

# **ACTIVATED CARBON AND DRY SORBENT INJECTION SYSTEMS: PREPARING FOR MERCURY AND AIR TOXICS AND CROSS STATE AIR POLLUTION CONTROL RULES**

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## **ABSTRACT**

The proposed Mercury and Air Toxics Standard (MATS) in combination with the Cross State Air Pollution Rule (CSAPR) will increase demand for activated carbon injection (ACI) systems for mercury control and dry sorbent injection (DSI) systems for HCl, SO<sub>3</sub> and SO<sub>2</sub> control. Prior to the MATS, power companies awarded contracts for activated carbon injection (ACI) systems to control mercury emissions for 155 coal-fired boilers producing over 58 GW. This number is expected to triple in the three years between issuance of the final MATS and the compliance date. DSI systems will be installed to comply with HCl emission requirements in MATS and SO<sub>2</sub> requirements for CSAPR. Some estimates predict up to 400 DSI systems may be procured. Many of the components for these two systems overlap. Lessons learned from the operation and installation of the first wave of commercial mercury control systems will be presented, as well as recommendations to both ACI and DSI system users to manage procurement costs, scheduling, quality assurance, and performance.

## **INTRODUCTION**

EPA's proposed Mercury and Air Toxics Standards (MATS) and the Cross-State Air Pollution Rule (CSAPR) for coal-fired power plants will require new activated carbon injection (ACI) systems for reducing mercury emissions and dry sorbent injection (DSI) systems to control acid gases and SO<sub>2</sub>. Power plants affected by MATS currently are expected to have 36 months after the final rule is published to specify and install control equipment, with an expected compliance date of November 2014. CSAPR has two phases of compliance, one starting January 1, 2012 and the second on January 1, 2014.

For existing coal-fired units, the proposed MATS mercury emission limits for units firing coal greater than 8,300 Btu/lb is 1.2 lbs/TBtu. For units firing coal with a heating value less than 8,300 /lb, specifically lignite plants, the standard is 4 lbs/TBtu. The MATS limits will require many plants to install controls capable of reducing mercury, on average, by about 90%<sup>1</sup>. ACI is expected to be the primary technology choice for controlling mercury emissions for each of these regulations.

DSI has been used for controlling SO<sub>2</sub> and acid gases at coal-fired power plants for over 20 years, and continues to be an option considered to control these emissions.. Currently there are about 60 DSI systems installed and operational. .

Lessons learned from the first wave of ACI system awards and from the existing DSI systems can provide both users and suppliers with guidance on how to successfully procure and provide reliable, sorbent injection systems in a relatively short time frame to meet new regulations.

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<sup>1</sup> EPA Mercury and Air Toxics Standards Fact Sheet updated May 4, 2011

## **MARKET DEMAND FOR ACI AND DSI SYSTEMS**

The proposed Mercury and Air Toxics Standards and CSAPR will, in parallel, create new demand for both ACI and DSI systems. With multiple new rules being implemented in the same time frame, owners must evaluate the potential synergy and interferences created by operations and other air pollution control equipment at their plants. A high level analysis of the technology potential for ACI and DSI to meet the new emission rules is summarized in Figure 1. Visually, green indicates a high level of confidence in the capability of the technology in this application, yellow acknowledges that there are challenges that need to be addressed for success and red indicates a difficult application.

In response to earlier mercury rules from EPA for new power plants, state regulations and other agreements, about 155 ACI systems were purchased between 2006 and 2011 for use on coal-fired power plants (including several Canadian utilities responding to provincial limits). Experience gained over the past few years on these systems indicates that performance of ACI is sensitive to operating variables such as temperature, SO<sub>3</sub> concentrations and even baghouse cleaning frequency. Based on in-house experience, the technology potential of ACI was ranked for different configurations as a standalone technology or in combination with other air pollution control technologies, such as wet scrubbers, coal additives and DSI, to take advantage of co-benefits. The analysis shows that there is great potential for ACI in most configurations.

A similar analysis of technology potential was performed for DSI systems as a means to meet emissions targets defined in MATS and CSAPR. In this case the potential for DSI technology was evaluated for different plant configurations for each of the target pollutants, SO<sub>3</sub>, HCl and SO<sub>2</sub>. This analysis shows that DSI has broad application for SO<sub>3</sub> control and select application for HCl and SO<sub>2</sub> control.

