

# TOXECON II™ AND HIGH-TEMPERATURE REAGENTS OR SORBENTS FOR LOW-COST MERCURY REMOVAL

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## **ABSTRACT**

On March 15, 2005, EPA issued the Clean Air Mercury Rule, requiring phased-in reductions of mercury emissions from electric power generators. ADA-ES, Inc., with support from DOE/NETL and industry partners, is conducting evaluations of EPRI's TOXECON II™ process and of high-temperature reagents or sorbents to determine the capabilities of sorbent/reagent injection, including activated carbon, for mercury control on different coals and air emissions control equipment configurations.

The TOXECON II™ technology injects sorbents in the latter fields of an electrostatic precipitator to achieve emissions reduction, allowing recovery and sale of the ash from the first fields since only the last fields are collecting an ash/reagent/sorbent mixture.

Injecting non-carbon-based reagents or sorbents in a high-temperature flue gas zone allows a low-cost approach for moderate levels of mercury removal at plants equipped with hot-side electrostatic precipitators.

This paper presents an outline of the overall testing program, a description of the TOXECON II™ installation and testing at Entergy's Independence Steam Electric Station (ISES) in Newark, Arkansas, and a description of the anticipated testing program for testing of high-temperature reagents at MidAmerican Energy Company's Louisa Station in Muscatine, Iowa.

Entergy's Independence Station burns PRB coal and employs high-SCA cold-side electrostatic precipitators for particulate emissions control. This part of the testing program consists of installing injection grids between the latter precipitator fields and injecting powdered activated carbon into the flue gas stream inside of the precipitator and measuring the resulting mercury removal.

MidAmerican's Louisa Station burns PRB coal and employs hot-side electrostatic precipitators with flue gas conditioning for particulate control. This part of the testing program consists of using the existing flue gas conditioning system to inject non-carbon-based reagents upstream of the ESP and measuring the resulting mercury removal.

Due to the testing schedules, the results of the tests for both of these plants are unavailable at the writing of this paper, but testing at Independence is scheduled to be complete by the time of POWER-GEN International 2005, so the conference presentation will include any available results.

## **BACKGROUND**

The U.S. Department of Energy's National Energy Technology Lab (DOE/NETL) is conducting a comprehensive research and development program directed at advancing the performance and the resulting economics of mercury control technologies for coal-fired power plants.

This testing program (Program) is a part of the Department of Energy/Office of Fossil Energy's Innovations for Existing Plants (IEP) Program, whose goal is to develop advanced technology and knowledge products that enhance the environmental performance of the existing fleet of coal-fired power plants.

To date, the numerous mercury removal test programs have addressed many combinations of power plant emissions control configurations, including cold-side electrostatic precipitators, FFDCs (baghouses), FFDC/spray dryer absorbers (SDA), and wet scrubbers. In these efforts, these programs have also addressed units burning many different fuels, including Powder River Basin (PRB), subbituminous, bituminous, low and high sulfur, blends, and the like.

An excellent reference that summarizes the past and on-going efforts is the article entitled "*DOE/NETL's Field Test on Mercury Control Technologies for Coal-Fired Power Plants.*" by Thomas Feeley, James Murphy, Lynne Brickett, and Andrew O'Palko, published in the August 2005 AWMA EM Journal.

This paper presents an outline of the overall testing program, a description of the TOXECON II™ installation and testing at Entergy's Independence Steam Electric Station (ISES) near Newark, Arkansas, and a description of the anticipated testing program for testing of high-temperature reagents at MidAmerican's Louisa Station near Muscatine, Iowa.

