Layered NOx Reduction Technologies on a 500 MW Cyclone-fired Boiler

Bradley Adams
Reaction Engineering International, 77 West 200 South, Suite 210, Salt Lake City, UT 84101
E-mail: adams@reaction-eng.com; Telephone: (801) 364-6925 x18; Fax: (801) 364-6977

Marc Cremer
Reaction Engineering International, 77 West 200 South, Suite 210, Salt Lake City, UT 84101
E-mail: cremer@reaction-eng.com; Telephone: (801) 364-6925 x14; Fax: (801) 364-6977

Andrew Chiodo
Reaction Engineering International, 77 West 200 South, Suite 210, Salt Lake City, UT 84101
E-mail: chiodo@reaction-eng.com; Telephone: (801) 364-6925 x46; Fax: (801) 364-6977

Craig Giesmann
Ameren, One Ameren Plaza, 1901 Chouteau Avenue, PO Box 66149, MC 450, St. Louis, MO 63166-6149
E-mail: CGiesmann@ameren.com; Telephone: (314) 554-2535; Fax: (314) 554-4084

Ken Stuckmeyer
Ameren, One Ameren Plaza, 1901 Chouteau Avenue, PO Box 66149, MC 450, St. Louis, MO 63166-6149
E-mail: KStuckmeyer2@ameren.com; Telephone: (314) 554-2535; Fax: (314) 554-4084

John Boyle
Fuel Tech, Inc., 512 Kingsland Drive, Batavia, IL 60510-2299
E-mail: JBoyle@fueltechnv.com; Telephone: (630) 845-4500

Summary

Cyclone fired boilers have historically been characterized as high NOx emitting units due to the very high combustion temperatures that are produced in the primary combustion zone. Uncontrolled NOx emissions ranging from 0.8 to 1.9 lb/mmBtu have been typical. Due to the design characteristics of cyclone fired units, they are not conducive to the application of conventional low NOx burner technology. Prior to 1997, the conventional wisdom was that cyclone fired boilers could not be practically operated under two stage combustion conditions due to concerns about the reducing conditions in the cyclone barrel leading to corrosion. Gas reburn technology and SCR were considered to be the technologies of choice in cyclone units for NOx reduction.

In anticipation of Title IV Phase II NOx limits, Reaction Engineering International (REI) participated with EPRI and their Cyclone NOx Control Interest Group (CNCIG) to evaluate alternative options for NOx control in cyclone fired boilers from 1995 to 2002. There were three significant outcomes of this work: 1) development of a CFD based model of cyclone barrel combustion for evaluation of cost-effective options for NOx reduction; 2) demonstration of two stage combustion in cyclone boilers as a cost-effective NOx reduction strategy; and 3) demonstration of Rich Reagent Injection (RRI) in combination with OFA for significant additional NOx reduction in cyclone boilers. The successes of the CNCIG group led to the installation of OFA in the majority of cyclone boilers currently operating in the United States allowing them to meet the Title IV NOx limit of 0.86 lb/MBtu at capital and operating costs significantly lower than that of gas reburn or SCR.

However, for the majority of cyclone fired boilers currently equipped with OFA, it is not expected that NOx emissions below a 0.15 lb/MBtu target will be achievable without installation of additional NOx controls. An attractive option for meeting sub-0.15 lb/MBtu NOx limits in cyclone fired units is the combination of deep

staging combined with reagent injection as part of the Rich Reagent Injection (RRI) and Selective Non-catalytic Reduction (SNCR) processes. This layered approach to NOx reduction is termed the Advanced Layered Technology Approach (ALTA).

This presentation summarizes the results of a recent Department of Energy (DOE) National Energy Technology Laboratory (NETL) funded program to evaluate ALTA in a full-scale cyclone fired boiler. The field testing was conducted in AmerenUE's Sioux Unit 1, a 540 MW cyclone fired boiler located near St. Louis, MO. The DOE-NETL program was divided into two components: 1) Model-based design, and 2) Field Testing. CFD based modeling was conducted by REI to guide the RRI and SNCR process design and to locate new RRI and SNCR injection ports. The focus of this presentation is the field testing component. The field testing was divided into two phases: 1) Parametric testing, and 2) Continuous Testing. The duration of the parametric testing was 14 days, beginning on May 16, 2005 and extending through June 3, 2005. Continuous testing of the temporary ALTA system was initiated on June 6, 2005 and proceeded through the morning of June 9, 2005. Testing support and equipment were provided Fuel Tech Inc., Ameren, EPRI, and REI.

The results of the field testing conducted in Sioux Unit 1 confirmed the model based predictions indicating that sub-0.15 lb/mmBtu NOx emissions could be obtained with ALTA. Specific conclusions based on the results of the parametric and continuous tests of ALTA in Sioux Unit 1 were:

- The combination of RRI and SNCR was able to reduce NOx emissions to 0.12 lb/mmBtu with less than 5 ppm ammonia slip in a reliable manner from baseline NOx emissions of 0.25 lb/mmBtu or less when firing the typical 80/20 PRB/Ill #6 fuel blend at 480 MW or lower.
- RRI alone reduced NOx emissions to 0.16 to 0.17 lb/mmBtu from baseline NOx levels of 0.25 lb/mmBtu or lower with less than 1 ppm ammonia slip when firing the typical 80/20 fuel blend at 480 MW or lower.
- Increasing the percentage of Illinois #6 fuel in the PRB/Ill. #6 blend led to a decrease in NOx reduction achievable with RRI when staging to achieve NOx emissions of 0.35 lb/mmBtu and below.
    - The lowest NOx emission achieved with a 60/40 blend was approximately 0.15 lb/mmBtu.
    - The lowest NOx emission achieved with 100% Illinois #6 was approximately 0.165 lb/mmBtu.
- There was no apparent decrease in SNCR performance with increasing percentages of Illinois #6 coal.
- Continuous testing showed that the water-cooled stainless steel RRI injectors used during the testing could withstand the harsh high temperature environment. Several injector tip failures confirmed that air cooling alone was not sufficient to protect the RRI injectors once inserted past the waterwall.
- Continuous testing indicated that the levels of ammonia slip generated by the ALTA process would not lead to dramatic ammonia bisulphate deposition causing air heater pluggage in the tubular air heaters in Sioux Unit 1 over short time periods.