There are over 1100 coal-fired boilers that will be affected by MATS and CSAPR. Some owners have already announced retirement of some of the units. Assuming that 300 of these units have a high probability of being retired, there will be about 800 units that will need to add some kind of technology to meet more stringent compliance standards. Based on the technology potential analysis above and assuming 800 units, it is reasonable to predict that MATS will create the need for between 350 and 600 new ACI systems for mercury control. This estimated demand for new ACI system over the next few years can be seen in Figure 2, along with the number of ACI systems that were purchased between 2005 and 2010 to meet current regulations.

It is likely that MATS and CSAPR will create a market for between 125 and 400 new DSI systems. Projections of demand and timing for new DSI systems is shown in Figure 3. The 57 DSI systems installed to date are shown cumulatively by a marker in 2011.

Figure 1. Technology potential matrix for ACI and DSI systems to meet new mercury, SO<sub>3</sub>, HCl and SO<sub>2</sub> emission standards required in MATS and CSAPR.

Technology Potential for ACI for Mercury Control

Configuration	ACI Only	ACI & Co-Benefit
PRB/SDA/FF	Green	Green
PRB/ESP	Yellow	Green
PRB/SCR/SDA/FF	Green	Green
PRB/ESP/TOXECON	Green	Green
LS Bit/SCR/FF or ESP	Yellow	Green
LS Bit/SCR/ESP/WFGD	Yellow	Green
LS Bit/SCR/ESP/TOXECON	Yellow	Green
HS Bit/SCR/FF/WFGD	Red	Yellow
HS Bit/SCR/ESP/WFGD	Red	Yellow

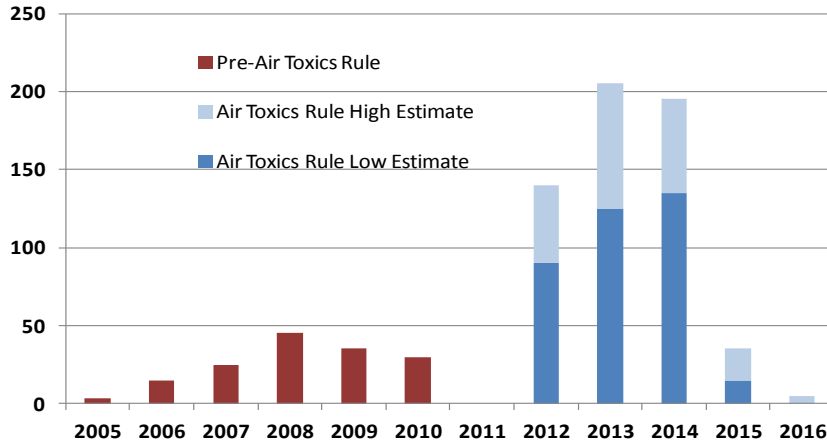
Technology Potential for DSI

Configuration	SO <sub>3</sub>	HCl	SO <sub>2</sub>
PRB/SDA/FF	Green	NA	NA
PRB/ESP	NA	Green	Green
PRB/SCR/SDA/FF	Green	NA	NA
PRB/ESP/TOXECON	NA	Green	Green
LS Bit/SCR/FF or ESP	Green	Yellow	Yellow
LS Bit/SCR/ESP/WFGD	Green	NA	NA
LS Bit/SCR/ESP/TOXECON	Green	Yellow	Yellow
HS Bit/SCR/FF/WFGD	Green	NA	NA
HS Bit/SCR/ESP/WFGD	Green	NA	NA

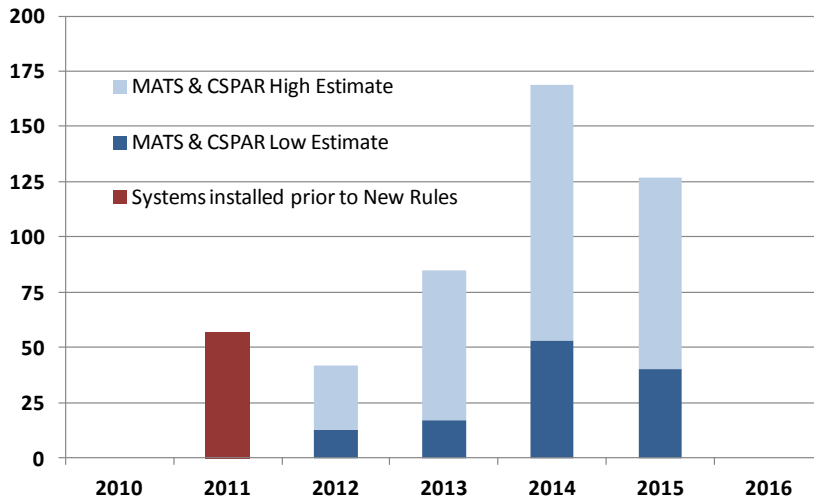
Legend Description

Viable application	Green
Some challenges	Yellow
Difficult application	Red
Not Applicable	NA

