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An ADA-ES, Inc. White Paper

Integrating ADAir™ Mixer Technology to Optimize System Performance with DSI Applications

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ABSTRACT

Utility and industrial coal-fired boilers are subject to multipollutant regulations covering emissions of mercury, acid gases, and particulate matter: the Mercury and Air Toxics Standards (MATS) and Industrial Boiler MACT (IB MACT), respectively. In addition, some boilers are subject to reductions of SO_2 emissions under the Cross-State Air Pollution Rule (CSAPR), National Ambient Air Quality Standards (NAAQS) and Regional Haze rules. For many coal-fired boilers, achieving MATS or IB MACT compliance utilizes activated carbon injection (ACI) for mercury control and dry sorbent injection (DSI) for acid gas removal. Dry sorbent injection is also an option for moderate levels of SO_2 control. This presentation will focus on the benefits of integrating the ADAir Mixer Technology with sorbent injection systems to optimize sorbent distribution and reduce system O&M costs. This proprietary technology improves particle distribution and reduces sorbent consumption, by as much as 40%, as part of an optimized compliance strategy. Other benefits include potential to reduce the number of injection lances leading to increased system reliability, reduced fly ash disposal costs, and decreased velocity and temperature variations inlet to the particulate collection device leading to lower particulate emissions. ADA-ES, Inc. (ADA) will present results utilizing this technology with a DSI system and present modeling results with different duct configurations.

INTRODUCTION

For nearly two decades, ADA has conducted more than 100 mercury control demonstrations at coal-fired power plants, sold activated carbon injection systems maintaining mercury control for more than 152 boilers, and provided dry sorbent injection systems on over 50 utility boilers. Our portfolio of products has grown to address limitations in coal composition, balance-of-plant impacts from alternate approaches, and operational challenges introduced by other technologies. We were the first to understand these environmental issues and provide a range of commercial solutions to the industry.

ADA delivers an important combination of hands-on experience, industry expertise, demonstrated commercial products, and commitment to collaborating with customers. Our track record includes securing more than 35 US patents, with additional US and international patents pending, and receiving numerous prestigious industry awards for emissions control technology and systems. No matter the challenges our customers face, ADA will continue to focus its significant expertise and resources on innovating for a cleaner energy future.

Legislation and Environmental Regulations

Air emissions from coal-fired boilers and industrial sources are regulated under the federal Clean Air Act as well as under state rules. These are multi-pollutant rules, which can increase the complexity of finding a compliance solution. As summarized below, specific federal rules apply to each source category.

Federal Mercury and Air Toxics Standards (MATS)

On December 16, 2011, the U.S. Environmental Protection Agency (EPA) issued the final MATS rule, which took effect on April 16, 2012. Affected units had to be in compliance on April 16, 2015, unless they received a one-year extension of the compliance date to April 16, 2016. The MATS rule is based on the maximum achievable control technology (MACT) framework for hazardous air pollutant (HAP) regulations. The rule is applicable to coal and oil-fired Electric Utility Steam Generating Units (EGUs) that generate electricity via steam turbines, and provides for, among other provisions, control of mercury and particulate matter, and control of acid gases and other HAPs.

State Mercury and Air Toxics Regulations Affecting EGUs

In addition to federal MATS rules, certain states have their own mercury rules that are similar to, or more stringent than MATS. Power plants around the country are also subject to consent decrees that require the control of acid gases and particulate matter, in addition to mercury emissions. Seventeen states have mercury-specific rules that affect more than 260 generating units.

Industrial Boiler MACT

In January 2013, the EPA issued the final rule limiting emissions of mercury, hydrogen chloride (HCl), particulate matter (PM) and other pollutants from industrial boilers through the National Emission Standards for Hazardous Air Pollutants, also known as the IB MACT. Starting January 31, 2016, industrial boilers must begin compliance with the Industrial Boiler (IB) MACT which limits emissions of mercury, acid gases, particulate matter, and carbon monoxide. Some boiler owners may be granted a one-year extension delaying the compliance date until January 31, 2017. The EPA estimates that approximately 600 coal-fired boilers will be affected by the IB MACT in industries such as pulp and paper.

