BALANCE OF PLANT CONSIDERATIONS FOR TOXECON ™ MERCURY AND MULTI-POLLUTANT CONTROL PROJECTS

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ABSTRACT:

Wisconsin Energies has recently completed the construction phase of a TOXECON™ installation for three 90 MW coal fired boilers at their Presque Isle Power Plant located in Marquette Michigan. The Project is sponsored in part by the U.S. Department of Energy under the Clean Coal Power Initiative. Additional team members are ADA-ES, Cummins & Barnard, and Electric Power Research Institute.

TOXECON™ is an EPRI patented process in which sorbents, for capturing pollutants are injected into the combustion gases downstream of an existing particulate control device and collected by a new particulate control device, typically a pulse jet fabric filter (baghouse).

The key objectives of the project are to demonstrate the TOXECON™ technology at full scale, operated over a long period of time under real conditions by 1) achieving very high levels of mercury removal, 2) increasing the collection efficiency of particulate matter, and 3) to determine viability of sorbent injection for SO_2 and NOx control, while maximizing the use of coal combustion by-products

Underlying the advanced technology and research that this project is undertaking is a fundamental engineering and construction project at an existing operating power plant. This paper will outline the balance of plant (BOP) considerations that need to be addressed in TOXECON™ retrofit project planning, and the potential impacts on BOP systems.

INTRODUCTION:

A Brief History of the Presque Isle Power Plant:

The Presque Isle Power Plant (PIPP) was developed by the Upper Peninsula Power Company in the early 1950's to initially meet the needs of the Cleveland-Cliffs Iron Company and other regional customers. The PIPP site is located in the northeastern portion of the city of Marquette, Michigan, along the shore of Lake Superior (see Figure 1). The power plant occupies a 65-acre site and is situated on a natural isthmus that joins Presque Isle, a 323-acre forested city park, to the mainland.

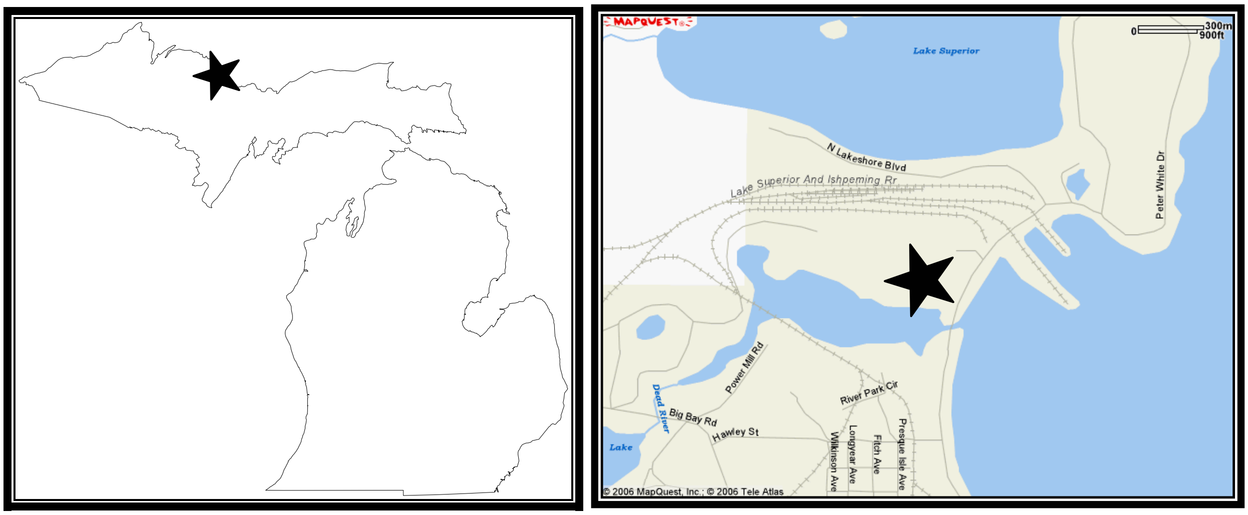


Figure 1 - Map Location of Presque Isle Power Plant

The plant site is bounded on the North and West by land belonging to the Lake Superior & Ishpeming Railroad; on the South by the mouth of the Dead River, which flows into Presque Isle Harbor on Lake Superior; and on the East by Lake Shore Drive that runs along the shore of Lake Superior. See Figure 2 – Presque Isle Power Plant

