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Reducing Reagent and Sorbent Costs for Mercury and Particulate Matter Control for Units with ESPs Requiring Flue Gas Conditioning

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ABSTRACT

The new Mercury and Air Toxics Standards (MATS) will increase demand for activated carbon injection (ACI) systems for mercury control. Many of the coal-fired utility boilers in the U.S. use electrostatic precipitators (ESPs) to control particulate matter. When powdered activated carbon (PAC) is used for mercury control on these systems, it is injected upstream of the ESP. Some ESPs require flue gas conditioning (FGC) to improve collection efficiency in order to meet the required limits on stack opacity. Sulfur trioxide (SO_3) is typically injected into the flue gas at plants where the resistivity of the fly ash is high. However, the presence of SO_3 in the flue gas reduces the effectiveness of PAC for mercury control, resulting in higher injection rates to meet compliance limits. ADA® R**ESP**ond™ Liquid Chemical Additive is a non-sulfur based alternative to SO_3 flue gas conditioning that has been proven to significantly reduce total sorbent and reagent costs required to comply with mercury and particulate emission limits. In this paper, examples of the application of ADA® R**ESP**ond™ Flue Gas Conditioning Technology for MATS compliance will be presented.

INTRODUCTION

ADA-ES, Inc., an Advanced Emissions Solutions, Inc. company, was founded in 1996 to provide emissions control solutions for the coal-fired utilities industry. From its founding, ADA has been offering FGC agents for improving the performance of ESPs. We are currently providing FGC to meet the particulate control needs of several US power plants that are using activated carbon for mercury control. ADA has established one of the most highly recognized teams of industry experts and is the most recommended and trusted name in the emissions control industry, especially in mercury control.

For nearly two decades, ADA has conducted more than 100 mercury control demonstrations at coal-fired power plants and sold activated carbon injection systems maintaining mercury control for more than 140 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 to 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. The control of particulate matter (PM) must be accomplished while controlling both acid gases and mercury. As summarized below, specific federal rules apply to each source category.

Federal Mercury and Air Toxic 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.

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. Within 180 days of the compliance date, industrial boiler operators must demonstrate compliance. The EPA estimates that approximately 600 coal-fired boilers will be affected by the IB MACT in industries such as pulp and paper.

MATS COMPLIANCE CHALLENGES FOR AGING UNITS WITH MARGINALLY SIZED ESPS

New regulations on coal-fired boilers, like the MATS or IB MACT rules, represent challenges for ESPs used for particulate control. ESPs might face lower PM emission limits while at the same time, accommodating PAC injection for mercury control and possibly hydrated lime sorbent injection (DSI) for acid gas control (e.g., HCl, SO_3). This combination of lower PM limits and additional system loading may require an upgrade for marginally sized ESPs. As a further complication, there may be limited plant real estate available for required ESP upgrades.

Large capital cost expenditures for ESP upgrades or new fabric filter retrofits are not always justifiable and can be a contributing factor for early plant closings. Lower-cost technologies like FGC have helped to prevent the premature shuttering of many marginally sized boilers.

In the past, many ESPs were designed and built prior to modern clean air regulations and were thus undersized by today's standards. ESPs are designed based on specific coal, operating conditions, and fly ash properties. To understand the impact of changing fuels or operating conditions, it is useful to review the key factors that affect particle collection efficiency.

ESPs collect particles by electrically charging particles (using a discharge electrode) and then subjecting those charged particles to an electric field in which particles are collected on a collecting electrode. One of the most important parameters in determining how efficiently ESPs collect particles is the resistivity of the particles, which is an indication of how well the particles, when deposited on the collection surface (the ESP plates), conduct electricity to ground.

Resistivity can be measured in the laboratory (in units of ohm-cm) as the ratio of the applied electric potential across a layer of particles to the induced current density. The value of resistivity depends on a number of factors, including: composition of the particles, temperature, porosity of the layer, and moisture content of the gas.