Cross-State Air Pollution Rule

The Cross-State Air Pollution Rule (CSAPR) was finalized by the EPA in 2011 and took effect January 1, 2015. This rule replaces a 2005 rule known as the Clean Air Interstate Rule (CAIR). The CSAPR requires certain states to reduce annual SO_2 emissions, and annual or seasonal NOx emissions. According to the EPA, this rule will affect 3,632 electric generating units at 1,074 coal, gas, and oil fired facilities in 27 eastern states and the District of Columbia. Each state has different emissions reduction requirements. Compliance can take many forms, including using low sulfur coal, increased maintenance, or technologies such as scrubbers, dry sorbent injection, and low NOx burners.

National Ambient Air Quality Standards

On August 10, 2015, the EPA finalized the National Ambient Air Quality Standards (NAAQS) Data Requirements Rule ("DDR") that addresses the need for additional air quality data in areas that do not have sufficient monitoring required to allow the EPA to carry out the 2010 revised SO2 NAAQS ("2010 1-hour SO_2 NAAQS"). The DDR directs states and tribal air agencies to characterize current air quality in areas with large SO_2 sources (2,000 tons per year or greater). The DDR requires air agencies to establish ambient monitoring sites or conduct air quality modeling, and submit air quality data to the EPA or, establish federally enforceable emission limit(s) and provide documentation of the limit(s) and compliance to the EPA by 2017. The EPA will use this information for future designations under the 2010 1-hour SO_2 NAAQS. Of the areas that had sufficient air quality monitoring in place from 2009-2011 to be tested against the 2010 1-hour SO_2 NAAQS, the EPA designated 29 areas in 16 states as Non-attainment Areas. Those states submitted State Implementation Plans ("SIP") by April 4, 2015 demonstrating how the areas will meet the 2010 1-hour SO_2 NAAQS by July 15, 2018 (5 years after the non-attainment designation). Per the agreement between the EPA and the Sierra Club and National Resources Defense Council, which was accepted as an enforceable order by the Northern District of California on March 2, 2015 to resolve litigation concerning the completion of designations, the EPA must complete designations for all remaining areas in the country in up to three additional rounds: the first, by July 2, 2016, the second by December 31, 2017, and the final round by December 31, 2020. On April 23, 2014, the EPA recognized in a memorandum regarding guidance for 1-hour SO_2 Non-attainment Area SIP Submissions that the emission control equipment used to comply with the EGU MATS and IB and Cement MACTS regulations will concurrently reduce SO_2 emissions. We expect that the SO_2 NAAQS will impact several plants in affected areas that have inadequate or nonexistent SO_2 controls installed. Some of these plants are expected to rely on DSI to meet control requirements.

Regional Haze Rule

In 1999, the EPA established the Regional Haze Rule ("RHR") to improve air quality in national parks and wilderness areas. States must meet requirements established in their specific Regional Haze Plan prior to 2018, with equipment typically installed by 2017, while meeting reasonable progress goals prior to that. In 2018 the state plans will be reevaluated and revised as necessary to set new progress goals and strategies to meet the goals. NO_X, SO_2 and particulate matter all can contribute to regional haze. Some of these plants may use DSI to help meet the limits imposed by the rules.

WHAT IS ADAIR™ MIXER TECHNOLOGY?

Environmental regulations on coal-fired utility and industrial boilers have led many boilers to install sorbent injection systems to control mercury and/or acid gas emissions. Minimizing the requirements for sorbent helps facility owners save money and potentially reduce emissions of particulate matter.

Reducing sorbent consumption while continuing to meet stack emission limits might seem difficult to achieve, but there is a way to meet both these objectives: increasing the efficiency of the sorbent by improving contact in the flue gas between the sorbent and the pollutant to be removed.

