Cost-Effective Control of NO_x with Integrated Ultra Low-NO_x Burners and SNCR

Technical Progress Report

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INTRODUCTION

Coal-fired electric utilities are facing a serious challenge with regards to curbing their NO_x emissions. At issue are the NO_x contributions to the acid rain, ground level ozone, and particulate matter formation. Substantial NO_x control requirements could be imposed under the proposed Ozone Transport Rule, National Ambient Air Quality Standards, and New Source Performance Standards.

McDermott Technology, Inc. (MTI), Babcock & Wilcox (B&W), and Fuel Tech are teaming to provide an integrated solution for NO_x control. The system will be comprised of an ultra low-NO_x pulverized coal (PC) burner technology plus a urea-based, selective non-catalytic reduction (SNCR) system. This system will be capable of meeting a target emission limit of 0.15 lb $NO_x/10^6$ Btu and target ammonia (NH_3) slip level targeted below 5 ppmV for commercial units. Our approach combines the best available combustion and post-combustion NO_x control technologies. More specifically, B&W's DRB-4Z^{TM} ultra low-NO_x PC burner technology will be combined with Fuel Tech's NO_xOUT (SNCR) and NO_xOUT Cascade (SNCR/SCR hybrid) systems and jointly evaluated and optimized in a state-of-the-art test facility at MTI. Although the NO_xOUT Cascade (SNCR/SCR hybrid) system will not be tested directly in this program, its potential application for situations that require greater NO_x reductions will be inferred from other measurements (i.e., SNCR NO_x removal efficiency plus projected NO_x reduction by the catalyst based on controlled ammonia slip). Our analysis shows that the integrated ultra low-NO_x burner and SNCR system has the lowest cost when the burner emissions are 0.25 lb $NO_x/10^6$ Btu or less. At burner NO_x emission level of 0.20 lb $NO_x/10^6$ Btu, the levelized cost per ton of NO_x removed is 52% lower than the SCR cost.

Large-scale testing will be conducted in B&W's Clean Environment Development Facility (CEDF). Testing in the CEDF will provide the premise for the evaluation and optimization of the integrated NO_x control system at conditions representative of pulverized coal-burning utilities. Past experience has shown that a large prototype, 100 million Btu/hr burner design can be readily scaled with minimal risk for commercial retrofit where a typical burner size is about 150 to 200 million Btu/hr. It is anticipated that a commercial offer can be made around the 2001-2002 timeframe.

A wide range of commercially available utility coals including Powder River Basin (PRB) subbituminous, high-volatile bituminous, and medium-volatile bituminous with respective baseline NO_x levels of 0.20, 0.30, and 0.45 lb $NO_x/10^6$ Btu will be tested with the DRB-4Z™ ultra low-NO_x PC burner at different loads and excess air levels. It was expected that NO_x emissions in some commercial units could be higher than in the CEDF due to flame interactions, hotter furnaces, coal property value variations, imperfect mixing of NO_x reducing reagent with flue gas, etc. Therefore, to ensure that NO_x emissions of 0.15 lb $NO_x/10^6$ Btu or lower can be attained in the field, the CEDF target level was set at 0.125 lb $NO_x/10^6$ Btu or less. However, after refractory maintenance was performed in the CEDF, the furnace became very hot, and resulted in higher NO_x emissions. A new target of 0.15 lb $NO_x/10^6$ Btu was established. The estimated market size for the integrated system is approximately 86,000 MW_e.

OBJECTIVES

The objective of this project is to develop an environmentally acceptable and cost-effective NO_x control system that can achieve less than 0.15 lb $NO_x/10^6$ Btu for a wide range of coal-burning commercial boilers.

The system will be comprised of an ultra low-NO_x PC burner technology plus a urea-based, selective non-catalytic reduction (SNCR) system. In addition to the above stated NO_x limit of 0.15 lb $NO_x/10^6$ Btu, ammonia (NH_3) slip levels will be targeted below 5 ppmV for commercial units. Testing will be performed in the 100 million Btu/hr Clean Environment Development Facility (CEDF) in Alliance, Ohio.

Finally, by amendment action, a limited mercury measurement campaign was conducted to determine if the partitioning and speciation of mercury in the flue gas from a Powder River Basin coal is affected by the addition of Chlorides to the combustion zone.

WORK PERFORMED

Task 1: Project Planning and Deliverables

Subtask 1.1 – Planning & Coordination

The purpose of this activity is to account for those project management and tracking activities and associated costs necessary to carry out the project in a timely, cost-effective manner.

Coordination of different tasks has been accomplished by discussions between combustion and SNCR task leaders. A Job Safe Practice was written to cover any safety concerns associated with testing the aqueous urea-base injection solution in the CEDF. A test plan was drafted describing the test matrix that would be followed during the SNCR injection testing in the CEDF.

