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Project Summary

Pollutant Formation During Fixed-Bed and Suspension Coal Combustion

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This summarizes a 3-year laboratory study of factors controlling the formation of nitrogen and sulfur oxides (NO_x and SO_x) in industrial coal-fired boilers, with emphasis on stoker-fired units. The study identified the combustion phenomena governing conversion of coal constituents to NO_x and SO_x, and investigated approaches to controlling these emissions. The study also considered possible detrimental effects of control technology on boiler operation.

Study results indicate that two types of NO_x controls appear to be viable: (1) the coal feed could be screened to remove the fines (particles less than 0.1 in.), essentially eliminating the high conversion of nitrogen evolved in the suspension zone and resulting in an overall emissions reduction of about 10-40%, depending on the amount of fines normally present in the raw coal; or (2) the primary overfire-air injection port could be moved to above the spreader and the suspension zone and bed region could both be operated substoichiometric, reducing emissions by as much as 50%. Unfortunately, controlling SO_2 formation in either a spreader or mass-burning stoker unit appears to be difficult. Coal/limestone pellets can significantly reduce SO_2 emissions, and the effectiveness of the sorbent appears to increase when the bed-region stoichiometry is reduced below 1.0.

This Project Summary was developed by EPA's Industrial Environmental Research Laboratory, Research Triangle Park, NC, to announce key findings of the research project that is fully documented in a separate report of the same title (see Project Report ordering information at back).

Purpose and Scope

This report summarizes the results of a 3-year research program to study the formation and control of nitrogen and sulfur oxides (NO_x and SO_x) in industrial coal-fired boilers with emphasis on stoker-fired units. In particular, this program considered the following major research areas:

1. the evolution and oxidation of fuel nitrogen and sulfur;
2. the retention of SO_x by ash and/or solid-chemical sorbents; and
3. the effectiveness of distributed air addition for NO_x control.

In addition, the study attempted to quantify the combustion process in a stoker environment and considered possible detrimental effects of control technology on boiler operation. The work considered conditions typical of both spreader-stoker and mass-burning systems.

The approach was primarily experimental; three types of laboratory furnaces were utilized to investigate the various combustion regimes of major importance in stoker-fired systems:

1. A 200,000 Btu/hr tower furnace was used to characterize the *suspension phase* oxidation of fuel nitrogen and sulfur as a function of local oxygen concentration, temperature, and particle size.

2. A 300,000 Btu/hr *fixed-bed* furnace was used to study NO_x and SO_x formation in mass-burning units as a function of stoichiometry distribution, burning rate, and overfire-air height. The effectiveness of coal-limestone pellets for SO_x control was also considered in this system.
3. A 750,000 Btu/hr model *spreader-stoker* furnace was used to investigate NO_x formation and control in a system where both suspension-phase and bed combustion are significant.

All of the experimental studies were conducted with high volatile bituminous coals from Utah (low sulfur) and Indiana (high sulfur).

Complete details of all of the experimental systems (including fabrication drawings), analytical methods, and experimental data are available.

Discussion

Study results indicate that NO emissions from spreader-stoker fired coal furnaces are the result of relatively high conversions (25-45%) of the fuel nitrogen evolved from particles less than 0.11 in. in the suspension phase and low conversions (5 to 15%) of fuel nitrogen from the bed combustion. Mass-burning stokers (e.g., traveling grate units) almost certainly yield lower NO_x emissions because of the absence of significant overthrow combustion. In the suspension phase, the nitrogen is evolved at approximately the same rate as the carbon is oxidized, and the percentage conversion is relatively insensitive to reaction zone temperature. Decreasing particle size dramatically increases the amount of fuel nitrogen evolved; however, it had little effect on the percentage conversion of that nitrogen to NO_x.

Local oxygen availability is the primary control parameter for both phases of the combustion. Substantial NO_x emission reductions were achieved when the fuel bed was operated under substoichiometric conditions (fuel rich). NO_x emissions decreased further when the stoichiometry of the suspension zone was reduced below 1.0 by moving the overfire air injection to above the spreader. Under these conditions, a minimum overall fuel nitrogen conversion of approximately 6% was achieved, suggesting that under staged combustion conditions, positive synergism can be achieved between the suspension phase and the bed combustion. The suspension zone almost certainly provides both the sites for heterogeneous reduction of NO formed in the bed and the free radical concentrations necessary to accelerate the decay of total fixed nitrogen formed in the bed. In addition, the low oxygen partial pressure decreases the conversion of nitrogen evolved in the suspension zone.

Thus, two types of NO_x control technology appear to be viable. First, the coal feed could be screened to remove the fines (particles less than 0.1 in.). This would essentially eliminate the high conversion of nitrogen evolved in the suspension zone and would result in an overall emissions reduction of approximately 10 to 40%, depending on the amount of fines normally present in the raw coal. Alternatively, the primary overfire-air injection port could be moved to above the spreader and the suspension zone and bed region could both be operated substoichiometric. This could result in an emission reduction as large as 50%; however, before this concept can be applied commercially, the influence on other important combustion parameters (e.g., bed thickness, grate temperature, and ash characteristics) should be evaluated.

Unfortunately, control of SO_2 formation in either a spreader or mass-burning stoker unit appears to be difficult. The rate of sulfur evolution and oxidation in both the suspension and fixed-bed phases can be influenced by local temperature; however, if the coal is completely burned, the sulfur is ultimately oxidized to SO_2. Utilization of coal/limestone pellets can result in significantly reduced SO_2 emissions, and the effectiveness of the sorbent appears to increase when the bed-region stoichiometry is reduced below 1.0.

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The complete report, entitled "Pollutant Formation During Fixed-Bed and Suspension Coal Combustion," (Order No. PB 84-163 286; Cost: $11.50, subject to change) will be available only from:
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