Whether injecting powdered activated carbon (PAC) for mercury control or alkaline sorbent for acid-gas control, the sorbent particles are injected into the flue gas and subsequently collected in the boiler's particulate control device. Sorbent particles are typically injected through a small number of lances located in the duct. Sorbent must mix with the flue gas to be effective. Adding a sorbent injection system usually means retrofit into an existing duct. The residence time for sorbent particles from injection point to particulate control device may be as low as 0.5 seconds. Given possibly short residence times and a limited number of injection points, mixing of sorbent with the flue gas might be limited.

The ADAir Mixer Technology is an in-duct static (non-rotating) mixer that induces counter rotational and intersecting turbulence patterns to improve gas mixing with minimal pressure drop. The ADAir Mixer Technology influences mixing in the entire cross-section of the duct, as illustrated in Figure 1. This mixing improves sorbent dispersion in ACI and DSI systems and promotes more efficient pollutant capture. No additional compressed air or blowers are required. The ADAir Mixer Technology is custom-designed for each application, as discussed later in this paper.

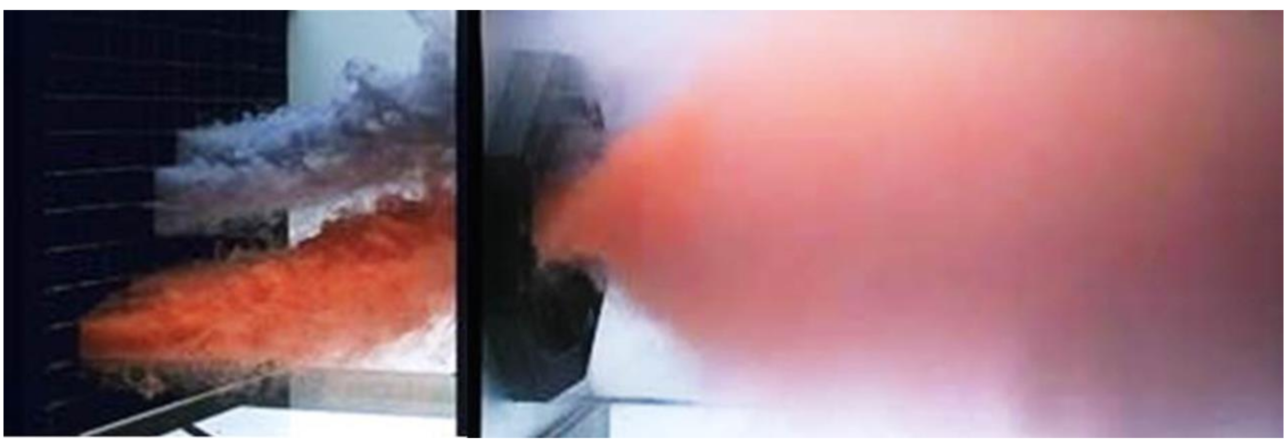


Figure 1. Illustration of the ADAir Mixer Technology.

CASE STUDIES

Industrial DSI

Case 1 is an industrial boiler with an existing DSI system injecting trona for HCl removal. The sorbent is injected upstream of a baghouse. The plant operator wanted to reduce sorbent injection rates and for this reason installed an ADAir Mixer System. The duct had a circular cross section. Therefore, a single mixer was designed to fit in the existing duct (Figure 2).

After the ADAir Mixer Technolgy was installed, the required sorbent consumption (expressed as mass sorbent/mass fuel) dropped by about one-third, as illustrated in Figure 3. Assuming a trona cost of $400/ton, this reduction would result in annual savings of sorbent greater than $400,000. The return on investment for the ADAir Mixer Technology at this site was less than one year.

Figure 2. ADAir Mixer Technology for Case 1 Industrial Boiler.