**Figure 2. Number of ACI systems sold to meet first wave of mercury control regulations and estimate of number of systems and timing for the Mercury and Air Toxics Standard.**



**Figure 3. Number of DSI systems sold prior to 2011 and estimate of number of systems and timing for the Mercury and Air Toxics Rule and Cross State Air Pollution Rule.**



Combining market demand created by MATS and CSAPR could result in a projected need for over 1000 ACI and DSI systems combined in the next four years. This demand coincides with demand for a host of other air pollutions control technologies such as wet and dry scrubbers, SCR's and fabric filters.

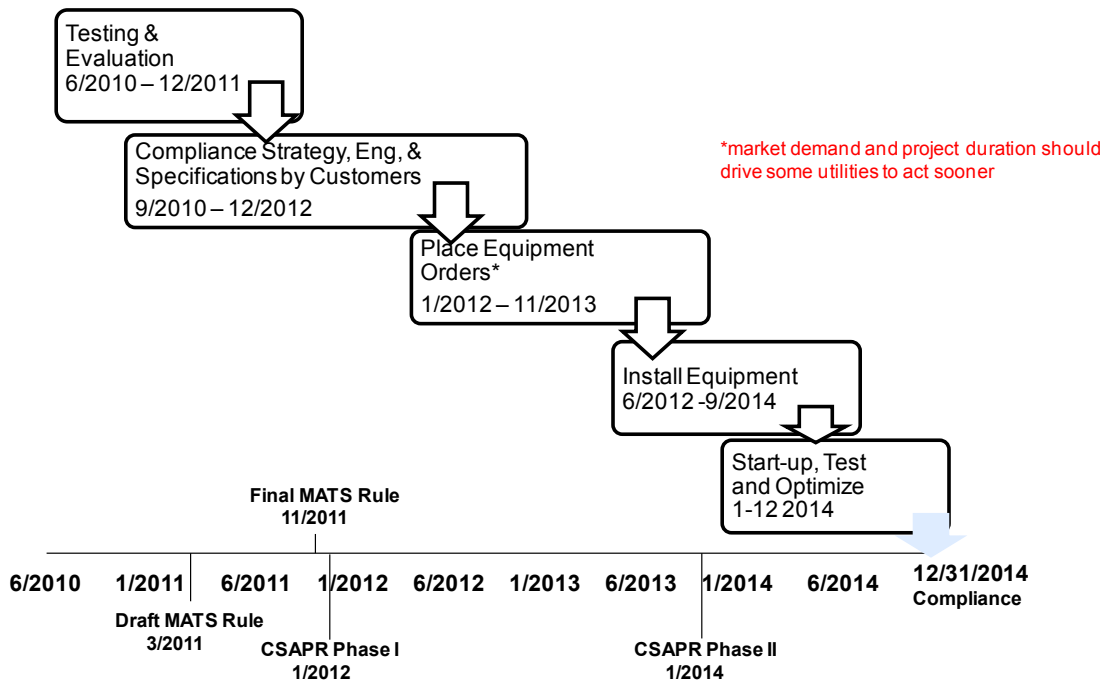
In conversations with operators of coal-fired power plants, a concern expressed by many is the short time period between November 2011 and November 2014 to determine control strategies, procure equipment for the multiple regulations and avoid creating and getting caught in a shortage of supply of both equipment and labor.

A timeline for procurement and installation of ACI systems to meet MATS and CSAPR compliance as it is understood today is illustrated in Figure 4. This timeline shows system awards need to start being made at the end of 2011. And even more pressing, control technology and site emissions evaluations need to be in progress to assure that the appropriate information is available on which to base these important control equipment decisions.

