METHANE de-NOX® for Utility PC Boilers
Quarterly Technical Progress Report
for the period ending March 31, 2004

Covering Period: April 1 – June 30, 2004

Principal Authors: Bruce Bryan
Joseph Rabovitser
Serguei Nester
Stan Wohadlo

Date of Report: July 29, 2004

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:

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

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

Subcontractors: Riley Power Inc. (RPI), a subsidiary of Babcock Power Inc., formerly Babcock Borsig Power.
All-Russian Thermal Engineering Institute (VTI)

DISCLAIMER

ABSTRACT

The primary focus for the project during the quarter was shakedown testing of the large-scale coal preheater prototype in the CBTF with non-caking PRB coal. Additional pilot-scale tests were conducted in the PSCF in support of developing a preheating system design suitable for use with caking coals.

Thirty-two additional pilot tests were conducted during the quarter with caking coal. These tests further evaluated the use of the air-bleed and indirect air-cooled liner designs to reduce or eliminate combustor plugging with caking coal. The air-bleed configurations tested used air injection holes perpendicular to the liner's longitudinal axis with the number, size and air flow though the air-bleed holes varied to determine the effect on combustor plugging. The indirect cooling configurations tested included a stainless steel liner with spiral fins in the annular space between the liner and the combustor wall, and a silicon carbide liner without fins. Continuous pilot operation was maintained for up to 30 minutes at a coal feed rate of 50 lb/h with the air-bleed liner. The best result achieved was for the stainless steel indirect air-cooled liner with 20 minutes of continuous operation at 126 lb/h of coal followed by an additional 20 minutes at 150 lb/h. The NOx results from these continue to indicate that even greater NOx reduction is possible with caking coal than with the PRB coal tested.

The installation of the large-scale prototype coal preheater for PRB testing in the CBTF was completed and shakedown testing with natural gas and PRB coal started during the quarter. Stable operation of the coal system, combustor and burner were achieved at coal feed rates up to 6000 lb/h (50 MMBtu/h).

TABLE OF CONTENTS

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 ready technology for full-scale commercial deployment to meet the market demand for NO_x reduction technologies resulting from the EPA's NO_x SIP call.

Background: A novel pulverized coal-preheating approach for NO_x reduction was developed by the All Russian Thermal Engineering Institute (VTI) for use on PC utility boilers. The approach 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 PC preheating burners of 30 and 60 MW_t capacity were developed and demonstrated in field tests conducted in several Russian power stations.

The advanced PC preheating combustion system being developed in this project for direct-fired PC boilers combines the modified VTI preheat burner approach with elements of IGT's successful METHANE de-NOX technology for NO_x reduction in stoker boilers. The new PC preheating system combines several NO_x reduction strategies into an integrated 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.

Design, installation, shakedown and initial PRB coal testing of a 3-million Btu/h pilot system at RPI's Pilot-Scale Combustion Facility (PSCF) in Worcester, MA demonstrated that the PC Preheat process has a significant effect on final NO_x formation in the coal burner. Modifications to both the pilot system gas-fired combustor and the PC burner led to NO_x reduction with PRB coal to levels below 100 ppmv with CO in the range of 35-112 ppmv without any furnace air staging. Pilot testing with PRB coal is complete.

Initial pilot testing with caking coal resulted in deposition and plugging by caked material inside of the gas combustor. A series of modifications to the combustor configuration and operation have been developed and tested during previous quarters, and testing of several more versions was continued in the current quarter. One of these approaches using a stainless steel liner indirectly cooled with air was successful in sustaining operation with caking coal up to 150 lb/h.

The installation of the large-scale prototype coal preheater for PRB testing in the CBTF was completed and shakedown testing with natural gas and PRB coal started during the quarter. In the initial shakedown tests, stable operation of the coal system, combustor and burner were achieved for the first time with coal feed rates up to 6000 lb/h (about 50 MMBtu/h). Attempts to increase the firing rate to the design level of 85 MMBtu/h were prevented by a high-amp condition in the coal mill, which is currently under evaluation.

