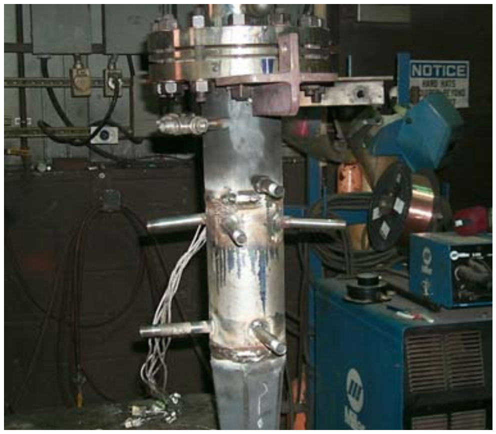

Figure 2. Modified gas-fired combustor for pilot-scale testing

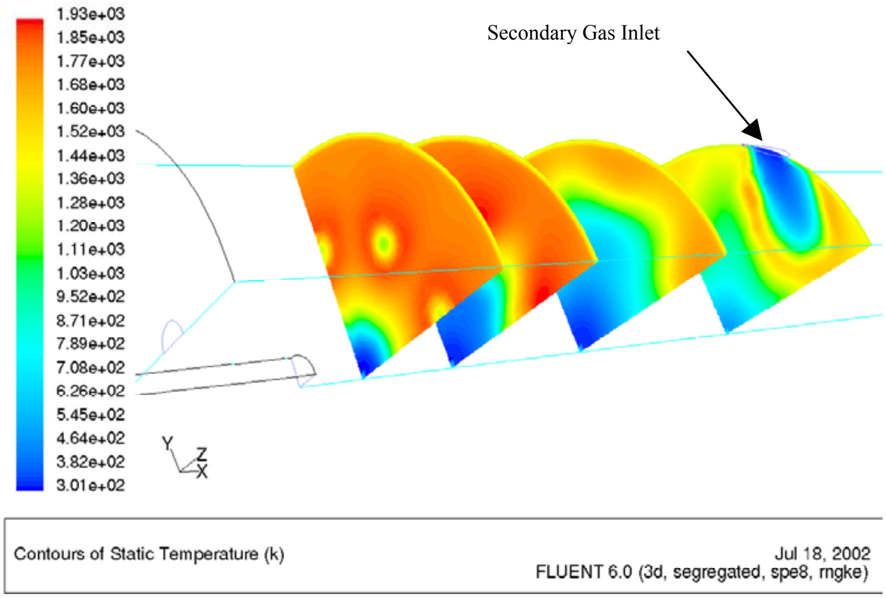

Figure 3. Temperature contours for the modified gas combustor

Previous evaluation of data from pilot-scale testing with the unmodified gas combustor clearly indicated that in addition to changes in the gas combustor design, the pulverized coal (PC) burner would also require modification from the original pilot-scale design in order to perform as a low-NO_x burner in the PC Preheat system. The original PC burner, shown in Figure 4, would have been an appropriate low-NO_x design for unheated pulverized coal applications. With preheated coal, however, the hot char and pyrolysis gas mixture entering the burner combusts much more rapidly than unheated coal, producing a very short, intense flame as shown in Figure 5.

Figure 4. Original PC burner used for pilot-scale PC Preheat testing

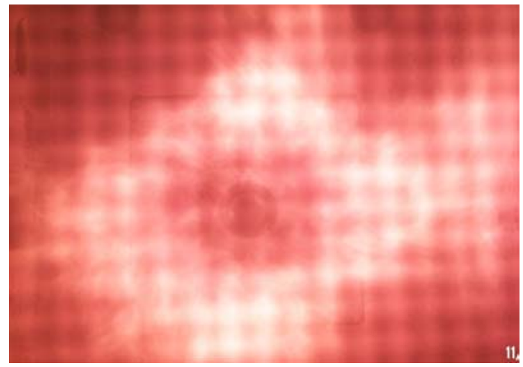

Figure 5. Short, intense coal flame produced with the original PC Burner design

It is apparent that the PC burner design must be modified to significantly improve air staging to allow low-NO_x combustion of the highly reactive preheated coal products. A modified PC Burner design was therefore developed around design concepts normally employed in GTI's natural gas-fired low-NO_x burner designs. Computational meshes were developed for both the original and modified burner designs in order to compare their flame characteristics and optimize the modified design for preheated coal. Modeling of velocity vectors in the original PC burner design is presented in Figure 6, which shows the original three tangential air inlets with swirl.

