

**TOXECON™ RETROFIT FOR MERCURY AND
MULTI-POLLUTANT CONTROL ON THREE
90-MW COAL-FIRED BOILERS**

Quarterly Technical Progress Report

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ABSTRACT

With the Nation's coal-burning utilities facing tighter controls on mercury pollutants, the U.S. Department of Energy is supporting projects that could offer power plant operators better ways to reduce these emissions at much lower costs. Sorbent injection technology represents one of the simplest and most mature approaches to controlling mercury emissions from coal-fired boilers. It involves injecting a solid material such as powdered activated carbon into the flue gas. 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 by a particulate control device along with the other solid material, primarily fly ash.

We Energies has over 3,200 MW of coal-fired generating capacity and supports an integrated multi-emission control strategy for SO₂, NO_x, 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 oxide (NO_x), sulfur dioxide (SO₂), and particulate matter (PM) emissions, allow for reuse and sale of fly ash, demonstrate a reliable mercury continuous emission 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 (the Participant) will design, install, and operate 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 particulate control device is used in conjunction with sorbent injection for removal of pollutants from combustion flue gas. For this project, the flue gas emissions will be controlled from the three units using a single baghouse. Mercury will be controlled by injection of activated carbon or other novel sorbents, while NO_x and SO₂ will be controlled by injection of sodium-based or other novel sorbents. Addition of the TOXECON™ baghouse will provide enhanced particulate control. Sorbents will be injected downstream of the existing particulate control device to allow for continued sale and reuse of captured fly ash from the existing particulate control device, uncontaminated by activated carbon or sodium sorbents.

Methods for sorbent regeneration, i.e., mercury recovery from the sorbent, will be explored and evaluated. For mercury concentration monitoring in the flue gas streams, components available for use will be evaluated and the best available will be integrated into a mercury CEM suitable for use in the power plant environment. This project will provide for the use of a control system to reduce emissions of mercury while minimizing waste from a coal-fired power generation system.

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EXECUTIVE SUMMARY

Wisconsin Electric Power Company (We Energies) signed a Cooperative Agreement with the U.S. Department of Energy (DOE) in March 2004 to fully demonstrate TOXECON™ for mercury control at the We Energies Presque Isle Power Plant. The primary goal of this project is to reduce mercury emissions from three 90-MW units (Units 7, 8, and 9) that burn Powder River Basin (PRB) coal. Additional goals are to reduce nitrogen oxide (NO_x), sulfur dioxide (SO₂), and particulate matter (PM) emissions, allow for reuse and sale of fly ash, demonstrate a reliable mercury continuous emission monitor (CEM) suitable for use in the power plant environment, and demonstrate a process to recover mercury captured in the sorbent.

We Energies teamed with ADA-ES, Inc., (ADA-ES) and Cummins & Barnard, Inc., (C&B) to execute this project. ADA-ES is providing engineering and management on the mercury measurement and control systems. Cummins & Barnard is the engineer of record and was responsible for construction, management, and startup of the TOXECON™ equipment.

This project was selected for negotiating an award in January 2003. Preliminary activities covered under the “Pre-Award” provision in the Cooperative Agreement began in March 2003. This Quarterly Technical Progress Report summarizes progress made on the project from October 1, 2008, through December 31, 2008. During this reporting period, work was conducted on the following tasks:

- Task 15. Operate, Test, Data Analysis, and Optimize TOXECON™ for Mercury Control
- Task 17. Carbon-Ash Management System
- Task 18. Revise Design Specifications/O&M Manuals
- Task 19. Reporting, Management, Subcontracts, Technology Transfer

INTRODUCTION

DOE awarded Cooperative Agreement Number DE-FC26-04NT41766 to We Energies to demonstrate TOXECON™ for mercury and multi-pollutant control, a reliable mercury continuous emission monitor (CEM), and a process to recover mercury captured in the sorbent. Under this agreement, We Energies is working in partnership with the DOE.

Quarterly Technical Progress Reports will provide project progress, results from technology demonstrations, and technology transfer information.

Project Objectives

The specific objectives of this project are to demonstrate the operation of the TOXECON™ multi-pollutant control system and accessories, and

- Achieve 90% mercury removal from flue gas through activated carbon injection
- Evaluate the potential for 70% SO₂ control and trim control of NO_x from flue gas through sodium-based or other novel sorbent injection
- Reduce PM emission 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
- Demonstrate a reliable, accurate mercury CEM suitable for use in the power plant environment
- Successfully integrate and optimize TOXECON™ system operation for mercury and multi-pollutant control

Scope of Project

The “TOXECON™ Retrofit for Mercury and Multi-Pollutant Control on Three 90-MW Coal-Fired Boilers” project will be completed in two Budget Periods. These two Budget Periods are:

Budget Period 1: Project Definition, Design and Engineering, Prototype Testing, Major Equipment Procurement, and Foundation Installation. Budget Period 1 initiated the project with project definition activities including NEPA, followed by design, which included specification and procurement of long lead-time major equipment, and installation of foundations. In addition, testing of prototype mercury CEMs was conducted. Activities under Budget Period 1 were completed during 1Q05.

Budget Period 2: CEM Demonstration, TOXECON™ Erection, TOXECON™ Operation, and Carbon Ash Management Demonstration. In Budget Period 2, the TOXECON™ system was constructed and will be operated. Operation will include optimization for mercury control, parametric testing for SO₂ and NO_x control, and long-term testing for mercury control. The mercury CEM and sorbent regeneration processes will be demonstrated in conjunction with the TOXECON™ system operation.

The project continues to move through Budget Period 2 as of the current reporting period. Each task is described in the Statement of Project Objectives (SOPO) that is part of the Cooperative Agreement.

EXPERIMENTAL

None to report.

RESULTS AND DISCUSSION

Following are descriptions of the work performed on project tasks during this reporting period.

Task 1 – Design Review Meeting

Work associated with this task was previously completed.

Task 2 – Project Management Plan

Work associated with this task was previously completed.

Task 3 – Provide NEPA Documentation, Environmental Approvals Documentation, and Regulatory Approval Documentation

Work associated with this task was previously completed.

Task 4 – Balance-of-Plant (BOP) Engineering

Work associated with this task was completed during 1Q05 in Budget Period 1.

Task 5 – Process Equipment Design and Major Equipment Procurement

Work associated with this task was completed during 1Q05 in Budget Period 1.

Task 6 – Prepare Construction Plan

Work associated with this task was completed during 1Q05 in Budget Period 1. The Construction Plan was issued on January 26, 2005.

Task 7 – Procure Mercury Continuous Emission Monitor (CEM) Package and Perform Engineering and Performance Assessment

The overall goal of this task was to have a compliance-grade, reliable, certified mercury CEM installed and operational for use in the TOXECON™ evaluation. Installation and checkout of

two CEMs at the inlet and at the outlet of the baghouse was completed in 1Q06. The long-term evaluation of the mercury CEMs is described in Task 15 for the remainder of the project.

Task 8 – Mobilize Contractors

Primary work associated with this task was completed in 1Q06.

Task 9 – Foundation Erection

All major foundation work was completed during 1Q05.

Task 10 – Erect Structural Steel, Baghouse, and Ductwork

Primary work associated with this task was completed in 4Q05.

Task 11 – Balance-of-Plant Mechanical and Civil/Structural Installations

Primary work associated with this task was completed in 4Q05.

Task 12 – Balance-of-Plant Electrical Installations

Primary work associated with this task was completed in 4Q05.

Task 13 – Equipment Pre-Operational Testing

Pre-operational testing was completed in 4Q05.

Task 14 – Startup and Operator Training

Startup of all major equipment was completed in 4Q05. Final O&M manuals were received for most major equipment in 2005. Startup of the PAC system occurred in 1Q06.

The operator-training program was completed during 4Q05 to train the plant operations personnel.

The baghouse was initially brought into operation on December 17, 2005, with flue gas from Unit 7. Initial operation with Unit 8 occurred on January 5, 2006, and Unit 9 on January 27, 2006.

Task 15 – Operate, Test, Data Analysis, and Optimize TOXECON™ for Mercury Control

CEM Update

During 4Q08, the mercury Continuous Emissions Monitors (CEMs) located at the inlet and outlet of the baghouse were monitored for long-term operation. A summary of the operation of each system including any maintenance is presented below:

Inlet

The inlet CEM system availability for 4Q08 is estimated since there were many interference periods with the amount of valid data collected. Some of the unavailability was accurate due to system component failure and maintenance while others are not, such as sampling from offline units and sorbent screening tests being performed.

The inlet CEM system availability for October was estimated at 84%. The system began the month in an “out-of-control” state due to a failed calibration on September 30th but was corrected after a manual calibration on October 1st. This was due to switching probes and a PMT voltage adjustment. On October 3rd there was a miscalculation of calibration factors but was corrected later that day. From October 10th through 13th the system failed calibrations due to a lamp replacement, actuator service and probes were switched twice. On October 21, 23, 26 and 27 the system failed calibration checks but this was due to sorbent screening tests.

Availability for November was 94%. The system failed the calibration checks on three separate occasions. The first failed cal was on November 2nd but corrected itself the next day. The second came on November 4th due to failed probe heater in the Unit 8 probe and switching to the Unit 9 probe. The third was on November 19th and was corrected by a manual recalibration. On November 22nd Unit 9 went offline but sampling continued on that unit for the three day duration of the outage.

Availability for December was 74%. Maintenance was performed on December 5th and did not pass calibration until December 8th. On December 9th through 15th the system did not pass calibration checks due to sorbent screening tests being performed. There was a failed calibration check on December 18th due to a lamp replacement on the 17th. Probes were switched on the 19th and the system was recalibrated. Another failed calibration check occurred on the 27th but self-corrected on the 28th.

Maintenance:

- **October:**
 - Switched sampling from probe #1 (Unit 8) to probe #2 (Unit 9) on October 1st. The actuator valve on probe #1 was sticking in the closed position.
 - Mercury lamp replaced on October 9th.
 - Serviced actuator valve on probe #1 (Unit 8) on October 9th. Had problem of sticking in place rather than opening and closing.
 - Switched sampling from probe #2 (Unit 9) to probe #1 (Unit 8) on October 10th. Actuator on probe #1 sticking in the closed position again.
 - Switched sampling from probe #1 (Unit 8) to probe #2 (Unit 9) on October 13th.

- Sorbent Screening tests performed from October 21 - 28. CEM data was only available during the nighttime hours.
 - Cleaned probe #1 (Unit 8) on October 23rd.
 - On October 23rd, set screws were installed on the probe #1 (Unit 8) actuator valve to prevent the valve from sticking.
 - Cleaned probe #3 (Unit 7) on October 28th.
 - Switched sampling from probe #2 (Unit 9) to probe #1 (Unit 8) on October 28th.
- November:
 - Probe #1 (Unit 8) bench heater failed.
 - Switched sampling from probe #1 (Unit 8) to probe #2 (Unit 9) on November 4th.
 - Switched sampling from probe #2 (Unit 9) to probe #3 (Unit 7) on November 25th.
 - Probe #3 (Unit 7) high temperature failsafe thermistor connections failed which caused the bench heaters to not get power.
- December:
 - Repaired probe #3 (Unit 7) high temperature failsafe thermistor.
 - Replaced probe #1 (Unit 8) bench heaters, probe thermocouple, high temperature failsafe thermistor.
 - Cleaned probe #1 (Unit 8). Components of the slipstream sample gas line were clogged with fly ash most likely due to the probe not being heated.
 - Replaced probe #2 (Unit 9) bench heaters, probe thermocouple.
 - Rebuilt sample pump.
 - Sorbent Screening tests performed from December 7 - 14. CEM data was only available during the nighttime hours.
 - Switched sampling from probe #1 (Unit 8) to probe #3 (Unit 7) on December 15th. Probe #3's probe controller would not communicate with the analyzer for yet to be determined reasons.
 - Switched sampling from probe #3 (Unit 7) to probe #1 (Unit 8) on December 17th.
 - Mercury lamp replaced on December 17th.

Outlet

There were no failed calibrations for October and the availability for the month was 100%.

The availability for November is estimated at 100%. There was one failed calibration on November 20th but the system corrected itself and passed the next day's calibration check (Nov. 21st). The failed calibration was due to a failed linearity check which is not counted against the availability time.

The estimated availability for December is 97%. Between December 1st through 9th the baghouse outlet was being bypassed but the calibration checks during this period passed. The system failed the calibration and was placed into service mode on December 18th due to a lamp replacement which requires a "burn in" time before getting valid data. On December 19th the system passed the recalibration and check.

Maintenance:

- October:
 - The Cl₂ in N₂ cylinder used for integrity checks was replaced during the week of October 20th.
 - Mercury lamp replaced on October 26th.

- November:
 - None.

- December:
 - Mercury lamp replaced on December 17th.