Assuming that the purchase of the 1000 systems will be mostly spread over a three year period, 2012 through 2014, the number of systems procured in each of these years is in some cases greater than the total number of system purchased between 2006 and 2011. The largest number of ACI systems purchased in one year was 48 in 2008. To meet compliance, we are predicting that up to 300 systems must be purchased in 2012 and over 200 systems in other years. Hopefully many buyers will anticipate this potential supply situation and place orders well ahead of time to avoid creating a supply shortage.

The key factors necessary to ensure successful delivery of ACI and DSI systems is prudent planning and incorporation of lessons learned from the recent procurement cycle for ACI systems into new RFQs.

**Figure 4. Timeline for Procurement and Installation of ACI Systems to meet MATS and CSAPR.**



## LESSONS LEARNED

Much can be learned from previous injection system awards by evaluating past purchasing patterns, buyer preferences and operating experience. With the potential need to deliver hundreds of systems, these lessons learned will help improve bid specifications, streamline the procurement process and anticipate optimization requests.

### Procurement Process

Capital equipment procurement is a sophisticated process within most electricity generating utility (EGU) supply chain departments. Steps key to suppliers in a typical procurement process include:

- RFQ development
- Vendor pre-qualification
- RFQ released with defined submission deadlines
- Pre-bid site walk down/meetings
- Quote submission date
- Proposal review period
- Select vendor
- Contract negotiations
- Contract award
- Contract execution
  - Submit design drawings
  - Receive design drawing approval
  - Release fabrication and component purchase
  - Engineering detail and documentation
  - Fabrication and assembly
  - Ship to site
  - Installation and startup
  - Performance test and system acceptance

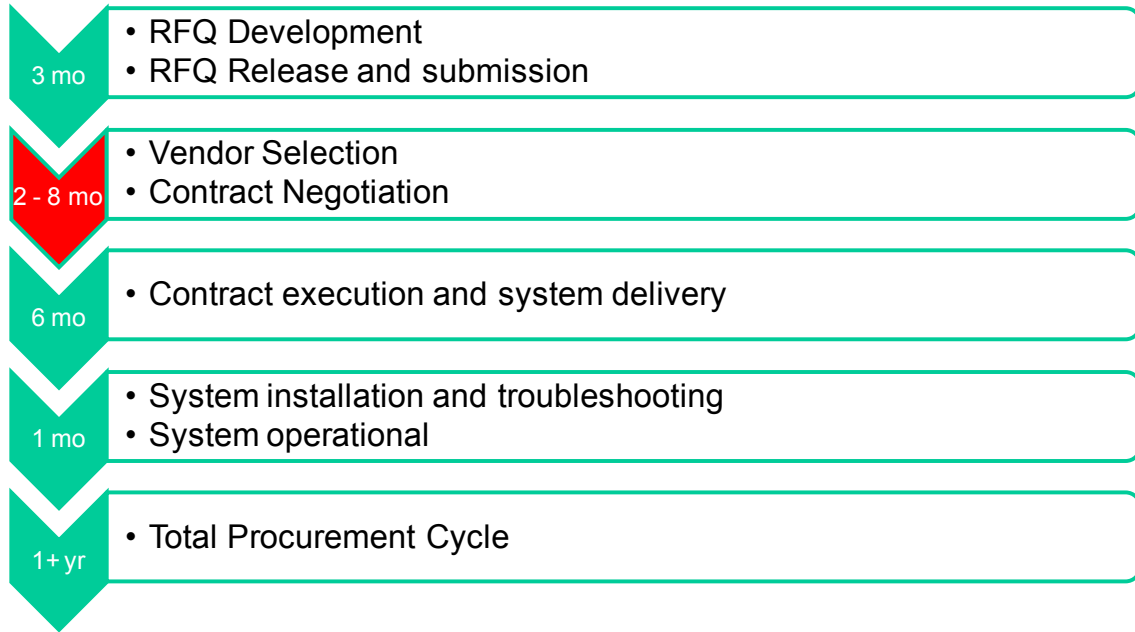
The process for getting an injection system purchased, installed and operational can typically take between 12 and 18 months. An example of the timing associated with the major steps outlined above can be seen in Figure 5. The steps that create the most uncertainty in meeting schedule are the time it takes to select a vendor and the contract negotiation.

Typical injection system components include:

- Storage
  - Silo
- Process equipment
  - Metering
  - Conveying
- Distribution
  - Manifolds
  - Lances

Figure 6 shows a cutaway of a typical ACI system, including the storage module and process equipment, and a photograph of an ACI system installed at a coal-fired power plant showing the storage silo with an enclosed process equipment room at grade level and a separate power and control building.