For coal-fired boiler applications, the optimum value of resistivity is in the range of 10^8 to 10^{11} ohm-cm.[1] When the resistivity is higher than 10^{11} ohm-cm, the particles are difficult to charge and, once collected on the plate (i.e., the dust layer), do not easily conduct their charge to ground. Electrical charges accumulate on and beneath the dust layer surface creating a strong electric field. High resistivity dust layers are held too strongly to the plate, making them difficult to remove and causing rapping problems. Particles with low resistivity (less than 10^8 ohm-cm) easily become charged and readily release their charge to the grounded collection plate. However, the low resistivity particles in the dust layer are readily re-entrained into the gas, reducing the net collection efficiency.

Over the past several decades, many plants switched from higher to lower sulfur coals to comply with SO_2 regulations. In some of these cases, ESP performance was impacted when plants switched from firing Eastern bituminous coal to Western subbituminous coal; the latter was often from the Powder River Basin (PRB) region. The composition of ash from PRB coals is different from that of Eastern bituminous coals, which has a pronounced effect on the resistivity of the ash and on the ability of ESPs to collect the ash. The ash from PRB coals contains a high percentage of calcium (20-25% as CaO in the ash), while ash from Eastern bituminous coals contains less calcium (generally 2-6% as CaO). The resulting difference in resistivity is illustrated in Figure 1 for typical ash samples measured in the laboratory.[2] The data also illustrate the impact of temperature on resistivity, which typically has peak values at approximately 300°F.

Some boilers use dry sorbent injection (DSI) of hydrated lime to control SO_3 or HCl in the flue gas. The added calcium from hydrated lime injection will increase resistivity of the fly ash, as shown in Figure 2. In this figure, a bituminous fly ash is combined with hydrated lime ($Ca(OH)_2$) or a mixture of $Ca(OH)_2$ and $CaSO_4$, the latter being the principal reaction product expected in the fly ash from hydrated lime injection.

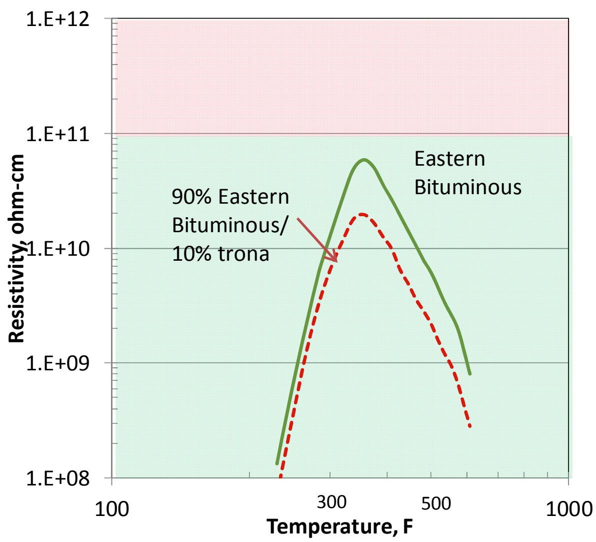

Figure 1. Laboratory ash resistivity measurement, comparing fly ash from Eastern bituminous coal with Western Powder River Basin (PRB) coal. (Source: Reference 2)

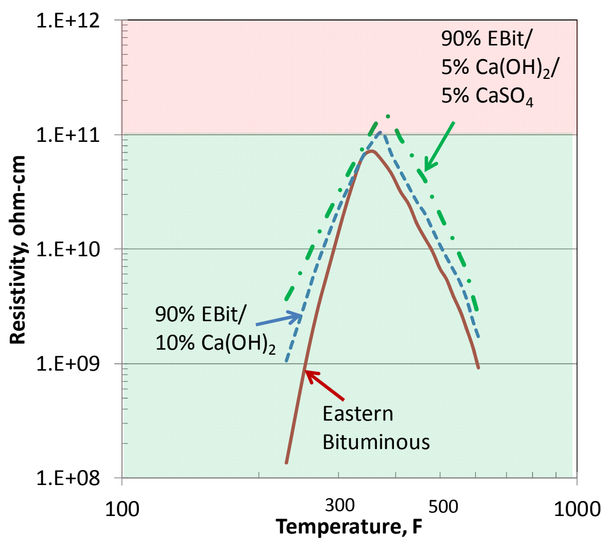

Figure 2. Laboratory ash resistivity measurement (9% H_2O in gas), comparing fly ash from Eastern bituminous coal with mixtures of $Ca(OH)_2$ and $CaSO_4$. (Source: Reference 2)