Bag Replacement

During 4Q08, replacement PPS bags were ordered for the baghouse due to bag strength deterioration. These new bags will be stored on site until the installed bags begin to fail and require replacement.

Ash Silo

During 4Q08, there were still issues with excessive dusting during unloading of the ash silo using the wet unloader, primarily during startup of the pin mixer. United Conveyor Corporation (UCC) and We Energies continued to work on modifications to the mixer and optimizing its operation to reduce dusting. There continue to be problems with overloading the motor, breaking the chain tensioner and jamming the mixer shafts. In December a new pin mixer was ordered from UCC with delivery expected in 1Q09.

The plant began to build a partial enclosure around the base of the ash silo to eliminate the wind tunnel effect and prevent airborne dusting. This work is scheduled to be complete in 1Q09.

Exterior Duct Repair Work

In 2Q08, plant workers noticed severe corrosion on some sections of the return duct insulation and lagging. The ducts were inspected from the inside on May 20th during the scheduled baghouse outage. No leaks were identified during the internal inspection. After the baghouse was returned to service additional removal of lagging and insulation uncovered a weld that was not completed. This was the likely source of flue gas corrosion of the exterior.

During 3Q08, additional corroded insulation and lagging was removed from the ducts. Repairs were made to the structural steel duct where the flue gas was leaking, then new insulation and lagging were installed. These repairs were completed in the early part of 4Q08.

The addition of insulation around the duct expansion joints began in 3Q08. The insulation should reduce internal corrosion which was noticed at the expansion joints during the duct inspection in 2Q08. This work was completed in October.

Baghouse Emissions Testing

On November 4-6, 2008, Platt Environmental Services, Inc. conducted a series of mercury, particulate, halogen, and trace metals tests. A mercury continuous emission monitoring system

relative accuracy test audit (RATA) on the Unit 9 TOXECON™ inlet and outlet was also performed using Method 30B. For the Method 30B mercury tests, paired sorbent traps were used at each location. Samples were analyzed onsite using an Ohio Lumex, Inc. analyzer for total gaseous mercury. The results of these tests were then compared with the Thermo Continuous Emissions Monitors installed at the inlet and outlet of the baghouse.

Table 1 shows the results from the mercury testing. The results from this program indicate that the Unit 9 TOXECON™ inlet CEM system meets the US EPA annual performance specification of less than 20% RA as published in 40 CFR Part 75 and the outlet CEM system meets the US EPA alternative annual performance specification of less than 1 µg/wscm mean difference for units emitting less than 5.0 µg/wscm.

Table 1. Results from Mercury Testing (Method 30B)

Location	RM Ave. Concentration (µg/wscm)	CEM Average Concentration (µg/wscm)	Relative Accuracy	Bias
Unit 7 Inlet	5.52	N/A	N/A	N/A
Unit 8 Inlet	6.11	N/A	N/A	N/A
Unit 9 Inlet	5.76	6.11	8.31	1.000
Common Outlet	0.46	0.38	0.08*	1.111**

*Based upon <1.0 µg/wscm mean difference

**Maximum BAF

Table 2 below shows results from the particulate testing. During this test, the inlet was sampled at the common inlet duct to the baghouse. These results therefore include both ash and PAC particulate. Tests from previous years showed an inlet particulate loading of 110 lb/hr upstream of PAC injection and outlet of 17 lb/hr, indicating that the emissions from the baghouse have been constant since startup.

Table 2. Results from Particulate Testing (Method 17)

Location	Ave. Result (lb/hr)	Ave. Result (lb/MMBtu)
Common TOXECON™ Inlet (includes ash and PAC)	413.758	0.1157
Common TOXECON™ Outlet	17.043	0.0066

Table 3 shows results from the halogen and halide testing using Method 26A. These tests were performed at 3 locations to understand in affect of PAC on halogens, regarding both scrubbing of native species or emissions of halogens from the PAC. The first location was upstream of PAC injection to determine what would be emitted without PAC injection and a baghouse. The second location is in the common inlet duct to the baghouse. This data gives an indication of scrubbing of native species by the PAC in-flight. The third location is the common outlet duct. This gives the true emissions to the stack, and can show if there are emissions of halogens from the PAC as well as further scrubbing of native species.

Data from the Unit 8 inlet shown in lb/hr should be tripled to account for the fact that this duct represents one third of the total flue gas going into the baghouse. Comparisons of the emissions in lb/MMBtu are more directly applicable. These results show a decrease in emissions from the baghouse for HCl and Cl₂. HBr shows an increase in emissions while Br₂ and HF show little or any change in emissions.

Table 4 shows the results from trace metals testing at the common baghouse inlet and in the Unit 8 flue in the stack. Emissions reductions across the baghouse were seen for the following metals: selenium, manganese, cadmium, chromium, and nickel. Arsenic, beryllium, and lead showed little change in emissions across the baghouse.

Table 3. Results from Halogen and Halide Testing (Method 26A)

Parameter	Location	Ave. Result (lb/hr)	Ave. Result (lb/MMBtu)
HCl	Unit 8 TOXECON™ Inlet (upstream PAC injection)	1.919	0.0172
	Common TOXECON™ Inlet (downstream PAC injection)	4.7173	0.0133
	Common TOXECON™ Outlet	3.2377	0.0125
HBr	Unit 8 TOXECON™ Inlet (upstream PAC injection)	0.0277	0.0002
	Common TOXECON™ Inlet (downstream PAC injection)	1.595	0.0044
	Common TOXECON™ Outlet	0.6227	0.0024
HF	Unit 8 TOXECON™ Inlet (upstream PAC injection)	0.9343	0.0083
	Common TOXECON™ Inlet (downstream PAC injection)	1.8063	0.0051
	Common TOXECON™ Outlet	2.008	0.0077
Cl2	Unit 8 TOXECON™ Inlet (upstream PAC injection)	0.08	0.0007
	Common TOXECON™ Inlet (downstream PAC injection)	0.2807	0.0008
	Common TOXECON™ Outlet	0.1517	0.0006
Br2	Unit 8 TOXECON™ Inlet (upstream PAC injection)	0.0277	0.0002
	Common TOXECON™ Inlet (downstream PAC injection)	0.102	0.0003
	Common TOXECON™ Outlet	0.081	0.0003

Table 4. Results from Volatile Metals Testing (Method 29)

Parameter	Location	Ave. Result (ppb)	Ave. Result (lb/TBtu)
Arsenic (Ar)	Common TOXECON™ Inlet (downstream PAC injection)	1.07	28.31
	Unit 8 Flue at Stack	1.0	26.55
Selenium (Se)	Common TOXECON™ Inlet (downstream PAC injection)	5.27	146.32
	Unit 8 Flue at Stack	3.73	106.87
Manganese (Mn)	Common TOXECON™ Inlet (downstream PAC injection)	16.63	320.97
	Unit 8 Flue at Stack	0.8	15.93
Beryllium (Be)	Common TOXECON™ Inlet (downstream PAC injection)	2.03	6.46
	Unit 8 Flue at Stack	1.67	5.31
Cadmium (Cd)	Common TOXECON™ Inlet (downstream PAC injection)	0.23	8.78
	Unit 8 Flue at Stack	0.1	2.66
Chromium (Cr)	Common TOXECON™ Outlet	5.57	102.15
	Unit 8 Flue at Stack	1.5	28.19
Lead (Pb)	Common TOXECON™ Inlet (downstream PAC injection)	0.4	29.42
	Unit 8 Flue at Stack	0.4	26.55
Nickel (Ni)	Common TOXECON™ Inlet (downstream PAC injection)	4.23	87.33
	Unit 8 Flue at Stack	1.5	31.99

Baghouse Outage and Duct Inspection

There was a baghouse outage and duct inspection during the first week of December. This inspection was scheduled because of the corrosion seen during the May, 2008 inspection. General conclusions from the duct inspection are as follows:

Duct Steel

Visual inspection showed significant corrosion on the return duct and mild corrosion on the supply duct. Duct wall thickness was measured in three 6 ft by 8 ft areas of both the supply and return duct. Data showed between 5-10% metal losses in the bottom half of the return duct between unit 9 and unit 7 diverter damper. The corrosion visually gets progressively worse from unit 9 to unit 7. Supply duct steel showed mild signs of corrosion between the unit 7 and the unit 8 diverter damper.

Expansion Joints

There are 13 joints on the supply duct and 12 joints on the return duct. Expansion joints were filled with fiberglass “pillows” to insulate and prevent accumulation of material. Expansion joint pillows show significant deterioration in the floor and lower side wall areas due to acidic condensation. In early 2008, two inches of insulation was placed over the exterior of all expansion joints.

As the pillows deteriorate, ash and scale material can accumulate in the joints of the supply duct. Material build up in the joints is a concern because it would lead to the loss of expansion at the joints. The current buildup is not interfering with movement.

During the inspection, one previously damaged joint was repaired by patching. Although a successful repair was made, the OEM (PAPCO) recommended replacing the entire patched joint at the next available opportunity. The design of expansion joints will make it very difficult to change them in the future due to lack of accessibility.

Inspections identified significant corrosion of the duct steel frame that holds the expansion joints. Chunks of metal could be peeled off frames. Further corrosion will lead to leaks. In duct areas under pressure, flue gas will escape under lagging. The spacing between the duct and insulation allows a chimney effect under the lagging. When this occurs, significant damage to the insulation and lagging can be expected.

Duct Insulation and Design

The duct has two inches of insulation mounted on top of eight inch wide duct stiffeners. The duct stiffeners are mounted to the duct steel on approximately four foot centers. Draft stops were not installed. The cavity between insulation and duct wall with lack of draft stops could be a major factor in cooling of the lower portion of duct steel and resulting corrosion issues.

Diverter Dampers

Unit 7 and unit 9 diverter dampers show significant corrosion around flanges and seals. Flange nuts are corroded to the point where it would not be possible to put a wrench on the nut. It is assumed this will eventually compromise integrity of the flange bolts. The unit 8 diverter damper did not show any significant corrosion. The issues could be a result of operating seal air fans continuously during the first year of operation. There is a concern regarding potential loss seal due to frame failure.

The seal air flow is unbalanced. There is a much higher volume of seal air flowing through the supply side than the return side at each of the diverter dampers.

Drag Testing

Bag testing was conducted during the baghouse outage on December 3, 2008. In-situ drag measurements of test and standard bags were made and select bags were removed for laboratory analysis. In February 2007 and May 2008 bags were inspected and a similar set of measurements were taken. The results from these tests and the drag test procedure can be found in previous Quarterly Reports.

Background

The TOXECON™ baghouse is a pulse-jet design supplied by Wheelabrator Air Pollution Control Inc. It has 10 compartments, each with 648 bags. Each compartment is separated into two, 18 x 18 row bag bundles: there are 648 bags per compartment. The diameter of the circular bag is approximately 5.25 in., the length is 26.25 ft and the filtering area is 35.5 ft²/bag. The total filtration area in the baghouse is 230,000 ft². With all units in service at full load, the gross air-to-cloth ratio is 5.0 ft/min.

Compartment 8A 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/yd²
- Singed on both sides
- Scrim material made from 3 ounces/yd² of PPS
- Mullen burst minimum of 500 psi
- Permeability at 0.5 inches H₂O of 25–40 cfm/ft²

A description of all the different types of test fabrics installed in Compartment 8 can be found in Table 5. All test bags are installed in bundle A, or the bundle closest to the inlet and outlet plenums. In the case of the Ahlstrom fabric, 4.75" x 9.5" swatches were installed in frames in a swatch holder, which was placed on the supporting steel above the bags and pulse pipes. Although full-scale bags are preferred for the tests, using swatches reduces the risk of premature failures with experimental bags. For comparison, PPS felt swatches were also installed.