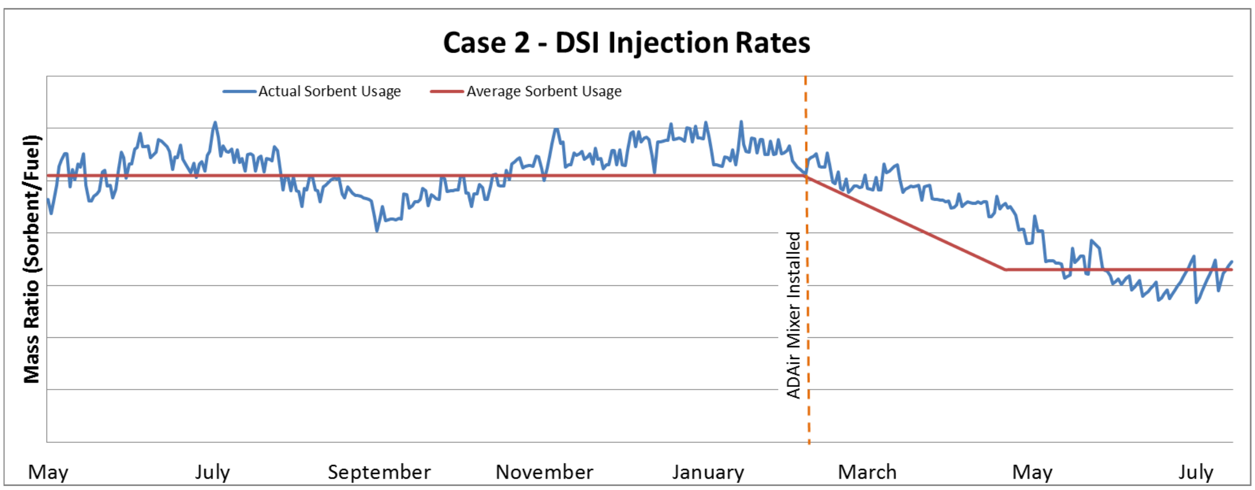


Figure 3. Sorbent Usage (lb sorbent/lb fuel) at Case 1 Industrial Boiler.

Utility DSI

Case 2 is a utility boiler firing a high-sulfur bituminous coal with selective catalytic reduction (SCR) for NO_x control, electrostatic precipitator (ESP) for particulate control, and wet flue gas desulfurization (FGD) for SO_2 control. Hydrated lime injection is used for SO_3 control. The plant replaced an existing DSI system located downstream of the air preheater with a new DSI system located upstream of the air preheater. In the new injection location, there was a short distance for conditioning flue gas to remove SO_3 to the guaranteed level at the ESP inlet. The plant operator was interested in minimizing sorbent costs. Therefore an ADAir Mixer System was installed upstream of the new DSI injection lances as illustrated in Figure 4. Carefully locating the DSI lances in the turbulence zone just downstream of the ADAir Mixer System can result in mixing efficiencies equal to those achieved by installing lances mixers upstream of the ADAir Mixer System. The figure shows one half of the flue gas path; the flue gas splits after the economizer into two separate sets of air preheaters and ESPs.

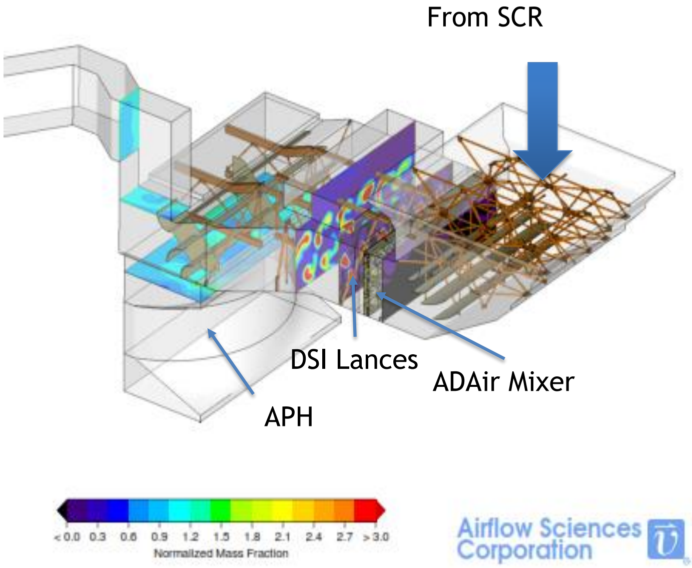


Figure 4. Case 2 Utility Boiler Application: CFD Modeling Results from SCR Outlet to Air Preheater Inlet.