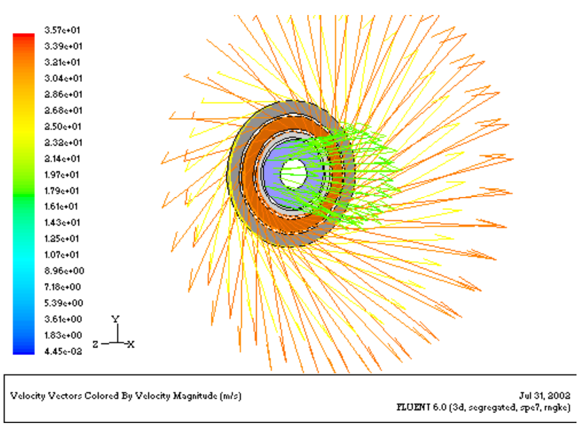

Figure 6. Velocity vectors for the original PC burner design

The resulting flame is very short, with a very limited fuel-rich zone indicative of a poorly staged flame. Figures 7 and 8 compare the reducing regions produced in the original and modified pilot PC burners, respectively. In the modified burner, a much longer "reducing zone" is produced, allowing NO_x precurors to be destroyed and more heat to be removed from the flame before final burnout. This comparison indicates that the modified burner design approach is much more suitable for the highly reactive preheated fuel produced by the PC Preheat process. Another comparison of the original and modified burner design is shown in Figures 9 and 10, which look at fuel particle path lines from the burner in the pilot furnace. Again, a short, intense mixing region is shown immediately in front of the burner with the original design with very little recirculation of particles in the upper and lower furnace.

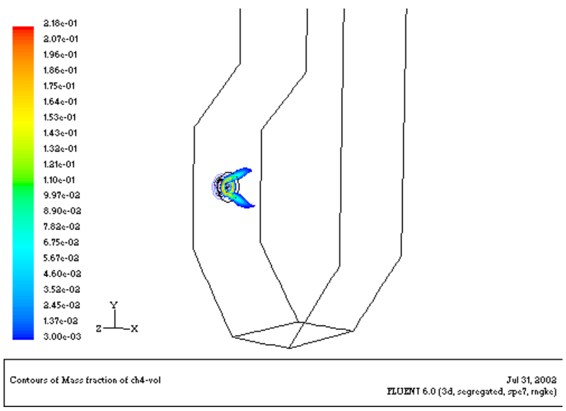

Figure 7. Vertical cross section of the fuel-rich region in the original PC burner flame

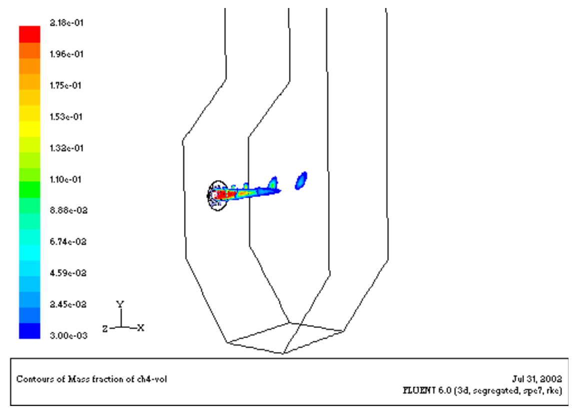

Figure 8. Vertical cross section of the fuel-rich region in the modified PC burner flame

Figure 10, however, shows a significantly longer mixing profile with much more recirculation of particles in both the lower and upper furnace. The result will be a longer, more staged flame and a significantly more reducing atmosphere in the lower furnace, both of which will contribute to much lower NO_x production.