## **OVERALL PROGRAM DESCRIPTION**

### **Process Descriptions**

Injecting a sorbent such as powdered activated carbon into the flue gas is one of the simplest and most thoroughly studied approaches to controlling mercury emissions from coal-fired boilers and power plants. The gas-phase mercury in the flue gas contacts the sorbent and attaches to its surface. The sorbent, with the mercury attached, is then collected either by the existing particulate control device, such as an electrostatic precipitator (ESP) or fabric filter, or by a secondary particulate control device. Over the past several years, the results from numerous full-scale evaluations of activated carbon injection (ACI) for mercury removal indicate that activated carbon is a viable technology for mercury control on many coal-fired power plants (Durham, 2005; Sjostrom, 2005).

For plants that sell fly ash for use as a concrete admixture, one of the disadvantages of injecting activated carbon upstream of the main particulate control device is its impact on the salability or reuse of ash. Tests show that the activated carbon interferes with chemicals used in making concrete.

For plants equipped with cold-side ESPs, the TOXECON™ and TOXECON II™ technologies offer an approach for maintaining fly ash sales while using low-cost activated carbon sorbents for mercury removal.

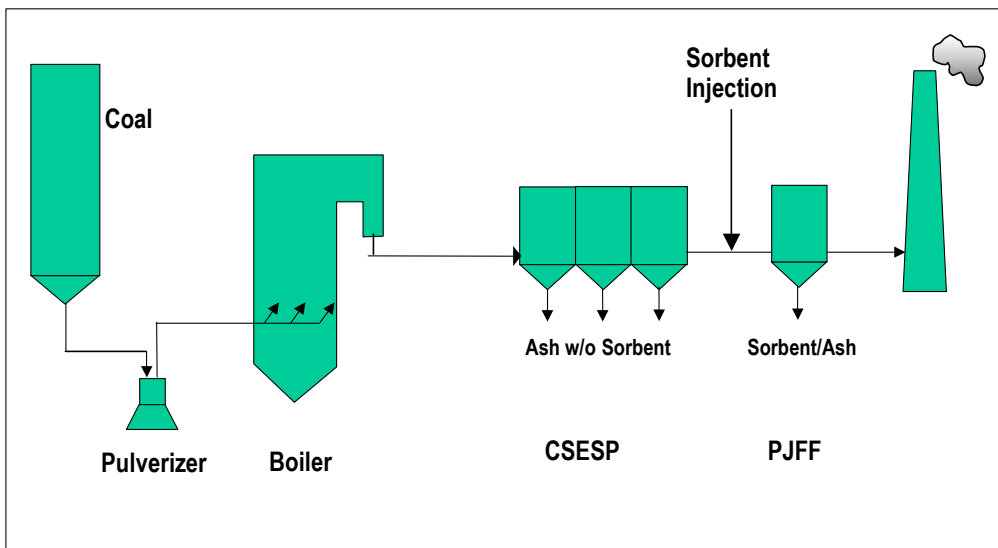
### **TOXECON™**

The TOXECON™ technology injects reagents and/or sorbents, including powdered activated carbon for mercury control, and others for NO<sub>x</sub> and SO<sub>x</sub> control, into the inlet duct of a secondary particulate control device that is downstream of the existing primary particulate control device. This configuration thus segregates the ash collected in the primary particulate control device from the ash/reagent/sorbent mixture collected in the secondary (downstream) particulate control device, preserving the salability of the fly ash from the primary particulate control device. In the TOXECON™ process, the secondary particulate control device is generally a pulse jet fabric filter dust collector.

The advantages of the TOXECON™ configuration are:

- The ash/reagent/sorbent mixture from the secondary particulate control device contains only a small fraction of the ash (typically in the range of 1% of the total ash), which reduces the impact of reagent/sorbent on ash reuse and waste disposal.
- Full-scale field tests confirm that fabric filters require significantly less sorbent than ESPs to achieve similar mercury removal efficiencies.
- Outage time for installing the TOXECON™ technology is significantly less than major ESP rebuilds or upgrades required to handle the increased loading and greater collection difficulty of the injected carbon.

Figure 1 shows the general configuration for the TOXECON™ process.



