



MSE Technology Applications, Inc.



## Plasma-Enhanced Electrostatic Precipitator

*90% removal efficiency of elemental mercury from flue gas*

- Easily retrofitted to WESP systems
- Retrofitting costs half of a dry adsorption system
- No additional floor space required
- Multi-pollutant control system

*Technologies for the Future, Responsible Solutions for Today*

As a means to control mercury emissions, MSE Technology Applications, Inc. (MSE) and Croll-Reynolds Clean Air Technologies, Inc. (CRCAT) have teamed to develop an innovative process that applies plasma physics to a wet electrostatic precipitator



**Figure 1. Corona discharge of 1-scfm test cell.**

(WESP), creating a plasma-enhanced electrostatic precipitator (PEESP).

The PEESP concept relies on the central electrode of a WESP to inject a reagent gas directly into the flue gas stream. At an operating voltage between 10 and 20 kV (negative polarity with respect to the collection plate), a

visible corona discharge is generated around the electrode (Figure 1). As the reagent gas passes through this corona discharge, reactive species are formed, which subsequently oxidize the elemental mercury vapor. In its oxidized state, mercury takes the form of fine particulate that acquires a negative charge in the electrical field of the precipitator. The charged mercury particles are attracted to the electrically positive electrode where they are collected into the wash-down liquor and are removed from the process.

### POTENTIAL BENEFITS OF PEESP

- 75% mercury reduction
- Installation and operating costs less than carbon injection systems
- No secondary waste stream
- Maintains fly ash as a saleable commodity
- Multipollutant control system (mercury, PM<sub>2.5</sub>, and SO<sub>3</sub>)

### NEED

Under the authority of the 1990 Clean Air Act Amendments, the U.S. Environmental Protection Agency announced that coal-fired power plants would be required to meet new Federal Emission Regulations. In response to this announcement, the President in his State of the Union Address *“urged congress to pass his Clear Skies Initiative for the good of both our environment and our economy.”* The proposed Clear Skies Act of 2003 would establish federally enforceable emission caps on NO<sub>x</sub>, SO<sub>2</sub>, and for the first time, mercury.

### PROBLEM

Coal is our nation’s most abundant source of fossil fuel; however, coal combustion produces sulfur oxides, nitrogen oxides, and trace metals emissions. Mercury, a toxic metal identified under the Resource Conservation and Recovery Act, exists naturally in coal; and during coal combustion, it is volatilized and become part of the flue gas. At temperatures >1,200 °F, elemental mercury is the predominant form. But, as the flue gas cools, part of the mercury vapor is adsorbed onto fly ash. At these lower gas temperatures, oxidizing constituents within the flue gas also start to oxidize part of the mercury vapor. Recent power plant studies have shown that mercury speciation is largely dependent on the type of coal being burnt. For example, mercury emissions from eastern bituminous coal are 60% to 80% in the oxidized state. Comparably, emissions from western lignite coals—because of their inherently lower sulfur and chlorine content—are only 10% to 20% in the oxidized state.

Mercury adsorbed onto fly ash and oxidized mercury compounds are easily removed from the flue gas through a wet flue gas desulfurization system. However, because of its high vapor pressure and insolubility in water, elemental mercury passes through most air pollution control systems unabated.

### CURRENT STATE-OF-THE-ART

In low flow applications, the current accepted method for mercury abatement is to pass combustion gases through a packed bed containing an adsorbent material, for example, activated carbon. As the combustion gas passes through the packed bed, the elemental mercury vapor is adsorbed onto the carbon. Theoretically, the equilibrium adsorption capacity for activated carbon is 85 lb<sub>m</sub>-Hg per 100 lb<sub>m</sub>-C. However, achieving this adsorption capacity is impractical because of variations in temperature, pressure, residence time, and relative humidity. Realistically, the dynamic adsorption capacities are 20 to 30 lb<sub>m</sub>-Hg per 100 lb<sub>m</sub>-C.

