

# **TOXECON™ Demonstration for Mercury and Multi-Pollutant Control at We Energies**

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## **ABSTRACT**

We Energies and DOE, under a Clean Coal Power Initiative program, are working together to design, install, evaluate, and demonstrate the EPRI-patented TOXECON™ air pollution control process as an integrated emissions control system for mercury and particulate matter from three 90-MW units at the Presque Isle Power Plant located in Marquette, Michigan. Additional goals are to reduce nitrogen oxides (NO<sub>x</sub>), sulfur dioxide (SO<sub>2</sub>), and particulate matter (PM) emissions, allow for reuse and sale of fly ash, and demonstrate a reliable mercury continuous emissions monitor (CEM) suitable for use in the power plant environment.

Demonstration of TOXECON™ began in February 2006. This paper will discuss the overall design of the installation, balance-of-plant issues, and results from mercury optimization testing, mercury long-term testing, and SO<sub>2</sub> and NO<sub>x</sub> removal testing.

## **INTRODUCTION**

The Department of Energy's Clean Coal Power Initiative (CCPI) is an industry/government cost-shared partnership to increase investment in clean coal technology by demonstrating advanced coal-based, power demonstration technologies, consistent with the Energy Policy Act of 2005. The CCPI goal is to accelerate the readiness of advanced coal technologies for commercial deployment, thus ensuring that the United States has clean, reliable, and affordable electricity and power.

We Energies has over 3,200 MW of coal-fired generating capacity and supports an integrated multi-emissions control strategy for SO<sub>2</sub>, NO<sub>x</sub>, and mercury emissions while maintaining a varied fuel mix for electric supply. The primary goal of this project is to reduce mercury emissions from three 90-MW units that burn Powder River Basin coal at the We Energies Presque Isle Power Plant. Additional goals are to reduce nitrogen oxides (NO<sub>x</sub>), sulfur

dioxide (SO<sub>2</sub>), and particulate matter (PM) emissions, allow for reuse and sale of fly ash, demonstrate a reliable mercury continuous emissions monitor (CEM) suitable for use in the power plant environment, and demonstrate a process to recover mercury captured in the sorbent. To achieve these goals, We Energies has designed, installed, and is operating a TOXECON™ system designed to clean the combined flue gases of Units 7, 8, and 9 at the Presque Isle Power Plant.

TOXECON™ is a patented process in which a fabric filter system (baghouse) installed downstream of an existing particle control device is used in conjunction with sorbent injection for removal of pollutants from combustion flue gas. For this project, the flue gas emissions are controlled from the three units using a single baghouse. Mercury is controlled by injection of activated carbon or other novel sorbents, while NO<sub>x</sub> and SO<sub>2</sub> will be controlled by injection of sodium-based or other novel sorbents. Addition of the TOXECON™ baghouse also provides enhanced particulate control. Sorbents are injected downstream of the existing particle collection device to allow for continued sale and reuse of captured fly ash, uncontaminated by activated carbon or other sorbents.

The project team includes We Energies, ADA-ES, Inc., DOE-NETL, Cummins & Barnard, and EPRI. We Energies is providing and operating the demonstration site, as well as project management, environmental permitting, and reporting. ADA-ES is the project management interface with NETL, and is responsible for reporting, design of the mercury control system, design of the mercury monitoring system, and demonstration testing of the entire process. Cummins & Barnard provided architect and engineering services, construction management, design and specification of equipment, equipment installation, and startup training for plant operators. EPRI provides technical advice to We Energies.

## **PROJECT DESCRIPTION**

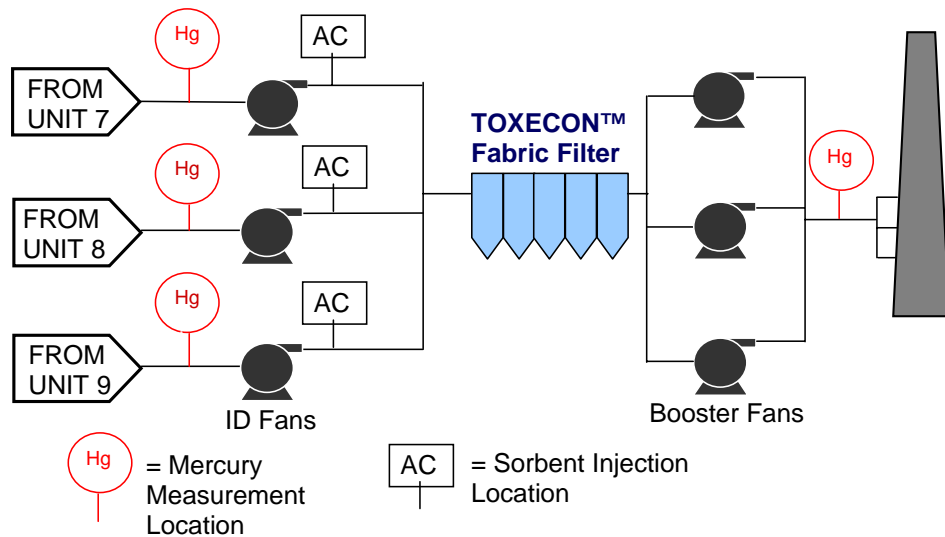
The project is taking place at We Energies' Presque Isle Power Plant (PIPP) located in Marquette, Michigan. This project was applied to Units 7, 8, and 9, each of which is a 90-MW unit with an individual hot-side electrostatic precipitator (HESP) as the primary particulate matter (PM) control device. The exhausts from the three HESPs were originally ducted into individual flues of a common stack. The project involves controlling the emissions from the three units using a single baghouse. Integrating the three units into one project and structure provides cost savings over treating the units separately, and optimizes the use of space.

The TOXECON™ process is ideal for Presque Isle because the existing HESP exhausts benefit from the additional PM control, especially during startup and shutdown. Also, the existing HESPs used for PM control do not have the ability to remove mercury from the flue gas, and injection of powdered activated carbon (PAC) into these HESPs is not feasible due to the high flue gas temperatures. The TOXECON™ process also allows We Energies to continue to sell its fly ash from the HESPs because the carbon is injected downstream of these units.

The Powder River Basin subbituminous coal used in Units 7–9 is supplied by several mines in Wyoming and Montana (dependent on the price of the fuel) and shipped by rail to Superior, Wisconsin, where it is then loaded onto a lake boat for delivery to the PIPP.