**Figure 1. General Configuration for TOXECON™.**

## TOXECON II™

The TOXECON II™ technology is similar to the TOXECON™ technology described above, except that it injects the reagents and/or sorbents directly into the downstream collecting field(s) of an ESP. Since the ESP collects the majority of the fly ash in the upstream collecting fields, only a small portion of the total collected ash contains reagents/sorbents. The TOXECON II™ technology requires minimal capital investment because it uses only minor retrofits to the ESP for the carbon injection system instead of installing a separate secondary particulate control device.

In this process, the sorbent injection lances are located within the ESP box, injecting sorbent across the front face of a downstream field. A normal sorbent storage silo and feeder system provides the sorbent to the injection grid. The location of the injection grid is dependent on the ESP SCA, the number of fields in the ESP, and the physical size of the fields.

Since the sorbent/ash mixture from the latter fields is primarily sorbent, this process also allows for the possibility of recycling of the partially spent sorbent back into the process to achieve greater sorbent utilization.

Figure 2 shows the general configuration and the typical sampling for the TOXECON II™ process.

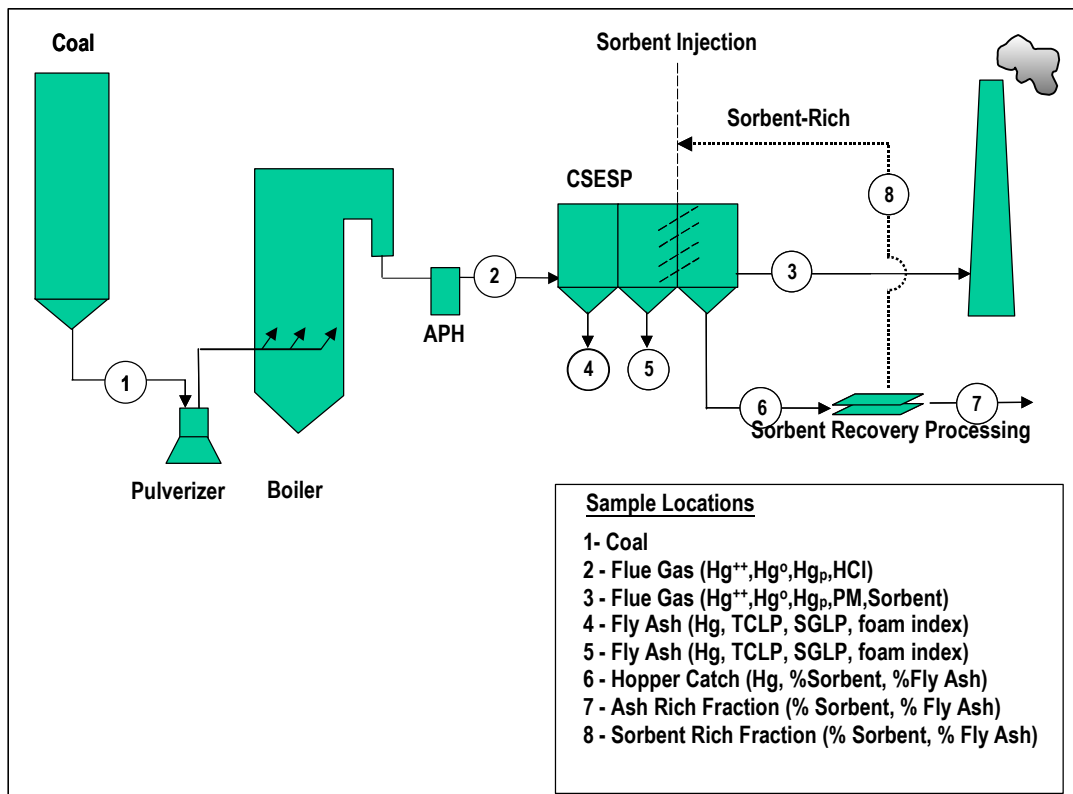


Figure 2. General Configuration and Sampling in TOXECON II™ Tests.