Table 5. Test Bag Description

Bag ID	Material/Design	Benefit	Quantity
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	8
1342	P84	Higher temperature, higher efficiency	10
GE BHA-TEX	Scrim-supported PPS felt with a BHA-TEX Expanded microporous PTFE Membrane	Membrane provides higher collection efficiency and promotes light dustcake formation	9
Toray	Proprietary material		1
Environmental Products and Systems, Inc.	PPS fabric	Alternate source of PPS bags	1
GE PS050	PPS fabric with 0.5 and 2.9 denier fibers on filtration side, 7.9 denier on other side	High Perm on one side, high collection efficiency on other side	5
Ahlstrom GFTS #4406	Armorguard felt, proprietary blend		Swatches only
9054 ^a	High- perm, 7 denier Torcon with 2.0 oz. PTFE scrim	High Perm fabric with more robust scrim	8
9055 ^a	High-perm, 7 denier Torcon with 4.0 oz. PTFE scrim	High Perm fabric with more robust scrim	8
9056 ^a	High-perm, 7 denier Torcon with Torcon scrim	High Permeability fabric	12
Kermel ^b	Proprietary material		Swatches only

a. All high-perm test bags removed in April 2007 because of high particle penetration

b. Fabric failed from chemical attack, swatches removed in February 2007

A schematic of the compartment layout, bag numbering scheme and locations of the different bag types in bundle A of Compartment 8 is shown in Figure 1. This schematic also documents when new bags were installed to replace bags that were removed for various reasons, including:

- Heat damage from the overheating incident in February 2006
- Unacceptable emissions from the high-perm test bags, these bags were replaced in April 2007
- Replacement bags for bags removed for testing

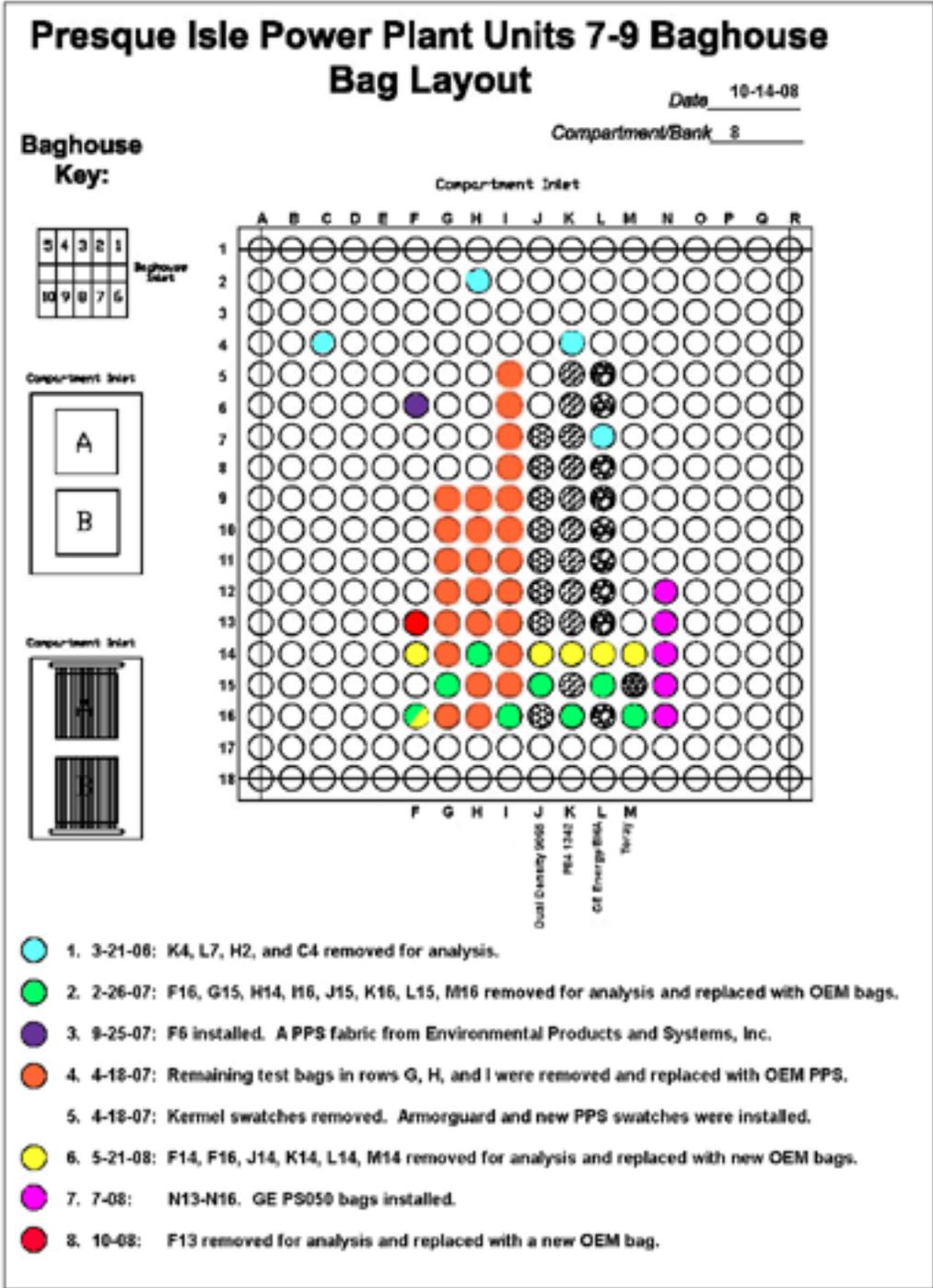


Figure 1. Test Bag Layout

Results, Observations and Analysis

- The tube sheet was clean, indicating that the bags were in good shape with a very low probability that any bags had failed (Figure 2).

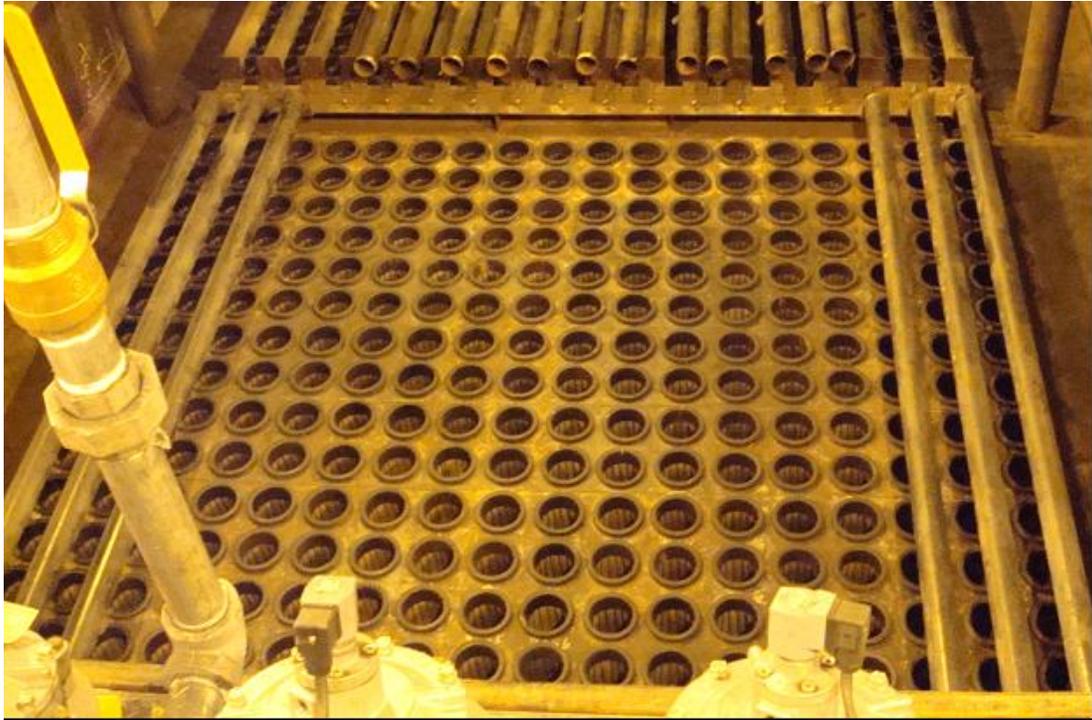


Figure 2. Picture of Compartment 8 Tube Sheet

- Average drag measured for each of the bag sets is presented in Table 6. These results are presented by consecutive rows in the compartment.
- Drag provides an indication of the filterability of the bags after a period of operation. Ideally, the bags are cleaned, one pulse per bag, prior to taking the compartment off line so that the measurements represent the lowest possible drag with the dust cake formed in the conditions at this site. Not pulsing all of the bags uniformly can significantly affect the drag measurements.
- Drag was measured on an installed, new, OEM bag in February 2007; the drag was 0.05 inches H₂O/ft/min.
- Bag weights of the eight bags removed for lab testing are presented in Table 7.
- For this baghouse, a drag below 0.3 inches H₂O/ft/min should be considered ideal and should result in acceptable filterability and pressure drop. At an air-to-cloth ratio of 5.5 inches H₂O and a drag of 0.3 inches H₂O/ft/min, the tube sheet pressure drop after cleaning would be nominally 1.6 inches H₂O/ft/min.

Table 6. Drag Measurements, 12/3/08 Drag Unit = inches H₂O/ft/min^a

Bag Description (Installation Date)	Row ID	Number of Bags Tested	Average Drag 12/3/08	Estimated Operating Hours
OEM Std (Jan 2006)	F	8	0.23	22,981
OEM Std (Apr 2007)	G	7	0.25	13,728
OEM Std (Apr 2007)	H	7	0.20	13,728
OEM Std (Apr 2007)	I	11	0.21	13,728
Dual Density - 9065	J	8	0.21	22,981
P84 - 1342	K	10	0.26	22,981
GE/BHA - Membrane	L	9	0.29	22,981
Toray	M	1	0.13	22,981
GE PS050	N	5	0.07	3,255
OEM Std (Jan 2006)	O	12	0.10	22,981
OEM Std (Feb 2006)	Mix	7	0.19	22,981
OEM Std (Feb 2007)	Mix	6	0.12	14,892
EPS – PPS Std	F	1	0.16	9,935

a. Order of results presented by consecutive rows in compartment, except for last three entries

- Trends and observations noted from drag data collected during this inspection include:
- The average drag of the originally installed standard PPS, OEM bags with nearly three years of service was 0.23 inch H₂O/ft/min in row F and 0.10 inch H₂O/ft/min in row O. These are excellent values and show that:
 - The difference in the average drag between the two rows is the result of row O being pulsed more recently than row F. This can also be seen in the low drag of the Toray bag in row M compared to bags with similar hours of operation in rows J – L.
 - The average drag of the OEM bags in row F in February 2007, May 2008 and December 2008 was 0.25, 0.19, and 0.23 inches H₂O/ft/min, respectfully. These data show that drag is not increasing with time, which is what would be expected. These low, steady drag values indicate that this baghouse design fully meets the requirements for this application and performance is above average.
- The average drag of the OEM PPS bags installed in April 2007 in rows G, H and I was 0.25, 0.20, and 0.21 inches H₂O/ft/min. These results provide additional confirmation that the drag of the standard bags is in an excellent range and that there are no indications that drag should increase to unacceptable levels any time soon, barring an upset condition.
- The average drag of the dual density test bags is higher than the previous measurement, 0.21 versus 0.1 inches H₂O/ft/min, but similar to the first set of measurements in

February 2007 of 0.19 inches H₂O/ft/min. These drag values are excellent and are a good indication that these bags should provide long term, acceptable filtering characteristics. The low drag measured in the previous tests may have been the result of when the bags were cleaned.

- The average drag of the P84 test bags was 0.26 inches H₂O/ft/min, which is slightly higher than the PPS bags with similar service hours. We have seen very little variation in the drag of these bags over the three tests, 0.25, 0.23, and 0.26 inches H₂O/ft/min. The drag results show that these bags should provide acceptable tube sheet pressure drop for several years, assuming similar operating conditions. P84 is capable of operating at a continuous temperature of 500°F while PPS maximum continuous temperature is 375°F.
- The average drag of the single Toray test bag was 0.13 inches H₂O/ft/min. This is excellent and lower than expected when compared to the drag measured in the previous two tests, 0.16 and 0.27 inches H₂O/ft/min. This low drag is probably the result of a very recent clean, similar to comments made above.
- The average drag of the GE/BHA membrane bags was 0.29 inches H₂O/ft/min, which is similar to the previous two tests, 0.32 and 0.30 inches H₂O/ft/min. This bag style has always had the highest drag of any of the other bag sets. This was expected early on because the membrane alone causes a higher drag. It is encouraging that this fabric has experienced no additional increase in drag over the three years. The dual purpose of the membrane is to reduce penetration of the particles into the fabric and provide a “slick” surface to hinder a dust cake from forming. At this time we are seeing no benefit of the membrane in maintaining lower drag than the standard PPS bags.
- In September 2007 a single PPS bag from Environmental Products and Systems, Inc (EPS) was installed in row F. The drag of this single bag was not measured during this test, but based on the consistent performance of all of the standard and test bags over time in this compartment it is expected that this style of bag would also have acceptable drag.
- In July 2008 five test bags from GE were installed in row N. These bags are identified as PS050 and are a type of dual density design with a combination of 0.5 and 2.9 denier fibers on the filtering side and 7.9 denier on the other side. The drag of these bags was very low at 0.07 inches H₂O/ft/min, which is only slightly higher than the drag of a new bag of 0.05 inches H₂O/ft/min. This low drag is not surprising considering that the bags have been in service for less than five months and they are in a row that may have been pulsed immediately before isolating the compartment.
- Eight bags were removed by first removing the cage, then the bag, and then folding the bag up and placing it into a plastic bag. One each of the dual density, P84, GE/BHA, Toray and GE PS050 bags was removed. Three OEM standard bags were removed, one that was installed since startup in January 2006, one that was installed in February 2007 and one that was installed in April 2007. The bag weight measurements can be found in Table 7.

