Introduction

With support from the U.S. Department of Energy (DOE) National Energy Technology Laboratory (NETL), the Energy & Environmental Research Center (EERC), along with Marsulex Environmental Technologies and the ALSTOM Power Inc. Air Preheater Company, has been working to develop solutions to sulfur trioxide (SO₃) emission problems in coal-fired boilers. A significant pollutant in its gaseous form, SO₃ is the primary agent in acid rain and a precursor to sulfuric acid (H₂SO₄).

To meet the specific reductions in sulfur dioxide (SO₂) and nitrogen oxide (NOₓ) emissions required by the 1990 Clean Air Act Amendments, coal-fired electric utility emission reduction strategies have included installation of flue gas desulfurization (FGD) systems for SO₂ control and selective catalytic reduction (SCR) technology for NOₓ control. However, while reducing SO₂ and NOₓ, these technologies have increased the potential for emission of SO₃ and sulfuric acid aerosols and, in turn, increased stack opacity (a measure of particulate emissions). The reasons are clear: 1) FGD systems allow power plant operators to fire cheaper high-sulfur coals, which generate more SO₃ than do more expensive low-sulfur coals. While effective for SO₂ capture, wet FGD has been shown to have a minimal effect on removal of SO₃; and 2) SCR for NOₓ control results in increased SO₃ concentrations in the flue gas as a result of catalytic oxidation of SO₂ by the SCR. The problem may be aggravated by fine particles formed by the reaction of SO₃ with excess ammonia present from the FGD or SCR process, resulting in a highly visible “blue plume” emitted from the stack.

Technical Approach

The basis of the SO₃ reduction technology being demonstrated by the EERC and its partners is to provide controlled condensation of SO₃ by injection of fine particles immediately upstream of the air preheater (APH). The particles provide nucleation sites for heterogeneous condensation in preference to homogeneous condensation on metal APH surfaces. The condensation process does not depend on the composition of the particles, but only on the particle-size distribution and particle concentration. Limestone was chosen for its low cost and its ability to provide a degree of acid neutralization after condensation has occurred.

A computer model developed by the EERC determines the amount of SO₃ transformations and interactions across an APH to assist in developing strategies to minimize the level of SO₃ released to the environment. The predictive model developed by the EERC utilizes 1) an ash
**Project 1:**
Evaluation of SO$_2$ Emission Control by Flue Gas Humidification at the R. Paul Smith Station

