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Project Summary

Evaluation of Internally Staged Coal Burners and Sorbent Jet Aerodynamics for Combined SO_2/NO_X Control in Utility Boilers: Volume 2. Testing in a 100 Million Btu/Hr Experimental Furnace

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As part of EPA's Limestone Injection/Multistage Burner (LIMB) program, testing was conducted on a 29 MWt (100 million Btu/hr) coal-fired experimental furnace. The primary objective was to explore the potential for effectively removing SO_2 using calcium-based sorbents, through appropriate selection of injection location and injector design and operating parameters. To reduce SO_2 and NO_X simultaneously, the sorbent was tested with the furnace operating with an internally staged low-NO_X burner, which was designed to stage fuel/air staging internally within the burner. Such internal staging is intended to avoid the need for external tertiary air ports, and thus simplify the retrofit of such a low-NO_X burner into existing pre- NSPS utility furnaces. The testing reported here was a follow-on to testing on a smaller scale (2.9 MWt, or 10 million Btu/hr).

Because this testing emphasized improving sorbent performance, the testing of options for reducing NO_X emissions from the burner by internal staging was limited. The options tested were limited to two coal splitters (referred to as the T-15 and T- 30 splitters), designed to divide the coal stream into four initially fuel-rich flames. The best set of conditions (the T-30 splitter with low swirl in the secondary air) resulted in NO_X emissions of 550 ppm (dry, 0% O_2), compared to 830-900 ppm from the baseline unstaged burner, a reduction of about 35 percent (less than the 50-60 percent desired). Flame length from the staged burner was acceptable (6.7 m, and CO was less than 40 ppm. Additional NO_X reductions might have been achieved had additional staging approaches (e.g., divided secondary air registers) also been tested.

Variables addressed during the SO_2 sorbent testing included: injection location (three locations on the front wall, one on the rear wall), injection velocity, injector diameter; number of injectors, and injector design (single-pipe vs. double-concentric jets). Three sorbents were tested. With the recirculation patterns

created in the furnace by the burner, reasonable SO_2 could be removed under only two conditions: injection from the rear wall at an optimum velocity, to avoid the sorbent's penetrating into the recirculation zone while at the same time getting adequate dispersion in the exhaust flow; and injection high on the front wall (5.8 m above the burner), using large jets having sufficient momentum to penetrate through the recirculation zone into the furnace exhaust flow. At a Ca/S molar ratio of 2, SO_2 removals under these injection conditions were: 30-40 % with Vicron 45-3 limestone (10 µm mass mean); 45-50% with D3002 dolomite (12 µm); and 58-62% with Type-S pressure-hydrated dolomitic lime (1.4 µm).

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

Introduction

LIMB technology is being investigated to control SO_2 and NO_x simultaneously for existing coal-fired utility boilers. The process envisions the use of calcium-based sorbent to remove intermediate levels of SO_2 (50 to 60%), and staged burners for NO_x reduction, for retrofit applications as a potential component of an acid rain control strategy.

The testing described in this report is part of a larger project to explore the potential for reducing combined SO_2/NO_x utilizing internally staged coal burners to reduce NO_x emissions, while selecting sorbent injector design and operating parameters to improve SO_2 capture. Testing on a 2.9 MWt experimental furnace was described earlier. This report addresses testing on a 29 MWt furnace, intended to confirm the most promising results from the smaller-scale testing.

Some staged burners which have been tested in other studies involve the use of external tertiary air ports to delay fuel and air mixing. In some cases, it could be difficult to retrofit such external ports into existing boilers, due to structural or other constraints. An objective of this study was to confirm certain burner design approaches which could achieve the benefits of air staging without external ports--i.e., with the staging *internal* to the burner, in a manner which would facilitate retrofit. Because the emphasis of the 29 MWt testing was to assess improved sorbent injection alternatives, only a limited number of burner internal staging options were tested here; these were the options which appeared to be the most promising based upon the smaller-scale testing.

The sulfur capture performance of a sorbent is dictated by the surface area it develops upon calcination, upon its residence time at sulfation temperature, and upon its dispersion in the furnace. Injection near the burner would provide the greatest residence time and the best dispersion, but could subject the sorbent to high temperatures which would greatly reduce its surface area/reactivity. Testing in this study focussed on sorbent injection remote from the internally staged burner, since the smaller-scale work had indicated that unacceptable sorbent deactivation could probably not be prevented during injection near the flame zone, no matter how the injectors were designed. The sorbent injector design/operating parameters tested during this study included: injector location, injector diameter, injection velocity, number of injectors at a given location, and injector configuration (i.e., single-pipe jets versus double-concentric jets, which provide a sheath of annular air around the sorbent jet to protect it from high temperatures). Three sorbents were tested.

Experimental Equipment

The testing was conducted on a 29 MWt (100 million Btu/hr) experimental furnace, referred to as the Large Watertube Simulator (LWS). The LWS is a full-scale model of a small wall-fired utility boiler, having a firing depth of 6.7 m, and cooled by external water sprays onto its corrugated steel walls. Insulation inside the furnace is designed to cause the furnace gas to drop to 1230°C (the upper end of the "sulfation temperature window"), just before the gas passes the furnace nose; this is the approximate location of that isotherm in a full-scale boiler.