In order to design the ADAir Mixer System for this application, a preliminary design incorporating an array of mixers was developed in conjunction with the DSI distribution lance array. Inducing additional turbulence in the flow results in a small increase in pressure drop across the mixer. The customer did not want the pressure drop across the mixer to be large enough that the boiler's induced draft (ID) fan would be limited in operation. The angle of the blades is adjusted to achieve the desired pressure drop. The number of individual mixer elements is selected, in this case, based on the location of the downstream DSI lances, in order to maximize additional turbulence-induced mixing at the plane of injection. Figure 5 gives a schematic of the mixer array for this application.

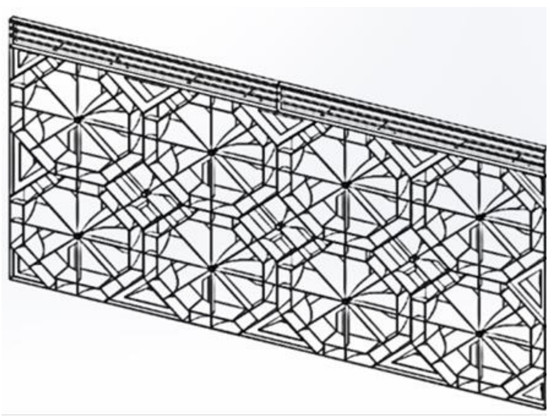


Figure 5. ADAir-Mixer Technology design for Case 2.

The design is validated for the specific application by carrying out a finite element analysis (FEA) for the temperature and flue gas velocities at the mixer location. Further design validation is carried out by doing computational fluid dynamic (CFD) modeling and physical flow modeling of the mixer installed in the duct.

The guaranteed pressure drop across the ADAir Mixer System was 0.48 inches WC. Both physical flow modeling and CFD modeling predicted pressure drop across the mixer of .03 inches WC less than the guaranteed pressure drop. Figure 6 provides pressure field information from the CFD model.