**Figure 5. Typical sorbent injection system procurement process and timing.**

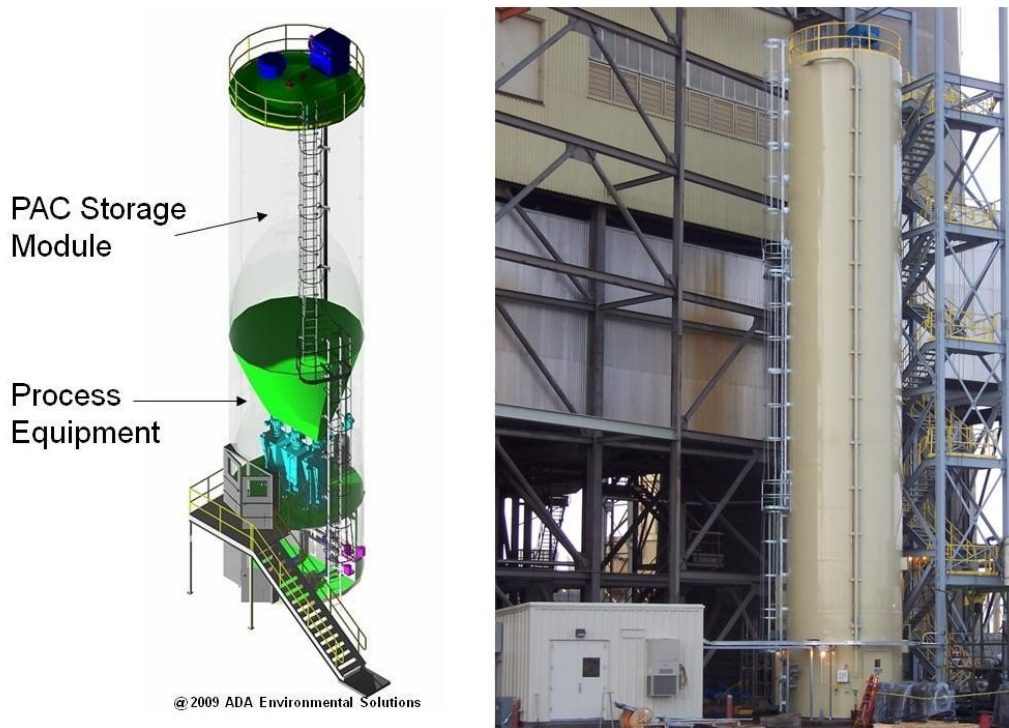


### **Bid Specifications**

Request for Quotes (RFQs) often include bid specifications that were adapted from material storage and injection systems other than their intended use. This causes suppliers to take numerous exceptions, resulting in extended Q&A exchanges and non conforming bid responses.

To help with the development of ACI bid specifications, ICAC’s mercury control division developed a sample bid specification that is publicly available on the ICAC website ([www.icac.com](http://www.icac.com)) and titled “Bid Specification Information Requirements and Bid Evaluation Form for Activated Carbon Injection Systems”. The stated objectives of this publication are “to help purchasers of activated carbon injection systems compile all information necessary for vendors to produce meaningful bids, and to enumerate those elements of the bids that the purchasers should consider in their evaluations of competing bids. This document does not recommend specific design criteria for the components of activated carbon injection systems.”

**Figure 6. Cutaway and photo of typical ACI system installed at coal-fired power plant**



### **Award and Delivery Dates**

In the proposal document, suppliers provide delivery and startup dates based on award date. For example, the supplier may guarantee delivery six months after award. Award date is different from notice of selection, because the contract terms have not yet been agreed to. Contract negotiations can sometimes take several months. With this in mind, it is important to allow sufficient time in the bid and proposal process to assure that equipment will be delivered with ample time for installation and check out prior to the compliance date.

Based on market projections, supply pressures on equipment components for ACI and DSI systems will increase. The storage silo is the single most expensive component in the system and demand for these welded; carbon-steel storage silos could result in extended lead times. In 2006 and 2007 when ACI system orders were being driven by state regulations and the economy was strong. Delays in silo orders resulted in losing a place in the production line these large, high quality silos.

It is important to understand that some of the system components have four to five month lead times. Allowing three months from release of RFQ to award date and at least seven months for system delivery is ideal when planning for the start of system installation.