For larger flow applications, a variation of the carbon fixed bed technology is to inject activated carbon into the combustion gas stream. The combustion gas then pneumatically conveys the carbon to a particulate separation device where the spent carbon is removed from the combustion gas for disposal. While in-flight, the activated carbon adsorbs the elemental mercury thereby reducing emissions. Compared to carbon fixed beds, the adsorption capacity of the in-flight carbon is significantly lower, averaging only 1 lb<sub>m</sub>-Hg per 100 lb<sub>m</sub>-C. By incorporating a bag house filter as the carbon separation device, the mercury adsorption

capacity is slightly increased as a function of the filter loading and the thickness of the carbon cake.

Drawbacks to the current accepted methods for mercury abatement are the low adsorption efficiency of the activated carbon and the volume of secondary waste that must be disposed into landfills. Using the 1999 mercury emission estimates and assuming most facilities would use carbon injection systems, the minimum amount of activated carbon required is estimated to be 2,400 tons/year. Depending upon the type of carbon used in the system, the bulk cost of activated carbon is between \$1 and \$5 per pound, which equates to an annual cost of \$4.8 to \$24.0 million nation wide.

### PEESP BENCH-SCALE TESTING

With matching funds from the Electric Power Research Institute, Inc. (EPRI), MSE and CRCAT repeated the proof-of-concept (POC) experiments with an emphasis on determining the mercury mass closure of the PEESP system. Results from this test campaign clearly showed that the PEESP technology was capable of oxidizing elemental mercury vapor into a form that could be readily removed using a WESP.

Encouraged by the results, EPRI awarded a contract extension to demonstrate the PEESP concept on a larger scale using a multi-discharge electrode and various reagent gases that when passed through a corona discharge would efficiently oxidize elemental mercury in the presences of NO and SO<sub>2</sub> emissions (Figure 2).



Figure 2. 1-scfm multidischarge electrode.

### EXPERIMENTAL SETUP

The 1-scfm bench-scale test cell, used in the recent experiments, was a 10-fold scale-up in flow rate compared to the POC test cell (Figure 3). At this scale, the residence time of the process gas through the treatment zone was approximately 1 second.

The temperature of the simulated flue gas entering the test cell was maintained at 300 °F. Depending on test conditions, the outlet temperature averaged between 90 and 100 °F. By circulating plant water around the shell of the precipitator, a wet wall was created within the precipitator that optimized mercury collection efficiency.

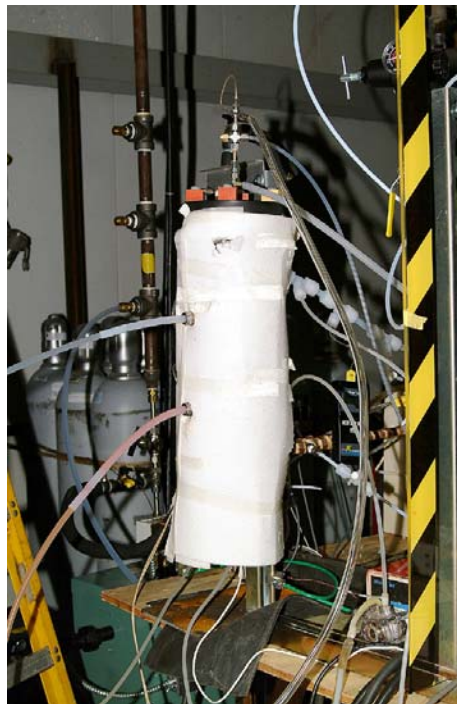


Figure 3. 1-scfm test cell.

### SCALE-UP TEST RESULTS

#### *Mercury Reduction (Saturated Flue Gas)*

A reagent gas consisting of an oxidizing agent mixed with steam was demonstrated as a possible mercury selective reagent gas. The composition of the reagent gas mixture was nominal 0.2% oxidizing agent and 99.8% steam. At this composition, the total concentration of oxidizing agent added to the flue gas was nominally 70 ppmv.

With the ability to vary the composition of the flue gas, competitive reactions were determined by isolating selected pollutant gases (CO, NO, and SO<sub>2</sub>). These gases were then individually added back into the process gas while measuring the elemental mercury concentration at the precipitator outlet using an online mercury analyzer to provide real-time mercury concentration data.