EXPERIMENTAL

Pilot Unit

Fabrication, installation and initial testing of the pilot-scale coal preheating system were completed in the fall of 2001. The unit is sized for operation with natural gas and pulverized coal at a total firing rate of approximately 3-million Btu/h and includes all equipment and controls necessary to operate and monitor energy and environmental performance of the system. A gravimetric feeder is used to regulate pulverized coal flow through a rotary airlock into a natural gas-fired preheater combustor. The combustor produces hot combustion gases, which combine with the pulverized coal to produce a mixture of coal char and pyrolysis products at the desired test temperature.

In the original pilot system configuration, the combustor centerline was vertical and two pipe sections after the combustor provided additional residence time for the coal at the preheated conditions prior to entering the PC burner. However, pilot testing experience together with commercial design guidance from RPI redirected the development of both the pilot and commercial units toward a horizontal combustor design with no diameter change between the combustor and burner. The preheater combustor was therefore relocated to a horizontal configuration with the combustor exit coupled directly to the PC burner inlet, eliminating the two pipe sections.

In the modified pilot unit, the velocity of the devolatilization products in the combustor and burner is increased over previous pilot testing to minimize separation and impingement of coal on inner surfaces prior to reaching the burner face. The higher velocities are more consistent with standard design criteria developed by RPI for their commercial CCV burners. The higher combustor velocities were achieved by inserting a liner in the combustor to reduce its internal diameter. The liner also facilitates testing of various designs and operating approaches to eliminate plugging of the combustor with caking coals. Various liner materials, including metal and ceramic, and liner cooling methods are being developed and tested to determine their effect on wall deposition and plugging.

During testing, real time operating data are collected at 1-second intervals and recorded by the personal computer-based data acquisition system (DAS). The concentrations of CO, CO_2, O_2, THC and NO/NO_x in the pilot unit exhaust and the furnace exit are continuously monitored by on-line gas analyzers, including a Rosemount Analytical Model 880A infrared CO analyzer, a Rosemount Analytical Model 880A infrared CO_2 analyzer, a Rosemount Model 400 flame ionization total hydrocarbons (THC) analyzer, a Rosemount Analytical Model 755R paramagnetic O_2 analyzer, and a ThermoElectron Model 14A chemiluminescence NO_x analyzer.

The preheater gas combustor temperatures are monitored by thermocouples installed on both the outer walls and inside of the combustion chamber. Temperature of the gas/air mixture is monitored in the gas/air plenum entering the combustor nozzles.

Large-Scale Prototype Unit

The CBTF comprises a large horizontally fired dry bottom furnace capable of testing full-scale burner systems with firing capacities up to 100 MMBtu/h. The furnace is fully integrated with coal storage, grinding and feeding, emissions control, and continuous flue gas sampling and analytical subsystems.

Coal is pulverized and dried in a DB Riley Model 350 Atrita pulverizer, which is fed from a 40-ton bunker by a weigh-belt feeder and rotary valve. The mill's air supply system includes a Venturi air flow meter, fan and natural gas direct-fired heater to supply a measured amount of hot air to the pulverizer to dry and transport the coal. The CBTF is capable of firing in both the direct fire mode and from an intermediate storage bin (indirect fire). All testing will be conducted in the direct fire mode to simulate the most common firing method in the U.S market. Drying and transport air will be separated from coal stream immediately ahead of the preheater combustor inlet. The separated air will be directed to one of the three air channels in the coal burner. Secondary air will be preheated to 600 ºF by a separate fan and heater and routed to the coal burner. Air can be routed to the burner through an integral windbox plenum or through separate external ducts. Flow to each burner air channel can be regulated independently. Ports are also available at several locations for furnace air staging.

Flue gas composition will be monitored continuously. A multiple-probe sampling grid consisting of sintered Hasteloy filters is mounted in the CBTF exit duct, just upstream of the flue gas scrubber. The in-duct filters remove the majority of particulate, and the flue gas is drawn through stainless steel tubing, ice-bath conditioners, and a final filter by individual sample pumps. A rotameter at the outlet of each pump is used to admit equal flow of clean, dry sample from each grid probe to a manifold. The proper flow of sample for each continuous analyzer is supplied from the manifold.