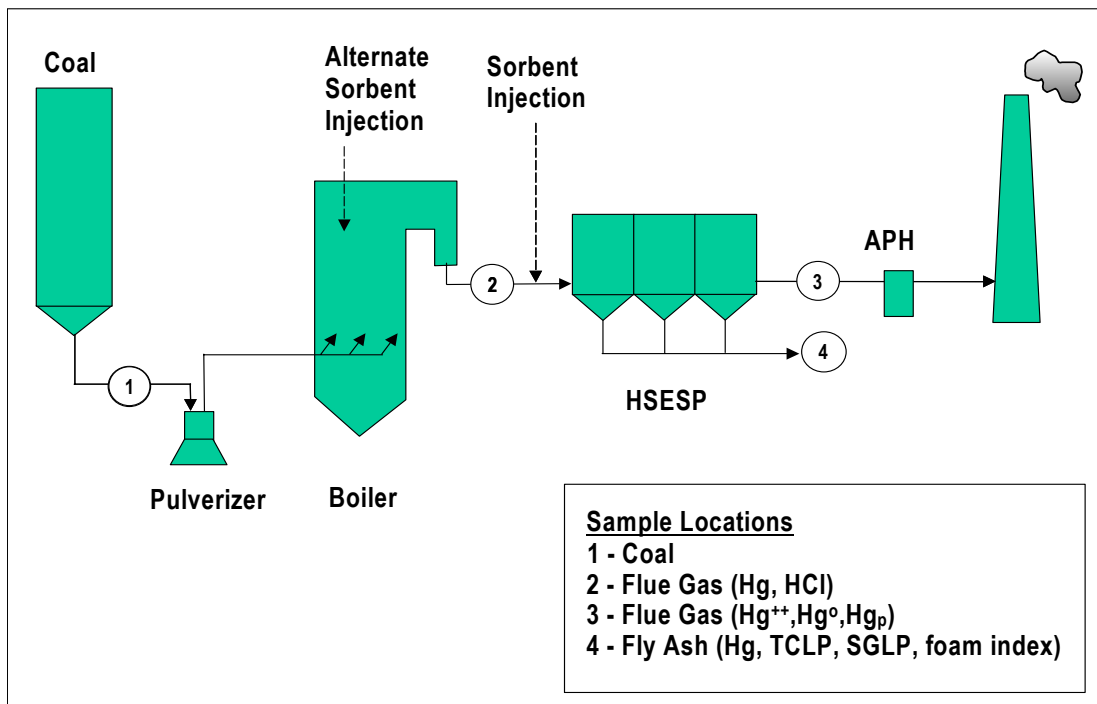
### ***High-Temperature Reagents or Sorbents***

For plants equipped with high-temperature electrostatic precipitators, previous testing shows that carbon injection for mercury control is not a viable option due to the poor mercury capture capability of carbon at the elevated temperatures. The various test programs to date have not addressed other options for mercury removal with the high-temperature ESP configuration. The goal of this segment of the Program is to investigate several promising technologies to determine the mercury removal capability and the viability of using high-temperature reagents or sorbents to achieve moderate levels of mercury control.

The majority of the potential reagents or sorbents are the result of either lab-scale or pilot-scale testing efforts. The Program will identify several such reagents or sorbents and test them in a full-scale test approach, similar to the testing efforts using carbon for cold-side ESP and fabric filter dust collector applications. As such, the Program will develop the specific injection details and testing protocol depending on the specific requirements for each potential reagent/sorbent.

The basic process consists of injecting reagents/sorbents upstream of the existing particulate control device and measuring the resulting mercury removal and determining the impacts on the existing plant equipment.

Figure 3 shows the general configuration and the typical sampling for the high-temperature reagent/sorbent process.



**Figure 3. General Configuration and Sampling in High-Temperature Reagents/Sorbents Tests.**

## **Project Test Program**

### ***Objectives***

The purpose of this Program is to evaluate two technologies that utilize the injection of sorbent materials to remove mercury from coal-fired power plant flue gas—TOXECON II™ and high-temperature reagents or sorbents.