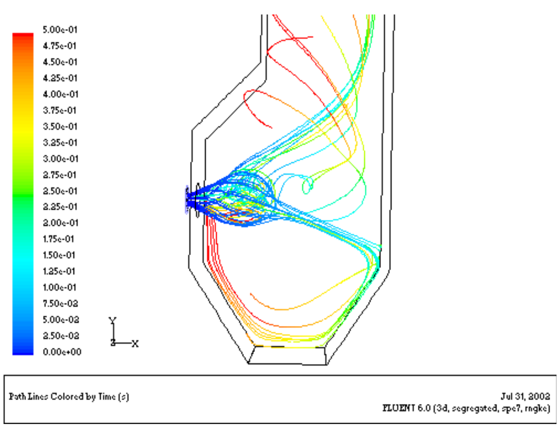

Figure 9. Fuel particle path lines with the original PC burner design

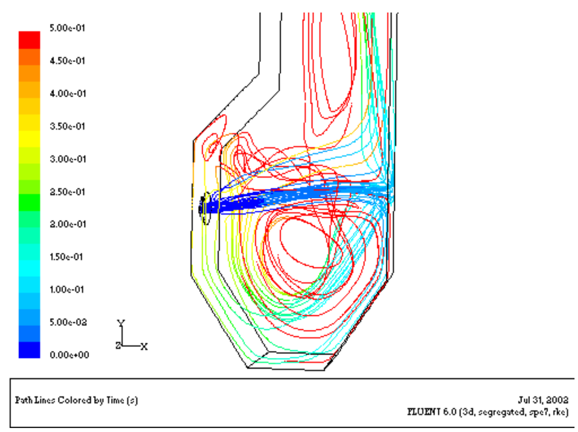

Figure 10. Fuel particle path lines with the modified PC burner design

Task 1.3 *Pilot-Scale Equipment Fabrication and Installation*

PCP Combustor Pretesting

All work in this task is complete.

Pilot Test Unit Installation at BBP

Fabrication, installation and shakedown of the original pilot-scale PC Preheat system equipment are complete. Based on initial testing of this system, a modified gas-fired combustor design was developed for the pilot test system. Fabrication of the modified combustor was completed during the previous reporting period. The pilot facility is currently being readied to accept the modified gas combustor.

Task 1.4 *Pilot-Scale Testing*

No testing was conducted during the reporting period while the BBP subcontract scope was modified to include materials and services for testing of the modified gas combustor and PC burner in the pilot-scale test facility. The modified subcontract has now been signed and personnel assigned by BBP to prepare the facility for the resumption of testing. Once the modified combustor is installed in the facility, the following testing sequence will be followed:

- Conduct up to 3 days of testing with PRB coal to confirm proper operation of the modified combustor and characterize NO_x reduction.
- Modify the existing PC burner to provide a distributed, internally-staged flame
- Complete testing with remaining PRB coal to characterize NO_x reduction for the modified preheat combustor and burner system.
- Conduct PCP pilot tests with the other test coals, Central Appalachia, Southern Appalachia and Illinois Basin.

Task 1.6 Task 1 Management and Reporting

Work during the quarter included project review and planning correspondence with VTI and BBP, completion of the BBP subcontract modifications to accommodate changes in the pilot test program, and preparation of the quarterly report. In addition, a presentation on the project results to date was given at the NETL-sponsored 2002 Conference on SCR and SNCR for NOx Control on May 15-16, 2002 in Pittsburgh PA.

Plans for Next Quarter:

- Install the modified gas-fired combustor and make combustion tests with PRB coal
- Finalize PC Burner modifications with VTI and BBP burner design experts
- Fabricate the modified PC Burner and install in the pilot test facility
- Continue pilot testing with PRB, Central Appalachia, Southern Appalachia and Illinois Basin coals.
- Update the overall project schedule and cost plan based on revisions to the pilot test plans and the BBP subcontract. Develop a revised Estimated Cost to Complete.

Milestone Status Table: The planned completion dates for all project tasks and major milestones are currently be revised.

ID No.	Task / Milestone Description	Planned Completion	Actual Completion	Comments
♦	Kickoff Meeting	5/2/2000	5/2/2000	Complete
1.0	Technology Development			
1.1	Pilot-Scale Design	8/31/2000	12/31/2000	Complete
1.2	CFD Modeling-Pilot and Commercial Scale	6/30/2001		Modeling modified pilot-scale combustor and burner
1.3	Pilot-Scale Equipment Fabrication and Installation	11/30/2000	9/30/2001	Initial equipment installation complete. Modifications now underway
1.4	Pilot-Scale Testing	3/31/2001		Initial PRB testing complete. Testing to resume with modified combustors
1.5	Pilot-Scale Data Evaluation	4/30/2001		Initial PRB test data processing completed.
1.6	Task 1 Management and Reporting	4/30/2001		Completion expected 3/2003
♦	Task 1 Report	4/30/2001		Completion expected 3/2003
2.0	Technology Validation			
2.1	Commercial Prototype Engineering Design	7/31/2001		
2.2	Baseline Data Review	7/31/2001		
2.3	Commercial Prototype Construction	10/31/2001		
2.4	Commercial Prototype Testing	2/15/2002		
2.5	Data Processing and Evaluation	3/31/2002		
2.6	Commercialization Plan Development	6/15/2002		
2.7	Design and Fabrication of Commercial Burner System	7/31/2002		
2.8	Task 2 Management and Reporting	8/10/2002		
♦	Final Report	8/10/2002		