The effects of high resistivity on ESP performance can generally be reduced by doing the following:

- Adjusting the temperature of the gas;
- Increasing moisture content of the gas;
- Increasing the collection surface area;
- Adding conditioning agents to the gas stream.

In general, the temperature and moisture content of the flue gas at the ESP inlet is related to the fuel being burned and to how the boiler is operated. Increasing the collection surface area might mean a capital investment in an ESP upgrade. The method often used by coal-fired boilers in which ESPs are undersized relative to the operating parameters and ash composition, is to add FGC agents to the flue gas.

The most commonly used FGC agent is SO_3, which is typically added to the flue gas by burning elemental sulfur and converting it to SO_3 over a catalyst. The added SO_3 combines with moisture in the flue gas, condenses on the surface of fly ash particles, and reduces the surface resistivity of the fly ash.

Some older ESPs require SO_3 FGC to achieve their PM emission limit. If utilizing lime-based DSI systems for SO_3 or HCl control, resistivity of the fly ash will increase both from the removal of SO_3 from the flue gas as well as from the increase in lime in the fly ash. In order to remain compliant with PM emission limits, some ESPs might require additional FGC.

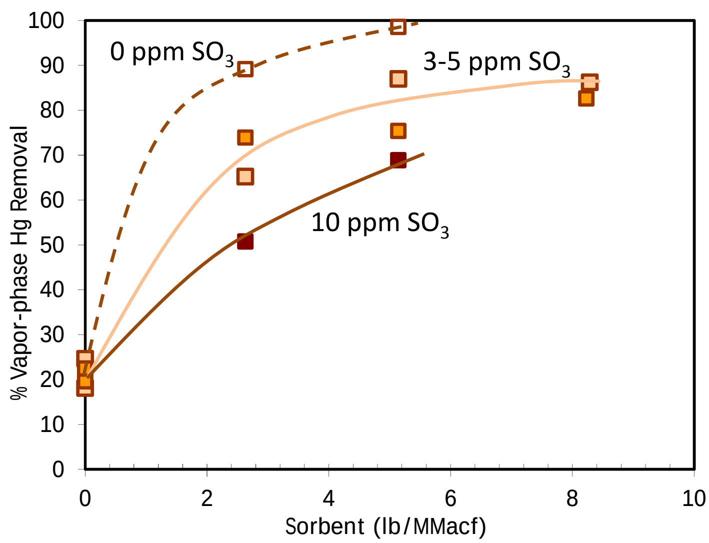

Figure 3. Mercury removal as a function of brominated PAC injection at different levels of SO_3 injection for flue gas conditioning. (Source: Reference 3)

Furthermore, many units will likely require PAC injection to meet the MATS limits for mercury or depend upon natural unburned carbon in the fly ash to remove sufficient mercury. Relatively modest concentrations of SO_3 in the flue gas post-air preheater (greater than 5 ppmv) interfere with the performance of PAC for Hg control. As illustrated in Figure 3, Hg removal across an ESP on a PRB-fired boiler with a SO_3 FGC system decreases significantly as SO_3 concentration increases at a given activated carbon injection concentration (in lb/MMacf). In this illustration, a brominated PAC was injected upstream of the air preheater (APH). As the concentration of SO_3 increases in the flue gas, more and more PAC is required to achieve a fixed level of mercury removal. The data suggest that high levels of Hg removal (greater than 90%) might not be achievable with greater than 5 ppmv SO_3 at this plant.