Table 7. Bag Weights (lbs) December 3, 2008.

Bag #	Bag I.D.	Plastic Bag Tare	New Bag Weight	Test Bag Weight	Net Wt.
F12	OEM Jan 2006	0.06	5.1	6.3	0.9
G12	OEM Apr 2007		5.1	6.1	0.8
J12	Dual Density		4.3	5.8	1.3
K12	P84		3.8	4.7	0.7
L12	GE/BHA		5.0 (estimated)	4.8	0.5
M15	Toray		4.6	7.3	2.4
N12	GE PS050		5.0 (estimated)	5.9	0.7
J15	OEM Feb 2007		5.1	6.0	0.7

Trends and observations noted from the bag weight measurements include:

- The dust cake weights of the three different vintages of OEM bags were 0.9, 0.8 and 0.7 lbs, which is very low and correlates with the low drag numbers. These values have not changed over time, again matching the drag results that have also not changed over time.
- The GE/BHA membrane bags have consistently had the lowest dust cake weight, 0.6 lbs, see Table 5. This shows that the pressure drop is caused by the membrane and not embedded dust in the fabric.
- The dust cake weights of the P84 bag, 0.7 lbs is similar to the OEM bags.
- The dust cake weight of the dual density bag was slightly higher at 1.3 lbs. High perm bags typically have higher bag weights than standard denier fabric even though the drag is often lower. Half of this fabric is made from higher perm fibers, higher denier, and we may finally be seeing that this portion of the fabric is starting to hold more dust than the standard fabrics. Bag weights of the high perm bags at other sites were consistently higher than the standard bags even though the drag was typically lower.
- The dust cake weight of the Toray fabric was again higher than others, 2.4 lbs. This has been consistent throughout all of the tests. Even with the significantly higher bag weights, this fabric has acceptable drag.

The final Ahlstrom test swatch and the standard PPS swatch were removed. The test fabric had shrunk, become discolored, and could easily be torn by hand. This kind of failure often indicates chemical attack from exposure to the flue gas. A photo of the test and PPS swatches can be seen in Figure 3.

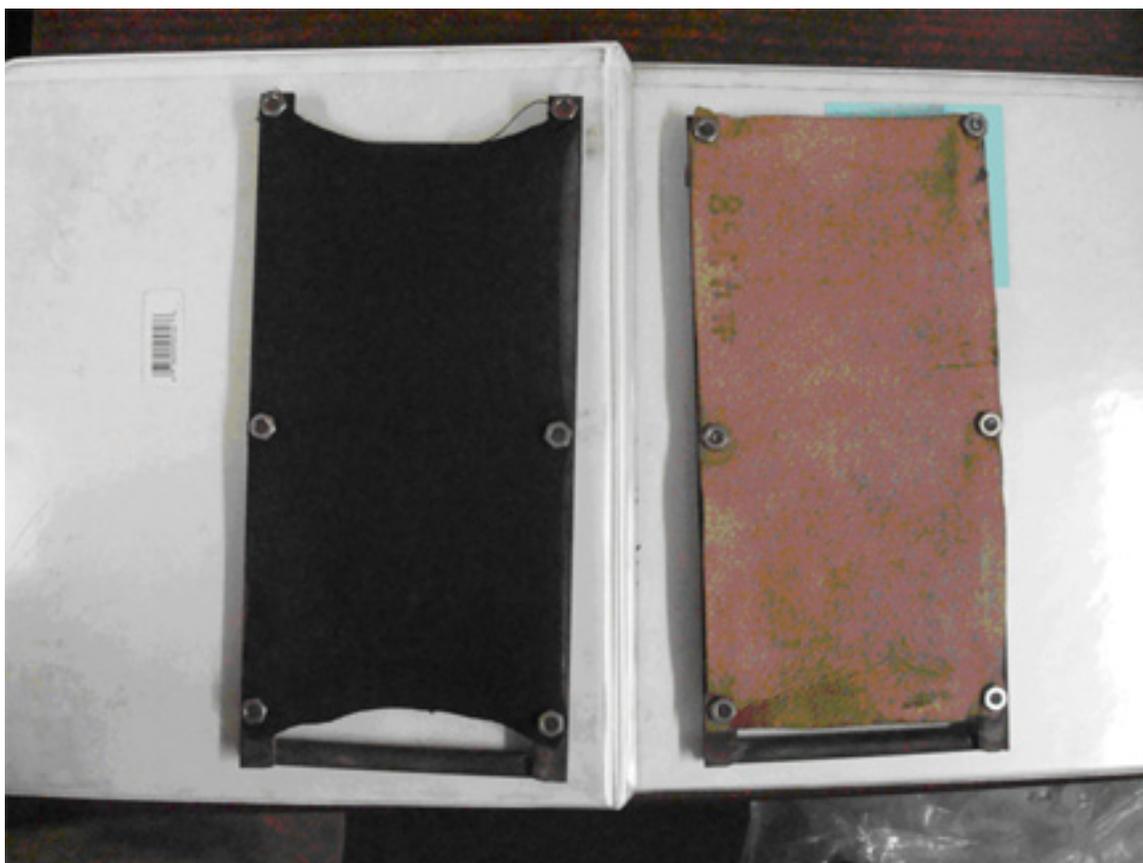


Figure 3. Picture of test and PPS swatches removed from Compartment 8

Discussion

All of the bags tested in Compartment 8A are in excellent filtering condition. The drag tests have shown that there are some differences in performance between the different bag types, but nothing that would eliminate any of these bags from consideration due to filtering properties.

This is the first installation of TOXECON™ so there are no other results available to use as a direct comparison of performance. There are two COHPAC™ baghouses installed in the US and operating experience from these was considered in the design of TOXECON™. The gross air-to-cloth ratio of the COHPAC™ baghouses are 12 ft/min and 8 ft/min and they both have seen significant increases in drag within the first year or two of operation which resulted in high pressure drop and cleaning frequencies. Because of this, this baghouse was designed at a lower air-to-cloth ratio, 5 ft/min. The performance of this baghouse since start up and the results from these drag measurement indicate that the combination of the lower air-to-cloth ratio and the optimized cleaning logic implemented by We Energies are ideal for this application and overcome the pressure drop and operation & maintenance issues with the COHPAC™ baghouses, especially the unit installed at Luminant's Big Brown station.

Nine different test bags and two set of swatches have been tested in this test program, including three different high-perm bags that were removed because of particle bleed through that was causing opacity spikes. The other six types of bags all performed well in this application. However, some of these alternative bags come with either a direct or operation & maintenance cost adder that is probably not justifiable for this site.

The dual density fabric has performed, but no better than the standard fabric. It is unknown whether the dual density fabric would have the same, high collection efficiency as the standard fabric.

The P84 fabric provides the ability to operate at higher operating temperatures. These bags are more expensive and are also harder to remove from the cages, so O&M costs for a bag change out would be slightly higher. The only justification for purchasing these bags would be if operating temperatures increased.

The membrane bags offer no advantage in this application and are considerably higher in cost. These bags also are difficult to remove and would result in higher costs when bags are replaced.

The Toray material had acceptable performance, but costs more than the PPS fabric.

A single PPS bag from Environmental Products and Systems was installed and appears to be similar to the other standard PPS bags in terms of drags. Laboratory integrity tests have not been performed.

The new GE bags have too little operating time to make any conclusions on long term performance. Laboratory testing is expected to be completed in March 2009.

Baghouse Operations

DARCO[®] Hg-LH, a brominated carbon, has been used throughout 2008. Figure 4 shows TOXECON[™] data for October 2008. Mercury removal was over 90% for the majority of the month using 1.2 lb/MMacf PAC. Mercury removal dropped below 90% during part of the time when the injection rate was decreased to 1.0 lb/MMacf. The baghouse cleaning frequency was steady at 0.18 p/b/hr. The tube sheet pressure drop was around 2.0 inches of water with two units at full load.

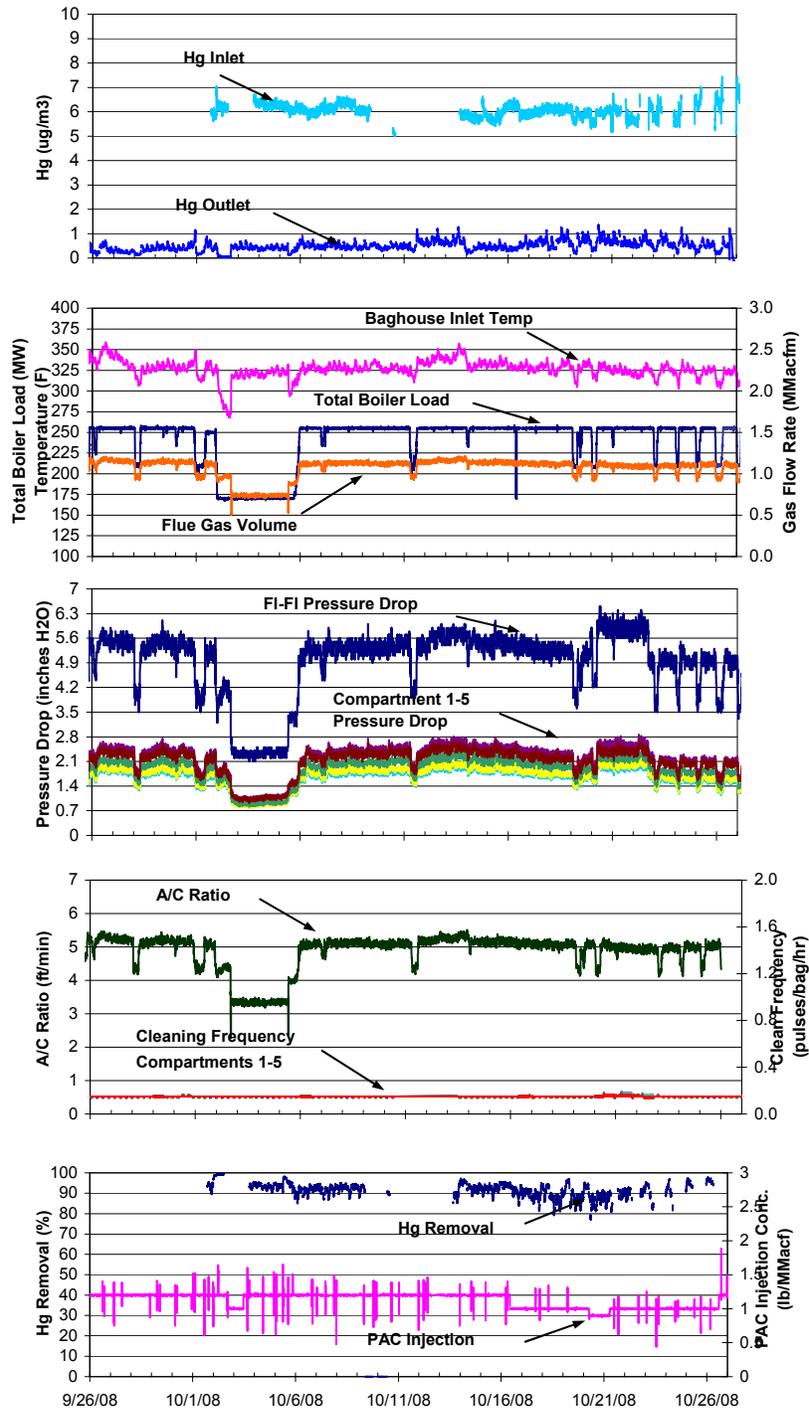


Figure 4. TOXECON™ Performance Data for October 2008.

Figure 5 shows TOXECON™ data for November 2008. Mercury removal was over 90% at a PAC injection rate of 1.0 - 1.2 lb/MMacf. The baghouse cleaning frequency was steady at 0.18 p/b/hr. The tube sheet pressure drop was around 2.0 inches of water when all units were at full load.