The main challenge in applying the TOXECON™ process at PIPP was to combine the flue gas streams from three independent Units into one combined stream and then separate the streams after the baghouse and connect to the three separate flues in the existing chimney. The process layout is shown in Figure 1. From a Mechanical and Process standpoint, the combined flue gas flow is not unitized. However, the Electrical and Control Systems were installed primarily on a Unit basis. The design of these systems was done to minimize the possibility of a single generation Unit failure from tripping the remaining two units. A design philosophy of “no single Unit trip should trip the remaining two Units” was repeated throughout the design phase of the project.

**Figure 1.** Basic schematic of PIPP TOXECON™ process.



A pulse jet style baghouse was selected for Presque Isle. This style reflects a typical industry standard and requires a small footprint area for the congested Presque Isle site. Based on a competitive bid process, a baghouse provided by Wheelabrator Air Pollution Control was selected. The baghouse is appropriate for the Presque Isle TOXECON™ project since baghouses of this type have been installed successfully in other power plant applications where the flue gas flow and particulate loading were much higher than the conditions at Presque Isle.

## Project Goals

The specific goals of this project are:

- Achieve 90% mercury removal from flue gas through activated carbon injection
- Demonstrate a reliable, accurate mercury CEM suitable for use in the power plant environment

- Successfully integrate and optimize TOXECON™ system operation for mercury control
- Evaluate the potential for 70% SO<sub>2</sub> control and trim control of NO<sub>x</sub> from flue gas through sodium-based or other novel sorbent injection
- Reduce PM emissions through collection by the TOXECON™ baghouse
- Recover 90% of the mercury captured in the sorbent
- Utilize 100% of fly ash collected in the existing electrostatic precipitator

Actual demonstration of the TOXECON™ technology began when flue gas from the first boiler was first introduced into the new TOXECON™ baghouse in December 2005. On January 27, 2006, all three Units were in service and at that time ADA-ES began commissioning the PAC injection system to begin the technology demonstration phase of the project.

## RESULTS

### Baseline Tests

TOXECON™ testing officially began after all three Units were tied into the baghouse. Baseline tests without PAC injection were performed during the week of February 13, 2006. Efforts included sampling of coal and ash, monitoring the CEMs and plant data, and performing mercury, halogen, and particulate testing on the flue gas into and out of the baghouse.

For particulates, a total of 24 test points were sampled using six ports at the baghouse common inlet and outlet test locations. The particulate sample trains met all specifications required by Method 5, 40CFR60. The baghouse particulate removal was 99.6% during baseline.

For mercury, a total of 24 test points were sampled using six ports at the baghouse common inlet and outlet test locations. The speciated mercury sample trains met all specifications required by the Ontario Hydro method. Table 1 shows a comparison of the average inlet and outlet measurements from 10 a.m. through 4 p.m. using the Thermo CEM and the Ontario Hydro Method. There was a 0.6% difference between inlet and outlet based on the CEM, but 9% when using the Ontario Hydro Method. The CEM and the Ontario Hydro results differed by 12% and 4.6%, which was well within the 20% agreement required by EPA to pass the Relative Accuracy Test Audit (RATA) for mercury.

**Table 1.** Comparison of Thermo CEM and Ontario Hydro data.

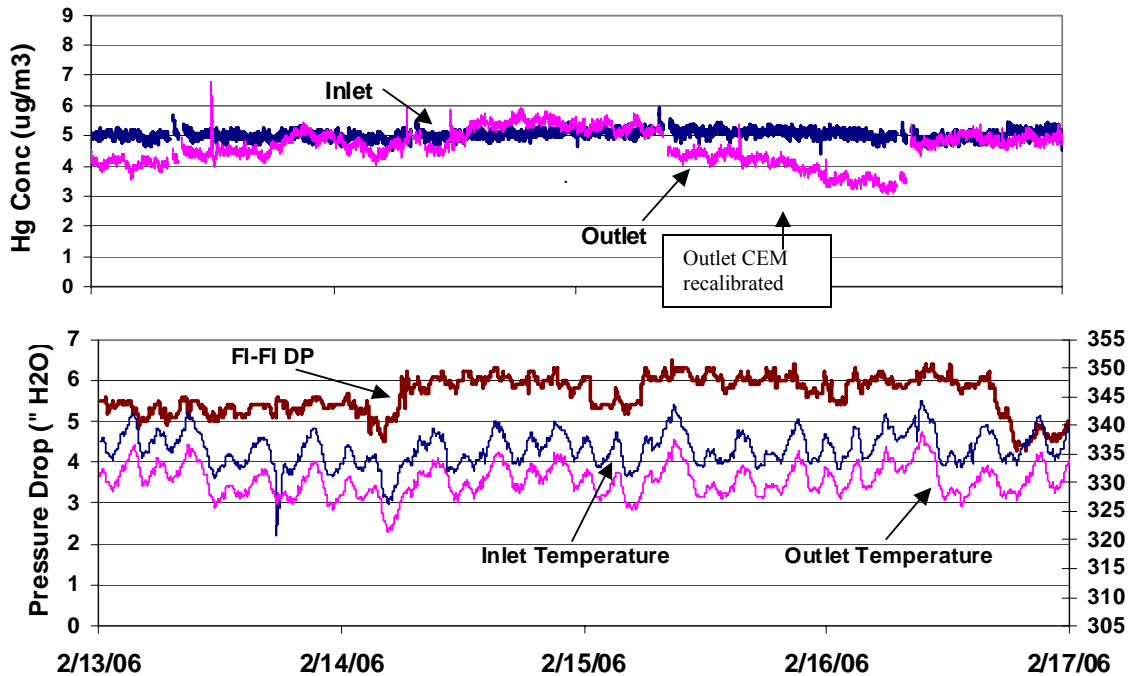
Test Method	Inlet Average (µg/sm <sup>3</sup> )	Outlet Average (µg/sm <sup>3</sup> )	Differential (%)
Thermo CEM	4.99	4.96	<b>0.6%</b>
Ontario Hydro	5.67	5.20	<b>9.0%</b>
<b>Differential (CEM &amp; O-H)</b>	<b>12%</b>	<b>4.6%</b>	

Based on the Ontario Hydro data, the elemental mercury at the inlet was 91% of the total. Oxidized mercury comprised the balance, with just a trace of particle-bound mercury. At the outlet, the elemental portion was 88%, with the remainder in the oxidized form.

## Baseline Performance Data

Figure 2 shows inlet and outlet mercury concentrations, flange-to-flange (fl-fl) pressure drop (pressure drop between inlet and outlet of the baghouse), and baghouse inlet temperature. There was some drift on the outlet CEM because the calibration routine was not programmed properly. When this was corrected and the instrument began undergoing daily calibrations, the mercury levels returned to the expected values.

