Quarterly Technical Progress Report
for the period ending December 31, 2001

METHANE de-NOX® for Utility PC Boilers

Covering Period: October 1, 2001 to December 31, 2001

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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 the quarter included completion of the equipment fabrication and installation efforts for the 3-million Btu/h pilot system at BBP's Pilot-Scale Combustion Facility (PSCF) in Worcester, MA. Selection and procurement of the first two test coals and preliminary selection of the final two test coals were completed. Shakedown and commissioning activities were finished and PC Preheat pilot scale tests commenced with PRB coal.

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.

Status:

EXPERIMENTAL

Task 1.1 *Pilot-Scale Design*

All work in this task is complete.

Task 1.2 *CFD Modeling*

Development of a CFD model of the pilot-scale PC preheat system was completed during the 4th quarter of 2000. Modeling of the 100-million Btu/h PC Preheat prototype will be started once pilot-scale operating data is available.

Task 1.3 *Pilot-Scale Equipment Fabrication and Installation*

<u>PCP Combustor Pretesting</u>

All work in this task is complete.

<u>Pilot Test Unit Installation at BBP</u>

Fabrication of all pilot-scale PC Preheat system equipment is complete. Refurbishment of BBP's pilot-scale 3 mmBtu per hour combustion facility is complete. Installation of the PC Preheat (PCP) system simulating an indirect or bin-fired PC burner system is complete. Final shakedown and commissioning is complete of all pilot-scale facility and PC Preheat mechanical equipment, electrical power, instrumentation, controls and data acquisition. A pictorial arrangement of the PCP unit is illustrated in figures #1 through #3

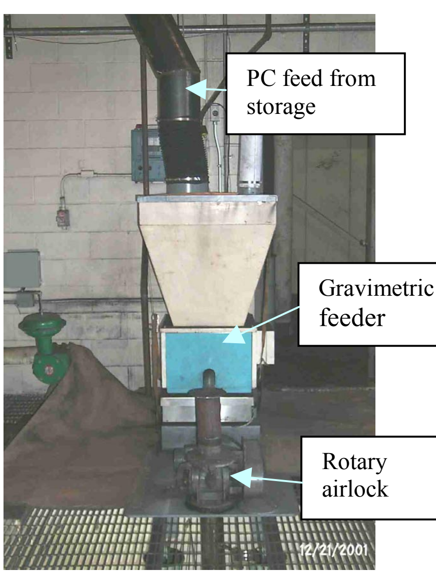

Figure 1.

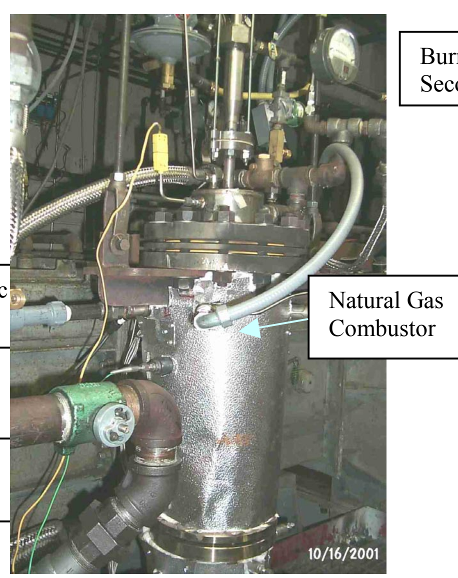

Figure 2.