The primary objectives of the Program are to:

- Test control technologies that can reduce the cost of mercury control
- Test control technologies that are applicable to the largest population of power plant configurations
- Test a control technology that is applicable to hot-side ESPs, a power plant configuration that is currently not adequately addressed
- Continue to expand the available data about mercury removal and control systems

The Program will test TOXECON II™ at Entergy's Independence Station (PRB), and at AEP's Gavin Plant (tentative) (high sulfur bituminous). The Program will test high-temperature reagents at MidAmerican Energy Company's Louisa Station (PRB) and Council Bluffs Station (PRB).

Because these technologies have not had previous widespread testing at plants burning different ranks of coal, testing will include both low-rank subbituminous and bituminous coal-burning plants to evaluate whether fuel rank makes a difference in performance of the technologies.

These technologies are directly applicable to coal-fired power plants that employ ESPs as the primary particulate removal system. This configuration represents approximately 797 plants that produce a combined 277,000 MW, or approximately 72% of existing coal-fired generating capacity and potentially a significant portion of new plants.

The test sites for the Program will allow documentation of reagent/sorbent performance on the following configurations:

- PRB coal with cold-side ESP using the TOXECON II™ configuration
- Bituminous coal with cold-side ESP using the TOXECON II™ configuration
- PRB coal with hot-side ESP using high-temperature reagents/sorbents

The secondary objectives of the Program are to:

- Accelerate the scale-up and availability of commercial mercury control systems for subbituminous and bituminous fired plants with conventional particulate control systems
- Evaluate technological advancements likely to improve the performance and reduce the costs of mercury control
- Obtain data on operability, maintainability, and reliability

- Document technology to reduce impacts on the utilization of coal burning byproducts
- Determine maximum mercury removal for various plant configurations
- Determine the total costs associated with mercury control as a function of fuel and plant characteristics, including both capital and operating costs

**Test Sites**

The Program will test at four host sites. It will test TOXECON II™ at two sites and high-temperature reagents/sorbents at two sites. The characteristics of each site are itemized in Tables 1 and 2.

Table 1 delineates the applicability of the Program’s sites to provide test experience and data for configurations with minimal previous testing. Testing at these sites will help round out the base of data for mercury removal with varying site configurations.

**S**

Area of Interest	AEP Gavin (tentative)	Entergy Independence	MidAmerican Council Bluffs	MidAmerican Louisa
Technology	TOXECON II™		High-Temperature Reagents/Sorbents	
Approximate no. of units of applicability	715		82	
Low-rank fuels		X	X	X
Bituminous fuels	X			
Blended fuels				
Test size (MW)	200	105	88	350
Longer-term tests (1–2 months)	X	X	*	*

\* The Program will test dry sorbents at Council Bluffs and liquid reagents at Louisa. The Program will perform long-term testing at only one site based on the parametric testing results.

Table 2 provides a brief listing of some of the descriptive information for each of the test sites, showing the range of plant characteristics and configurations.

**Table 2. Host Site Descriptive Information.**

	<b>AEP Gavin (tentative)</b>	<b>Entergy Independence</b>	<b>MidAmerican Council Bluffs</b>	<b>MidAmerican Louisa</b>
Technology	TOXECON II™		High-Temperature Reagents/Sorbents	
Unit No.	1 or 2	2	2	1
Size (MW)	1,200	842	88	700
Test Portion (MW)	200	105	88	350
Coal	Bit	PRB	PRB	PRB
Heating Value (as received)	11,111	8,870	8,425	8,500
Sulfur (% by weight)	3.9	0.32	0.32	0.32
Chlorine (ppm)	1,333	50	50–100	50–100
Mercury (µg/g)	0.17	0.04	0.08	0.08
Particulate Control	CS-ESP	CS-ESP	HS-ESP	HS-ESP
SCA/fields (ft <sup>2</sup> /kacfm)	430/6	542/4	224/4	459/5
Sulfur Control	Trona/FGD	Compliance Coal	Compliance Coal	Compliance Coal
Disposition of Ash	Disposed	Sold	Some Sold	Sold
Typical Inlet Mercury (µg/dncm)	13–18	6–7	11.1–13.5	11.1–13.4
Typical Native Mercury Removal	0% ESP 70%+ in FGD	10%–20%	0%–10%	0%–10%