Continuous monitors are used to measure O_2, CO_2, CO, NO/NO_x and SO_2. In addition to the gas sampling grid, a separate water-cooled probe is used to withdraw particulate samples at the CBTF outlet for determination of carbon burnout. A high velocity thermocouple probe monitors furnace outlet temperature.

The CBTF is fully instrumented to allow continuous measurement and recording or all relevant flow, pressure and temperature readings to allow complete material and energy balances to be developed for each testing period.

RESULTS AND DISCUSSION

Project Status:

Task 1.1 Pilot-Scale Design

Process variables affecting coal deposition on the preheater combustor walls have been found to include velocity in the preheater, the mixing pattern of the coal particles with products of natural gas combustion, combustion air distribution in the preheater and the surface temperature of the combustor walls. Previous pilot-scale testing demonstrated that plugging is initiated by agglomeration of coal particles on the preheater inner walls and no contribution of volumetric agglomeration was detected in all tested regimes. This indicates that adequate local protection of the combustor walls against deposition of coal volatiles should resolve the issue. Current technical approaches under development and testing include (i) creation of a thin oxidizing film over the preheater inner wall, (ii) use of less adherent inner wall material, and (iii) use of indirect cooling of the preheater inner wall. Two liner designs were developed and tested during the quarter based on the oxidizing film or "air-bleed" approach. Two additional liner designs, including one stainless steel and one ceramic liner, were developed and tested based on the indirect air-cooled approach.

Task 1.2 CFD Modeling

Pilot Unit

No work was performed on this task during the reporting period.

Large-Scale Prototype Unit

CFD Modeling was completed during the quarter with the combined preheater combustor/CCV burner model based on a Test Matrix developed for the 100 MMBtu/h unit test operations with PRB coal.

Task 1.3 Pilot-Scale Equipment Fabrication and Installation

The two modified "air-bleed" liners and two indirect air-cooled liners developed in Task 1.1 were fabricated and installed in the 3 MMBtu/h pilot combustor. The air-bleed liners were fabricated from stainless steel with 1/8-in diameter holes at regular intervals along the length of the liner as shown in Figure 1. A version with 54 holes and another with 79 holes were fabricated and tested. The two indirect air-cooled liners are shown in Figure 2 (stainless steel) and Figure 3 (Silicon carbide).

Figure 1. Air-bleed stainless steel liner with 54 1/8-in diameter holes prior to attachment of transition pieces.

Figure 2. Stainless steel indirect air-cooled liner with spiral fins and transition pieces

Figure 3. Silicon carbide indirect air-cooled liner with transition pieces

Task 1.4 Pilot-Scale Testing

Thirty-two additional pilot tests were conducted during the quarter with caking coal. These tests further evaluated the use of the air-bleed and indirect air-cooled liner designs to reduce or eliminate combustor plugging with caking coal. The air-bleed configurations tested used air injection holes perpendicular to the liner's longitudinal axis with the number, size and air flow though the air-bleed holes varied to determine the effect on combustor plugging. The indirect cooling configurations tested included a stainless steel liner with spiral fins in the annular space between the liner and the combustor wall to increase turbulence and heat transfer surface, and a silicon carbide liner without fins. Continuous pilot operation was maintained for up to 30 minutes at a coal feed rate of 50 lb/h with the 79-hole air-bleed liner. The best result achieved was for the stainless steel indirect air-cooled liner with 20 minutes of continuous operation at 126 lb/h of coal followed by an additional 20 minutes at 150 lb/h. The SiC indirect air-cooled liner achieved 5-10 minutes of continuous operation at 126 – 150 lb/h of coal feed.

Operating conditions for these tests were selected to evaluate impact on caking rather than optimized combustion or emissions performance and steady-state operating periods were therefore not defined. All operational data including flue gas analyses were recorded as usual, however, to aid in the evaluation. While not measured under steady-state operating conditions, NOx results in the range of 150 ppmv were measured with 3.5 – 5.5% O_2 at the boiler exit. NOx results for test conducted with PRB coal were around 180-200 ppmv at this exit oxygen level, indicating the potential for equal or better NOx reduction with caking coal than with PRB.

Task 1.5 Pilot-Scale Data Evaluation

Data evaluation from the pilot-scale unit is ongoing and the results from the most recent testing are discussed above.