Figure 2 - Presque Isle Power Plant

Over the years, the plant has expanded to serve the growing needs of the Cleveland-Cliffs Iron Company and other customers. The plant has 9 coal fired Units placed into service in 1955, 1962, 1964, 1966, 1974, 1975, 1978, 1978, and 1979, respectively. We Energies acquired the Presque Isle Power Plant in 1988

Combined, the Units generate approximately 625 MW of electricity. The largest customer of the plant continues to be the iron company, which requires about 260 MW of electricity 24 hours per day to operate its iron ore mines located about 12 miles west of Marquette in the Ishpeming-Negaunee area. The power plant is a vital asset to the Upper Peninsula of Michigan since the plant represents approximately 50% of the power generation in the U.P.

The DOE Clean Coal Power Initiative:

The Department of Energy's (DOE) Clean Coal Power Initiative (CCPI) is an industry/government cost-shared partnership to implement clean coal technology under the National Energy Policy. The National Energy Policy investment in clean coal technology focuses on increasing the domestic energy supply, protecting the environment, ensuring a comprehensive energy delivery system, and enhancing national energy security. The CCPI was initiated in 2002 with a goal of accelerating commercial deployment of advanced technologies to ensure the United States has clean, reliable, and affordable electricity.

In 2002 We Energies decided to apply for a CCPI project nominating PIPP Units 7, 8 and 9 as the host Units for a combined TOXECON™ installation. The Units burn a western sub-bituminous Powder River Basin (PRB) coal and have "hot side" (i.e., upstream of the air pre-heater) electrostatic precipitators that made this project favored in the DOE selection process.

In January of 2003, The PIPP TOXECON™ project was selected as one of the first eight CCPI Round I projects. The DOE's National Energy Technology Laboratory is managing the project. This five-year, $50 million project, of which the DOE is contributing 24.9 million, is the nation's first full-scale test of the TOXECON™ process to control emissions of mercury and other air emissions. If successful, the technology could become one of the most effective mercury control technologies for power plants that burn western, sub-bituminous coal. The following summarizes the objectives of this project:

- Reduce mercury emissions by at least 90 percent
- Develop a reliable Continuous Emissions Monitoring System for mercury
- Increase collection efficiency of particulate matter, especially during "upset" conditions
- Determine whether sorbent injection can reduce SO_2 emissions by 70 percent while also optimizing the control of NO_x emissions
- Recover at least 90 percent of mercury captured in collected sorbent
- Beneficially use 100 percent of the fly ash collected by the electrostatic precipitators

Results from the project construction and test phase will be made public through the DOE.

Benefits to We Energies for installing a TOXECON™ System:

As research test data results were published on mercury removal, We Energies began to realize that wet scrubber technology might not be sufficient to achieve the levels of mercury reduction that would be necessary with burning western, sub-bituminous coal. The use of activated carbon injection would be a strategic technology for mercury reduction and We Energies began to appreciate the following benefits for a TOXECON™ installation at the PIPP:

- Purchase and use of fuels that minimize power production costs—ensuring affordable energy prices for their customers.
- Control mercury without contaminating ash—enabling them to continue their pursuit of beneficially using 100 percent of the ash from Presque Isle Power Plant.
- Enhance the particulate control of Units 7-9 reducing the visible emissions from the plant
- Reduce the mercury emissions in the Lake Superior watershed.

TOXECON™ System:

TOXECON™ is an Electric Power Research Institute (EPRI) patented process in which sorbents including powder activated carbon for mercury control and others for NOx and SOX control are injected into the combustion gases downstream of an existing particulate control device and collected by a new particulate control device, typically a pulse jet fabric filter (baghouse). See Figure 3.