For EGUs that burn low-sulfur, western coals and have marginal ESPs, meeting both the Hg and the PM emission limits under the MATS or IB MACT rules might be expensive or impossible to achieve. Thus, an alternative to SO_3 flue gas conditioning is needed – an alternative FGC agent that does not interfere with the performance of activated carbon for mercury control.

ALTERNATIVE TO SO_3 FLUE GAS CONDITIONING

ADA's RESPond Additive is a highly effective, surface-ash resistivity modifier for power plants operating cold-side ESPs and requiring FGC. The aqueous-based proprietary material is non-hazardous and RESPond Additive does not contain SO_3 or interfere with activated carbon for Hg control.

RESPond Additive is injected into flue gas between the APH and the ESP as an ultra-fine mist. ADA employs a novel dual-fluid atomizing nozzle technology that mitigates deposition/fouling inherent to other liquid injection systems. Internally mixed, air-assisted nozzles create an ultra-fine aerosol mist. Droplets quickly evaporate in the duct to minimize deposition potential on duct internal structures and supports. Figure 4 shows a typical lance array in a cross sectional view of a duct.

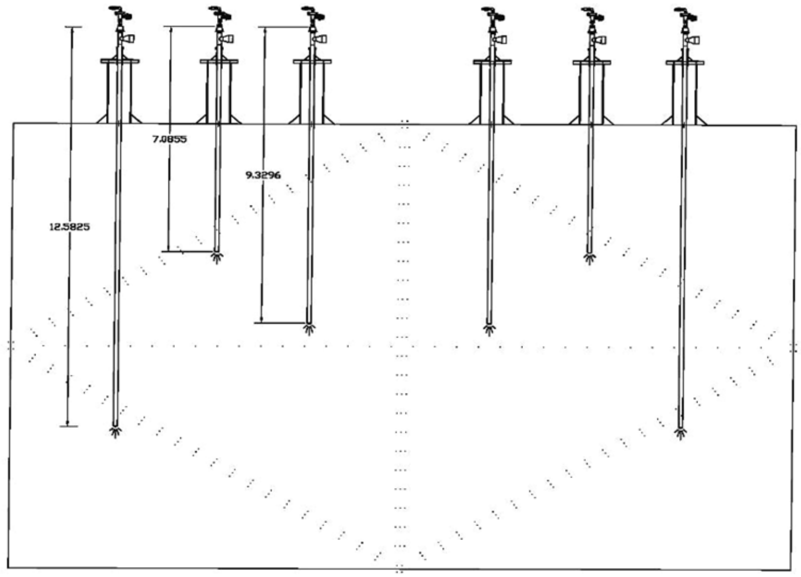

Figure 4. Example of RESPond™ Technology injection lance array in a duct cross section.

Concentrated reagent is metered and diluted to less than 10% aqueous solution and injected into the duct. A low-cost, skid-based injection system is used to deliver the RESPond solution to the duct, as shown in Figure 5.

Sufficient in-duct clearance is required for droplet evaporation. The temperature of the flue gas and the velocity in the duct are also important in determining the application parameters for RESPond Technology in a given boiler. ADA supports the reliability of the RESPond Injection Equipment by providing regular maintenance and inspection of the system.

Computational Fluid Dynamic (CFD) modeling is used to design the injection array in order to minimize deposition and reagent usage. The CFD model takes into account the duct geometry and internal structure (e.g., turning vanes, cross braces, perforated plates), as well as the operating conditions from high to minimum load. ADA's proprietary droplet-evaporation model is utilized within the CFD model to accurately predict droplet evaporation times.

Figure 6 gives an example of the CFD modeling output, showing particle trajectories and residence times.

Figure 5. ADA® RESPond™ Injection Equipment: control skid and chemical storage tank.