**Figure 2.** Inlet and outlet mercury concentrations and baghouse pressure and temperature, February 13–17, 2006.



## Parametric Testing

The overall goal of these tests was to establish a correlation between injection of a standard PAC, NORIT Americas DARCO<sup>®</sup> Hg, a halogenated PAC, DARCO<sup>®</sup> Hg-LH, and mercury removal. Secondary goals included understanding the variables that impact mercury removal performance and to document any changes in baghouse performance. To minimize variables, it was decided to operate the baghouse at a pressure drop of nominally 6 inches W.C. and use a cleaning logic that was similar to baseline testing.

## Parametric Performance Data

PAC injection was started on February 20, 2006, using DARCO<sup>®</sup> Hg. During the following months, several balance-of-plant issues interrupted the parametric tests (discussion below). Parametric testing using both DARCO<sup>®</sup> Hg and Hg LH was completed in December 2006.

The graph in Figure 3 summarizes the results of the parametric testing for the two sorbents tested; NORIT DARCO<sup>®</sup> Hg and Hg-LH. The data is limited to test results at flue gas inlet temperature of 330 °F and baghouse cleaning set point of 6.5 inches W.C.

**Figure 3.** Parametric test results—330 °F.

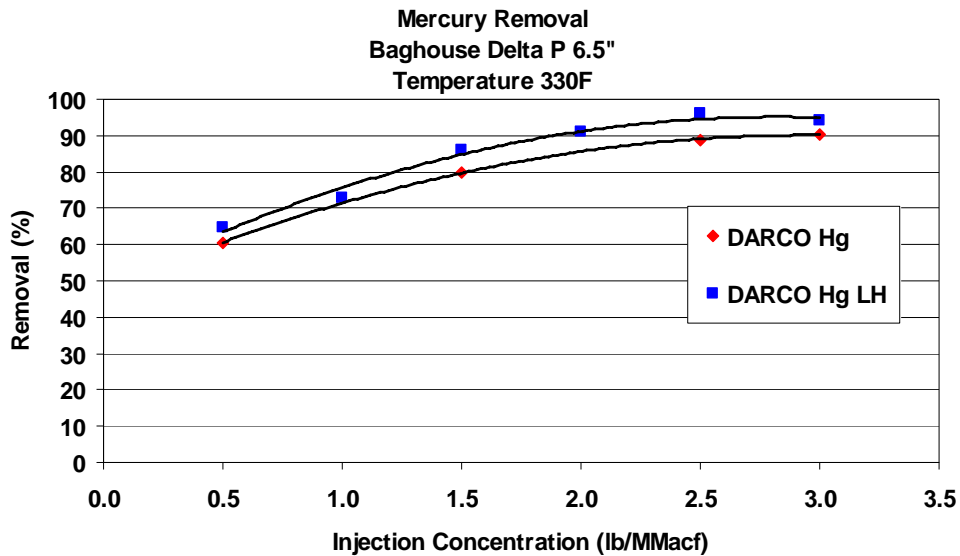
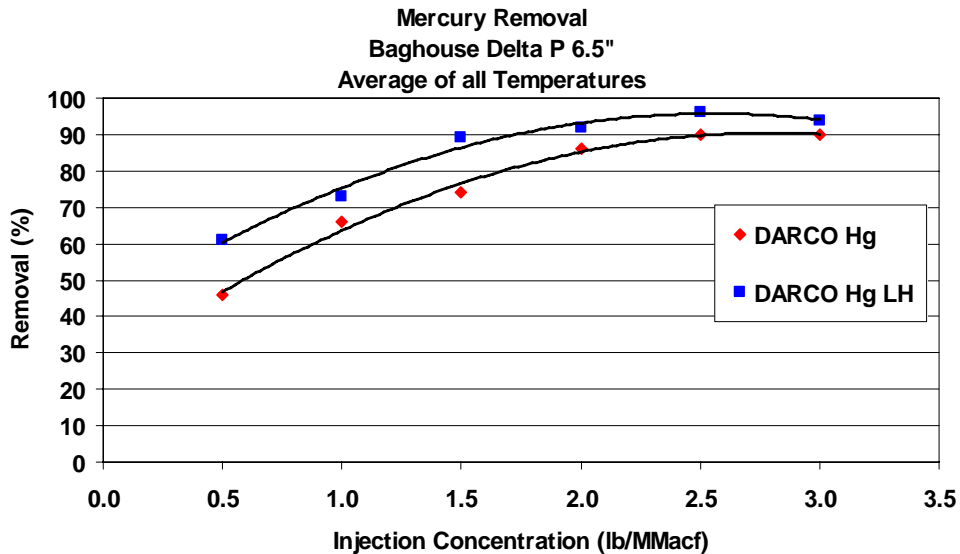


Figure 4 summarizes the results for all temperatures during parametric testing. This shows that DARCO<sup>®</sup> Hg at the lower injection concentrations was more affected by temperature than DARCO<sup>®</sup> Hg LH.

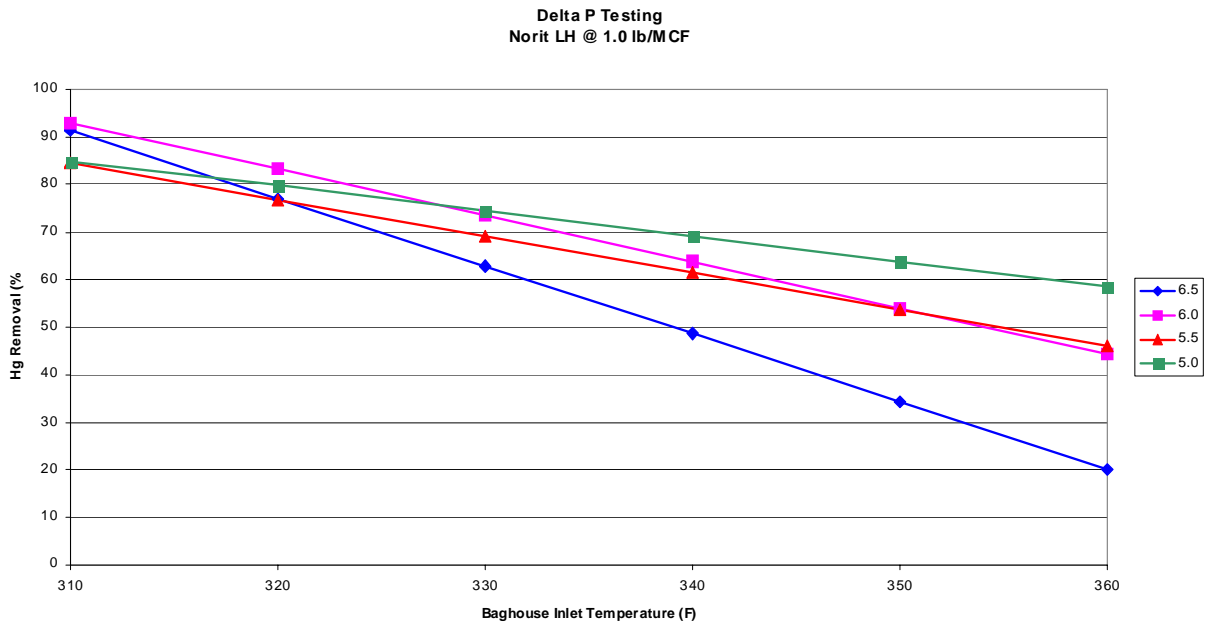
**Figure 4.** Parametric test results—all temperatures.