Subtask 1.2 – Management Plan Preparation

Management Plan - MTI had prepared and submitted a Management Plan for the project. No activity in this reporting period.

Subtask 1.3 – Quarterly Reports

Project Status Report **–** The quarterly report covering April through June 2001 was prepared.

Quarterly Financial Report **–** The report is attached.

Subtask 1.4 – Data Analysis & Report Preparation

Final Report – No activity.

Task 2: Modeling Application for Ultra Low-NO_x PC Burner and NO_xOUT™ Performance Optimization

Subtask 2.1 – Burner and Furnace Simulations

The objective of the subtask is to generate data sets for the determination of the optimum location for SNCR urea injection in the CEDF. B&W's proprietary flow and combustion modeling code, COMO, was used to model the plug-in DRB-4Z™ burner firing three coals. Each coal has been modeled at three loads: 40, 60 and 100 million Btu/hr. The single-burner CEDF furnace and convection pass shown was modeled based on as-built furnace dimensions and refractory specifications. The modeling study, as well as in-furnace temperature and gaseous measurements, has been used at Fuel Tech, Inc. (FTI) to assist in the design of the SNCR system.

This modeling work is completed for now. Revisions may be needed for calculations after experimental measurements are taken.

Subtask 2.2 – Additive Injector and SNCR Performance Simulations

The purpose of this subtask is to determine the optimum SNCR port locations. Fuel Tech has developed procedures for extracting and visualizing data from B&W's modeling of the test unit. Fuel Tech is performing SNCR performance predictions using MTI's data sets that will provide input to Fuel Tech's Chemical Kinetics Model (CKM) to predict SNCR and CASCADE performance. As mentioned in the last quarterly report, after performing some of these calculations, MTI and Fuel Tech discussed MTI's numerical modeling, the baseline test with the three coals (see task 3), and Fuel Tech's SNCR predictions. Although the SNCR predictions were not finalized, it was decided that the original SNCR port locations, described in the project kick-off meeting, were flexible enough to use for the tests.

Task 3: Ultra Low-NO_x DRB-4Z™ PC Burner Performance Evaluation at 100 million Btu/hr

Subtask 3.1 – Coal Procurement

230 tons of Middle Kittanning (medium volatile bituminous) coal was purchased from the Bradford Coal Company located in Pennsylvania. 450 tons of Spring Creek Powder River Basin coal was purchased from DTE Coal Company. The coals were delivered to MTI and used during June for the SNCR injection testing.

Subtask 3.2 – Ultra Low-NO_x PC Burner Hardware Selection

It has already been decided to use a plug-in DRB-4Z™ PC-fired burner for this project. This task is completed.

Subtask 3.3 – Coal Rank Variations Effects on Ultra Low-NO_x PC Burner Performance

Burner optimization tests have been completed. These tests were reviewed and the optimum burner hardware configuration and settings were determined for each coal utilized for SNCR injection testing. The second series of burner optimization tests showed that after refractory maintenance was performed in the CEDF, the furnace became very hot, and resulted in higher NO_x emissions. To re-confirm this occurrence and to determine initial NO_x values, baseline testing was performed with the various coals at the start of each SNCR injection test series. The baseline values obtained corresponded to the burner optimization tests performed after the refractory maintenance. Baseline conditions were also repeated throughout the test series to check for any system variances.

Subtask 3.4 – Gas Species and Temperature Mappings

During the previous burner optimization tests, temperature and gaseous species measurements were performed in the existing ports in order to validate the MTI model and to determine the SNCR port locations. The measurements were obtained at three elevations and at two nominal loads of 100 and 40 million Btu/hr. These data were used by Fuel Tech to determine the SNCR port locations. As discussed earlier, it was concluded that the pre-determined SNCR ports locations were flexible enough that they could be used for the SNCR injection tests.

Task 4: Integrated NO$_x$OUT^{TM} and Ultra Low-NO$_x$ PC Burner Performance Evaluation at 100 Million Btu/hr

Subtask 4.1 – SNCR Process Optimization

Site preparation activities were performed on the CEDF in support of the SNCR injection tests. CEDF boiler high velocity thermocouple (HVT) measurements were taken during previous burner optimization test campaigns. The temperatures were used with numerical modeling to determine the optimum injection port locations. Site ports were installed in the CEDF to accommodate the aqueous urea injection. Ports were added at three elevations and on all sides of the furnace to provide adequate penetration and coverage over various temperature ranges.

A tank with the urea-based injection reagent was placed outside the south side of the CEDF building. A portable trailer was set in this location to monitor and control the aqueous urea injection. Hoses were run from the tank to three floors of the CEDF. The lines were connected to a manifold system located on each floor for flow control to each injector series. Compressed air and aqueous urea lines were then run to each injector location in the furnace.