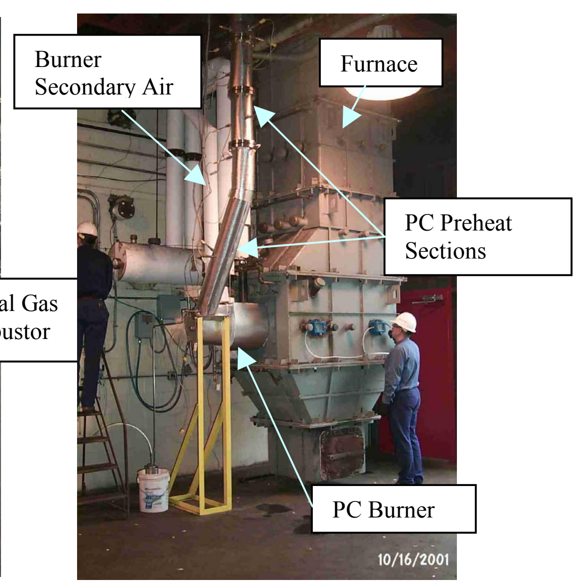

Figure 3.

Briefly, the PCP pilot system regulates PC flow with a gravimetric feeder; from the feeder PC gravity drops through a rotary airlock into the Natural Gas Combustor. The Combustor produces hot combustion gases, which combines with and preheats the PC to elevated test temperatures. Two preheat sections after the combustor provide additional time at preheat conditions. The PC burner via dedicated flow channels controls mixing of the preheat PC stream and hot secondary air in the furnace producing a coal flame.

The pilot-scale combustion facility control room is illustrated in figure 4. This room houses the facilities gas analyzers, central control panel and the data acquisition system (DAS). The central control panel operates the facilities major equipment such as the FD and ID fans. Flue gas samples are cooled, dried and filtered in the field before the analyzers and the data acquisition system (DAS) is based on a personal computer platform.

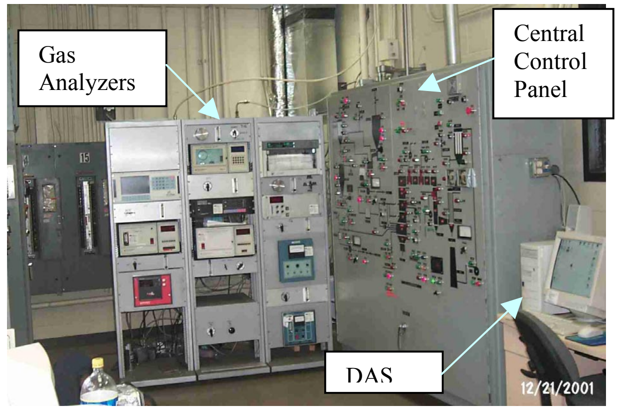

Figure 4.

Task 1.4 *Pilot-Scale Testing*

Operation and testing of the 3-mmBtu/hr PCP pilot unit started this quarter. The first test coal is a PRB coal out of the Rochelle/North Antelope mine from the Wyodak-Anderson seam in Wyoming. This coal was obtained with support of the Hennepin Power Station, figure 5, in northern Illinois. Five tons was delivered to the BBP Research Center in super sacks, figure 6.

Figure 5.

Figure 6.

Before introduction of coal, a functional check of the PCP pilot unit was conducted that confirmed proper and safe operation of the different test system components. A functional test of the Natural Gas Combustor (Combustor) light off discovered a problem with the Combustor's pilot flame operation. This problem was resolved and a reliable light-off procedure was established. Overall, the check out was completed without many troubles and in a timely manner.

Upon receipt, the as-received PRB coal was placed into a 20-ton storage silo and a partial amount pulverized on-site. The PCP pilot unit start-up procedure requires heat up of the test furnace and PC preheat sections to elevated temperatures prior to introduction of coal. Heat from natural gas combustion in the PCP Combustor raises temperatures in the preheat sections while furnace components are heated via insertion of a 1-mmBtu/hr gas-fired ignitor placed in the test furnace chamber. Spring hangars and a compensator element in the PCP pilot system worked well handling the system thermal growth of about 2 inches. PC flow starts after elevated temperatures are obtained in the PCP pilot system and furnace. Initial tests of the PCP pilot unit demonstrated stable PC flow rates up to 250 lb/hr. At PC flow rates above 150 lb/hr, the furnace gas ignitor is shut down and retracted from the chamber leaving the coal flame. A picture of the coal flame (with furnace ignitor retracted) produced from the PC Burner is shown in figure 7.