Task 2.1 Commercial Prototype Engineering Design

No work was performed on this task during the reporting period.

Task 2.2 Baseline Data Review

No work was performed on this task during the reporting period.

Task 2.3 Commercial Prototype Construction

Final installation work on the large-scale prototype coal preheating combustor for PRB coal, including the burner management system, final instrument installation and checks, wiring and data acquisition software configuration was completed during the quarter.

Task 2.4 Commercial Prototype Testing

Final commissioning and shakedown testing of the large-scale prototype unit firing natural gas in the preheat combustor was completed during the third week in June. The objectives for this testing were:

- Develop and test a startup procedure for the combustor firing natural gas
- Confirm mechanical integrity of the combustor including adequacy of thermal expansion provisions
- Confirm functionality of all instruments and controls
- Confirm combustor operation over the full design firing range
- Confirm ability to produce accurate heat and mass balances around the combustor/furnace
- Develop a final punchlist for necessary repairs and changes prior to testing with PRB coal

The completed coal preheater gas combustor for PRB coal is shown in Figure 4 as installed on the burner deck of the Coal Burner Test Facility. The PRB combustor is designed to preheat 85 MMBtu/h of PRB coal with 8 MMBtu/h of natural gas. Prior to testing with natural gas and coal, three cold flow tests were conducted in the unit at various combustor air flows to evaluate

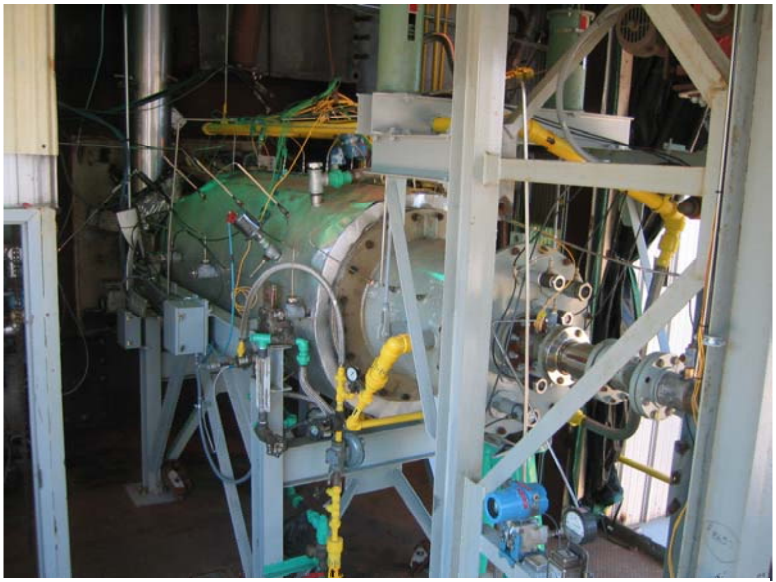

Figure 4. Large-scale prototype coal preheating combustor installed in the CBTF at Riley Power Inc's R&D Center

flow measurement accuracy and system pressure drops. During these tests the main furnace ignitor was fired at about 12 MMBtu/h to confirm proper ignitor operation. This ignitor is used to preheat the water-cooled furnace into which the preheater combustor and coal burner will be firing and to ignite the coal burner flame during PC burner tests. Following the cold testing, the 1 MMBtu/h preheater combustor ignitor was lit and test fired for about 30 minutes to confirm proper operation.

Following corrections to the auxiliary air flow measurement instruments, the combustor ignitor was fired at 0.8 MMBtu/h for about 1 hour to a combustor temperature of 500ºF to cure the combustor refractory. The main flame of the preheat combustor was then lit for the first time and fired for about 1 hour under lean conditions at about 3.3 MMBtu/h and a stoichiometric ratio (S_R) of about 1.4. The combustor was then switched to substoichiometric firing at its full gas firing rate (without coal) of about 12.5 MMBtu/h. The combustor ignitor was then shut off and the main flame maintained at an S_R of 0.43 while a full set of combustor and furnace data was collected to confirm proper operation of the units instrumentation and data acquisition system.

