TITLE: Minimizing NOx Emissions from Multi-Burner Coal-Fired Boilers

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ABSTRACT

OBJECTIVE

The focus of this program is to provide insight into the formation and minimization of NOx in multi-burner arrays, such as those that would be found in a typical utility boiler. Most detailed studies are performed in single-burner test facilities, and may not capture significant burner-to-burner interactions that could influence NOx emissions.

Our approach is to investigate such interactions by a combination of single and multiple burner experiments in a pilot-scale coal-fired test facility at the University of Utah, and by the use of computational combustion simulations to provide insight into the experimental results and to evaluate full-scale utility boilers.

The program is broken into four main tasks:

1- Fundamental studies on nitrogen release from coal. These studies will be used to enhance the predictive capabilities of the combustion simulations.
2- Comprehensive modeling of burner arrays.
3- Pilot-scale optimization of multi-burner arrays.
4- Technology transfer.

ACCOMPLISHMENTS TO DATE

Significant progress has been made on the fundamental studies of N release from coal, as such understanding is key to subsequent tasks in the program. Two different experimental programs are underway to obtain this information: Flat Flame Burner studies at BYU under the direction of Prof. Tom Fletcher; and drop-tube studies at the University of Utah under the direction of Prof. Adel Sarofim.

For the Flat Flame Burner (FFB) studies, nitrogen release characteristics of an Illinois and a Utah bituminous coal have been measured during high temperature pyrolysis. A Wyodak subbituminous coal is currently being examined. The FFB facility is operated with CO and air/N_2 to provide a stable, high temperature laminar environment for pyrolyzing the coal particles without a significant concentration of steam.

Centerline temperature profiles were measured and corrected for radiation loss during measurement. Four temperature conditions have been developed, but only two conditions were used in the experiments (peak temperatures of 1640 and 1743 K). The 45-75 μm size fraction was used in these experiments. Char and soot particles are collected using a gas-quenched probe and separated on-line using a virtual impactor and cyclone. FTIR analysis is currently being developed for the determination of the nitrogen trace gases (HCN, NH_3, etc.) in the combustion gases; the absence of steam permits determination of trace quantities.

The nitrogen distributions among char, soot and gas phase for the two coals under different conditions are similar. In condition 1 (1640 K CO flame), the N trapped in soot seems to increase with residence time for both coals. However, the soot-N release pattern shows some dependence on coal type. In condition 2, soot yield for the two coals increased with residence time, but the fraction of N in the soot remained constant. This means that soot particles formed at long residence times contain less nitrogen, which agrees with results of other investigators. The fraction of nitrogen in soot has been shown to decrease with increasing temperature. At higher temperatures, the nitrogen content in the char decreases monotonically, with a corresponding increase of nitrogen species in the gas phase.

As coal-fired utility boilers move to lower NOx emissions, the contribution of char N conversion to NO emissions becomes increasingly significant. Previous studies in the University of Utah combustion laboratory (Spinti, 1997) have indicated that the gas-phase concentration of NO has a significant effect on char N conversion. A laminar-flow drop-tube furnace, previously located at MIT, has been set up in the UofU combustion laboratory and is being utilized for more fundamental studies on char N conversion.

A detailed single particle model for char N conversion has been developed which accurately describes observed char N conversion phenomena noted in both the earlier UofU experiments and previous work performed at MIT (Goel, 1997).

Single-burner pilot-scale studies have been carried out indicating the effect of burner air distribution, air staging, and coal reburning on NO emissions. NO emissions within the pilot-scale facility range between 1200 ppm and 60 ppm NOx (dry, corrected to 3% O2), depending upon the conditions selected. The low NOx burner used is based on a DB Riley CCV IIA burner. The smaller burners used in the multi-burner firing mode are of the same design. Preparations are near completion for the switch to multi-burner firing. Burners have been fabricated, plumbing and testing of the modified gas preheat system is complete, modifications to the safety and control system are completed and auxiliary coal feed systems have been tested. The switch to multi-burner firing will be accomplished within the next two months, once single-burner testing is complete.

Combustion simulations of both single-burner and multi-burner firing within the L1500 test facility have been completed. Initial results have provided insight into some slagging problems encountered during the single burner testing. Simulations have also been performed of the multi-burner-firing mode to highlight any potential problems with the proposed installation. Results have illustrated considerably shorter flames than those observed in the single-burner simulations. Combustion simulations have also been performed of a full-scale utility boiler, and have highlighted the need to evaluate NO control strategies from a boiler perspective, as opposed to a burner perspective. Not all burners contribute equally to NO emissions, or to low-NOx-related problems such as unburned carbon and waterwall corrosion, and an optimal control strategy can take advantage of this non-uniformity.

PLANS FOR THE COMING YEAR

Fundamental studies will continue in both the FFB and the drop tube, with the FFB providing valuable information on N partitioning in different coals and the drop tube provide fundamental information on the conversion of char N. The change to multi-burner firing will take place this summer (1999) and testing will be carried out to compare results under conditions similar to the single-burner studies. Conditions for optimal multi-burner firing will be determined. The current char N conversion model will be implemented in a 3D combustion code (GLACIER). The model will then be used to evaluate the results from the pilot-scale experimentation under both single- and multi-burner firing. The model will also be applied to a full-scale utility boiler to facilitate evaluation of low-NOx firing strategies for multi-burner arrays.

ARTICLES, PRESENTATIONS AND STUDENTS

JOURNAL ARTICLES (peer reviewed)

There are no Journal Articles published yet for this project.

CONFERENCE PRESENTATIONS

Sarofim, A. F., E. G. Eddings and A. Molina, “Char Nitrogen Conversion: Implication to NO Emissions from Utility Boilers,” Plenary Lecture to be presented at the Mediterrean Combustion Symposium, June 20-25, 1999, Antalya, Turkey.

Zhang, H. and T. H. Fletcher, "Char Oxidation during Late Burnout," poster presentation at the 12th Annual ACERC Conference, Provo, Utah (March 25-26, 1998).

Molina, A., E. G. Eddings and A. F. Sarofim, “NOx Production During Pulverized Coal Combustion via the Char-N Route,” poster presentation at the 12th Annual ACERC Conference, Provo, Utah (March 25-26, 1998).

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