During the fourth quarter of 2006, tests were performed to determine the effect of reducing baghouse cleaning set point differential pressure ( $\Delta P$ ) on mercury removal efficiency. Up to this time, all of the testing had been with a set point of 6.5 inches W.C. When fl-fl  $\Delta P$  reached 6.5 inches, cleaning of the baghouse would commence until the  $\Delta P$  was reduced to 6.0 inches. For this testing, the set point was reduced by increments of 0.5 inches down to 5.0 inches. At each set point, data was taken for 2 days.

The data showed that at lower flue gas temperatures ( $< 320$  °F) there was little difference in mercury removal between the four set points. At higher temperatures, mercury removal was significantly affected by pressure drop settings. In Figure 5, the effect of flue gas temperature on mercury removal efficiency using DARCO® Hg LH is shown.

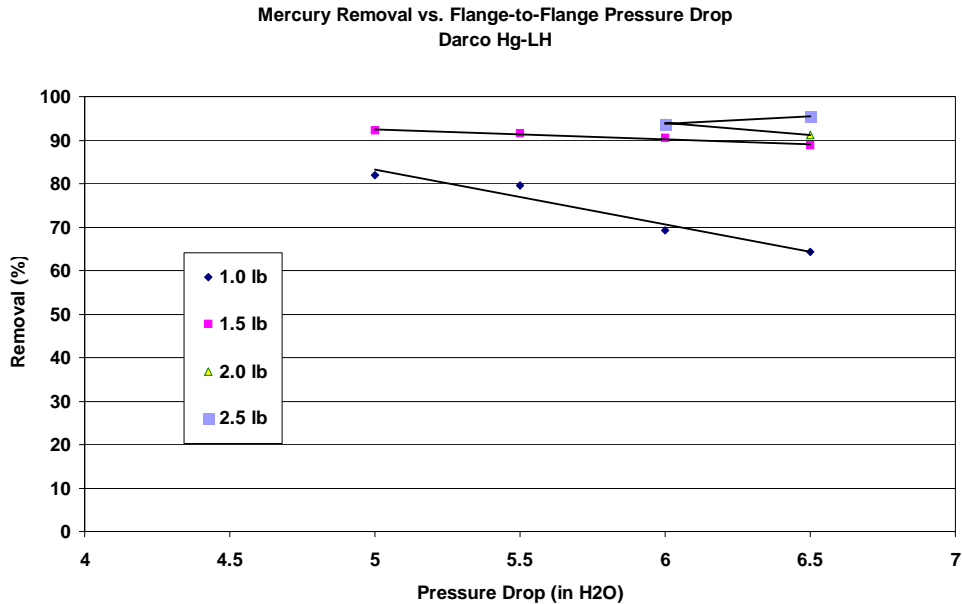
**Figure 5.** Effect of baghouse pressure drop on mercury removal for 1.0 lb/MMacf NORIT's DARCO® Hg LH.



The results of these tests indicated there is an advantage of running with reduced baghouse cleaning set point. Mercury removal was improved at higher inlet temperatures and fan power requirements were reduced. A significant increase in cleaning frequency did not become evident until the set point was reduced below 5.5 inches.

The pressure drop across the baghouse was then reduced from 6.5 to 5.0 in 0.5-inch increments at 1.0 and 1.5 lb/MMacf using DARCO® Hg LH sorbent at varying injection concentrations. At 2.0 and 2.5 lb/MMacf, tests were conducted at 6.5 and 6.0 inches only, since the effect of pressure drop was less noticeable at higher injection concentrations. Figure 6 shows the data for these tests. The removal efficiency is an average during the specific pressure setting and when temperatures were somewhat steady.

**Figure 6.** Effect of baghouse pressure drop on mercury removal for various PAC injection rates.



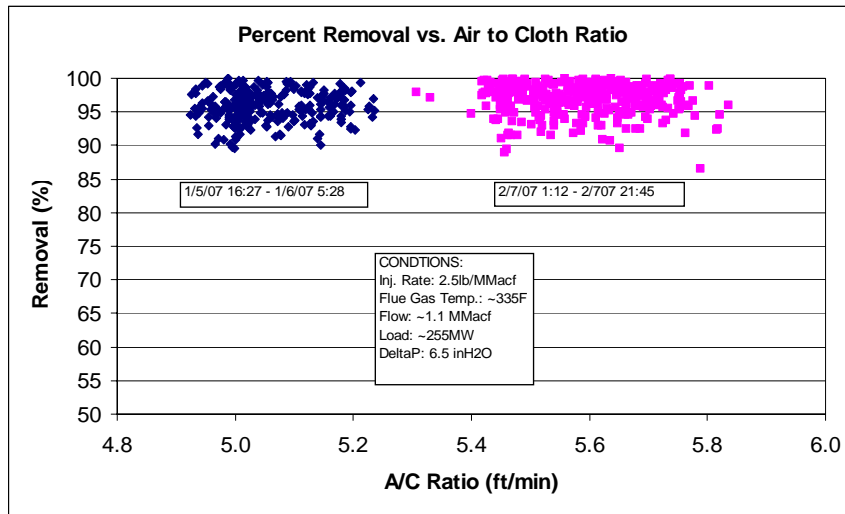
### Long-Term Mercury Control Results

A significant milestone was met on January 19, 2007. The mercury removal was above 90% for 48 consecutive days (1152 hours), and We Energies determined that this was a sufficient time period to prove that the technology was capable of the targeted removal. During this time, both the DARCO<sup>®</sup> Hg and Hg-LH were being used, so both showed the capability of removing mercury at a high level. During calendar year 2007, the project averaged 90% mercury removal. This included downtime for maintenance, inspections, and special testing.

