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Obtaining Low N₂O, NO, and SO₂ Emissions from Circulating Fluidized Bed Boilers by Reversing the Air Staging Conditions

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Obtaining Low N_2O, NO, and SO_2 Emissions from Circulating Fluidized Bed Boilers by Reversing the Air Staging Conditions

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A method for decreasing N_2O without increasing the emission of the other pollutants NO_x and SO_2, reversed staging, was investigated in the 12 MW circulating fluidized bed boiler at Chalmers University of Technology. It was possible to reduce the emission of N_2O to one-fourth (25 ppm) and NO to half (about 40 ppm) compared to normal staging and normal temperature, without significantly affecting the sulfur capture efficiency (being about 90%).

Air staging, which is normally used in circulating fluidized bed boilers, means that only a part of the combustion air, primary air, is added to the bottom zone, resulting in a lower oxygen concentration in the bottom part, while the secondary air results in more oxidizing conditions in the upper part of the combustion chamber and the cyclone. The principal idea with *reversed staging* is to reverse the conditions in top and bottom, *i.e.*, to decrease the oxygen concentration in the upper part and to increase it in the bottom part.

It is well-known that the emissions of NO_x, SO_2, and N_2O can be significantly decreased or increased by changes in operational parameters like bed temperature and air supply. The problem is that, while a measure taken to decrease one of the emissions may prove successful, it has the opposite effect on one or two of the others.[1]

The method is based on the difference in the effect of oxygen on the various emissions depending on the location in the combustor (bottom part vs upper part and cyclone) and a reversal of the conditions normally used was found to give a considerably lower emission of NO and N_2O without increasing SO_2.

A circulating fluidized bed boiler is normally operated with a significant amount of secondary air, and the bottom part of the combustion chamber is, to a great extent, under reducing conditions, while oxidizing conditions in the upper part are necessary to obtain acceptable sulfur capture and combustion. In order to reverse the situation, *i.e.*, to obtain more oxidizing conditions in the lower part and less oxidizing conditions in the upper part, the following strategy was used.

The combustor air ratio, *i.e.*, the air ratio in combustion chamber and cyclone, was kept close to unity. No secondary air was used and all air was added in the bottom zone, except for some air which was added for final combustion after the cyclone giving a total air ratio of 1.2.

The increased air ratio of the bottom part makes this part more oxidizing compared to normal staging. The gradual consumption of oxygen with height decreases the average oxygen concentration from the bottom and upwards, approaching very low oxygen concentrations in the top zone of the combustion chamber and the cyclone, since the combustor air ratio is kept at about unity.

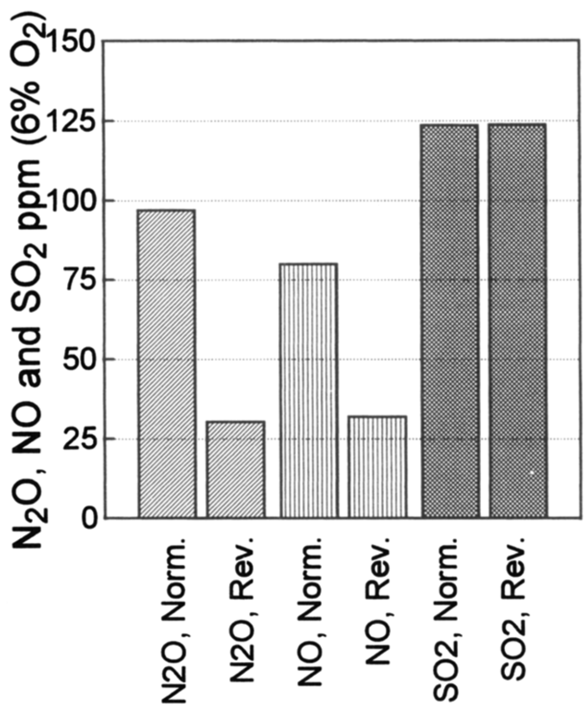

Figure 1. Emissions of N_2O, NO, and SO_2 for normal air staging and reversed staging.

The 12 MW circulating FBB used for the experiments has the feature that air can be added in the outlet of the cyclone for final combustion. The coal was a bituminous coal with a sulfur content of 1.6% (dry, ash-free).

The test cases were run at constant load and the total air ratio was kept at 1.2. The bed temperature was 850 °C and the limestone addition molar Ca/S ratio was about 2.5.

About 60% primary air and 40% secondary air (2.2 m above air distributor) was used in the reference case (normal staging) . In the case of *reversed staging* there was no secondary air in the combustion chamber, but about 20% of the total air was added after the cyclone for final combustion. The combustor air ratio, before addition of final combustion air, was kept at about unity.

The emissions of N_2O, NO, and SO_2 in the two cases are shown in Figure 1. Additional runs of the reversed staging case under slightly varied conditions gave somewhat lower N_2O emissions and somewhat higher NO emissions than in Figure 1.

(1) Lyngfelt, A.; Leckner, B. *Fuel* **1993,** *72,* 1553–1561.

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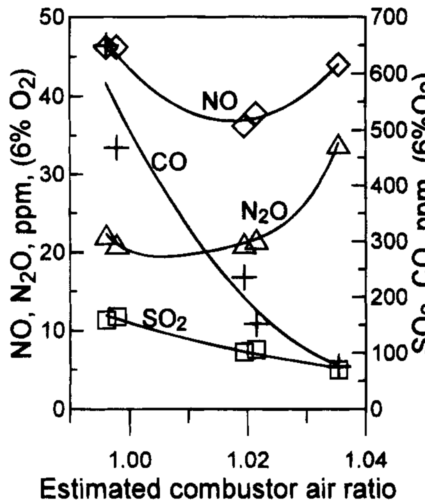

Figure 2. Emissions versus estimated combustor air ratio for the reversed staging case. The conditions are the same as in Figure 1, except that the limestone addition is 25% higher.

Reversed staging gives a reduction in the N_2O emission by about three-fourths, while the NO emission is halved and the SO_2 emission is not significantly affected. The CO emission, however, increased from about 50 to 300 ppm. The CO emission was found to be strongly dependent on the combustor air ratio and could be halved just by increasing this with about 1% without the low N_2O and NO emissions being affected. This is seen in Figure 2, where the effect of varied combustor air ratio on the emissions is shown.

The results indicate that it is possible to separate the effects of reducing/oxidizing conditions on the emissions by producing these conditions selectively in the bottom and top parts of the combustor. Thus, a major decrease of the N_2O and NO emissions was obtained without increasing the SO_2 emission.

A more detailed description of the test conditions and test results is given by Lyngfelt *et al.*[2]

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(2) Lyngfelt, A.; Åmand, L.-E.; Leckner, B. Low N_2O, NO and SO_2 emissions from circulating fluidized bed boilers. To be presented at the 13th International Fluidized Bed Combustion Conference, Orlando, FL, May 7–10, 1995.