***Field Testing Scope of Work***

To achieve its overall objectives, the Program will perform extensive field tests at each site. These tests include baseline testing, parametric testing, and long-term testing as follows:

**Baseline Tests**

After equipment installation, the Program conducts a set of baseline tests prior to the parametric testing. These baseline tests characterize the plant operation and the native mercury removal (without sorbent injection). This includes Ontario Hydro mercury measurements concurrent with SCEM measurements. During baseline tests, the unit operates at the conditions expected during the parametric tests, holding boiler load constant at full-load and operating the emissions control equipment under normal full-load conditions (e.g., normal soot blowing and ESP rapping sequences).

**Parametric Tests**

The parametric tests define the quantity of sorbent required to obtain various levels of mercury removal, such as 30%, 50%, and 70% above the native mercury removal level. The Program conducts parametric tests for up to four weeks depending on the specific host site test plan.

The parametric tests typically evaluate multiple reagents/sorbents varying the injection concentrations and the operating conditions. A parametric test will usually inject sorbent for

about 8 hours, and then shut the injection system down to allow the plant equipment to return to baseline conditions prior to the next parametric test.

### Long-Term Tests

The long-term tests uses the optimized sorbent and injection rate(s) determined during the parametric tests. Typically, long-term tests cover a period of at least four weeks. The long-term testing goals are to obtain sufficient operational data on mercury removal efficiency over a longer period of time, determine the effects of sorbent injection on the particulate control device, on the sulfur control equipment (if any), on byproducts, and to the balance of plant equipment to prove process viability and economics. This task is the single most important step in gaining acceptance from the utility industry as to the practical implementation of mercury removal technologies on coal-fired power plants.

## **SPECIFIC SITE TESTING**

### **Entergy Independence Test Site**

The Entergy Independence Steam Electric Station consists of two 840-MW PRB coal-fired electric generating units. Testing for this Program is on Unit 2.

These units are balanced draft Combustion Engineering tangentially fired divided furnace boilers, Ljungström regenerative air heaters, and CE Walther rigid frame cold-side electrostatic precipitators. The ESP for each generating unit has four boxes in a two-wide by two-high stacked arrangement, with each box consisting of eight transformer/rectifier (T/R) sets, sixteen physical fields arranged in a four wide by four deep configuration, and with each T/R set powering two physical fields. The gross SCA at design flow is 540 square feet per 1,000 ACFM.

The inlet and outlet ducts for each box are split into two separate ducts, making it convenient to have a test portion and a control portion in the same ESP box. The Program is testing one-half of one box, or one-eighth of the total flue gas flow.

For this test, the Program installed specially designed injection grids between the second and third fields and between the third and fourth fields. This allows collecting the injected sorbent at either an effective SCA of 270 or of 135.

The carbon injection system for the parametric tests consists of a portable feeder-blower unit that feeds the sorbent from 900 lb capacity bulk storage bags. With the normal parametric testing injection ranges, this configuration allows testing a single sorbent for approximately 8 hours using a single bulk storage bag. The feeder on this unit is a variable speed screw feeder that allows testing at various injection rates.

The carbon injection system for the long-term tests consists of a storage silo with approximately 40-ton storage capacity. Sorbent feeds from the silo into two feeder trains, which mix the sorbent with transport air and convey it to the injection grid connections at the top of the test ESP box. The transport air quantity is constant, but a variable speed screw feeder meters the sorbent into the transport air through an eductor. This allows testing at various sorbent injection rates.