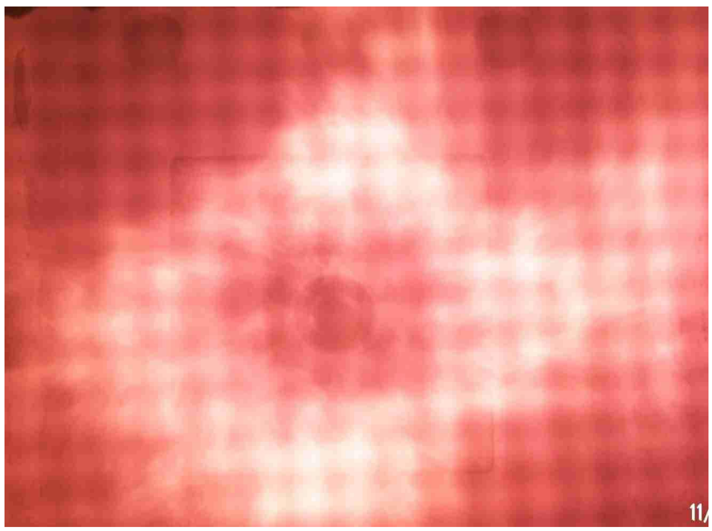

Figure 7.

The test objective with coal was to substantiate the NO_x reduction effectiveness of the PC preheat technology. On a high volatile coal such as PRB, VTI guidance estimated a preheat temperature of 1300 °F is needed. Early PCP pilot tests were unable to achieve this desired preheat temperature, however. High-pressure drops were observed in the Combustor air and natural gas piping, causing a reduction in flow capacity. This problem was fixed by changing the piping on both air and gas supply arrangements. The PCP pilot-scale system was now capable of preheat temperatures in the range of 1100° to 1400 °F in accordance with VTI guidelines.

Extensive testing ensued. During this quarter, approximately 5,000 pounds of the PRB coal was processed. Test data covering over 50 different periods were collected for analysis. The PCP pilot-scale test unit operated well, problems were experienced but with the continued cooperation of BBP personnel were readily resolved and testing continued. Two staff members from VTI traveled from Moscow and actively participated in PCP pilot-scale tests from end of November through mid December 2001.

During this quarter, a second test coal from Central Appalachia was received by BBP and stored for testing.

Task 1.5 *Pilot-Scale Data Evaluation –*

Major findings from these recent tests in the pilot system with PRB coal provided mixed results. Initial guidance and technology transfer information provided by VTI focused on preheat temperature as the key operating parameter for NO_x reduction, with the extent of NO_x reduction increasing with increasing temperature.

The PCP pilot test system was successfully constructed based on VTI guidance and operation achieved the design preheat temperatures of 1100° to 1400°F. Analysis of test data demonstrated that while the PC Preheat process has a significant effect on final NO_x formation in the coal burner, 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.

Pilot test results from three test runs with PRB coal are given in figure 8. Test parameters for these three tests such as furnace exit oxygen, coal flow, Combustor firing rate, Combustor stoichiometry and exit preheat temperature were very similar. The main difference between these tests was the Mixer gas flow; in test PRB40 Mixer gas flow was double compared to the gas flow rates in tests 41 and 42.

Mixer gas sweeps PC dropping from the rotary feeder through a ½" pipe section into the Natural Gas Combustor main chamber. Increasing the mixer gas flow increases the velocity in this pipe, which propels the coal particle towards the chamber exit changing internal circulation patterns and shortening PC residence time in the Combustor. Residence times given below are approximations predicted from GTI's CFD model of the pilot scale unit. A 45% reduction in NO_x was found as a result of decreasing mixer gas flow, which increased coal residence time in the Combustor zone from 21 ms to 42 ms.

