Quarterly Technical Progress Report
for the period ending December 31, 2002

METHANE de-NOX® for Utility PC Boilers

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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 per 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. 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 then begun with BBP personnel.

During the previous reporting period, reactivation of the pilot test system was completed with the modified Preheat gas combustor. Following shakedown of the modified gas combustor alone, a series of successful tests of the new combustor with PRB coal using the original PC burner were completed. NO_x at the furnace exit was reduced significantly with the modified gas combustor, to as low as 150 ppm with only 36 ppm CO (both corrected to 3% O_2). Concurrent with testing, GTI and BBP collaborated on development of two modified designs for the PC burner optimized to fire preheated char and pyrolysis products from the Preheat gas combustor.

During the current reporting period, one of the two modified PC burner designs was fabricated and installed in the pilot test facility. Testing of the modified pilot system (modified gas combustor and modified PC burner) during the quarter included 38 tests with PRB coal. NO_x reduction was significantly improved to levels as low as 60-100 ppmv with CO in the range of 35-112 ppmv without any furnace air staging.

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. A revised subcontract was then executed with BBP 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 then used to develop and verify revised design approaches for both the Preheat gas combustor and PC burner.

During the previous quarter, reactivation of the pilot test system was completed with the modified Preheat gas combustor. A series of shakedown tests firing the modified gas combustor alone were completed successfully, followed by successful tests of the new combustor with PRB coal using the original PC burner. NO_x at the furnace exit was reduced significantly with the modified gas combustor, to as low as 150 ppm with only 36 ppm CO (both corrected to 3% O_2). Redesign of PC burner based on the revised design approaches identified through modeling was completed in collaboration with BBP design engineers. A modified PC burner was fabricated,

installed and tested with the modified gas combustor during the current quarter. NO_x reduction was significantly improved to levels as low as 60-100 ppmv with CO in the range of 35-112 ppmv without any furnace air staging.

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 completed previously using flow conditions from the pilot-scale tests and the computational mesh generated for the modified combustor. As discussed in previous reports, combustor modifications were required to increase the residence time of the pulverized coal in the high temperature region of the combustor. Previous testing also clearly indicated that in addition to changes in the gas combustor design, the pulverized coal (PC) burner would also require modification from the original design in order to perform as a low-NO_x burner in the PC Preheat system. These modeling results were reviewed in detail with BBP engineering personnel and were used as the basis for developing two alternative designs for the modified PC burner. During the current quarter, one of the two PC burner designs developed from the modeling was fabricated, installed in the pilot system and tested. The results of this testing are reported under Tasks 1.3 and 1.4 below.

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. During the previous quarter, fabrication and installation of the modified combustor was completed and improved NO_x reduction performance with the combustor was confirmed. During the current quarter, fabrication and installation of one of the modified pilot-scale PC burner designs was completed.

Task 1.4 *Pilot-Scale Testing*

Shakedown testing of the modified Preheat gas combustor was completed for gas-only operation during the previous quarter. This testing verified mechanical and operational integrity of the combustor including operation in both one- and two-stage gas combustion modes. A series of twelve PRB coal-fired tests were then completed using the modified gas combustor and the original PC Burner design. Significant improvement in the previously attained NO_x emissions was achieved with the gas combustor fired in the single-stage mode. NO_x at the furnace exit was reduced to as low as 150 ppm with only 36 ppm CO (both corrected to 3% O_2). Testing further indicated that increased residence time for coal the high temperature region of the enlarged

combustion chamber was primarily responsible for the improvement in NO_x performance. Operation of the second combustion stage to bring additional heat to this zone was not necessary and indeed, could be detrimental to NO_x reduction. The dependence on residence time was further demonstrated by varying the amount of air entering with the coal into the chamber. Increasing this air increased coal velocity and reduced residence time in the preheat chamber. In all cases, reduced residence time resulted in increased NO_x levels at the furnace exit.

Observation of the PC burner flame during these tests confirmed that modification of the coal burner was still necessary to achieve the full NO_x reduction potential of the PC Preheat approach. For this reason, redesign of the PC burner was continued in collaboration with BBP design engineers. The design approach considered both NO_x performance and fabrication cost and complexity.

During the current quarter, fabrication and testing of one of the two versions of the modified PC burner was completed. Nine tests were then completed with the modified gas combustor and modified PC burner firing PRB coal. NO_x reduction was significantly improved to levels as low as 60-100 ppmv with CO in the range of 35-112 ppmv without furnace air staging. The coal flame from the modified PC burner was observed to be extremely stable and uniform and filled the combustion chamber.