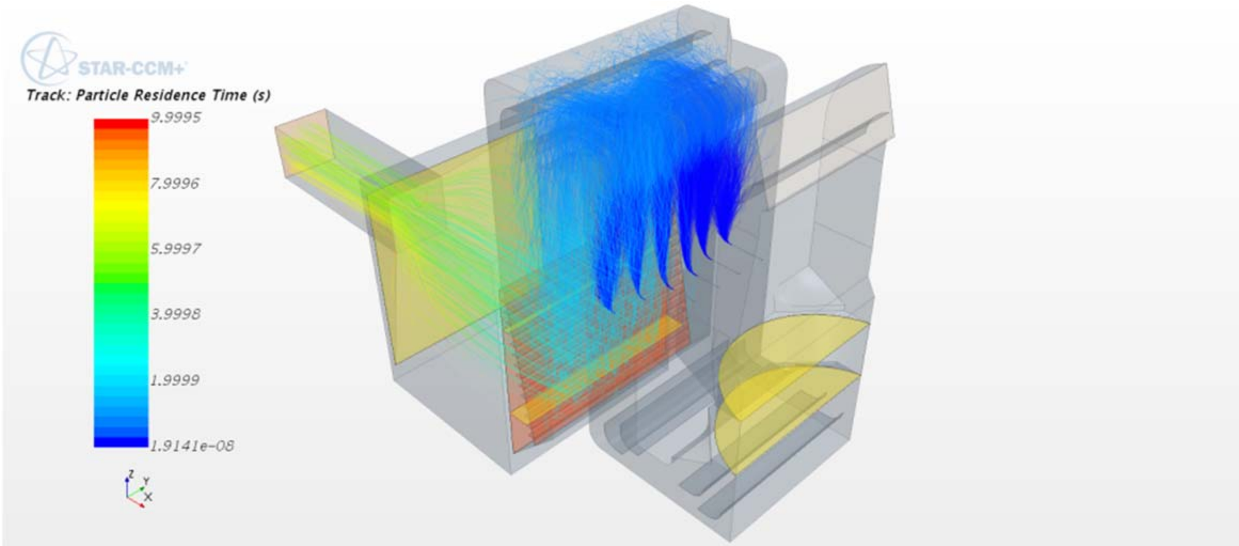

Figure 6. Example of CFD modeling of particle trajectories and residence times.

CASE STUDIES

RESPond Technology is an attractive option for many boilers with cold-side ESPs, particularly in light of the new MATS or IB MACT rules for control of PM, mercury, and acid gases. Some boilers may need to reduce PM emissions but the high capital costs of investments like new fabric filters or major ESP upgrades are not economically viable or there is insufficient real estate available for such upgrades.

Units currently using SO_3-based FGC that need to utilize ACI for Hg control can reduce sorbent consumption without significantly affecting PM emissions by switching to RESPond Technology. As previously noted, high concentrations of SO_3 in flue gas (greater than 5 ppmv) decrease the effectiveness of PAC for removing mercury.[3] Figure 7 gives a comparison of performance of activated carbon for Hg control at a PRB-fired boiler using either RESPond Flue Gas Conditioning Technology or SO_3 FGC. The use of SO_3 FGC in conjunction with ACI can result in an increase in PAC injection rates, loss of ash sales, and increase in overall operating costs.