Based on observations during the initial gas-fired testing, modifications were made to the combustor auxiliary air nozzles in order to anchor the combustor flame closer to the gas burner face. After resolving several flame sensor issues, the main combustor flame was lit in lean mode at about 3.2 MMBtu/h and an S_R of 1.6 and was eventually switched to rich mode at 12.5 MMBtu/h and 0.40 S_R to check the effects of the auxiliary air modifications, which proved to have the desired effect of moving the flame nearer to the burner face.

At the conclusion of the gas-fired shakedown tests, a punchlist was developed for repairs, adjustments and modifications to be completed prior to commissioning and testing with PRB coal. Several issues related to the supports for the combustor gas/air plenum and improvements to thermal expansion compensation for the combustor body were identified along with additional minor changes to instruments and controls.

All items on the punchlist were satisfactorily resolved and commissioning with PRB coal was started during the fourth week in June. The objectives for shakedown activities were:

- Repeat cold flow tests with mixer, combustor and auxiliary air flows
- Repeat gas firing test for the preheat combustor over the full design firing range to confirm instrument readings
- Test fire the unit with 2000 lb/h PRB coal feed after preheating with gas in rich (substoichiometric) mode to 2000ºF
- Confirm steady, non-pulsing coal feed and proper operation of the coal cyclone, rotary air lock feed and cyclone exhaust air transport to the inner (reagent) air channel to the coal burner
- Confirm coal system, combustor and burner operation at 4000, 6000 and 8000 lb/h (design) PRB coal feed rates
- Complete a series of quick parametric tests with the preheat combustor firing conditions to determine effect on combustor operating stability and the coal burner flame
- Conduct a series of quick parametric tests altering the swirl angle of the inner (drying agent) air channel in the coal burner

A brief cold flow test was conducted with auxiliary combustor air to characterize rotameter settings vs. nozzle pressures and data system flow readings. The combustor was then started on gas and operated for a brief period until an electrical problem in the furnace air heater caused the furnace ignitor to trip. The problem was determined to be a dead short in one of the control wires between the field panel and the control room. This ultimately required a full day to remove and relocate the conduit run and all of the associated control wiring.

Cold flow tests were then conducted to check the maximum air flow through the coal mixer, main combustor air and combustor auxiliary air flow loops. The combustor was started on natural gas and operated at two different sets of gas and air settings in order to verify flow readings by comparing calculated and measured O_2 concentration at the furnace exit.

The combustor was then heated to 2000ºF in gas-rich (substoichiometric) mode prior to introducing PRB coal to the combustor for the first time. The unit tripped after a brief period of coal feed at 1000 lb/h due to a logic error in the safety interlock system. This was corrected and the coal restarted at 1000 lb/h. Shakedown operation continued on coal with several intermittent shutdowns to repair leaks in the coal feed and reagent air lines. By 3:36 pm the unit was stable and firing 2000 lb/h of PRB coal. This was gradually increased to 6000 lb/h by 4:00 pm. Figure 5 shows (left to right) the flame at the coal burner face when firing the furnace igniter and reducing gases (CO and H_2) produced from the combustor firing in gas-rich mode, and firing coal at 6000 lb/h without the furnace ignitor.