**Duration**
Start Date: 04/01/2001
End Date: 06/30/2002

**Cost**
Total Project Value $244,000
DOE/Non-DOE Share $97,500 / $146,500

A full-scale field demonstration using the technology evaluated within this project was performed during late summer 2006. A commercial SO$_3$ generator that the plant uses for ESP conditioning was used to catalytically generate an elevated SO$_3$ concentration that was anticipated to result from firing a higher-sulfur coal (~35 ppm SO$_3$) with an SCR installed. The control technology used finely ground limestone to catalytically generate an elevated SO$_3$ concentration that was anticipated to result from firing a higher-sulfur coal (~35 ppm SO$_3$) with an SCR installed. The control technology used finely ground limestone to catalytically generate an elevated SO$_3$ concentration that was anticipated to result from firing a higher-sulfur coal (~35 ppm SO$_3$) with an SCR installed. The control technology used finely ground limestone to catalytically generate an elevated SO$_3$ concentration that was anticipated to result from firing a higher-sulfur coal (~35 ppm SO$_3$) with an SCR installed. The control technology used finely ground limestone to catalytically generate an elevated SO$_3$ concentration that was anticipated to result from firing a higher-sulfur coal (~35 ppm SO$_3$) with an SCR installed. The control technology used finely ground limestone to catalytically generate an elevated SO$_3$ concentration that was anticipated to result from firing a higher-sulfur coal (~35 ppm SO$_3$) with an SCR installed. The control technology used finely ground limestone to catalytically generate an elevated SO$_3$ concentration that was anticipated to result from firing a higher-sulfur coal (~35 ppm SO$_3$) with an SCR installed. The control technology used finely ground limestone to catalytically generate an elevated SO$_3$ concentration that was anticipated to result from firing a higher-sulfur coal (~35 ppm SO$_3$) with an SCR installed. The control technology used finely ground limestone to catalytically generate an elevated SO$_3$ concentration that was anticipated to result from firing a higher-sulfur coal (~35 ppm SO$_3$) with an SCR installed. The control technology used finely ground limestone to catalytically generate an elevated SO$_3$ concentration that was anticipated to result from firing a higher-sulfur coal (~35 ppm SO$_3$) with an SCR installed. The control technology used finely ground limestone to catalytically generate an elevated SO$_3$ concentration that was anticipated to result from firing a higher-sulfur coal (~35 ppm SO$_3$) with an SCR installed. The control technology used finely ground limestone to catalytically generate an elevated SO$_3$ concentration that was anticipated to result from firing a higher-sulfur coal (~35 ppm SO$_3$) with an SCR installed. The control technology used finely ground limestone to catalytically generate an elevated SO$_3$ concentration that was anticipated to result from firing a higher-sulfur coal (~35 ppm SO$_3$) with an SCR installed. The control technology used finely ground limestone to catalytically generate an elevated SO$_3$ concentration that was anticipated to result from firing a higher-sulfur coal (~35 ppm SO$_3$) with an SCR installed. The control technology used finely ground limestone to catalytically generate an elevated SO$_3$ concentration that was anticipated to result from firing a higher-sulfur coal (~35 ppm SO$_3$) with an SCR installed. The control technology used finely ground limestone to catalytically generate an elevated SO$_3$ concentration that was anticipated to result from firing a higher-sulfur coal (~35 ppm SO$_3$) with an SCR installed. The control technology used finely ground limestone to catalytically generate an elevated SO$_3$ concentration that was anticipated to result from firing a higher-sulfur coal (~35 ppm SO$_3$) with an SCR installed. The control technology used finely ground limestone to catalytically generate an elevated SO$_3$ concentr...
ground limestone injected immediately ahead of the APH as the SO\textsubscript{3} removal medium. Precise placement of 12 limestone injection lances provided a reasonably even distribution across the gas stream going into the APH.

SO\textsubscript{3} sampling was performed at three locations: 1) the inlet to the APH (after the SO\textsubscript{3} injection location), 2) the exit of the APH, and 3) the inlet to the ESP. The sampling was done at the APH inlet and outlet locations and at the ESP inlet using the controlled condensation method. The measured SO\textsubscript{3} levels in the flue gas during the tests are shown in Figure 1. There was a 53.6 percent average reduction in SO\textsubscript{3} (as measured at the ESP inlet location) as a result of limestone injection. No increase in APH pressure drop was observed, and there was no change in ESP performance or increase in stack opacity during the limestone injection.

From the model predictions, the calculated SO\textsubscript{3} removal results for the currently fired coal with an assumed SO\textsubscript{3} concentration of 36 ppm are shown in Figure 2 in comparison with the measurements obtained during the test program. At the ESP exit, a substantial reduction in gas-phase SO\textsubscript{3} was predicted for the case with limestone injection (25 versus 55 percent of the starting concentration) with the difference condensed on particulate material. Although the limestone only increases the particle loading from 1.5 to 3.0 to 4.0 percent, the small particle size results in significant additional condensation. The full-scale test results were in good agreement with the model predictions.

**Commercial Opportunity**

Improved sulfur control technologies such as an FGD combined with a fabric filter baghouse make possible the burning of higher-sulfur coals. However, reduction of SO\textsubscript{3} concentrations to less than a dew point temperature of 270°F is then required to avoid back-end corrosion, damage to fabric filters, and visible stack emissions. The operating criteria for the SO\textsubscript{3} control technology imposed the requirements of having no negative effect on unit operations, such as increased APH pressure drop or accumulation of material in the ductwork; high levels of reliability, operability, and maintainability; low operating cost; and a reasonable capital cost. All of these requirements are met using this SO\textsubscript{3} reduction technology. Other SO\textsubscript{3} abatement technologies—such as the use of fireside reagents, reagent-based postcombustion additives, and wet ESP technology—do not meet all of these desired performance and operating requirements.

“The results of the modeling work indicated a significant reduction of SO\textsubscript{3} in the presence of fine particles...as the flue gases containing SO\textsubscript{3} passed through the APH and ductwork upstream of the ESP, which was corroborated by early field observations at a full-scale utility boiler. This finding provided a unique opportunity to reduce the level of SO\textsubscript{3} in the flue gas as it passes through an APH.”

**States and Localities Impacted**

- Grand Forks, ND
- Lebanon, PA
- Chester, VA