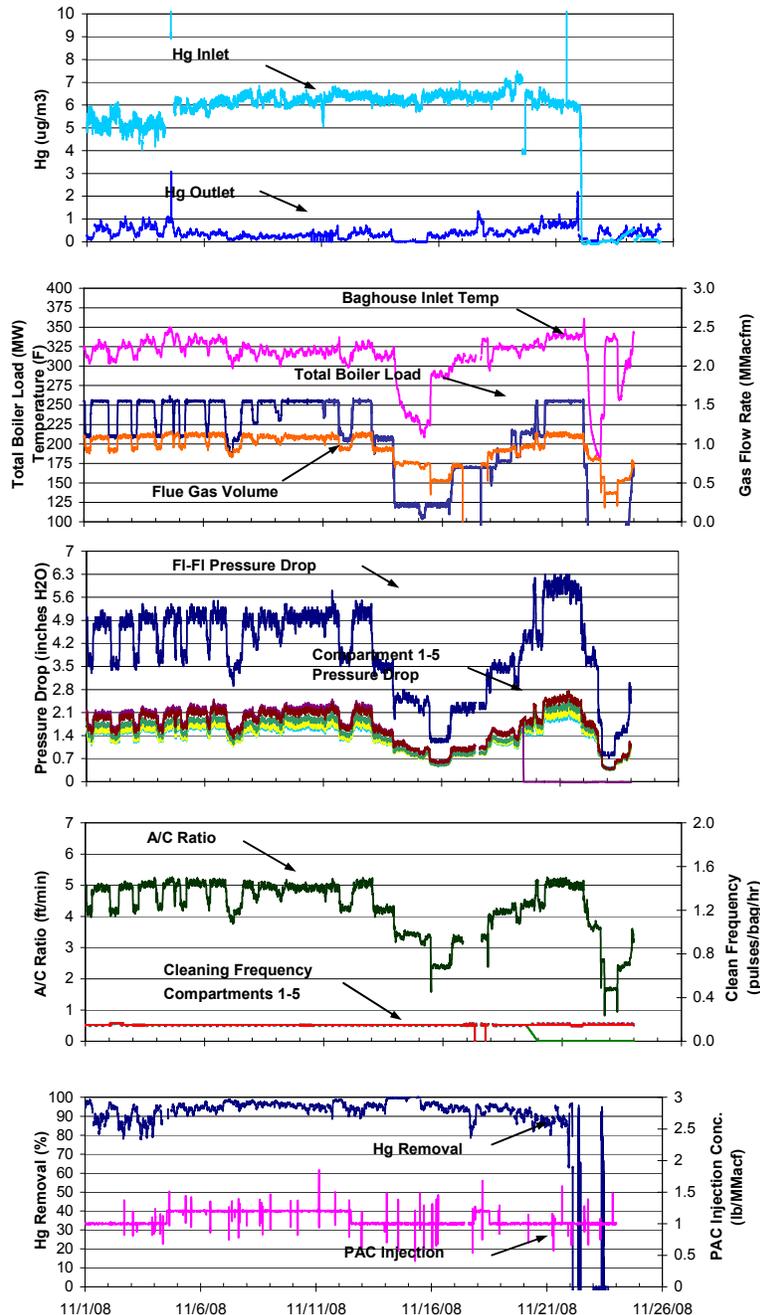


Figure 5. TOXECON™ Performance Data for November 2008.

Figure 6 shows TOXECON™ data for December 2008. The baghouse was off line the first week in December. Sorbent screening occurred during the second week in December so the inlet signal was intermittent. Problems with the outlet monitor during the last half of the month resulted in lost removal data for most of this time period. PAC injection rate was 1.0 lb/MMacf after the baghouse came back on line. The tube sheet pressure drop was around 1.0 inch of water with two units on at full load.

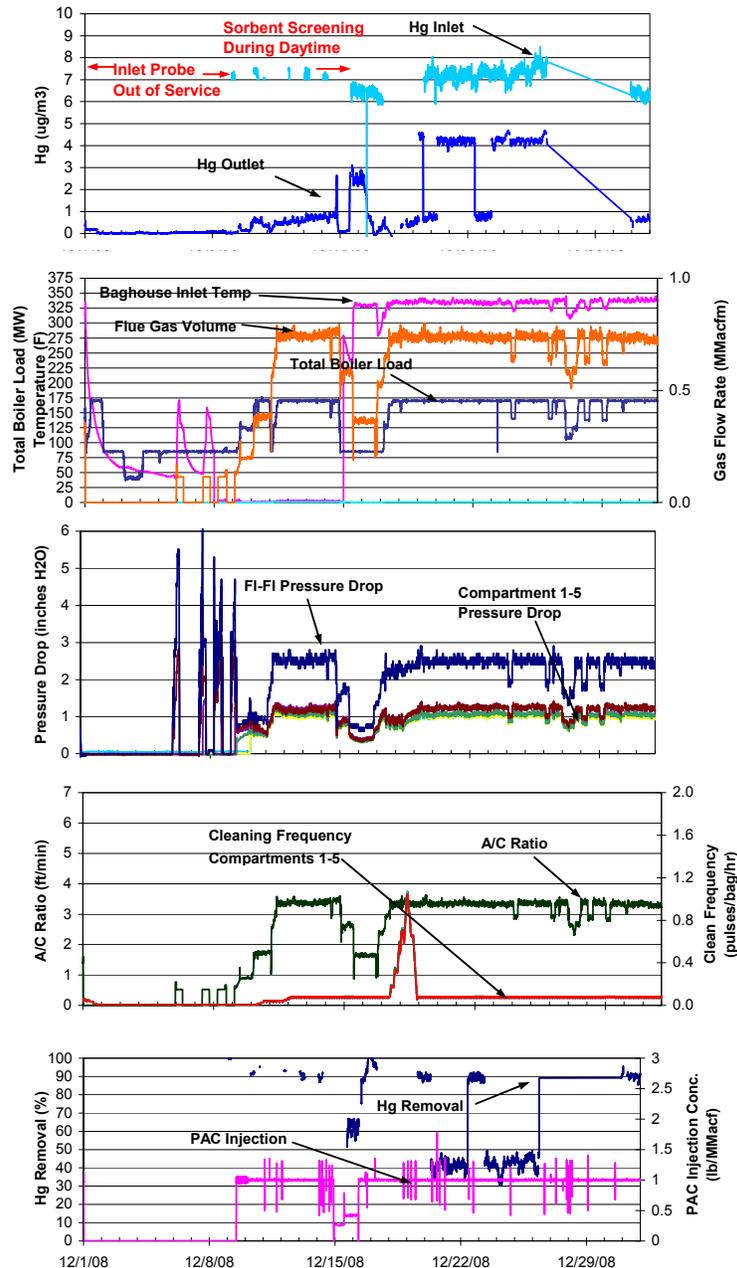


Figure 6. TOXECON™ Performance Data for December 2008.

Task 16 – Operate, Test, Data Analysis, and Optimize TOXECON™ for NO_x and SO₂ Control

Parametric tests were performed in August, 2007 to assess the capability of trona (sodium sesquicarbonate) injection upstream of the TOXECON™ baghouse to control SO₂ and NO_x. Injection equipment and measurement instrumentation were installed specifically for these tests.

Data and results from the testing in August were presented in the 3Q07 quarterly report. A draft topical report including technical results and economic assessment was submitted in late 1Q08. The final topical report was sent out for review and was submitted in 3Q08.

Task 17 – Carbon/Ash Management System

During 4Q07 a review on current technologies concerning mercury removal from high carbon ash was completed. Several thermal treatment technologies were identified as having potential for a pilot scale test in 2008. During 1Q08 two thermal technologies were identified as having the potential to treat the TOXECON™ baghouse ash. One process uses microwave energy while the other uses natural gas as the heating source. Several 55-gallon drums of baghouse ash were shipped out to be tested using both technologies.

Results of the work performed by United Environment & Energy (UEE), UP Steel, and ADA-ES are described.

UEE Final Report

Task 1. Obtain and characterize the fly ash/PAC mixture provided by We Energies

UEE received three 55-gallon drums of PAC-Ash from We Energies. The fly ash was transported in sealed steel containers. The fly ash sample was characterized in terms of composition, density, particle size (scanning electron microscopy), and surface area. The composition analysis was conducted at Test America Inc, a certified outside laboratory. It showed that the PAC-Ash contains 25% carbon and 31 ppm mercury, which are different from the numbers provided by We Energies. The carbon content of 25% is close to the optimal carbon content for the nitrogen fertilizer production (Table 8).

Table 8. PAC-Ash Composition

Sample	Analyzed by	Al (wt.%)	Si (wt.%)	C (Wt.%)	Ca (Wt.%)	Fe (Wt.%)	Hg (ppm)
PI 7-9 Ash analysis	We Energies	16	32	1	21	5	0.0045
PAC-Ash	We Energies			50			62
	UEE			25.46	7.1	1.8	31

The BET surface area of PAC-Ash was measured at UEE using the Quantachrome BET Surface Area System. The surface area of PAC-Ash was 123 m²/g. Because the PAC activated carbon had a surface area of 523 m²/g, the surface area of PAC-Ash correlated well with the carbon content in the ash of 25.46 wt% (Figure 7). The fly ash and activated carbon existed in the form of agglomerates. The density of the PAC-Ash was 0.60 g/ml.

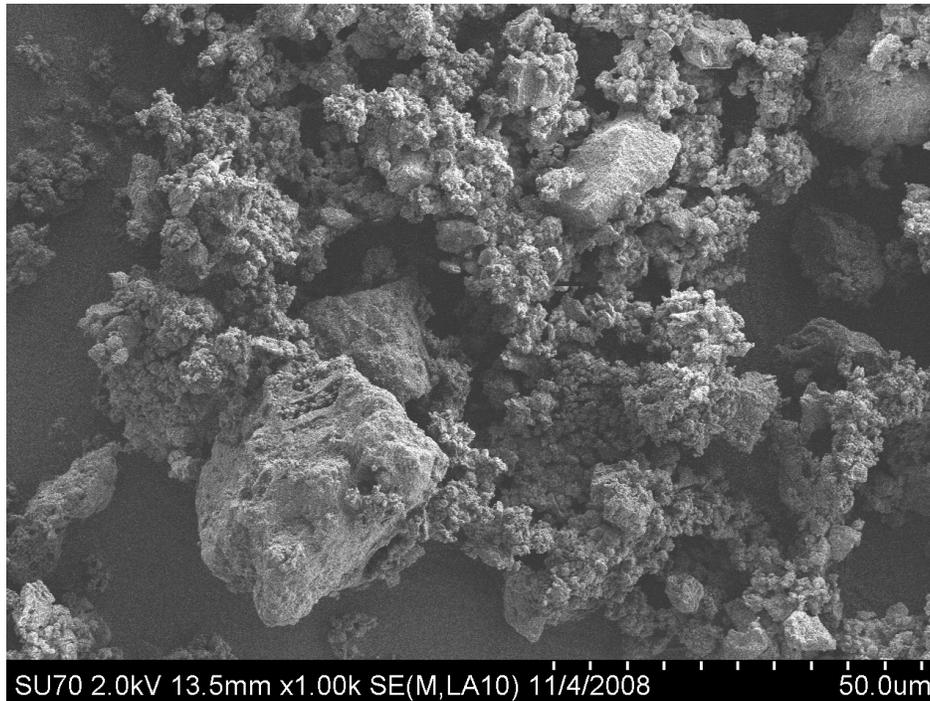


Figure 7. SEM Images of the PAC and Ash

Task 2. Set up a large batch reactor and run trials

A rotary furnace fertilizer production system has been set up and put into operation. The system mainly is comprised of the following main components:

- a sample hopper
- rotary tube reactor
- nitrogen gas control system
- mercury chemical absorbent
- carbon monoxide measuring system (GC)
- mercury analyzer

The fly ash powder is fed into the rotary reactor tube from the hopper. The maximum feeding rate of the rotary feeder is 3 kg/hour. The rotation and the slope of the reactor tube cause the

powder to gradually move downhill to the other end of the reactor tube. The residence time of the powder is controlled by the rotational speed and the degree of slope of the tube (Figure 8).



Figure 8. Large Batch Reactor

Task 3. Identify and obtain effective mercury capture chemical absorbent and integrate it into the reactor system

A new mercury chemical absorbent was developed at UEE to chemically capture mercury from the gas phase during fertilizer production. The absorbent was cylindrical pellets with 1 mm in diameter and 3-5 mm in length that consisted of activated carbon and sulfur powder. The pellets were extruded using a high throughput extruder. This chemical absorbent exhibited excellent mercury capture performance. However, the economic analysis on the production cost of this absorbent showed that it was too expensive for any commercial applications.

To commercialize the “fly ash to fertilizer” technology, an inexpensive mercury chemical absorbent should be obtained. After extensive literature search and discussion with sorbent manufacturers, a commercially available inexpensive mercury chemical absorbent was identified. The absorbent was produced by Calgon Carbon Corporation. It was a sulfur containing activated carbon in granular shape. The mercury was completely removed by thermal desorption from the fly ash and was captured by this absorbent. The resulting mercury containing material was thermally and chemically stable and presented no risk to the environment.

Task 4. Produce 50 lbs fertilizer

To perform a farmland field testing, a large quantity of PAC fly ash fertilizer is produced. The farmland testing will be conducted at Watts Farms. Watts Farms will provide one acre of corn ground for the testing. Around 50 lbs of fertilizer have been produced. A bottle of the sample will be sent to We Energies Project Manager.