## Engineered versus Standardized Designs

Specifications from owners and Consulting Engineers many times have very detailed design requirements and mandated components. Compliance with these requirements can increase costs, engineering manpower and delivery schedules. Compared to other, larger high CAPEX air pollution control systems that must be custom designed for each project, ACI and DSI system designs are conducive to an experienced supplier's standard designs and proven components. Reliance on a standard design that is applicable to a variety of plant configurations and can be sized for the required injection rate, storage capacity and conveying distance can result in significant time and cost saving for the end user.

## Plant Interface and Utility Requirements

Typical requirements for sites installing an ACI or DSI systems are summarized in Table 1. Clearly identifying scope and planning ahead for these interface and utility requirements assists with timeliness of installation.

**Table 1. Examples of plant interface utility requirements for ACI and DSI systems.**

Requirement	ACI	DSI
Power	30 – 50 kW per silo	50 – 60 kW per silo
Compressed Air	Clean, dry (-40 °F) compressed air, 20 scfm @ 100 psig for silo fluidizing and vent filter cleaning	Supplied by ADA
DCS Interface	Direct or via PLC communications link	Direct or via PLC communications link
Foundation	For 14 dia. ft silo	For one or more 14 ft dia. silos
Conveying Piping	2.5 to 3 inch pipe runs between silo and injection grids	3 to 4 inch pipe runs between silos) and injection grids
Duct Penetrations for Lances	4- to 6-inch NPT with 150-lb flange	6-inch NPT with 150-lb flange

## Distribution and Injection Location

AC distribution is important to assure that all of the flue gas is being treated. This is especially important for plants with electrostatic precipitators because most of adsorption of the pollutant (mercury, HCl, SO<sub>3</sub> or SO<sub>2</sub>) takes place in-flight. Either physical cold-flow or computational fluid dynamic (CFD) modeling can be used to predict whether an injection grid is capable of distributing the sorbent into all of the flue gas passages. Flow biases are often found in the duct as a result of several plant-specific factors such as ductwork design, turning vanes or other structural members, and primary/secondary air preheater flow distribution. Temperature biases are also common downstream of air preheaters. CFD modeling can assist in determining whether additional lances are needed or if injection should be biased into select lances to assure good distribution prior to the particulate collection device.

Injection location can make a significant difference in sorbent residence time, improve the likelihood of good distribution and, in some cases, reduce the required amount of sorbent. For example, in some configurations

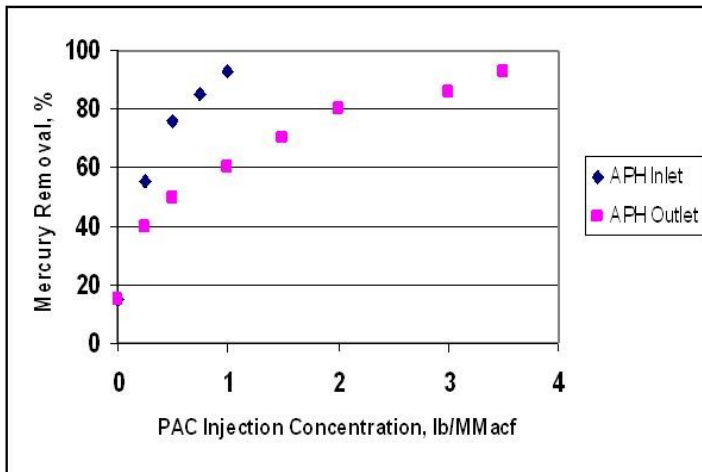
the biggest improvement in ACI performance can be attained by moving the injection location from downstream of the APH to upstream of the APH. This can be seen in Figure 8, which shows mercury removal at different injection concentration both upstream and downstream of the APH. In this case, higher mercury removal was achieved at half the injection rate when injected upstream of the APH.

The same considerations apply to DSI systems. Injection locations can be either upstream or downstream of the APH, or in some cases at both locations.

**Figure 7. Perspective on ACI system in relations to other air pollution control equipment at coal-fired power plant.**



**Figure 8. Mercury removal when AC injection upstream and downstream of APH.**



## **Dilute Phase Conveying**

### ***ACI***

Both regenerative and positive displacement (PD) blowers have been used successfully in ACI systems for dilute phase conveying of AC. Although there are currently more regenerative blowers installed, the trend is moving toward using PD blowers for greater flexibility. The choice of blowers depends on how much AC is being fed, conveying distance, number of elbows and change in elevation.