Subtask 4.2 – Coal Rank Variations Effects on the Combined Ultra Low-NO$_x$ PC Burner and NO$_x$OUT^{â} Performance

SNCR injection testing was composed of a series of parametric tests. An aqueous urea solution was sprayed from wall-mounted injectors in the furnace section at pre-determined flow rates, covering a wide NSR range while firing three different coals.

The SNCR system was designed to reduce NO_x from the expected low-NO_x burner baseline of 0.20 lb $NO_x/10^6$ Btu to below 0.15 lb $NO_x/10^6$ Btu (25%) while controlling NH_3 slip to less than 5 ppm. The system was also tested to assess the potential for improved performance using an SNCR/SCR hybrid in which SNCR performance can be improved with a controlled increase in the ammonia slip.

The baseline emissions firing PRB coal at 100 million Btu/hr was approximately 0.26 lb $NO_x/10^6$ Btu. The SNCR system provided control to 0.195 lb $NO_x/10^6$ Btu, or 25% reduction, with less than 5 ppm ammonia slip. The NO_x was further reduced to 0.17 lb $NO_x/10^6$ Btu with less than 10 ppm slip.

Performance of both the burner and the SNCR system improved at decreased firing rate. The NO_x baseline at 60 million Btu/hr dropped to 0.17 lb $NO_x/10^6$ Btu and the final controlled NO_x was 0.13 lb $NO_x/10^6$ Btu with less than 5 ppm NH_3. Improved performance, nearly 0.12 lb $NO_x/10^6$Btu, was possible as NH_3 slip increased to 10 ppm. At 40 million Btu/hr, the SNCR system reduced NO_x by more than 50% to 0.09 lb $NO_x/10^6$Btu with less than 5 ppm NH_3 slip.

The target full load baseline of less than 0.20 lb $NO_x/10^6$ Btu was achieved by co-firing 10% natural gas. Although this condition may not exactly match the desired parameters, testing revealed that convective pass injection would be required for effective treatment in the CEDF. NO_x reduction to 0.17 lb $NO_x/10^6$ Btu was achieved using wall-injectors and maintaining less than 5 ppm slip. Limited testing was performed using one convective pass lance in an existing observation port. The results of this testing were promising as reduction to 0.16 lb $NO_x/10^6$ Btu was achieved at 4 ppm NH_3 slip.

Testing of the SNCR system when firing Pittsburgh #8 coal at 100 million Btu/hr proceeded from a baseline of approximately 0.30 lb $NO_x/10^6$ Btu. NO_x reduction of 26% was achieved with less than 5 ppm slip. The performance improved, up to 33%, when the ammonia slip was allowed to increase to nearly 10 ppm.

Favorable temperatures and increased residence time existed at low load, 40 million Btu/hr, and the SNCR system achieved nearly the same level of controlled NO_x as was achieved with the low PRB baseline. NO_x reduction of 66%, from 0.31 to 0.105 lb $NO_x/10^6$ Btu, was accomplished with less than 5 ppm ammonia slip. Very limited testing at 60 million Btu/hr showed 31 % NO_x reduction with 2 ppm ammonia slip. This condition was not optimized.

The baseline increased to approximately 0.40 lb $NO_x/10^6$ Btu when firing Middle Kittanning Coal at 100 million Btu/hr. Furnace conditions for this fuel were less favorable for effective NO_x reduction as both the furnace exit gas temperature and the CO concentration increased. 18% NO_x reduction was possible while meeting the 5 ppm slip limit and as much as 27 % reduction was possible with ammonia slip between 10 and 15 ppm.

At low load, again 40 million Btu/hr, 43% NO_x reduction was achieved with less than 1 ppm of measured ammonia.

In summary, the preliminary results of testing are positive. Significant NO_x reductions were possible from very low baselines while controlling ammonia slip successfully to less than 5 ppm or 10 ppm, as desired. Improved performance may be possible with convective pass injection at full load.

Task 5: Commercial Assessment

No activity.

SCHEDULE AND MILESTONE PLAN

MTI's numerical modeling has been completed, and Fuel Tech has performed some modeling using MTI's results as input to the Fuel Tech models and provided MTI with the recommendations for SNCR port locations. The baseline (no SNCR) burner testing with PRB, Pittsburgh #8 and Middle Kittanning coals are completed. In-furnace probing was performed at the existing ports and was utilized to validate the MTI numerical modeling and subsequently identify the optimum SNCR ports locations. Testing in support of SNCR optimization and coal rank variation effects on the combined ultra low-NO_x PC burner and NO_xOUT® performance has been performed. Analysis of the test data is underway. Again, preliminary results are positive, but improved performance may be possible with additional testing. The project is back on schedule for finishing within the extended schedule (October 2001), and the technology should be ready for commercial offering before 2002.