Task 5. Conduct an economic analysis

Capital and operating costs to produce UEE's fertilizer correlate to size of the plant. Significant economies of scale can be more easily realized with a larger plant. The capital cost components include equipment, land and building, utilities, installation of electrical and water systems, transportation, engineering and permitting, and contingency. A kiln will be the major equipment cost for the facilities. A kiln similar to the commercial rotary cement kiln for clinker formation can be used. The production cost includes the cost of the day-to-day operation of the plant and is divided into three categories: direct production costs, indirect production costs, and general expenses. Direct production costs consist of raw material costs and labor related costs. The costs of raw materials were calculated based on the market price of each feedstock. Indirect production costs include overhead, local taxes, and insurance. General expenses include administrative costs, distribution, and selling costs.

The plant capacity is mainly determined by the fly ash availability on site. Fly ash is a bulky and heavy material, which limits how far it can be economically moved. It costs between \$0.10 and \$0.13 /ton/mile to transport fly ash. This estimate represents a plant built on a green site next to a We Energies power plant (within a mile from the power plant). We assume that all the fly ash contains mercury contaminated activated carbon.

A production plant, modified from industrial rotary kiln cement production process design, will be used for the fertilizer production. The plant mainly consists of a fly ash precalciner (to remove the mercury from fly ash and to heat the fly ash), a mercury capture column, a rotary kiln (to produce fertilizer), a cooler, a coal mill, and Fans.

For a plant with fly ash processing capability of 500,000 tons annually, the estimated fixed-capital is \$19.5 million and the working capital is \$2.93 million.

The reaction energy required to heat the fly ash and provide heat for fertilizer synthesis is provided by combustion of coal. The estimated costs of the coal is \$1.33 million.

We assume that 120,000 tons of fertilizer is produced in the first commercial plant. The following Table lists the production cost and final product price details:

Table 9. Fertilizer Product Cost Calculation

Items		Costs
Direct production costs (million \$)	Coal (the same coal used in power plant)	1.33
	Fly ash (transportation cost: move fly ash from power plant to fertilizer plant feed area within a mile distance)	0.02
	Nitrogen gas (generated on-site)	0.82
	Operating labor (5 FTE)	0.54
	Maintenance (9% fixed capital of \$19.5 million)	1.76
Indirect production costs (million \$)	Overhead (60% of sum of operating labor and maintenance)	1.38
	Local taxes (1.5% of fixed capital of \$19.5 million)	0.29
	Insurance (0.7% of fixed capital of \$19.5 million)	0.14
General expenses (million \$)	Administrative (16% of the overhead)	0.22
	Distribution and selling (9.5% of the total above expenses of \$6.49 million)	0.62
Annual capital charge (million \$)	15% of the total capital of \$22.43 million	3.36
Total annual production costs (million \$)	(120,000 tons of fertilizer)	10.47
Profit (annually in million \$)	(150% of the total production costs)	15.71
Production costs per ton fertilizer (\$)		87
Final product price to dealers (\$ per ton)		218

Even with 150% profit, the fly ash fertilizer price to dealers is only \$218 per ton. In contrast to the price of \$382 per ton paid by farmers for ammonia nitrate fertilizer in April of 2007, the price of this new fertilizer is significantly lower. In the calculation, the utilization of the power plant waste heat as well as the savings from avoiding fly ash disposal which will further reduce the production cost was not taken into account.

Task 6. Complete a preliminary design for a commercial-scale production plant

This Task aimed at a preliminary design for a commercial-scale production plant. However, with UEE’s extra efforts, a detailed plant design has been completed as shown in the following Figure 9. The fly ash powder is fed into the precalciner through the cone shaped hopper along with hot air (1). The hot air arrives in a duct directly from the fertilizer cooler. The fly ash feed speed is controlled by a rotary feeder with assistance from air and aeration stones. The fly ash-bearing hot air stream is passed tangentially into the conical precalciner vessel. This produces a

vortex within the vessel. Both fly ash and gas spiral down toward the vessel bottom. Pulverized coal is blown in by air (3) through the burner, producing a large concentric flame in the vessel. The precalciner has the advantage of controlling the flame core temperature by adjusting the air/coal flow to the burner and the hot air flow (2). An increase in hot air volume leads to a high acceleration of the initial combustion of coal, resulting in a higher temperature in the precalciner. The fly ash is heated by contact with the hot gases from combustion of coal. The gases leave the vessel through a vortex-finder. The hot exhaust gases are sent to a nitrogen gas heat exchanger and then flow to the mercury capture equipment to capture the mercury and remove other air pollutants. The fly ash is thrown to the outside edge of the vessel by centrifugal action and leaves through a valve in the bottom of the cone to the inlet of the rotary kiln.

At the inlet of the rotary kiln, the hot fly ash encounters a high flow nitrogen gas stream (4) containing pulverized coal. The coal reacts with the oxygen gas entering with the hot fly ash from the precalciner. An excess amount of coal will be added so that all the molecular oxygen will be consumed and a sufficient amount of carbon will be left and available for the fertilizer production. Because the coal is present in excess, carbon monoxide, instead of carbon dioxide, will be the major product. The carbon monoxide will leave the kiln with nitrogen from the kiln inlet and be sent to the precalciner. The reaction of coal with oxygen is exothermic and provides additional energy for the carbonitridation reaction. The high flow nitrogen stream (4) spreads the fly ash and mixes the fly ash and coal uniformly. The fly ash then undergoes the fertilizer forming process when it moves slowly through the rotary kiln. To guarantee the availability of sufficient nitrogen gas, the other stream of hot nitrogen flow (5) is injected into the kiln through the other end of the kiln in a counter current flow mode with respect to the fly ash/carbon. The hot fertilizer product is discharged from the kiln to the fertilizer cooler. In the cooler, most of energy from the fertilizer is recovered to the air stream by a heat exchanger. The hot air from the cooler is sent to the precalciner. A data logger connected to platinum thermocouples located at different locations in the plant is used to record the temperature readings. In addition, all necessary safety measures for the plant will be taken carefully to ensure a safe working environment.

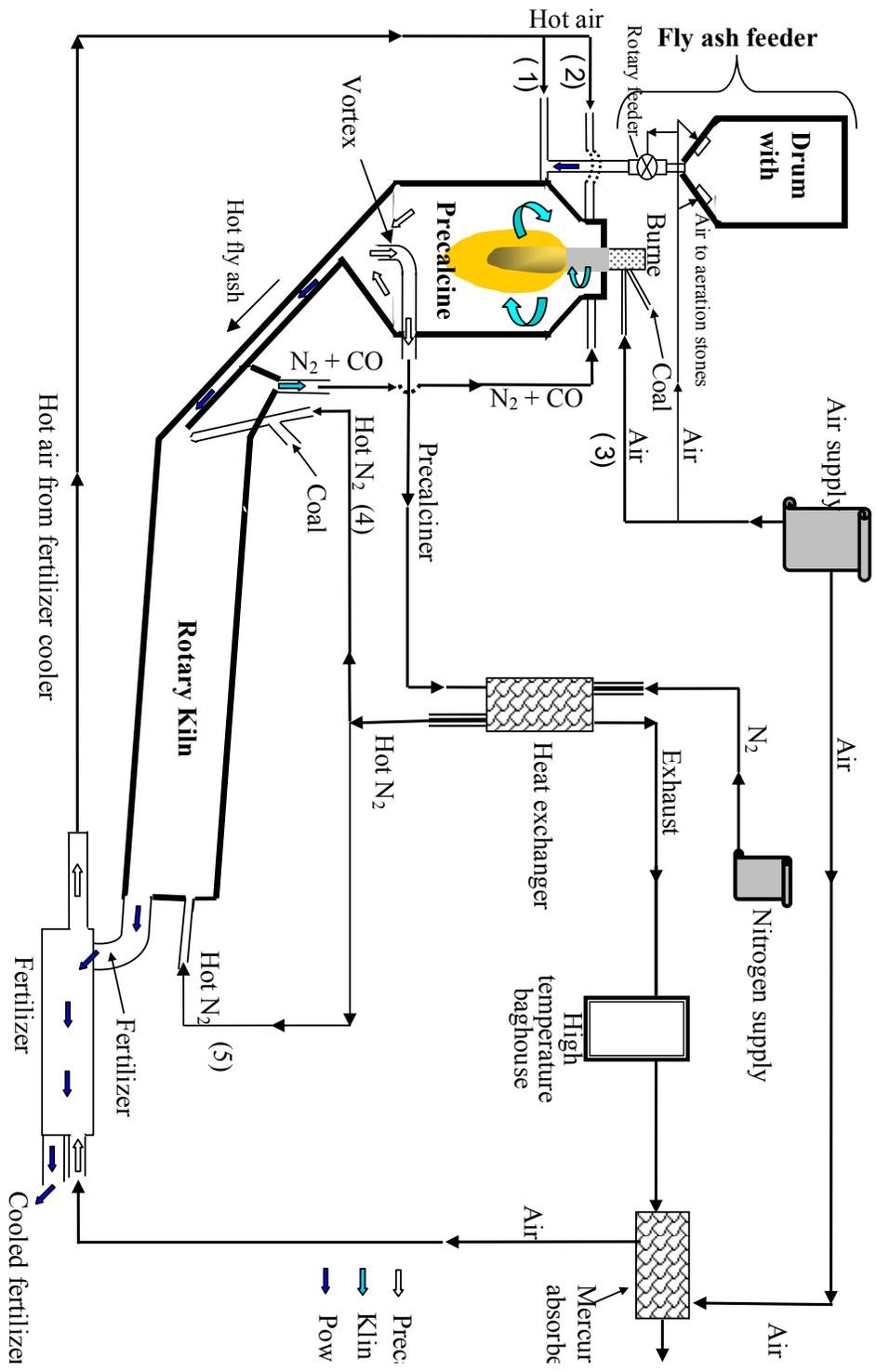


Figure 9. Fertilizer Production Diagram

Conclusions

This fly ash utilization and mercury capture technology has been successfully demonstrated in the study. The technology is technically and economically viable, which can meet the TOXECON™ project's two goals if it can be successfully scaled up for commercial application.

The PAC-Ash has been fully characterized. The activated carbon content in the ash is in the optimal range for fertilizer production. No additional carbon is needed.

A commercially available effective chemical absorbent has been identified and integrated into the fertilizer production system.

A rotary furnace fertilizer production and mercury capture system has been set up and put into operation.

The economic analysis verifies the economic viability of this technology.

A complete commercial scale fertilizer production plant has been designed.

UP Steel Update

Abstract

The consumed PAC sorbents from WE Presque Isle PJFF rejects were investigated for mercury removal from the sorbents utilizing the microwave technology developed by UP Steel. In this laboratory study, the consumed sorbents were irradiated with microwave for three minutes under a nitrogen gas flow. Mercury is evaporated from the consumed sorbents by microwave heating. The evaporated mercury is carried by the nitrogen gas to a condenser to condense the mercury by cooling down. The mercury that is not condensed is scrubbed by a potassium permanganate solution. The results of this study demonstrate the effectiveness of this approach. The mercury content in the consumed sorbents is reduced from 14,800 ppb to 252 ppb after the microwave treatment. Analysis of the condensed crystal products by SEM (Scanning Electron Microscope) shows the presence of mercury and that mercury is probably present in the form of mercury sulfate. Mercury is also present in the scrubbed solution and can be precipitated out from the solution with sodium sulfide. The precipitates have also been analyzed with SEM and the existence of mercury sulfide is confirmed.

Background

PAC has been utilized as the basic material for mercury adsorption from the emission gas. After adsorption, the disposal of the mercury loaded sorbents is an issue. In addition, it is desired to recover and reuse the PAC for mercury removal in the current system due to the high cost of PAC.

In the TOXECON system, PAC is injected in a PJFF for mercury removal. The PAC is collected together with fly ash particles that were not collected in the ESP. This results in a material coming out of PJFF with about 50% PAC and 50% fly ash.

The removal of mercury from loaded sorbents can be achieved by heating the sorbents to temperatures above the boiling temperature of mercury, as taught by Hwang and Li (1997) in US Patent 6,027,551. This heating approach for mercury unloading has also been adopted by Ramme et al (2007) of WE Energies as described in U.S. Patent 7,217,401.

The conventional heating of the carbonaceous material is a slow process. It takes a long period of time to heat the carbon material and unload the mercury from it. This will take a lot of energy and can cause serious oxidation or combustion of PAC in air and the loss of PAC recovery.

UP Steel has conducted a series of study led by Hwang to overcome these issues. A new, fast acting, process for mercury unloading from PAC has also been discovered. This process employs microwave to remove mercury from PAC. It was found in a UP Steel study that mercury removal for PAC can be accomplished within minutes under microwave irradiation.

The purpose of this study is to verify that two products, a mercury removed sorbent product and a mercury concentrate product can be obtained from the process.