### *Effect of Air-to-Cloth Ratio*

To determine the effect of air-to-cloth (AC) ratio on mercury removal, two time periods were chosen having constant PAC injection rate, flue gas temperature, flue gas flow rate, boiler load, and baghouse pressure drop. The only variable was the AC ratio. Figure 7 clearly shows that the mercury removal was not noticeably affected by the AC ratio at these conditions.

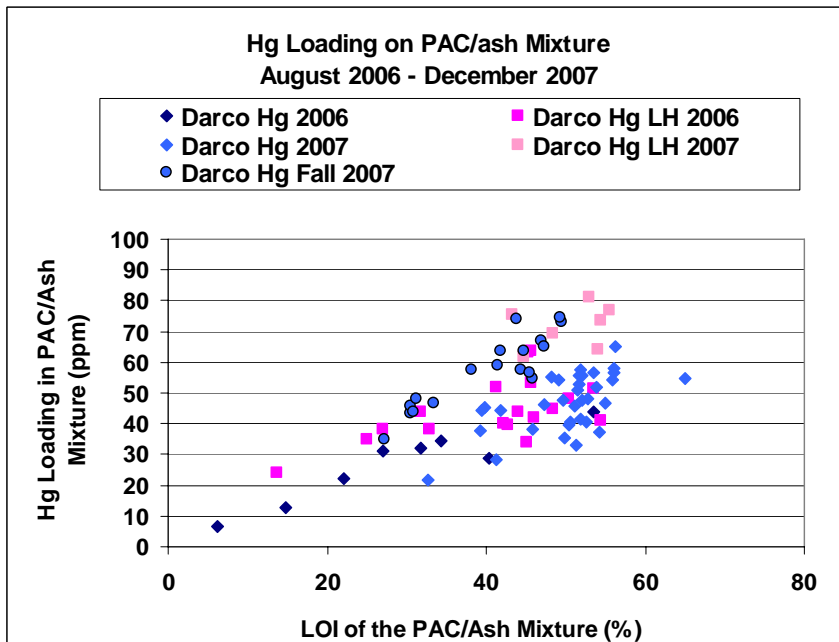
**Figure 7.** Effect of AC ratio on mercury removal.



**Mercury Loading on PAC/Ash Mixtures**

Samples of PAC/ash mixture from the baghouse were analyzed for mercury content and Loss on Ignition (LOI) throughout long-term testing. The ash from Units 7–9 at Presque Isle has a measured LOI of typically less than 1%, so the LOI in the PAC/ash mixture is primarily due to the PAC. Figure 8 shows the mercury loading in the mixture during several injection periods from 2006 through 2007. The mercury loading increased as the LOI (PAC fraction) increased, which is expected. There was higher overall loading for both types of carbon in the later part of 2007 when compared to their counterparts in 2006. This may be due to improved baghouse operation.

**Figure 8.** Mercury loading on the PAC/ash mixture.



### ***Drag Testing – Compartment 8***

During the baghouse outage in February 2007 and then again in May 2008, compartment 8 was opened and the test bags previously installed were inspected and drag measurements made. This compartment has OEM bags as well as experimental bags installed. The OEM bags in use are PPS fabric bags with the following specifications:

- Felted, 2.7-denier PPS fabric
- Weight of nominally 18 ounces/yd<sup>2</sup>
- Singed on both sides
- Scrim material made from 3 ounces/yd<sup>2</sup> of PPS
- Mullen burst minimum of 500 psi
- Permeability at 0.5 inches H<sub>2</sub>O of 25–40 cfm/ft<sup>2</sup>

Table 2 presents the array of other bag materials installed for testing. In the case of the Kermel fabric, five swatches approximately 4” x 11” were installed in 2006 in the compartment above the bags and pulse pipes. The swatches were exposed to flue gas and periodically one could be removed for strength tests. Although full-scale bags were preferred for the tests, using swatches reduced the risk of premature failures with experimental bags. For comparison, five OEM swatches were also installed. In 2007, a similar set of swatches made by Ahlstrom using a proprietary Armorguard™ felt blend replaced the Kermel swatches.

**Table 2.** Test bag materials.

<b>Bag ID</b>	<b>Material/Design</b>	<b>Benefit</b>	<b>Quantity</b>
9054	7-denier Torcon with 2.0 oz. PTFE scrim	High-perm fabric with more robust scrim	8
9055	7-denier Torcon with 4.0 oz. PTFE scrim	High-perm fabric with more robust scrim	8
9056	7-denier Torcon with Torcon scrim	High-permeability fabric	12
9065	Dual density Torcon (0.9- and 2-denier blend on filter side, 7-denier on other side)	High-perm on one side, high collection efficiency on other side	10
1342	P84	Higher temperature, higher collection efficiency	13
BHA-TEX	Scrim-supported PPS felt with a BHA-TEX expanded microporous PTFE membrane	Membrane provides higher collection efficiency and promotes light dustcake formation	12
Toray	Proprietary material		4
Kermel	Proprietary material		Swatches
Environmental Products and Systems, Inc.	PPS Fabric	Alternate source of PPS bags	1
Ahlstrom	Armorguard™ felt, proprietary blend		Swatches

Drag is a critical parameter in evaluating the performance of a fabric filter. Drag normalizes pressure drop to flow by dividing the average tube sheet pressure drop by the air-to-cloth ratio.

In 2007, the drag of eighty bags was measured in the compartment and eight bags were removed for weighing and laboratory testing—one each of the seven different types of test bags and one OEM bag. In addition, two Kermel swatches were removed. During the inspection, there was obvious discoloration above rows G, H, and I in the area where three types of test bags were installed. The bags in these rows were all high-perm bags, types 9054, 9055, and 9056. The rest of the tube sheet looked clean. The test bags in these rows were removed several weeks later when small opacity spikes were seen at the stack when these rows were pulsed. The bags were replaced with OEM PPS bags. At the same time, the Kermel swatches were removed due to failure and the Ahlstrom swatches installed along with a new set of PPS swatches as controls.