In the absence of pollutant gases, the mercury oxidation efficiency of the PEESP technology averaged 95%. Adding CO and NO to the flue gas had no significant affect on the mercury oxidation efficiency. However, the addition of SO<sub>2</sub> caused an increase in the outlet elemental mercury concentration to an equilibrium value of 18 µg/dscm, resulting in an average oxidation efficiency of 42% (Figure 4). At this time the increase in the outlet mercury concentration with the addition of SO<sub>2</sub> is unclear.

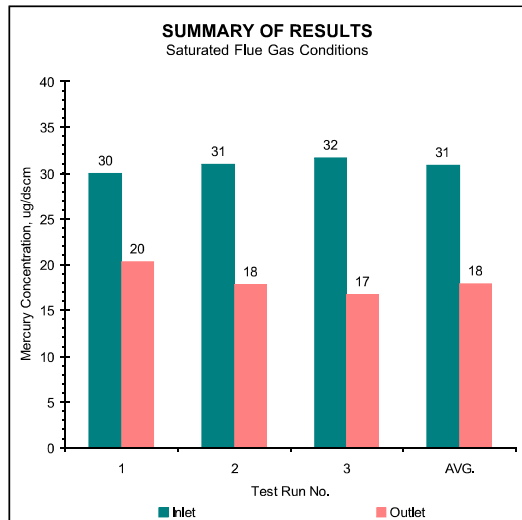


Figure 4. Test results using a saturated flue gas.

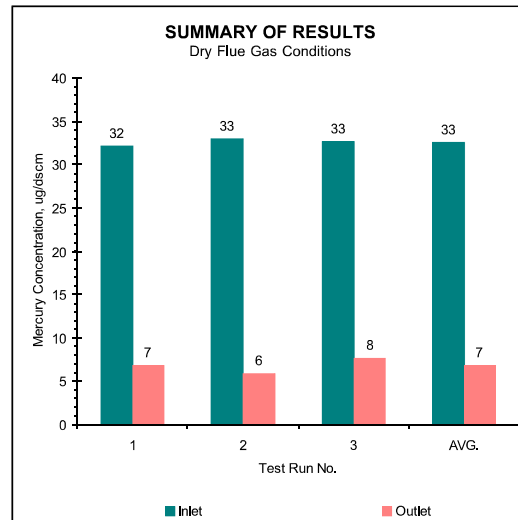


Figure 5. Test results using a dry flue gas.

### Mercury Reduction (Dry Flue Gas)

Although not fully understood, operating the precipitator at the flue gas saturation temperature is believed to be an underlining cause for the observed decrease in mercury oxidation efficiency. To evaluate this theory, testing was repeated using a dry flue gas and injecting only the oxidizing agent as the reagent gas. To maintain consistency with the previous test condition, the concentration of the oxidizing agent added to the flue gas was maintained at 70 ppmv.

To determine if SO<sub>2</sub> had the same affect under the dry test conditions, pollutant gases (CO, NO, and SO<sub>2</sub>) were again isolated and then individually added back into the process gas while measuring the elemental mercury concentration at the precipitator outlet. In the absence of pollutant gases, the mercury oxidation efficiency of the PEESP technology averaged 79%. (Figure 5). The addition of CO, NO, and SO<sub>2</sub> to the flue gas had no significant affect on the mercury oxidation efficiency indicating that the saturation theory is plausible.

### CONCLUSIONS

Testing demonstrated that the PEESP technology could be scaled for larger flow rates and that the tested proprietary reagent is capable of selectively oxidizing elemental mercury. Currently, a pilot-scale WESP—incorporating the PEESP technology—is being fabricated for EPRI and will be installed at Alabama Power Company’s Plant Miller. The pilot-scale unit will be capable of treating a flue gas flow of 5,000 acfm at 260 °F with a superficial gas velocity in the treatment zone of approximately 5 ft/sec.

A flue gas slipstream will be drawn through pilot to determine the degree of mercury capture that can be achieved with PEESP. Because a Powder River Basin coal is burned at the Miller Plant, most of the mercury in the flue gas is expected to be in the elemental state; hence, this site provides a good test of the ability of PEESP to both oxidize and capture mercury.

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