Experimental Methods

Experimental Setup

Figure 10 shows a schematic of the setup for the experiment. Weigh $22\text{g}\pm 0.2\text{g}$ dried carbon sample (PAC) into a glass test tube, and place some glass fibers on top of the sample to prevent the carbon powder flying into the connecting tube. Then put the tube in the middle part of a microwave oven. Pure nitrogen is utilized to carry the vapor generated in the tube forward. The flow rate of nitrogen is measured with a Cole Parmer flow meter at $600\text{ml}/\text{min}$, which gives a continuous bubble stream in the KMnO_4 scrubbing solution. The carbon sample was irradiated with a 1 KW microwave oven at power 4 of maximum setting 10 for 2.5 min. The evaporates are carried by the nitrogen gas to a water cooled condenser and then the KMnO_4 scrubbing solution. Figure 11 is a picture of the microwave apparatus.

Mercury concentration in the gas flow after the microwave irradiation and the scrubbing can be determined with a gold film mercury vapor analyzer (JEROME 431-X, Arizona Instrument Corp.). The measuring range of the analyzer is 0.000 to $0.999\text{mg}/\text{m}^3$, with a resolution of $0.001\text{mg}/\text{m}^3$ and a sensitivity of $0.003\text{mg}/\text{m}^3$.

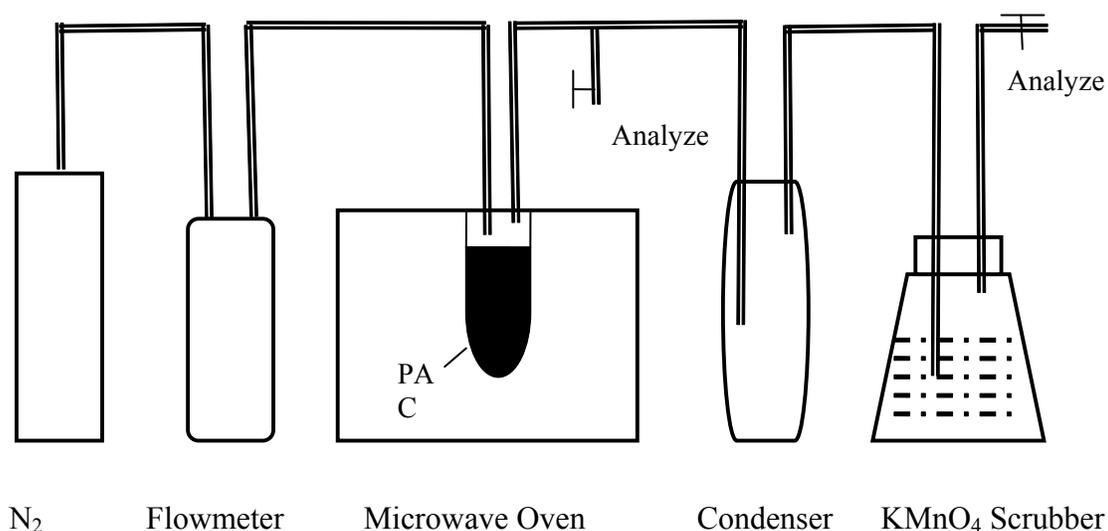


Figure 10. Schematic diagram for the mercury separation experiment.



Figure 11. Apparatus of Microwave Experiment.

Materials

Consumed TOXECON™ sorbent samples were obtained from WE Presque Isle power plant. For each test, the sample is first dried in an oven to remove most of the water adsorbed in the activated carbon. Heat the carbon at 105°C for 4 hours. The sample is utilized for mercury desorption experiments within 2 hours in order to avoid adsorbing water vapor from the air.

The scrubbing solution contains 1.5% potassium permanganate in 10% sulfuric acid (Shendrikar et al., 1984). The gas was introduced into a flask of 200ml solutions before being exited into the air.

Results and Discussion

Mercury Contents and Weight Loss

The mercury content of the feed sample is 14,800 ppb. After the microwave treatment, the mercury content is 252 ppb. The mercury concentration of the gas coming out from the glass test tube at 1, 2, and 3 minutes is 0.015, 0.012, and 0.002 mg/m³, respectively. The mercury concentration for the gas exiting from the scrubber is not detectable.

The weight loss from each run is shown in Table 10. The average weight loss is about 12%. There is still quite a bit of water condensed in the condenser. It is also observed that carbon powders are accumulated in the connecting tubes and condensers.

The experiment has been repeated for over 300 times to see if metallic mercury liquid droplets or film can be observed. This was found not possible because the carbon powder has covered all the surfaces.

Table 10. Weight Change of Carbon before and after Heating.

Sample	Weight of Carbon before heating(g)	Weight Loss (g)	Weight Loss %
1	22.023	2.611	11.86
2	22.077	2.490	11.28
3	22.093	2.774	12.42
Average	22.064	2.625	11.90

Condensed White Crystals

When the microwave experiments were started over with new Tygon tubing, some white crystals can be found in the connecting Tygon tube outside the microwave furnace after repeating the experiments for 8~10 times. The crystals are disseminated on the inside wall of the Tygon tube, as shown on Figure 12(a). These crystals can turn into liquid droplets after cool down under the atmospheric conditions (Figure 12(b)). By heating, the droplets turn back to crystals.

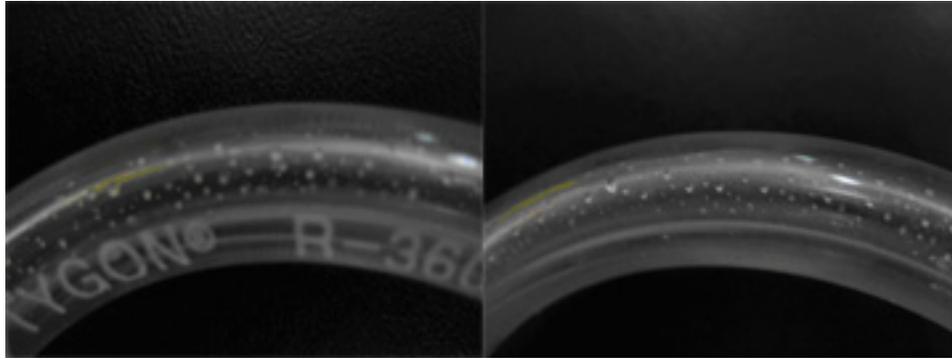


Figure 12. The crystals condensed on the connecting tube and (b) liquid droplets.

The white crystals condensed on the inside wall of the Tygon tube were analyzed with SEM. Figure 13 shows the SEM images of the crystals. They are mostly in plate shape. The chemical compositions of the crystals were analyzed qualitatively with the electron probe. The EDS spectrum, as shown in Figure 14, reveals that the crystal has the characteristic peaks of mercury, sulfur and oxygen. Since the crystals can absorb moisture and turn into liquid droplets, it is reasonable to believe that the crystals are primarily mercury sulfate crystals with various amount of crystalline water. The standardless analysis of the spectrum gives an estimation of 7.89% mercury in the crystal (Figure 15).

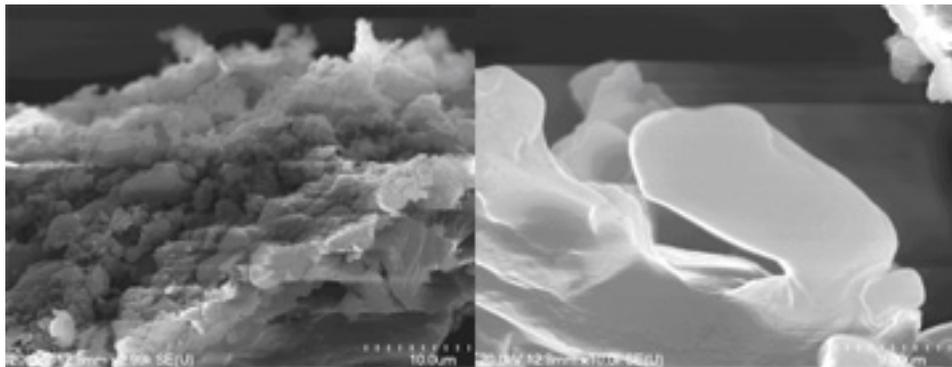


Figure 13. SEM image of the condensed white crystals.

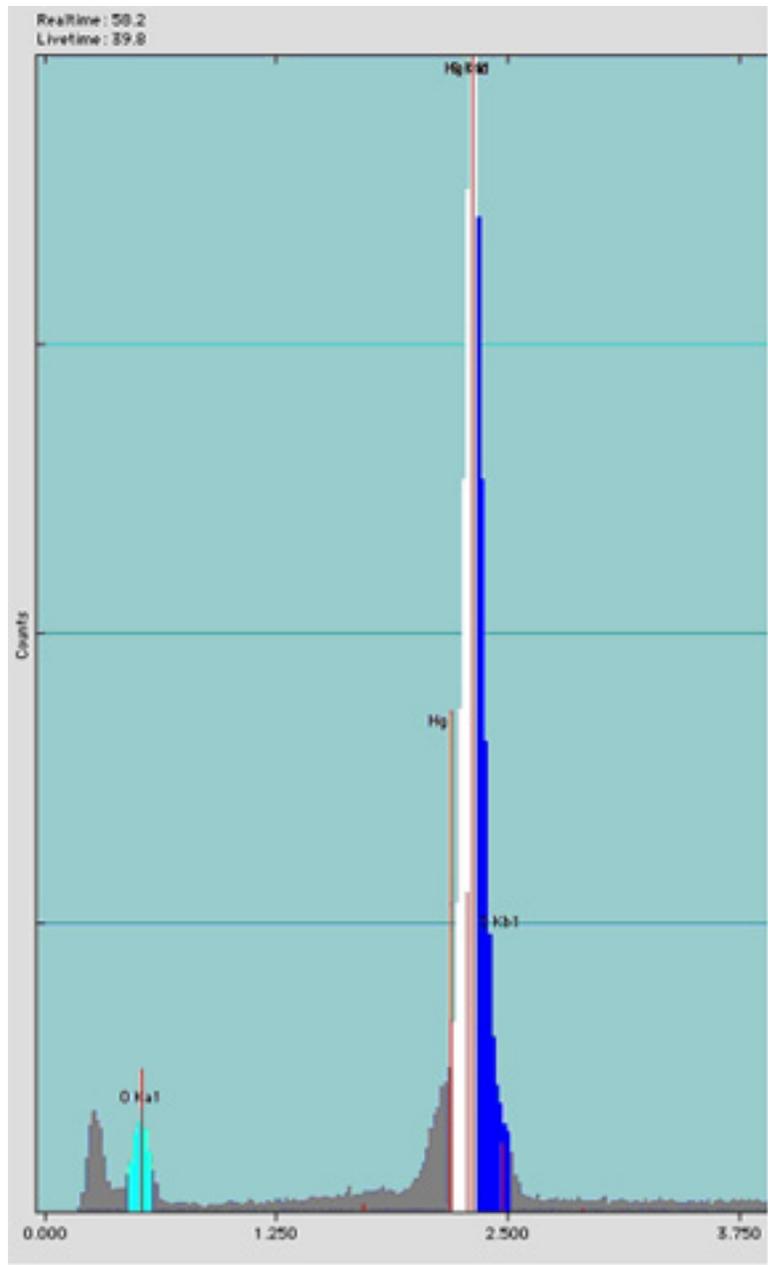


Figure 14. EDS spectrum of the condensed white crystals.

Quantitative Results for Spectrum1
 Analysis: Bulk Method: Standardless
 Acquired 09-Sep-2008, 20.0 KeV @20 eV/channel

Element	Weight %	Std. Dev.	MDL	Atomic %	k-Ratio	Intensities	ROI (gross)
O	21.78	1.34	1.39	37.88	0.1023	1857.6	2230.21
S	70.33	1.81	0.46	61.03	0.6413	29723.5	31232.49
Hg	7.89	1.07	1.29	1.09	0.0784	1955.2	
Total	100.00						

Figure 15. EDS standardless analysis of the condensed crystals.

Scrubbing without Condenser

In a separate set of experiments, the gas was bubbled into the scrubbing solution without going through the condenser. The experiments were repeated 8 times. After that, we add 10 grams of $\text{Na}_2\text{S}\cdot 9\text{H}_2\text{O}$ to a beaker contains 100 ml of the original solution (Figure 16b) and 10 grams of $\text{Na}_2\text{S}\cdot 9\text{H}_2\text{O}$ to a beaker contains 100 ml of the evaporated gas scrubbed solution (Figure 16a). Dark precipitates were formed from the scrubbed solution. The precipitates were filtered and dried.

