IMPROVED RICH REAGENT INJECTION (RRI) PERFORMANCE FOR NOx CONTROL IN COAL FIRED UTILITY BOILERS

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SUMMARY

Most efforts devoted to modification of the combustion process to reduce NOx formation in fossil fuel fired boilers and furnaces involve the use of air or fuel staging. Low NOx burners utilize aerodynamic staging through the burner design to separate the majority of the combustion air from the fuel within the primary combustion zone to create a locally fuel rich reducing zone. Overfire air (OFA) employs furnace level air staging to create a high temperature fuel-rich reducing zone. Both strategies are used heavily in state-of-the art low-NOx coal-firing systems to achieve cost-effective NOx reductions and the majority of coal-fired utility boilers are presently equipped with combustion modifications of this type. In particular, since 1996, the majority of existing cyclone-fired boilers have been retrofit with OFA systems which have been demonstrated to reduce full load NOx emissions from 1-2 lb/MBtu down to emissions as low as 0.2 – 0.3 lb/MBtu. The lowest NOx emissions have been attained in units with good air flow measurement and controls to accommodate deep levels of staging (e.g. 0.8 - 0.9 barrel stoichiometric ratio) without compromising unit operability. However, even with significant levels of furnace staging, well-controlled and designed OFA systems are not expected to lead to full load NOx emissions below a 0.15 lb/MBtu limit in most cyclone fired units, regardless of coal type. Rich Reagent Injection (RRI), co-developed by EPRI and REI, provides a strategy that works synergistically with air staging to yield significant additional NOx reduction with no associated NH_3 slip.

RRI has been previously demonstrated during field-testing to achieve 30% NOx reductions in two existing cyclone fired utility boilers equipped with OFA. These tests were conducted in B.L. England Unit 1 (BLE1), a single wall-fired 130 MW unit, and Sioux Unit 1, an opposed wall-fired 500 MW unit. Full load NOx emissions of 0.39 lb/MBtu were obtained in BLE1 and 0.27 lb/MBtu were obtained in Sioux Unit 1 through the use of OFA and RRI. Computational fluid dynamics (CFD) based modeling was utilized to design the reagent injection systems in both units as well as to predict the performance of RRI. In both cases, the field test results confirmed the CFD model predictions (Cremer, 2001; Cremer, 2002). These full-scale NOx reductions are in contrast to results from pilot scale testing that showed that NOx reductions of up to 90% could be obtained with RRI under ideal conditions. Thus, it is to be expected that in furnaces and boilers exhibiting conditions more conducive to the RRI process, significantly higher NOx reductions than 30% and lower emissions than 0.27 lb/MBtu could be obtained.

Recent CFD modeling of existing full-scale cyclone boilers has shown this to be true. Three evaluations have been completed:

1. 205 MW opposed wall-fired cyclone
2. 330 MW front wall-fired cyclone
3. 500 MW opposed wall-fired cyclone

RRI performance was evaluated in a 205 MW opposed wall-fired cyclone unit with an existing OFA system. Typical full load NOx emissions in this unit under operation with OFA are 0.60 lb/MBtu. Utilizing 12 RRI injectors at two boiler elevations below the OFA ports, the model predictions indicate that full load NOx emissions will be reduced by 57% to yield NOx emissions of 0.26 lb/MBtu with less than 1 ppm NH_3 slip. These estimates assumed a normalized stoichiometric ratio (NSR) of 2.0. For NSR=1.0, 41% NOx reduction was predicted. The predictions also showed significantly better RRI performance when the cyclones barrels were operated at 90% of their stoichiometric air requirement rather than 95% (i.e. SR=0.90). The model evaluation also showed that RRI performance is expected to be similar (59%) under reduced load conditions.

RRI performance was also evaluated through CFD modeling of Edgewater Unit 4, a 1969 vintage, 330 MW, 7-barrel cyclone boiler, designed originally to fire bituminous coal. In this case, RRI performance was evaluated in combination with Alliant Energy's SmartBurn^{SM} combustion technology. RRI was predicted to achieve a reduction in full load NOx emissions of 52% from the 0.46 lb/MBtu baseline to a NOx level of 0.22 lb/MBtu with less than 1 ppm NH_3 slip. In this evaluation, it was assumed that the cyclone barrels were staged to achieve SR=0.9. Alliant Energy has recently reported (Vásquez et al, 2003), that under deeper staging conditions and firing 100% Powder River Basin (PRB) coal, NOx emissions below 0.30 lb/MBtu have been obtained. Thus, combining SmartBurn^{SM} combustion technology with RRI, has good potential for achieving full load NOx emissions lower than 0.15 lb/MBtu in this cyclone unit.

Following the demonstration of RRI in AmerenUE's Sioux Unit 1, a model based evaluation was conducted to investigate RRI in this unit under more deeply staged conditions. These results showed that full load NOx emissions could be reduced significantly below the 0.27 lb/MBtu levels that were obtained during the RRI field testing (Cremer, 2002). By staging the cyclone barrels to SR=0.90 and operating the RRI system that was previously tested, model predictions indicated that full load NOx emissions of 0.18 lb/MBtu are achievable with < 1 ppm NH_3 slip. This represents approximately 50% NOx reduction from current full load NOx emissions.

These three model based evaluations indicate that:

- Combined with combustion modifications including deeper staging, efficient OFA, and barrel optimization, RRI has potential for achieving 0.15 lb/MBtu levels in certain cyclone fired units with <1 ppm NH_3 slip
- The improved NOx reduction through RRI, which is predicted in the 205 MW and 330 MW units, is due in part to the relatively high residence time in the fuel rich zone of these units, as well as the well targeted reagent injection design
- RRI will likely achieve in excess of 50% NOx reduction in certain cyclone fired units

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