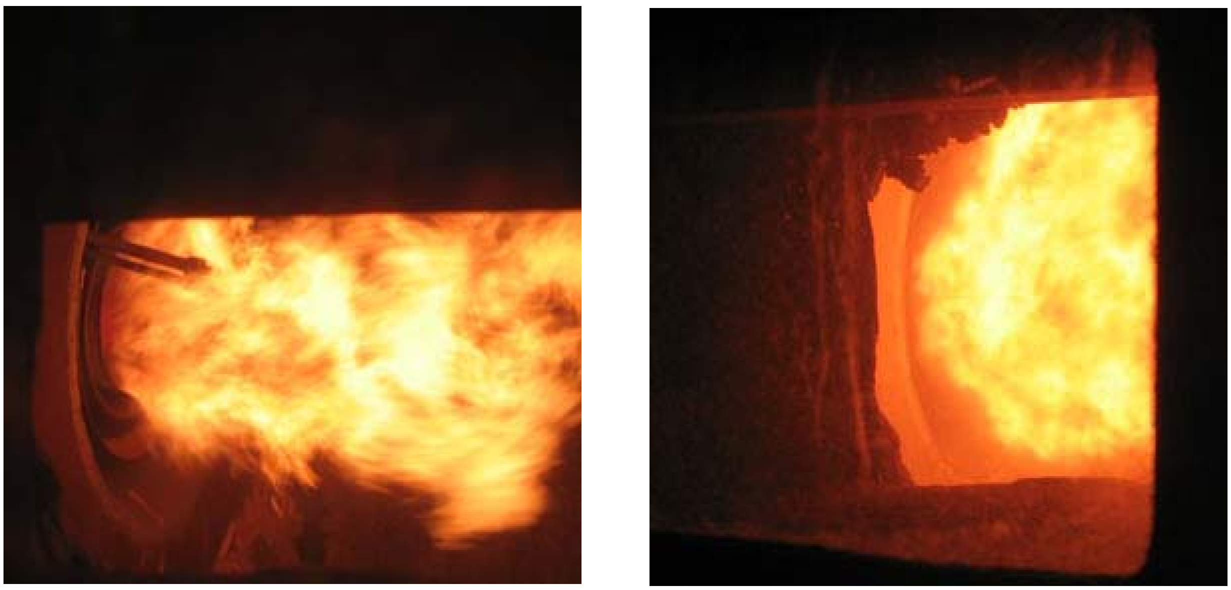

Figure 5. Flame at the coal burner face with the combustor in substoichiometric firing with gas only (l) and with gas plus 6000 lb/h PRB coal feed (r)

The coal mill reached its high amp limit at about 6400 lb/h so the balance of the shakedown was conducted at about 6000 lb/h. A full set of operating data was taken at 6000 lb/h and 1400ºF preheat temperature. A series of brief parametric tests was then conducted over a range of combustor, mixer and auxiliary air flows to determine operating limits and the effect on combustor and burner operating stability. Additional operating data was collected at four different settings for the swirl vanes in the inner air channel of the burner around the coal channel. This is where the drying agent air that is separated from the coal stream by the cyclone is utilized after it is exhausted from the cyclone. The swirl vane angle was varied from 20º to 35º in these tests. System operation was maintained at 6000 lb/h coal feed for about 3.5 hours after which testing was voluntarily terminated. Over 20,000 lb of PRB coal was fired during this shakedown operating period.

The best NOx reading observed at the furnace exit during the initial shakedown testing was about 260 ppm (corrected to 3% O_2) with an actual exit O_2 above 6%. This is a promising initial result considering the high exit O_2, which resulted from the coal feed being limited to 75% of its design value. For reference, the initial NOx readings from the pilot unit were about 600 ppm, and were eventually reduced to below 100 ppm once the combustor and burner operation were optimized. The furnace exit O_2 varied in a range from about 6.5% to 9% during the various shakedown conditions tested, and CO in all cases was below 10 ppmv.

A turnaround period of about 2 weeks is expected to resolve the various mechanical, operational and control issues identified during shakedown operations. The coal mill settings will be evaluated before the next coal tests to bring the mill back to its previously proven capacity of 8000-9000 lb/h with PRB coal at 28% moisture. The combustor support system will be further evaluated to see if additional spring hangers are required at the furnace windbox end of the combustor. The use of a toothed vs. smooth ring at the burner face as a flame holder will also be re-evaluated. A smooth ring is currently used. The flow range of the mixer air loop will be increased by about 150% by changing the orifice plate and/or re-ranging the flow transmitter. Additional inspection and cleaning of the burner, combustor and connecting process, instrument impulse and sample lines will be completed. Provisions for sampling coal from the concentrated coal line below the cyclone and from the drying agent air exhaust line after the cyclone will be completed. Provisions for videotaping the coal flame in the furnace will also be completed. Data from the shakedown testing will be reconciled and evaluated and used to prepare the coal test matrix for the balance of the PRB coal test campaign.

Task 2.5 Data Processing and Evaluation

This activity is on-going and preliminary results from the shakedown testing are given under Task 2.4 above.

Task 2.6 Commercialization Plan Development

This task has been deleted from the project workscope.

Task 2.7 Design and Fabrication of Commercial Burner System

This task has been deleted from the project workscope.