In all testing, the LWS was operated with a single 29 MWt burner mounted in the front wall. During the initial optimization of the limited internal staging options, this burner was operated with and without two different coal splitters which had provided good NO_x reductions during the earlier smaller-scale testing. During the sorbent injection testing, the burner was operated at the conditions which gave the best NO_x performance during the initial optimization testing (T-30 coal splitter, low swirl setting in secondary air register). Sorbent was injected at three locations on the front (firing) wall of the furnace, and one on the rear wall.

Results

The burner optimization studies showed some potential for NO_x reduction with the internally staged burner tested here (the IS-100 burner). The intent of the internally staged burner is to achieve NO_x reductions without the external tertiary air ports characteristic of commercial low-NO_x burners, and to achieve the internal fuel/air staging with high burner velocities (to facilitate retrofit into existing pre-NSPS boilers without extensive modifications to increase the size of the burner opening in the firing wall). The baseline unstaged burner tested here with the annular coal nozzle (a typical pre-NSPS burner configuration) gave NO_x emissions of 830-900 ppm (dry, 0% O_2), typical of pre-NSPS burners. Significant reductions were achieved with the staged IS-100 burner using axial coal nozzles employing the T-15 or T-30 coal splitters, which were designed to divide the coal stream into four initially fuel-rich flames. These splitters reduced NO_x by about 150-200 ppm. The optimum configuration in these tests was with the T-30 coal nozzle and the low swirl register setting. This configuration gave 550 ppm NO_x (dry, 0% O_2), with an acceptable flame length of 6.7 m, and CO less than 40 ppm. The NO_x reductions achieved were limited in part because--due emphasizing the SO_2 portion of this project--the full range of internal staging options was not investigated (e.g., divided secondary air registers were not employed in the IS-100 burner).

Sorbent injection from the front wall of the furnace gave unexpectedly poor SO_2 capture; better sorbent performance would have been anticipated, considering that the gas temperatures at the injection points were near optimum. Cold-flow physical modelling showed that this poor capture was caused by a strong recirculation zone above the burner which extended into the upper furnace region. This zone created a downflow of furnace gas along the front wall, which drew the sorbent into the flame. The bulk of the gas flow to the furnace exit took the form of a relatively thin layer of gas, about 0.6 m thick, flowing up the rear wall. In view of this flow pattern, sorbent injection from the rear wall appeared to be an attractive approach, because of the low risk of the injected sorbents being carried into the flame.

Sorbent injection from the rear wall gave reasonable SO_2 capture, reaching 35% capture at Ca/S = 2 for Vicron 45-3 limestone (10 µm mass mean). Capture was very sensitive to sorbent injection velocity, because it was necessary to match the jet penetration to the thickness of the gas flow up the rear wall. If injection velocity was too high, sorbent penetrated across the thin exit flow layer into the recirculation zone, and was carried down into the flame zone. If the injection velocity was too low, the sorbent was not adequately dispersed in the upflow stream.

Reasonable SO_2 was also captured from front wall injection in the upper furnace region, 5.8 m above the burner. However, good front-wall performance could be achieved only with large-diameter, high-velocity jets. These jets had sufficient momentum to penetrate across the recirculation zone and carry most of the sorbent into the exiting flue gas flow. With four 15-cm diameter jets at an injection velocity of 21 m/s, the SO_2 capture by Vicron at Ca/S = 2 was 30%. Capture was improved when the jets were configured in a double- concentric mode, with the sorbent injected in a 2.5-cm diameter jet along the axis of the larger (15-cm diameter) annular air jet. Apparently, this allowed a greater fraction of the sorbent to reach the exit gas flow without being drawn down into the flame zone. The capture increased as the sorbent jet velocity was increased, consistent with results observed with double-concentric jet tests in earlier, smaller-scale testing. The reason for this effect is not clear, but it is thought to be related to changes in mixing conditions in the jet. Capture during front-wall injection was also greater with a larger number of jets (4 vs 2), probably because, with four jets, the two outermost jets near the sides of the furnace were delivering sorbent to a region where the recirculation down-flow into the burner zone was not so strong. The best capture achieved with the double-concentric jets was about 40% at Ca/S = 2 for Vicron limestone.

Tests were conducted using D3002 dolomite and Type S pressure- hydrated dolomitic lime, as well as Vicron limestone, for the best front- and rear-wall injection configurations. The dolomitic sorbents gave superior capture to the limestone. Dolomite gave SO_2 captures in the range 45 to 50% at Ca/ S = 2, and the pressure hydrate gave captures in the range 58 to 62%. The relative performance of these three sorbents (dolomitic hydrate better than raw dolomite better than limestone) is similar to results that have been observed in other experimental investigations.

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The complete report, entitled "Evaluation of Internally Staged Coal Burners and Sorbent Jet Aerodynamics for Combined SO_2/NO_x Control in Utility Boilers: Vol. 2. Testing in a 100 Million Btu/Hr Experimental Furnace," (Order No. PB 90-108 846/AS; Cost: $23.00, subject to change) will be available only from:
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