This set of drag measurements taken in 2007 was the first opportunity to quantify the filterability of the bags in a TOXECON™ baghouse after a period of operation. The bags were cleaned prior to taking the compartment off line, so these measurements should represent the residual drag of the dust cake formed in this application at this site.

In May 2008, drag testing was repeated on 93 bags and one of each test bag type and two PPS bags were removed for analysis. Two Ahlstrom swatches and two PPS swatches were also removed for analysis. A listing of the bag type, drag measurement, and operating hours is shown in Table 3 for both sets of drag testing.

**Table 3.** Comparison of drag measurements and operating hours, February 2007 and May 2008.

<b>Bag Type</b>	<b>Average Drag 02/26/07</b>	<b>Estimated Operating Hours 02/26/07</b>	<b>Average Drag 05/21/08</b>	<b>Estimated Operating Hours 05/21/08</b>
2.7-denier Torcon (OEM)	0.25	8089	0.26	18,745
2.7-denier Torcon (OEM)	0.05	0		
9054—high-perm	0.25	8089		
9055—high-perm	0.24	8089		
9056—high-perm	0.22	8089		
9065—dual density	0.19	8089	0.10	18,745
1342—P84	0.25	8089	0.23	18,745
GE/BHA Energy—membrane	0.32	8089	0.30	18,745
EPS-PPS			0.20	5,640

## **Balance-of-Plant Issues**

### ***Overheating of PAC/Ash in Baghouse Hoppers***

In early March 2006, after several weeks of parametric testing, hot, glowing embers were found in one hopper while operators were working to unplug and evacuate it. This compartment was isolated and the baghouse remained in service. All of the compartments were then checked and embers were found in all of the hoppers. The compartments were isolated, PAC injection was discontinued, and the baghouse put into bypass mode. The hot PAC/ash in each hopper was cooled and removed.

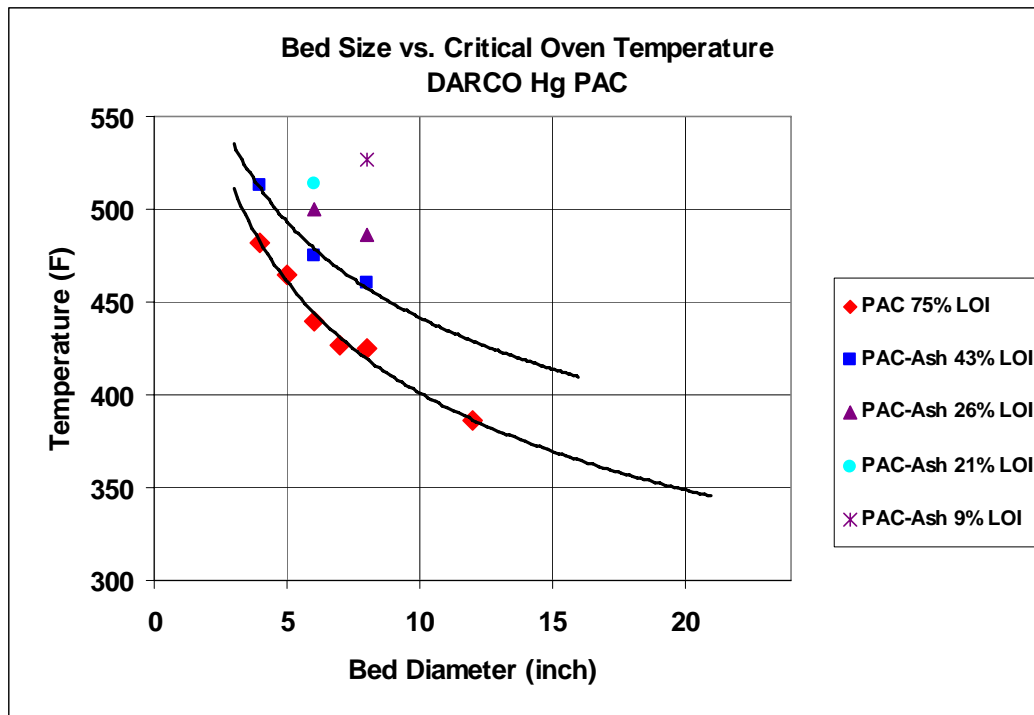
Thermogravimetric tests performed on the PAC and PAC/ash mixture showed an ignition temperature of around 850 °F although smoldering of the PAC occurred at around 780 °F. Heaters are used on the hoppers in this baghouse and specifications showed that they could reach temperatures up to 800 °F. At the time of the incident, they were set to maintain an average temperature of 290 °F. After all of the hoppers were emptied, thermocouples were placed on the hopper walls and the maximum wall temperature measured at the original setting was 407 °F.

Literature searches revealed a model to predict auto-ignition of combustible materials called the Frank-Kamenetskii Model. This model predicts that spontaneous combustion can result from internal heating of a combustible solid if the solid is sufficiently porous to allow oxygen to permeate it and if it produces heat faster than it can be liberated, which can happen with a highly insulating material. This phenomenon is normally associated with a relatively large mass of material (small surface-to-volume ratio). The model describes a relation among the radius of a specimen, time, and the self-ignition temperature in a defined geometry.

Laboratory oven tests were conducted on different size square containers filled with PAC/ash mixtures from the hoppers at PIPP. Thermocouples were placed in the oven and inserted into the bed of material at different levels to track temperature profiles over time. These tests confirmed that at 430 °F, sufficient heat was generated to increase the temperature of the mixture to ignition temperatures.

Figure 9 shows the results of the tests using DARCO<sup>®</sup> Hg PAC and mixtures of PAC and ESP ash, resulting in varying LOI in the blends. As expected, the temperatures required to ignite the lower-LOI PAC/ash mixtures are higher than for pure PAC and are dependent on bed size.

**Figure 9.** Autoignition correlation using DARCO<sup>®</sup> Hg PAC.



Working with industry, the following preliminary design considerations and procedures are recommended to minimize the risk of overheating high carbon ash in hoppers:

- Eliminate the use of hopper heaters.
- If using hopper heaters, change the hopper heater control from an on-off mode to a more tightly constrained temperature band. This should result in a lower peak temperature output of the heater. Also, consider using hopper heaters only during startup and shutdown.
- Add or increase temperature monitoring in the hopper to include temperature sensors inside the hopper. This will help with early indication of unusual temperature increases.
- Consider hopper design issues to ensure proper flowability of the collected material, especially with a high PAC-to-ash ratio.
- Select a means of fluidization other than vibrators that does not promote packing of the material. Current options that are in operating systems throughout the utility industry and other industrial sites are fluidization using a gas (air) or sonic horns. Further testing should be conducted to determine the effectiveness of vibrators for TOXECON<sup>™</sup> systems.
- Employ a hopper evacuation schedule that frequently removes hopper materials from the hoppers, preventing material buildup.
- Install a hopper level detector system and ensure its reliable operation.