Tasks 1.6 &2.8 Management and Reporting

Amendment M007 to the contract was executed by DOE and GTI during the quarter. The amendment 1) recognized additional cost sharing by the recipient, 2) amended the Statement of Project Objectives to delete Task 2.6 Commercialization Plan Development and Task 2.7 Design and Fabrication of Commercial Burner System in their entirety, and 3) extended the budget and project period to 3/31/05.

Upon receipt of Amendment M007, change orders were submitted internally and fully executed for the two major subcontracts (RPI and a burner design consultant) extending their performance periods through the March 31, 2005. Time extension requests were submitted and executed internally for related cost sharing projects to conform to the underlying DOE contract.

An abstract was prepared for a technical paper to be presented at the 2004 IGRC symposium in Vancouver this fall. The paper was selected for the poster session.

Plans for Next Quarter:

- Evaluate the large-scale test unit coal mill performance and take necessary actions to increase its throughput on PRB coal to the stated capacity of 85 MMBtu/h.

- Complete testing in the large-scale unit with PRB coal.
- Initiate design and modification of the large-scale test unit for caking coal
- Continue securing additional funding from cost share sources sufficient to complete the remaining work scope.

CONCLUSIONS

Initial shakedown tests in the large-scale unit with PRB coal at 75% of the design coal rate have confirmed the operability of the scaled-up design, including smooth, non-pulsing coal flow through the cyclone separator to the preheating combustor, and smooth non-pulsing flow of the separated reagent air from the cyclone into the inner air channel of the coal burner.

The "hot wall" design of the prototype combustor also appears to be serviceable for the planned test work. This design approach is the same used for the pilot unit in order to allow a multitude of penetrations into the combustor for auxiliary air ports, temperature and pressure sensors and observation ports. Adequate allowance was made for thermal expansion of the unit, but addition spring hanger supports will be added to better carry the weight of the combustor in the hot position.

The coal burner operation during the initial shakedown was fairly good, although flame shape and attachment were issues at some operation conditions. Relatively high pressure drops across all three air channels indicate that the various swirl vanes and internal windbox dampers may not be properly adjusted, and these will be inspected. It is expected that a toothed ring will be added to the coal channel to improve flame attachment.

The coal mill was unable to deliver the design coal feed rate to the unit. Both the preheat combustor and burner are sized for about 33% more coal flow than was available from the mill in shakedown testing. It appears that the backpressure on the mill from the coal cyclone and reagent air ducting and channel may be partially responsible for the reduced coal rate. This will be evaluated to determine how to reduce backpressure and what other actions that can be taken to restore mill capacity.

REFERENCES

N/A

Milestone Status Table: The proposed revised completion dates for all project tasks and major milestones are shown below.

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	Modified gas combustor & burner installation complete
1.4	Pilot-Scale Testing – Caking Coal	6/15/2004		Hold
1.5	Pilot-Scale Data Evaluation – Caking Coal	6/15/2004		Hold
1.6	Task 1 Management and Reporting	7/15/2004		
♦	Task 1 Report	8/15/2004		Hold
2.0	Technology Validation			
2.1a	Commercial Prototype Engineering Design - PRB Coal	4/15/04		
2.1b	Commercial Prototype Engineering Design - Caking Coal	8/30/2004		
2.2	Baseline Data Review	4/15/2004	4/15/2004	Complete
2.3a	Commercial Prototype Construction - PRB Coal	4/15/04	6/15/2004	Complete
2.3b	Commercial Prototype Construction - Caking Coal	9/30/2004		
2.4a	Commercial Prototype Testing - PRB Coal	6/30/04		Underway
2.4b	Commercial Prototype Testing - Caking Coal	11/30/2004		
2.5a	Data Processing and Evaluation - PRB Coal**	7/30/04		Underway
2.5b	Data Processing and Evaluation - Caking Coal	12/31/2004		
2.6	Commercialization Plan Development	--		Task Eliminated
2.7	Design and Fabrication of Commercial Burner System	--		Task Eliminated
2.8	Task 2 Management and Reporting	5/31/2005		
♦	Final Report	5/31/2005		

*Revised schedule under development by GTI and RPI.