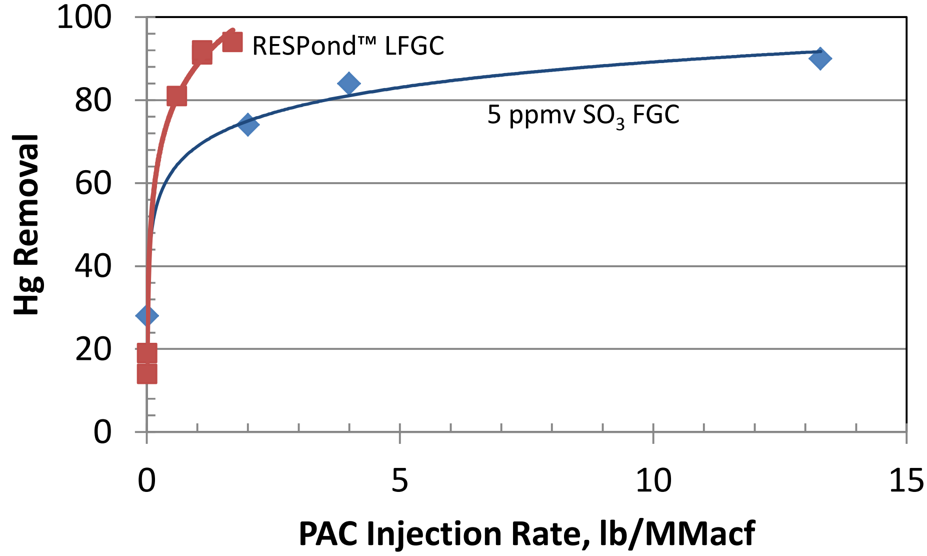

Figure 7. Mercury removal as a function of activated carbon injection rate (in lb/MMacf) at boiler firing PRB coal; 50 µg/g bromine added to the fuel and non-brominated activated carbon injection upstream of air preheater.

Units that have installed lime-based DSI systems for acid gas control will have reduced SO_3 levels entering marginally sized ESPs. While this will have a positive effect on the performance of PAC for mercury control, there may be an impact on performance of the ESP for PM control due to higher inlet loadings and higher resistivity ash. In this situation, additional flue gas conditioning using RESPond Technology may be able to keep the unit in compliance for emissions of PM, Hg, and acid gases.

RESPond Additive is an effective flue gas conditioning agent for reducing spark rate and ESP power, resulting in lower PM emissions (opacity). In Figure 8, ESP power, spark rate, and opacity are shown for a cold-side ESP during baseline operation and when RESPond Additive is in use.

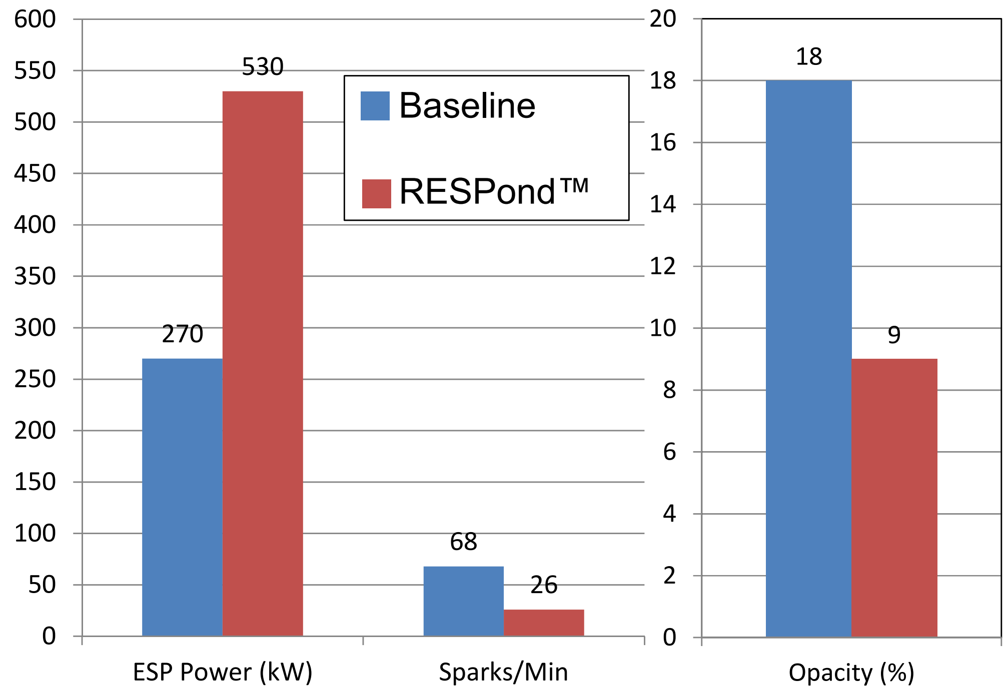

Figure 8. Comparison RESPond™ Additive performance vs. baseline: ESP power, spark rate, and opacity.