### ***Fly Ash/PAC Dusting Problem***

Because of the nature of the TOXECON™ installation at PIPP being a test activity, it was known that the ratio of fly ash to PAC in the baghouse hoppers would be highly variable, resulting in extremes in the composition of the ash mixture. It was also not possible to look to industry to see how other installations had selected their ash handling system for this type of application, since PIPP was really the first installation of this nature to attempt to handle this waste stream. An initial concern of the design team was not with conveying PAC/ash to the storage silo, but with unloading the silo to trucks for disposal.

United Conveyor Corporation (UCC), the supplier of the system, provided equipment that was proven to be successful handling normal power plant ash. A wet unloading system was selected to condition the ash/PAC mixture leaving the storage silo with water, thereby binding the dust to allow transportation by open bed trucks. During the initial days of PAC injection, there were difficulties with unloading the PAC/ash mixture due to uneven flow from the storage silo to the wet unloader. Modifications to the initial control system settings were made along with hardware modifications to provide more fluidizing air to the silo bottom and discharge control valve to help even out the flow variances. These modifications improved the unloading situation but still did not provide dustless operation.

UCC next provided modifications including adding air cannons to the bottom of the silo, increasing the size of the water spray nozzles, modifying the fluidizing control valve, and making additional control logic changes. These changes corrected the uneven flow problem but still resulted in excessive dusting when dumping into the open bed truck. Further modifications were tried including adding a flexible chute, internal baffles to the mixer, and adding a surfactant to the water sprays. Again there was improvement, but not to the point where acceptable dustless operation was achieved.

At the end of third quarter 2006, there were still problems with excessive dusting during unloading of the ash silo using the wet unloader. The primary issue was controlling the flow of PAC/ash into the pin mixer. The diffuser valve was designed to meter PAC/ash from the silo into the pin mixer, where it was then sprayed with water. The PAC/ash mixture would bridge across the opening in the valve, resulting in limited flow into the mixer. When the valve would be opened further to reestablish flow, the PAC/ash mixture would break loose and overwhelm the ability to control dusting.

UCC conducted extensive pilot-scale testing using PAC. They reported successfully generating a dust-free product in their test lab. They indicated that a redesign of the wet unloader based on their test results should effectively solve the ongoing material handling issue. The redesign included a new mixer cover, raising the spray nozzles, dividing the mixer into three compartments, increasing the mixer speed, and adding a stop to the diffusion valve. The modifications to the wet unloader were completed in early October and tested. The results of these tests still showed uneven feeding of the PAC/ash mixture into the pin mixer.

UCC replaced the diffuser valve with a rotary valve. The silo was then unloaded using the wet unloader and there were minimal dusting issues. The ash flow into the mixer was controlled very well, and chemical surfactant was not needed even though it had been required previously to control fugitive dust. At the present time, there are still occurrences of excessive dusting, primarily when starting the unloading process.

UCC continues to work on modifications to the wet unloader. As of this writing, several ideas have been presented and testing is being planned. It is expected that stopping the dusting that occurs when the wet unloader is initially started will result in satisfactory overall operation.

## **SO<sub>2</sub> and NO<sub>x</sub> Control Testing**

Trona injection tests were performed at PIPP from July 31 through August 10, 2007. The purpose of these tests was to determine if dry trona injection prior to the TOXECON™ baghouse would result in at least 70% SO<sub>2</sub> reduction at the stack. Some minor NO<sub>x</sub> reduction was also anticipated from these tests. Balance-of-plant issues associated with trona injection and subsequent ash handling were also evaluated.

A temporary injection system was set up near the Units 7–9 stack with individual hoses and lances feeding each of the Unit ducts. The injection point was near the existing PAC injection ports in each duct and downstream of the plant NO<sub>x</sub> analyzers used for boiler feedback. SO<sub>2</sub> and NO<sub>x</sub> analyzers were temporarily installed upstream of the trona injection point on each of the three ducts for monitoring during the tests. Existing analyzers were used at the stack to measure SO<sub>2</sub>, NO<sub>x</sub>, and opacity.

During the test period, the trona injection rate was varied to determine SO<sub>2</sub> removal. PAC injection continued with trim control on, which allowed some variability (+/- 20%) in injection rate. PAC injection was turned off one day to determine if there was an effect from PAC on SO<sub>2</sub> removal.

### ***Trona Injection Equipment***

The injection equipment for this test program was obtained from Bulk Conveyor Specialist, Inc., and staged near the Units 7–9 stack. This equipment consisted of a trailer holding approximately 40 tons of trona and a separate trailer housing the blowers and controls. This system injected sorbent at the shipped particle size. Feedrate for the trona was from 2,200 lb/hr up to 5,900 lb/hr at full load to cover a wide range of stoichiometric ratios.

The trona was fed to three injection lances that were located downstream of the ID fan discharges, but upstream of the point where the ducts combine. Each lance discharged sorbent into the center of its duct, where turbulent flow provided gas/sorbent mixing. The lances were located below the current PAC injection lances.