### ***DSI***

When conveying hydrated lime, ADA believes it is important to manage conveying fluid temperatures as a means to minimize the rate of carbonate formation that leads to calcium carbonate deposits and plugging. DSI system reliability and availability have been negatively impacted by buildup of carbonates in the equipment and conveying lines. Motive air for traditional pneumatic DSI systems is compressed ambient air. Similar to ACI systems most traditional DSI systems use regenerative or positive displacement blowers. To provide greater control of material temperatures, ADA's patent pending approach to DSI uses compressed air for hydrate applications.

## **Gravimetric versus Volumetric Feeders**

Debate continues on the merits of gravimetric versus volumetric feeders. Gravimetric feeders are more accurate than volumetric feeders, but substantially more expensive. One of the main disadvantages of volumetric feeders is they may need to be recalibrated whenever a different sorbent with different properties is used. This can be a problem for sites that use multiple sorbents on a frequent basis. A cost effective alternative to gravimetric feeders is to use volumetric feeders with a feedback control algorithm from the mercury CEMS. This will limit the PAC usage to what is needed to maintain the compliance set-point.

## **Equipment Access**

Adequate footprint is often a challenge when determining where to locate new ACI and DSI system. Location selection must include space availability, truck access and conveying distance. Access to silo roof mounted equipment can be by OSHA caged ladder, wrap-around staircase or cross over platforms from the plant. Equipment arrangement within silos is limited by the silo diameter, but can be optimized to provide acceptable access for maintenance.

## **Balance of Plant Cautions: Self Heating of Powdered AC in Ash Hoppers**

There have been several reports of burning embers in baghouse and ESP ash hoppers collecting ash/AC mixtures that have relatively high ratios of AC to ash, such as TOXECON® configurations where the majority of ash is removed prior to injecting AC into the fabric filter. AC can be oxidized via exothermic reactions in an air- or oxygen-rich environment. AC can act as an insulator, which may prevent sufficient heat dissipation and allow a local hot-spot to form. If temperatures increase enough, the carbon may reach ignition temperatures. Key factors contributing to self-heating are size of the bed or amount of ash/AC in the hopper, temperature surrounding the bed, particularly from hopper heaters or high flue gas temperatures, concentration of carbon in the ash and oxygen concentration.

Plants where auto-ignition has occurred have implemented maintenance procedures to prevent future occurrences of self-heating. Successful maintenance procedures include:

- Eliminate use of hopper heaters or lower the set point;
- Pull ash more frequently to minimize ash in the hopper;
- Ensure complete emptying of ash hoppers because AC becomes sticky when hot;
- Minimize fluidization.

### **Future Design Considerations**

New regulations are posing new opportunities and challenges for ACI and DSI systems designs. Some considerations to keep in mind include:

- Integrated solutions to optimize sorbent usage and thereby minimize O&M costs. Evaluating co-benefits from other air pollution control technologies, such as wet scrubbers and coal additives will probably be part of an O&M cost optimization program. With lower emission limits and less room for error, more plants will look at some kind of injection feedback control.
- Plants burning bituminous coals that rely on co-benefit removal may require variable amounts of ACI depending on the operation of the other air pollution control equipment, like SCR's and scrubbers.
- Careful analysis of results from various configurations. For example, there is still fairly limited data on the performance of ACI with fabric filters and the results to-date suggest that baghouse operation must be optimized to maximize mercury capture.
- Carbon vendors continue to develop improved sorbents to improve overall economics.

## **CONCLUSIONS**

The final MATS regulations with mercury emissions limits will create new demand for ACI systems. Projections indicate coal-fired power plants could procure up to 600 systems between now and 2015. MATS and CASPR will create demand for new DSI systems with projections as high as 400 new systems. In total, these new rules could result in the need for up to 1000 new ACI and DSI systems that use many of the same components. This spike in demand will stretch resources, but good planning and learning from the past will help suppliers and purchasers successfully meet upcoming compliance standards and dates.

## **REFERENCES**

1. EPA Mercury and Air Toxics Standards Fact Sheet updated May 4, 2011
2. ICAC (Bid Specification Information Requirements and Bid Evaluation Form for Activated Carbon Injection Systems)

## **KEY WORDS**

Mercury and Air Toxics Standards, Cross State Air Pollution Rule, Mercury control, activated carbon injection, acid gas control, dry sorbent injection, electric generating units