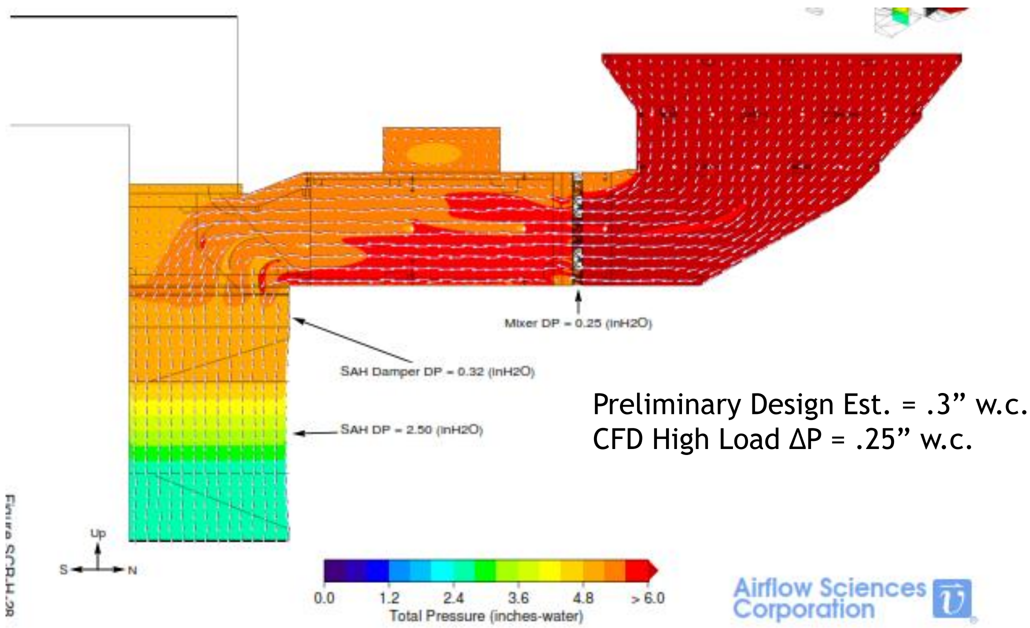
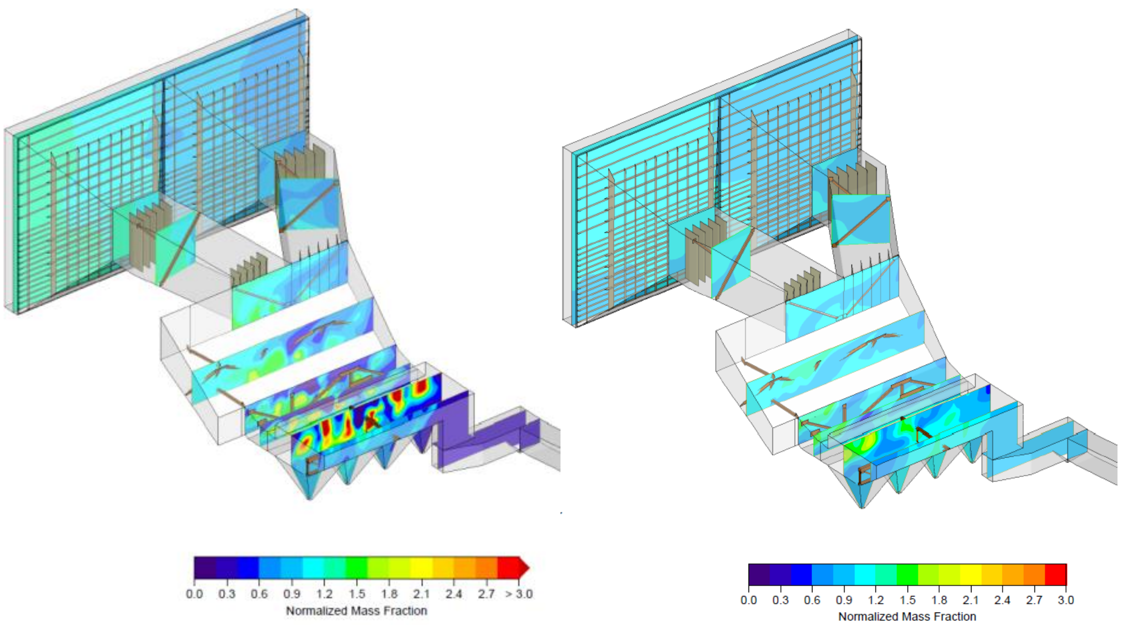


Figure 6. Case 2 Pressure Field from SCR Outlet to Air Preheater Inlet.



Case 2: No Mixer

Case 2: ADAir Mixer Technology

Figure 7. Mass Fraction of Sorbent from Air Preheater Outlet to ESP Inlet.

The CFD model quantifies the mixing of the sorbent with the gas in the form of the root-mean-square (RMS) of the sorbent loading in the gas at a given plane perpendicular to the gas flow. For example, consider the plane at the ESP inlet, as illustrated in Figure 7.The values of RMS of the mass loading without the mixer at each of the two ESP inlets were 9% on each side. However, when the ADAir Mixer System was included (upstream of the air preheater and thus not shown in the figure), the RMS values of sorbent loading at the two ESP inlets were 2% and 5%. Visually, the figure shows a more even distribution of sorbent at the air preheater outlet with the ADAir Mixer System.

Installation of the static mixer in the duct was accomplished in 48 hours during an outage. The individual mixing elements were delivered to site (Figure 8), moved into the duct, and then welded in place. Modular construction resulted in relatively fast and inexpensive installation. The cost of installation is expected to be on the order of the cost of the mixer for a typical installation.

