Evaluation of SNCR Performance in Ameren's Rush Island Unit 2

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INTRODUCTION

AmerenUE and AmerenCIPs operate eight very similar 600 MWe tangentially fired coal boilers equipped with advanced low NOx firing systems. These boilers will be affected by stringent ozone attainment regulations that require NOx controls beyond low-NOx burner technologies. Ameren and the Electric Power Research Institute (EPRI) funded this program to assess the expected performance capability of SNCR on large boilers of this type. The particular boiler selected for evaluation was AmerenUE's Rush Island Unit 2. Rush Island Unit 2 burns Powder River Basin coal and has been retrofitted with an ABB-CE LNCFS Level III low NOx firing system with 6 coal burner levels, 2 close coupled overfire air (CCOFA) levels and 5 separated overfire air (SOFA) levels.

The program consisted of three components: 1) field measurements, 2) physical cold flow modeling, and 3) computational fluid dynamics (CFD) modeling.

FIELD MEASUREMENTS

Temperature and emissions measurements were collected in Rush Island Unit 2 at loads of 600, 450, and 250 MWe. The measured data at full load were used in the CFD modeling phase of the program to aid in the development of a baseline computer model of full load conditions. Suction pyrometry, utilizing high velocity thermocouple (HVT) probes, was used to collect the furnace temperature data. The HVT measurements were made at nominal 4-feet intervals over the range of 4 to 20 foot depths using front and side wall ports. NO, O_2, and CO measurements were made at the same locations as the temperature measurements.

These data showed that the furnace exit gas temperatures at the nose, which are in excess of 2450°F, are too hot for effective SNCR performance at this location. In addition to the high temperatures, the measured CO levels were also very high. The measurements through the upper front and side wall ports indicated more optimal SNCR conditions where the gas temperatures averaged 1980^{o}F and the CO levels averaged 390 ppm.

PHYSICAL COLD FLOW MODELING

Physical cold flow modeling was conducted to screen possible SNCR injection scenarios for Rush Island Unit 2, ultimately limiting the number of cases investigated during the CFD modeling phase of the program. Although not capable of simulating temperature effects, physical cold flow modeling provided a method for quickly screening the mixing performance of different injection configurations. Velocity and tracer gas concentration measurements were used to quantitatively define mixing performance in the 1:24 scale model for a total of 21 different injection strategies. Parameters that were considered included: 1) location and number of injectors, 2) injector orientation, and 3) jet momentum ratio. The low energy strategy (representative of aqueous urea injection) that resulted in the best overall mixing involved a combination of front wall injectors and a convective cavity lance that yielded approximately 70% mixing. Various strategies involving lower or upper front wall injection alone resulted in 50 - 55% mixing, while strategies involving only convective cavity injection resulted in 25 - 35% mixing.

CFD MODELING

The computational tools used during this program simulate reacting and nonreacting flow of gases and particles, applicable to gaseous diffusion flames, pulverized-coal flames, liquid sprays, reacting two-phase flows and other oxidation/reduction systems. *BANFF* is Reaction Engineering International's (REI) three-dimensional, gas-phase turbulent reacting flow code, and *GLACIER* adds physical models to treat two-phase flows. These software tools have been applied to a wide variety of industrial systems encompassing utility boilers, pyrolysis furnaces, gas turbine combustors, rotary kilns, waste incinerators, smelting cyclones and others.

BANFF and *GLACIER* fully couple together the chemistry of reacting gases, solids and liquids with turbulent mixing and radiative heat transfer. Coupling turbulence and heat transfer with finite-rate reaction chemistry requires the number of chemical kinetic steps to be relatively small. *BANFF* and *GLACIER* use assumptions of partial equilibrium and steady state species to compute local finite-rate chemistry using a set of reduced kinetic steps for slow reactions and minimize Gibbs free energy for all other species. A reduced set of seven global SNCR reactions is fully coupled into *BANFF* and *GLACIER*. This reduced chemistry is based on the kinetic rates of Miller and Bowman (1989) with recent literature modifications.

The CFD modeling study to investigate expected SNCR performance in Rush Island Unit 2 included examination of eight different injection strategies. All of the strategies utilized low-energy aqueous urea injection, since the relatively high furnace exit temperatures and CO concentrations make the use of anhydrous ammonia injection problematic. A wide range of strategies was simulated to examine the effects of:

- injection locations,
- injector orientation,
- distribution of reagent between wall injectors and lance injectors,
- aqueous urea droplet size distribution,
- reagent dilution, and
- normalized stoichiometric ratio (NSR).

The droplet size distribution ranged from 40 μm Sauter Mean Diameter (SMD) for the lances to 300 or 500 μm SMD for the wall injectors. The injected urea concentration ranged from 5 to 10% by weight. Of the six injection locations investigated in the physical cold flow modeling, three were considered in the CFD modeling.

RESULTS AND DISCUSSION

The best results in terms of overall SNCR performance involved NOx reductions in the range of 25-30% with less than 5 ppmv ammonia slip. All estimates were under full load conditions, and performance at reduced loads was not investigated in this program. Of the strategies evaluated, the most promising scenario involved a combination of upper front wall injectors evenly spaced between the front superheat division panels at an elevation of 603 ft. and one elevation of lances immediately downstream of the front reheater pendant assemblies at an elevation of 594 ft. The combination of front wall injectors and lances was predicted to achieve nearly a 10% improvement in overall NOx reduction, compared to the use of front wall injectors alone (27% versus 25%), with a corresponding lower level of NH_3 slip.