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

Anders Lyngfelt,* Lars-Erik Åmand, and Bo Leckner

Department of Energy Conversion, Chalmers University of Technology, 412 96 Göteborg, Sweden

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A method for decreasing N₂O without increasing the emission of the other pollutants NOₓ and SO₂, 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 N₂O 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 NOₓ, SO₂, and N₂O 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 N₂O without increasing SO₂.

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

Figure 1. Emissions of N₂O, NO, and SO₂ for normal air staging and reversed staging.

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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 N₂O 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 N₂O and NO emissions was obtained without increasing the SO₂ emission.

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

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