Low Emission Boiler System (LEBS)

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Summary

A new low NO_x coal firing system is being developed under the U.S. Department of Energy's low emission boiler system (LEBS) program. The goal of the LEBS program is to dramatically improve the environmental performance of pulverized coal-fired power plants by reducing emissions, increasing efficiency, and producing useful byproducts. The Riley Power boiler design utilizes a proven U-fired slagging furnace configuration, which converts nearly all of the ash contained in the coal to a vitrified byproduct. Because of the high temperature environment, conventional slagging furnaces typically produce higher NO_x than dry fired systems. The LEBS low-NO_x firing system integrates advanced low- NO_x coal burners with furnace air staging and coal reburning into the U-fired furnace design. Testing of LEBS combustion system was performed in Riley's 30 MWth U-fired combustion test facility. NO_x emissions of less than 0.2 lbs/10^6 Btu (86 g/GJ) were achieved on several U.S. coals. Plans are being made to commercially demonstrate this advanced low- NO_x U-firing system in a 91 MW_e LEBS proof of concept plant.

The LEBS firing system is based on the well-established U-fired slagging boiler design. The fuel is fired down into a refractory chamber. Slag forms on the chamber walls and bottom, and on the slag screen at the chamber exit. The slag is continuously tapped from the combustion chamber, quenched, and dewatered. The hot gases then flow up and out through the slag screen, and final air is added to complete combustion. The U-firing system can fire a wide range of coals under varying utility operating conditions.

High temperatures are needed to maintain slag flow in U-fired boilers resulting in high NO_x emissions. In early U-fired slagging boilers, highly turbulent burners produced NO_x emissions as high as 1.6 lbs/10^6Btu (688 g/GJ). Applying air staging and burner design improvements reduce the emission level to 0.8 lbs/10^6Btu (340 g/GJ) for currently operating units. A major challenge for Riley Power was to satisfy the LEBS emission goals while operating at high temperature slagging/conditions to satisfy the reduced waste generation goal. A NO_x emission target of 0.2 lbs/10^6Btu (86 g/GJ) was established for the firing system alone to minimize the amount of NO_x reduction for the post combustion emissions control system.

The approach for achieving the combustion system NO_x emission target was to apply the Controlled Combustion Venturi (CCV®) Dual Air Zone coal burner in combination with advanced air staging and coal reburning techniques in the U-fired slagging system. Riley Power built a 100 million Bu/hr U-fired combustion test facility to test the low NO_x firing approach in a U-fired slagging system for the U.S. DOE LEBS program. An existing CCV® dual air zone test burner was modified for down-firing and installed in the U-fired test facility.

Various air staging and coal reburning locations were evaluated in the test facility. These locations provide zones of various combustion stoichiometric ratios (SR) in the furnace. Various reburn residence times were tested depending upon the reburn injection and final air locations. Most of the tests conduced in the U-fired facility were completed with the Illinois No. 5 coal from Turris Mine site. Illinois No. 5 is a high sulfur, high volatile Bituminous C coal. Selected conditions were also tested with a medium sulfur, high volatile Bituminous A coal.

The test burner was also modified to simulate burners installed in a commercially operating U-fired slagging boiler. The total excess air was maintained at 15%. The CCV® Dual Air Zone Burner performance was significantly different than the baseline burner. The CCV® Dual Air Zone Burner NOx emissions were remarkably low for slag tap operation.

The NO_x levels in U-fired test facility were further reduced to below 0.2 lbs/10^6Btu (86 g/GJ) by operating the low- NO_x burner in combination with extended air staging or by introducing coal reburning. The residence time in the fuel rich zone was extended by introducing air staging farther downstream achieving the firing system target. The target was also achieved by coal reburning at about 10% of the total firing rate to lower the stoichiometry in the upflow section to 0.9.

Although coal reburning and extended air staging operate at similar stoichiometries, coal reburning provides a smaller fuel rich zone in the furnace. A shorter reducing zone minimizes the need for corrosion resistant materials in the furnace. Coal reburning also separated the substoichiometric zone from the slagging chamber in the furnace. Under U-fired reburn conditions, the firing chamber slag tap can be operated at a stoichiometry of 1.

Coal reburing required sufficient residence time to be effective. The maximum residence time for injecting reburn fuel after the slag screen was one second. A higher residence time was tested by injecting the reburn fuel before the slag screen. While NO_x was reduced further at the higher reburn residence, injecting the reburn before the slag screen caused poor slag flow. The best conditions for the low NO_x emissions and good slag flow was to set the slagging chamber at a stoichiometry of 1 and introduce the reburn fuel after the slag screen with at least one-second residence time.