Prior to installation of the module, but after start-up of the new DSI system, pre-mixer testing of SO_3 was carried out at the boiler. The concentration of SO_3 was measured upstream of the DSI system and at the air preheater outlet/ESP inlet using Method CTM-013. After installation of the mixer, SO_3 measurements were repeated in the same locations.

Results of the testing before and after installation of the ADAir Mixer System will be compared on both sides of the flue gas path (East and West sides) separately. Equal amounts of hydrated lime were injected on each side. The boiler was operated near full load for both tests. There were temperature differences in the flue gas at the air preheater outlet between the East and West sides that were consistent from one test to another.

Figure 8. Case 2: Module at Site before Installation.

The pressure drops across the mixer during the performance test were 0.35 inches WC and 0.30 inches WC on the East and West sides, respectively. These pressure drops were in line with the predictions from physical flow modeling and CFD modeling and were well below the guaranteed pressure drop of 0.48 inches WC.

Performance of hydrated lime for SO_3 removal improved in the performance test as compared to the pre-mixer test. At comparable sorbent flow rates, SO_3 removal was higher on both the East and West sides after installation of the mixer. Performance on the West side was consistently better than on the East side, which might be related to the lower post-air preheater temperature on the West side. Analysis of fly ash from the front field of the ESPs showed good distribution of the sorbent from side to side. Figure 9 shows the SO_3 removal as a function of normalized stoichiometric ratio, the molar ratio of calcium to SO_3, on each side for individual measurement runs. The results clearly show increased efficiency of SO_3 removal for similar stoichiometries after the mixer was installed.

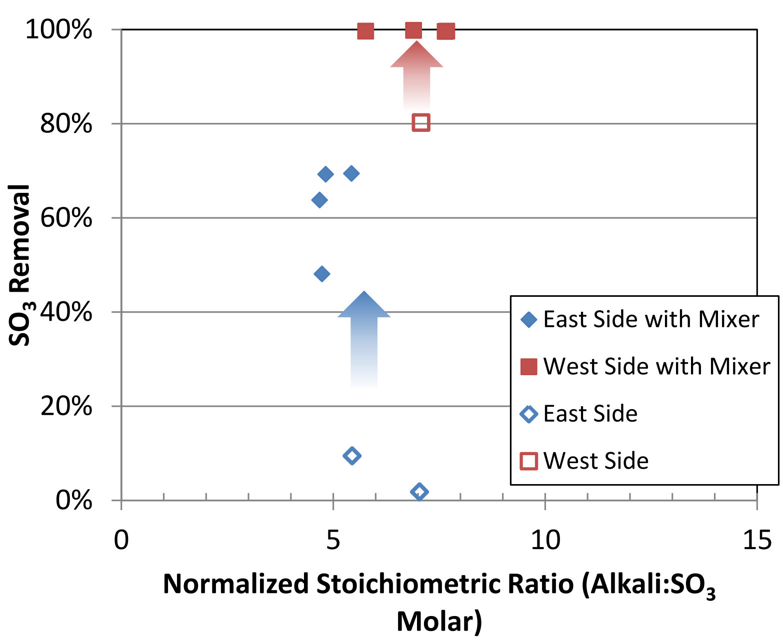


Figure 9. Removal of SO_3 as a Function of NSR with Respect to SO_3.

SUMMARY

The ADAir Mixer Technology improves contact between sorbent particles and pollutants resulting in more efficient pollutant capture, which reduces sorbent consumption required to maintain compliance. This reduction in sorbent consumption has important economic benefits, including reduced sorbent costs, reduced fly ash disposal costs, and reduced maintenance costs of ACI or DSI systems. In some cases, the ADAir Mixer System can also mitigate the temperature and velocity stratification that is common at the outlet of regenerative air preheaters, affording the further benefit of improving the performance of PAC for mercury control, reducing corrosion due to cold spots in the duct, and improving ESP performance. The potential savings with the ADAir Mixer System mean that the return on investment (ROI) is often less than one year.