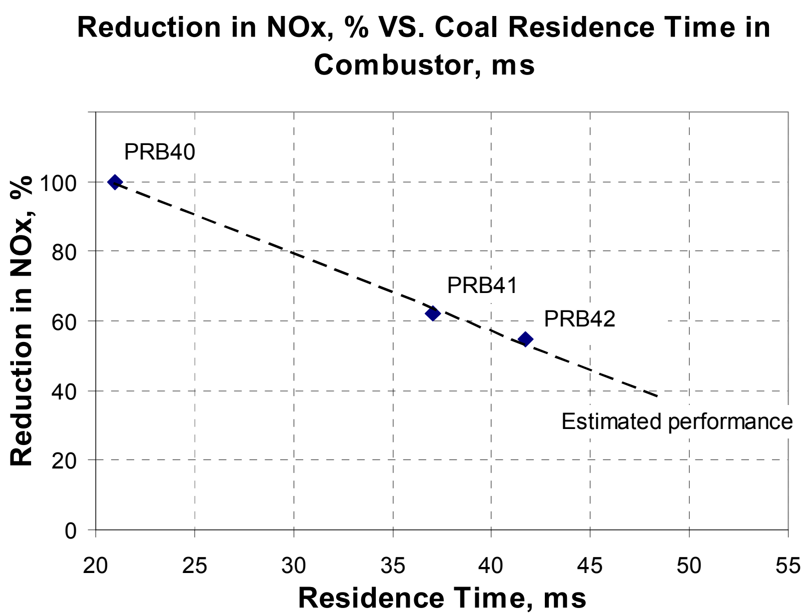

Figure 8.

A second significant determination from testing was that the VTI-designed PC burner was not optimally constructed for low-NO_x combustion of the preheated char and pyrolysis products generated in the preheat combustor. The VTI burner produces a short, hot, intense flame rather than the longer, cooler staged-combustion flame necessary to achieve low NO_x emissions. The required burner design must consider the high proportion of gaseous fuel components present and the fact that the char is already heated to about 1200°F before entering the burner, requiring a more distributed flame with internal staging as in, for example, GTI's gas-fired FIR burner design.

The most notable PCP pilot test period recorded with PRB coal achieved a NO_x emission level of 132 vppm NO_x @ 3% O_2. This test was conducted with the PC Burner operated at low excess air levels. At present, GTI is working with VTI and BBP to finalize modifications to the PCP pilot system Combustor and PC burner to allow testing to determine the full potential of the PC Preheat process for NO_x reduction.

The proposed sequence of steps to complete the pilot testing is as follows:

- Extend the existing gas-fired preheat combustor chamber to double the design residence time and add a tangential gas combustion stage about half way down the extended chamber to maintain elevated preheat temperature throughout the chamber.
- 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, follow-up with the DOE COR for a scheduled increase in the project's funding obligation, increasing the BBP and VTI subcontract funding obligations, and preparation of the quarterly report.

Plans for Next Quarter:

January 23 –February 15: Complete Combustor modifications and make combustion tests of new Combustor configuration to verify operational readiness.

February 18 - February22: Implement PC Burner modifications

February 25 – March 1: Conduct PCP pilot system tests of modified PC Burner with new Combustor configuration using PRB coal.

March 11- March 15: Conduct PCP pilot system tests of modified PC Burner with new Combustor configuration using Central Appalachian Coal.

March 25 – March 29: Conduct PCP pilot system tests of modified PC Burner with new Combustor configuration using Illinois Basin Coal

Milestone Status Table: The planned completion dates for all project tasks and major milestones are shown in the following table.

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		Pilot-scale modeling complete
1.3	Pilot-Scale Equipment Fabrication and Installation	11/30/2000	9/30/2001	Equipment installation complete
1.4	Pilot-Scale Testing	3/31/2001		PRB Testing starts 11/02/2001
1.5	Pilot-Scale Data Evaluation	4/30/2001		PRB test data processing in progress.
1.6	Task 1 Management and Reporting	4/30/2001		Completion expected 1/2002
♦	Task 1 Report	4/30/2001		Completion expected 1/2002
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		