The economic benefits of using RESPond Technology for managing PM emissions in conjunction with ACI for managing Hg emissions are illustrated in Figure 9. In this example, a 250 MW boiler with a cold-side ESP required ACI for mercury control and needs flue gas conditioning to maintain PM emissions below the limit. Using SO_3 as a flue gas conditioning agent requires more PAC than when RESPond Technology is used as the flue gas conditioning agent. In terms of annual cost of reagents, using RESPond Technology results in lower annual operating costs, because of savings on PAC costs, and thus provides a more cost-effective solution than using SO_3 flue gas conditioning.

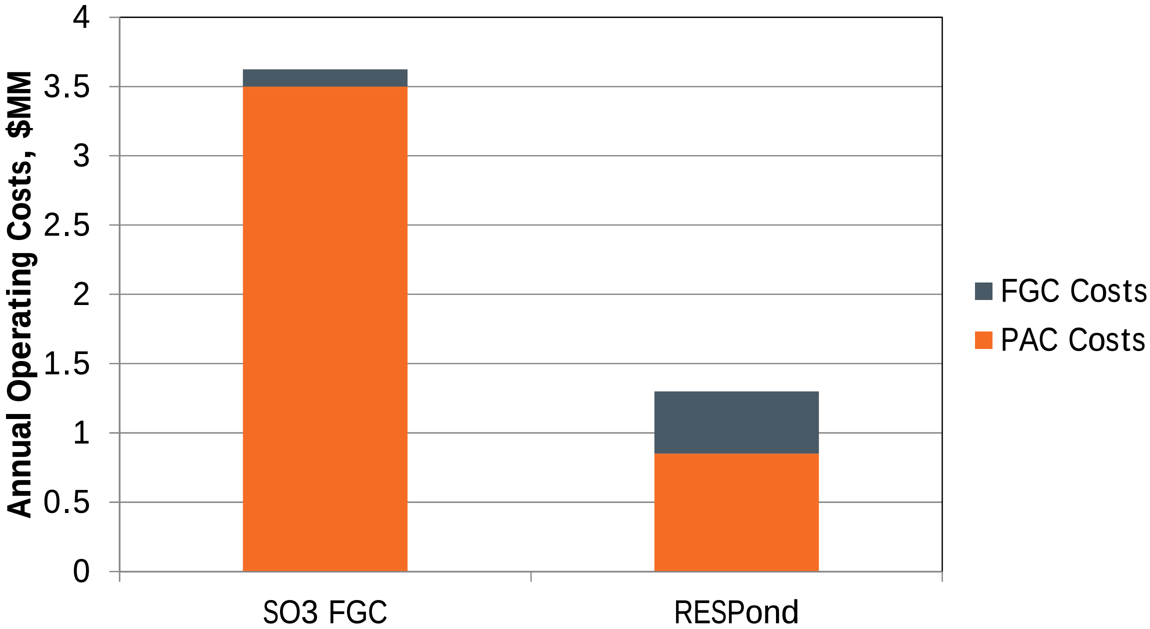

Figure 9. Annual operating costs for flue gas conditioning plus Hg control with powdered activated carbon on a 250 MW boiler.

SUMMARY

The MATS and IB MACT rules require control of Hg, acid gases, and PM. Boilers with marginally sized ESPs face challenges in cost-effective compliance with all of these emission limits. The presence of SO_3, which is often used as a flue gas conditioning agent, impacts the performance of PAC for Hg control. ADA offers RESPond Flue Gas Conditioning Technology as an alternative chemical and injection system that does NOT impact PAC performance. This technology can also be considered for ESPs where hydrated lime injection is required for HCl compliance.

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