The ash handling system is a dilute phase pressure system with pressure feeders at each ESP hopper outlet and has two storage silos, normally one for each generating unit. With minor modifications to the transport system for this test program, the system segregates the ash/carbon mixture from the four hoppers under the test fields and transports it to a dedicated silo.

For collection of plant operating data, the test site has a work-station connected to the plant control and information system which makes the necessary plant data immediately available to the testing efforts.

Figures 4 and 5 show the carbon injection system and the injection grids for the test installation at Independence:



**Figure 4. Long-Term Test Injection Silo.**



**Figure 5. Injection Grid Between ESP Fields.**

The parametric testing at Independence will use four powdered activated carbon sorbents during the parametric tests: DARCO<sup>®</sup> Hg, DARCO<sup>®</sup> Hg-LH, and two experimental DARCO<sup>®</sup> sorbents, DARCO<sup>®</sup> E-10 and DARCO<sup>®</sup> E-11. The Program will select one sorbent to use during the long-term tests based on results from the parametric tests.

The data collection at Independence includes mercury measurement using semi-continuous emission monitoring, Ontario Hydro method duct traverses, and sorbent trap method samples. It includes particulate measurement using two BHA CPM 5000 particulate monitors, one across the ESP outlet duct on the test half and the other across the outlet duct on the other half, a TEOM particulate monitor in the ESP outlet duct on the test half, EPA

Method 5 or Method 17 duct traverses, and collecting data from the Unit 2 plant opacity monitoring system.

### **MidAmerican Energy Company's Louisa Test Site**

The Louisa Generating Station consists of a single 700-MW PRB coal-fired electric generating unit.

This unit is a balanced draft Babcock & Wilcox front and rear fired boiler with two Ljungström regenerative air heaters, and a Research Cottrell hot-side electrostatic precipitator. The ESP for this unit has 4 boxes in a split wedge arrangement, with each box consisting of 27 transformer/rectifier (T/R) sets, 3 chambers, 51 gas passages, 5 fields, and 8 bus sections. The gross SCA at design flow is 459 square feet per 1,000 ACFM.

The inlet and outlet ducts for each pair of boxes are split into two separate ducts, making it convenient to have a test portion and a control portion. The Program at Louisa will inject the reagent in the entire ESP which is all of the total flue gas flow, but will only measure mercury removal across one pair of boxes, which is one-half of the total flue gas flow.

The ash handling system at the plant only has one storage silo. It would therefore be impossible under the current configuration to segregate an ash/reagent mixture from non-reagent laden ash. Since Louisa sells its fly ash, it is paramount that the reagents do not impact the marketability of the material.

For collection of plant operating data, the test site has a work-station connected to the plant control and information system which makes the necessary plant data immediately available to the testing efforts.

At Louisa, the Program will test one or more liquid reagents. Testing of the formulation(s) of liquid chemicals occurs by spraying these chemicals into the flue gas using the existing flue gas conditioning equipment already in service at the site. Mercury measurements will occur upstream of the liquid injection location and downstream of the ESP to measure mercury removal rates.

### **CONCLUSIONS**

At the writing of this paper, ADA-ES, Inc., has obtained very preliminary data from an abbreviated parametric test run at Independence which indicate promising results. However, these data are not fully verified and not ready for publication in this paper. We believe we will have the results by the time of POWER-GEN International 2005 and will formally present any available results at that time.

## **REFERENCED PUBLICATIONS**

Durham, M.D. (2005). “Mercury Control Fundamentals,” presented at the Mercury & Multi-Emissions Compliance: Strategies & Tactics for New & Existing Coal Plants, American Coal Council, St. Louis, MO, March 22–24.

Sjostrom S., (2005). “Evaluation of Sorbent Injection for Mercury Control,” presented at the DOE/NETL Mercury Control Technology R&D Program Review Meeting, Pittsburgh, PA, July 12–14.

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