### ***SO<sub>2</sub> and NO<sub>x</sub> Removal***

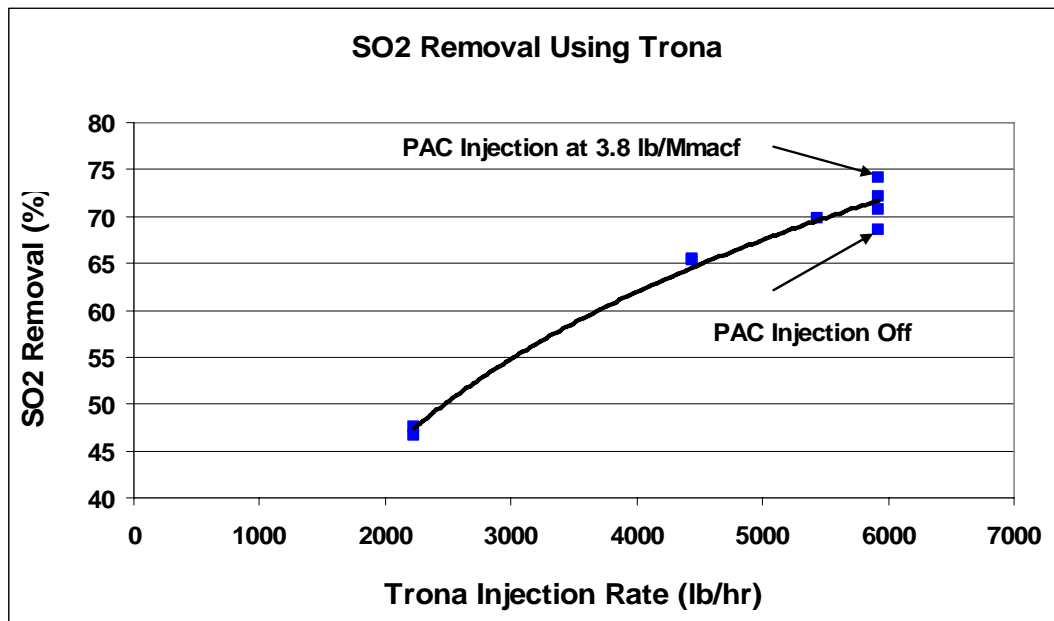
Table 4 shows the injection rate and SO<sub>2</sub> removal for the test period. The maximum removal achieved during the testing was 74.1% when co-injecting 3.8 lb/MMacf PAC.

**Table 4.** Trona injection results.

Date	Trona Injection Rate (lb/hr)	Average NSR	SO <sub>2</sub> Inlet (lb/MBtu)	SO <sub>2</sub> Removal (%)	Comments
08/01/07	2223	0.37	0.50–0.66	46.6	
08/02/07	2223	0.41	0.48–0.63	47.6	
08/03/07	4446	0.81	0.48–0.59	65.4	
08/04/07	4446	0.79	0.50–0.58	65.5	
08/05/07	5432	0.97	0.49–0.57	69.8	
08/06/07	5926	-	-	-	Difficulty feeding trona—test stopped
08/07/07	5926	1.02	0.52–0.60	70.7	
08/08/07	5926	1.02	0.52–0.66	68.5	PAC injection turned off during a.m.
08/09/07	5926	1.03	0.49–0.62	72.1	PAC injection ramped up to 3.8 lb/MMacf
08/10/07	5926	1.02	0.51–0.64	74.1	Started PAC injection at 3.8 lb/MMacf at start of trona injection

As seen in Table 4 and Figure 10 below, the best removal was when PAC was being injected at an unusually high level for this site (3.8 lb/MMacf). This was done to try to recover the > 90% mercury removal. During all trona injection tests, mercury removal degraded, and then slowly recovered overnight when no trona was injected.

**Figure 10.** SO<sub>2</sub> removal vs. trona injection rate.



### ***Conclusions from Trona Injection Testing***

The goal of 70% SO<sub>2</sub> removal was achieved during this two-week test period when using 5926 lb/hr of trona. This corresponds to an average NSR of 1.02. The inlet concentration of SO<sub>2</sub> varied from 0.48–0.64 lb/MBtu. The highest removal was 74.1%, requiring a PAC injection rate of 3.8 lb/MMacf which was used to reestablish 90% mercury removal. At the end of this test day, mercury removal was at 89% with 3.8 lb/MMacf so a slightly higher injection rate would be required to achieve > 90% mercury removal.

There was very little reduction in NO<sub>x</sub> during the test period, although the presence of the side reaction with NO producing NO<sub>2</sub> was seen on one test day when PAC injection was turned off. This indicates that there is some reaction with NO<sub>x</sub>, but not enough to measure on the stack CEMs and considerably below the target of 30% reduction. The NO<sub>2</sub> level was high enough to be visible and cause an increase in opacity of almost 3%. On days when PAC injection was occurring, the opacity increased by as much as 0.75%, but there was no visible plume.

Injection of trona for SO<sub>2</sub> control resulted in a decrease in mercury removal using activated carbon. This effect was seen every day that trona was injected. The mercury removal slowly recovered overnight to the pre-test level of > 90%. Baghouse and tube sheet pressure drop increased during trona injection, causing an increase in cleaning frequency from 0.18 p/b/hr to 0.22 p/b/hr.

An economic assessment of a full-scale trona injection system included equipment and other capital costs along with sorbent cost (trona and increased amount of PAC to maintain 90% removal) and O&M costs. The cost to remove SO<sub>2</sub> varied from \$1,440/ton at 45% removal and one silo to \$2,226/ton SO<sub>2</sub> at 70% removal with 3 silos.

## **CONCLUSIONS**

In collaboration with DOE in the CCPI program, We Energies and team members successfully completed the design, construction, installation, and startup of the first commercial mercury control system, EPRI's TOXECON™ process, on a coal-fired utility power plant. The new air pollution control system became commercially operational in late January 2006.

Parametric results with PAC injection indicated the mercury removal efficiencies were at the project stated goals of 90% mercury removal rates.

After several weeks of continued PAC injection, balance-of-plant issues related to high-carbon ash burning in the hoppers forced a delay in the testing. There have also been issues with the ash silo and wet mixing of the PAC/ash mixture from the baghouse. These balance-of-plant issues are exactly why DOE and industry team together to demonstrate new technologies. These alliances reduce financial and reliability risks to industry, while supporting the advancement of innovative, cost-effective new technologies. Working with industry, We Energies, DOE, and team members have identified the cause of burning PAC/ash in the hoppers, have developed preliminary guidelines for the safe operation of hoppers with high-carbon ash, and continue to evaluate and gain experience in the operation of a TOXECON™ system.

The goal of 70% SO<sub>2</sub> removal was achieved during August 2007 at an average NSR of 1.02. The highest removal was 74.1%, requiring a PAC injection rate of 3.8 lb/MMacf that was used to reestablish 90% mercury removal. At the end of this test day, mercury removal was at 89% with 3.8 lb/MMacf, so a slightly higher injection rate would be required to achieve > 90% mercury removal. There was very little reduction in NO<sub>x</sub> during the test period, although the presence of the side reaction with NO producing NO<sub>2</sub> was seen on one test day when PAC injection was turned off.

Injection of trona for SO<sub>2</sub> control resulted in a significant decrease in mercury removal using activated carbon. Based on an economic assessment of a full-scale trona injection system, the cost to remove SO<sub>2</sub> would be from \$1,440/ton to \$2,226/ton SO<sub>2</sub>.

Additional testing to evaluate fabric filters and ash management will continue until March 2009.

## **KEY WORDS**

TOXECON™, activated carbon, PAC, mercury, trona, autoignition