The balance of the original inventory of PRB coal was consumed in these tests, and it was therefore decided to conduct several tests with bituminous Central Appalachian coal at the end of the test week to evaluate operation of the PC Preheat system with caking coal. As anticipated, operation of the pilot unit with caking bituminous coal resulted in incidences of plugging in the system, the severity of which depended on the gas combustor operating conditions. Sufficient testing was completed to allow preliminary analysis of the plug formation and operating parameters used, which indicated several approaches to eliminate plugging in future tests.

Following the tests with Central Appalachian coal all equipment was cleaned to remove the caking coal and combustion residues. Additional PRB coal was obtained and PRB testing continued in order to fully characterize the PC Preheat system operation with respect to the gas combustor operating variables as well as the PC burner operating variables. This was necessary to facilitate development of a conceptual design for the 100 MM Btu/h prototype PC Preheat burner.

A parametric test plan was developed and reviewed with BBP for the additional PRB testing. The test plan addressed four objectives:

- Minimize gas usage
- Evaluate NO_x vs. excess air and air distribution in the new coal burner
- Evaluate NO_x vs. load
- Long term (4-8 hour) performance test

PRB testing was continued and focused on the first test objective of minimizing gas usage. Tests were conducted by varying air to the gas combustor from an S_r of about 0.6 to 0.9, varying the gas combustor firing rate and varying air distribution to the PC burner. The best results were achieved with all burner air directed to the tertiary channel producing a NO_x level of 97 ppm (corrected to 3 % O_2) with furnace exit O_2 at 1.5 % and CO at about 240 ppm.

Task 1.5 *Pilot-Scale Data Evaluation*

Data evaluation for the original pilot-scale system is complete. The data evaluation for the modified pilot-scale system is ongoing.

Task 1.6 Task 1 Management and Reporting

Work during the quarter included project review and planning correspondence with VTI and BBP and preparation of the Quarterly Report. BBP began developing a cost estimate for reactivation of their 100 MMBtu/h Coal Burner Test Facility (CBTF) and for the 100 MMBtu/h PC Preheat burner fabrication, installation and testing.

Plans for Next Quarter:

- Complete parametric testing of the modified PC burner, including "Baseline" test of the PC burner alone without the gas combustor (no preheating)
- Fabricate and install the second version of modified PC Burner and conclude combustion tests with the Preheat gas combustor and burner with PRB coal
- Perform pilot-scale testing with Central Appalachia, Southern Appalachia and Illinois Basin coals.
- Continue pilot data evaluation and modeling as required.
- Develop and review the costs for reactivation of the BBP 100 MMBtu/h Coal Burner Test Facility (CBTF) in preparation for the 100 MMBtu/h PC Preheat burner fabrication, installation and testing.
- Begin preliminary design of the 100 MMBtu per hour PC Preheat burner.

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 complete
1.3	Pilot-Scale Equipment Fabrication and Installation	11/30/2000	9/30/2001	Initial equipment installation complete. Modified gas combustor installation complete
1.4	Pilot-Scale Testing	3/31/2001		Initial PRB testing complete. PRB testing with modified gas combustor complete. Full completion expected 4/2003
1.5	Pilot-Scale Data Evaluation	4/30/2001		Initial PRB test data processing completed. Modified gas combustor data processing complete. Full completion expected 4/2003
1.6	Task 1 Management and Reporting	4/30/2001		Completion expected 5/2003
♦	Task 1 Report	4/30/2001		Completion expected 5/2003
2.0	Technology Validation			
2.1	Commercial Prototype Engineering Design	7/31/2001		Completion expected 5/2003
2.2	Baseline Data Review	7/31/2001		Completion expected 5/2003
2.3	Commercial Prototype Construction	10/31/2001		Completion expected 7/2003
2.4	Commercial Prototype Testing	2/15/2002		Completion expected 10/2003
2.5	Data Processing and Evaluation	3/31/2002		Completion expected 11/2003
2.6	Commercialization Plan Development	6/15/2002		Completion expected 1/2004
2.7	Design and Fabrication of Commercial Burner System	7/31/2002		Completion expected 2/2004
2.8	Task 2 Management and Reporting	8/10/2002		Completion expected 3/2004
♦	Final Report	8/10/2002		Completion expected 3/2004