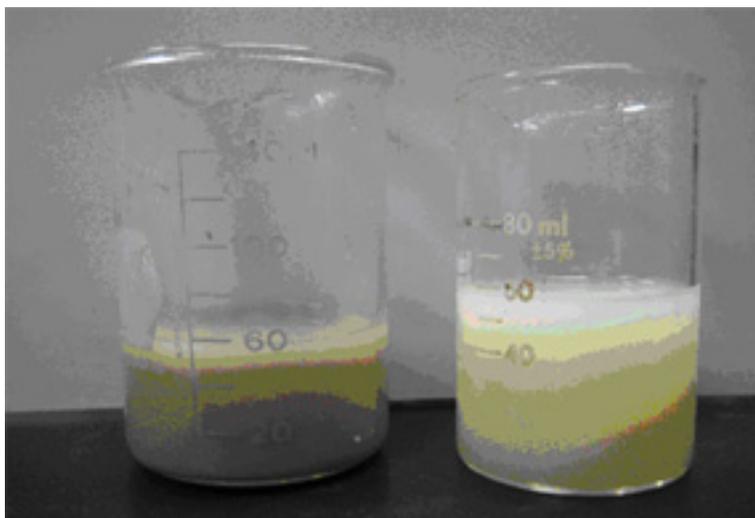
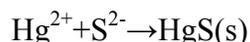
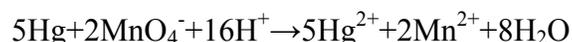


Figure 16. (a) The dark precipitates in the scrubbed solution with sodium sulfide addition on the left, and (b) the original solution with the addition of sodium sulfide on the right.

The precipitates are believed to be mercury sulfide (HgS). The reactions in the process are designed by the follows:



When the mercury in the gas passed through the scrubbing solution, it is oxidized into the soluble divalent mercury and is therefore dissolved in the solution. When sodium sulfide is added into the solution, the divalent mercury ions and the sulfide ions formed insoluble mercury sulfide and precipitates out.

To prove this is what happened, the precipitates were examined under the SEM as well. Figure 17 shows the SEM images of the sulfide precipitates. Figure 18 shows the EDS spectrum of the precipitates. Only the mercury and sulfur characteristic peaks are dominant. The oxygen peak is very weak. No other elements were found in the spectrum. The precipitates are, therefore, proved to be mercury sulfide. This demonstrates that mercury released from the sorbents in the microwave processing has been successfully scrubbed. A standardless analysis of the EDS spectrum gives an estimation of 23.07% Hg in the precipitates, as shown in Figure 19.

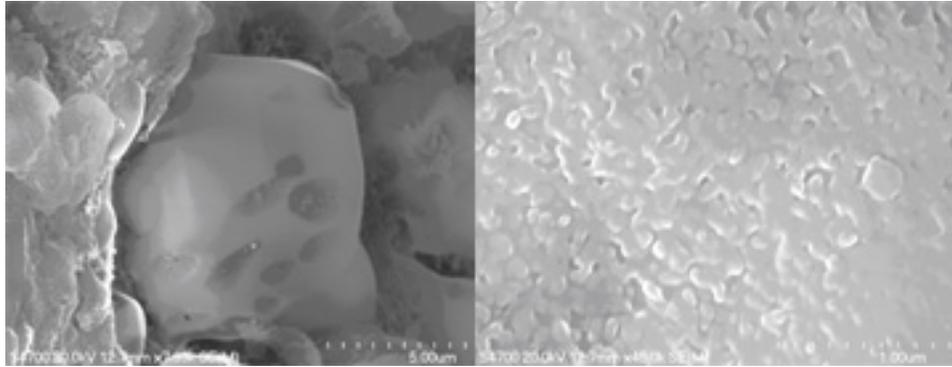


Figure 17. SEM images of the sulfide precipitates in the scrubbed solution.

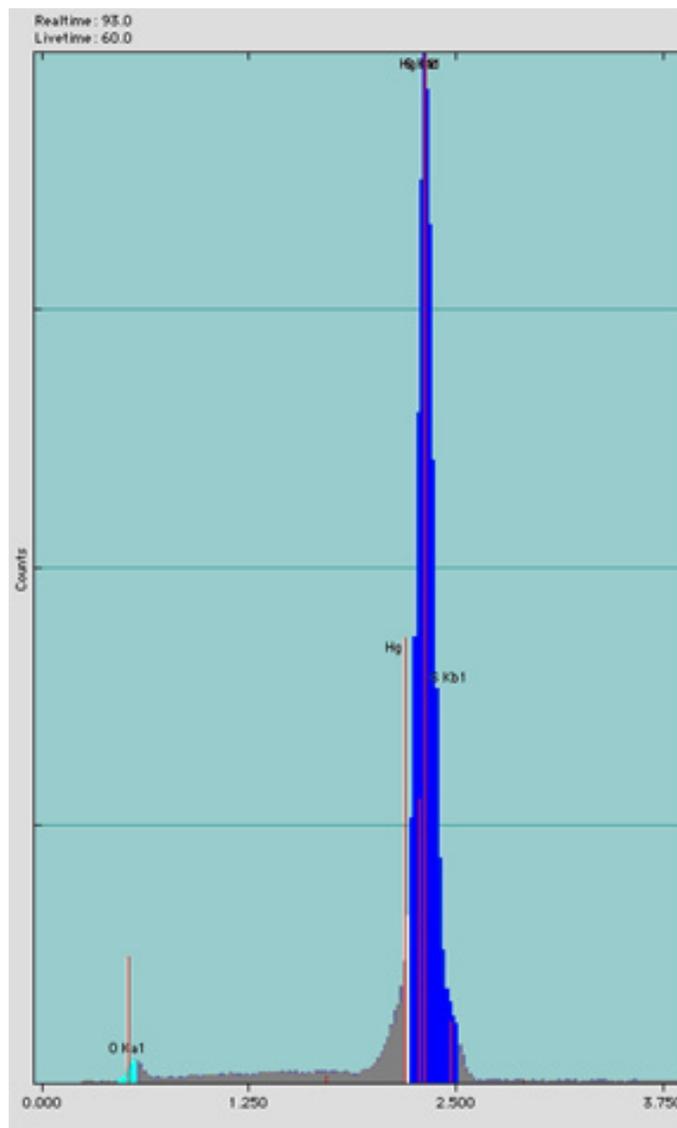


Figure 18. Spectrum of the sulfide precipitates in the scrubbed solution.

Quantitative Results for Spectrum1							
Analysis: Bulk Method: Standardless							
Acquired 13-Oct-2008, 20.0 KeV @20 eV/channel							
Element	Weight %	Std. Dev.	MDL	Atomic %	k-Ratio	Intensities	ROI (gross)
O	4.60	1.13	1.12	10.83	0.0236	925.1	1282.87
S	72.33	1.74	0.16	84.85	0.6266	62313.4	77697.20
Hg	23.07	1.06	1.84	4.33	0.2301	12262.8	
Total	100.00						

Figure 19. EDS standardless analysis of the sulfide precipitates in the scrubbed solution.

Conclusion

In this study, mercury has been successfully evaporated from the sorbents and can be condensed or scrubbed. Two products from the consumed sorbents can be obtained: a mercury depleted sorbent material that can be recycled for mercury adsorption and a mercury concentrate, either by condensation as a mercury sulfate crystals or by scrubbing and precipitation as a mercury sulfide precipitates.

ADA-ES Update

During the last two quarters of 2008 the concrete development effort focused on the largest application for fly ash, and that is structural concrete. Both low- and high-carbon ash mixtures were tested during these periods.

In order to create structural concrete suitable for exterior applications, the concrete must be able to withstand multiple freeze-thaw cycles. This freeze-thaw durability is obtained by the introduction of numerous small air bubbles in the concrete. The carbon content of fly ash has a negative effect on most air entrainment chemicals, resulting in increased cost for additional chemical and unreliable batching operations. During 4Q08, a foam air entrainment system developed by Miracon Technologies was further refined and tested on PAC-containing ash.

During 4Q08 ADA-ES prepared concrete formulations varying the amount of fly ash, LOI, commercial admixtures, and using different air entrainment chemicals. Cylinders from successful batches were tested at an independent laboratory for compressive strength. CTL Thompson, Inc. is a Denver-based laboratory that has worked with ADA-ES in the past and is known for their expertise in analyzing concrete.

Figure 20 shows a comparison of compressive strength results using the Miracon foam using ash and PAC at varying LOI levels. The 3% and 5% LOI ash tests show an increased strength when compared to the control. All three tests had similar admixtures and the same amount of Miracon foam added. The air content was stable for 90 minutes, which is sufficient for most applications.

The first field test of the new foam formulation will be performed in the first week of January at Sky Ute Sand & Gravel in Farmington, New Mexico. There are plans to use the TOXECON™ ash to make a large concrete pad at the Presque Isle Power Plant in 1Q09.

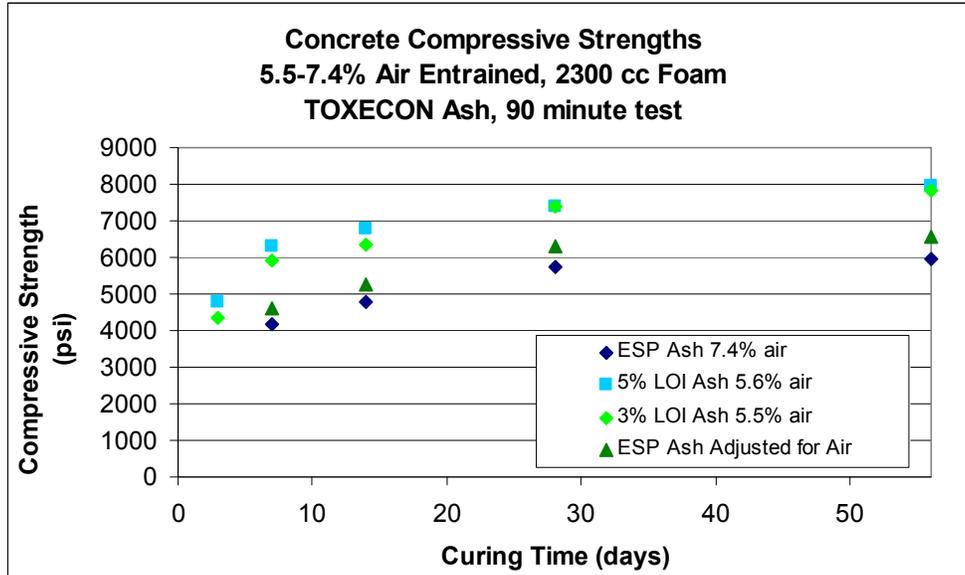


Figure 20. Concrete Compressive Strength Results

Task 18 – Revise Design Specifications, Prepare O&M Manuals

Work began this quarter on updating the Preliminary Design Document, focusing on changes to the ash unloading system and ductwork that have been completed since the initial installation.

Task 19 – Reporting, Management, Subcontracts, Technology Transfer

Reports as required in the Financial Assistance Reporting Requirements Checklist and the Statement of Project Objectives are prepared and submitted under this task. Subcontract management, communications, outreach, and technology transfer functions are also performed under this task.

Activity during this Reporting Quarter:

- Quarterly Technical Progress Report delivered
- Quarterly Financial Status Report delivered
- Quarterly Federal Assistance Program/Project Status Report delivered
- Presented at the EPRI Fabric Filter Conference in November 2008
- Discussed the project with GAO in November
- Attended an American Coal Ash Association meeting in October 2008
- Technical papers and presentations for future meetings include:
 - EUEC (February 2009)

CONCLUSION

This is the nineteenth Quarterly Technical Progress Report under Cooperative Agreement Number DE-FC26-04NT41766. All major construction efforts were completed during 4Q05, and only punch list items remained during the current quarter. Operational issues that were addressed included adding a partial enclosure around the base of the ash silo, duct insulation and lagging corrosion repair, and duct expansion joint insulation. A baghouse outage was scheduled for December and a duct inspection performed to determine the extent of corrosion.

A series of emissions tests was performed in November for mercury, particulate, halogens, and trace metals. Both inlet and outlet CEMs passed the mercury RATA. The baghouse, PAC injection system, and associated functions performed as planned this quarter. A set of new PPS bags were ordered and received. Drag testing was performed in December during the baghouse outage.

Work continued on the ash management task this quarter. Michigan Tech University submitted their final report on using microwave energy to remove and capture mercury from the spent PAC/ash sorbent. United Environment & Energy completed testing and submitted their final report on the use of a continuous rotary reactor system. They demonstrated production of fertilizer using the mercury-free, high carbon ash.

ADA-ES continued developing formulations for using PAC-containing fly ash in the preparation of structural and conductive concrete. Test results from several batches showed good air stability with the improved foam formulation and an increase in strength with higher LOI ash replacement.

Several CEM operational maintenance efforts were performed this quarter. The project team is actively involved in a number of reporting and technology transfer activities.