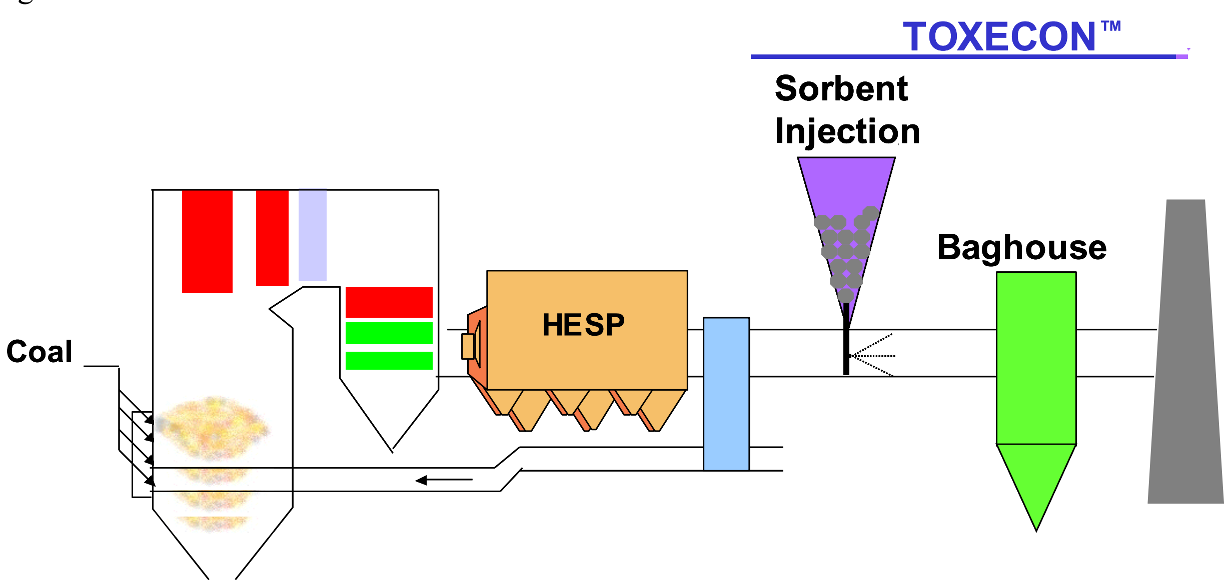


Figure 3 - Basic Schematic of the TOXECON Process

EPRI's TOXECON™ process is currently the only technology that has shown in commercial-scale demonstrations to reduce mercury emissions by up to 90 percent using activated carbon.

This technology also has been shown to be equally effective at reducing mercury emissions from a variety of fuels, including both bituminous and sub-bituminous coals.

Activated carbon is "a highly adsorbent powdered or granular carbon made usually by carbonization and chemical activation and used chiefly for purifying by adsorption" Activated carbon is manufactured from a variety of sources; primarily coal, wood, lignite, and coconut shells. The process includes first carbonizing the raw material at low temperatures, and then activating the carbon in a high temperature steam process. Any volatile content inside the carbon is driven off, leaving a beehive-like structured carbon with a high volume of pores and a large surface area. PAC (powdered activated carbon) is prepared by a pulverizing action, leaving a very fine powder. For this project most of the PAC will be supplied by NORIT Americas from Texas lignite feedstock. The PAC has a mass mean diameter of nominally 17 microns and a bulk density of about 30 lbs/ft^3. 1 cubic centimeter of powdered activated carbon has the surface area of a football field.

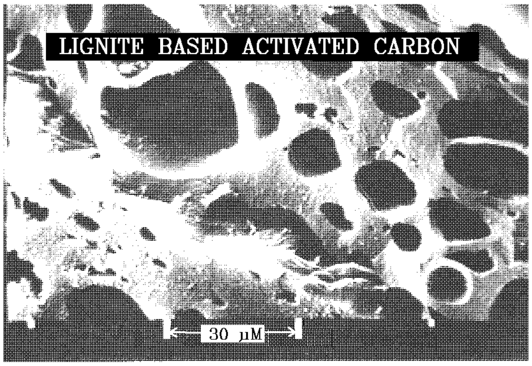


Figure 4 - Lignite Based Activated Carbon

<u>*Application of the TOXECON™ Process at Presque Isle Power Plant:*</u>

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.

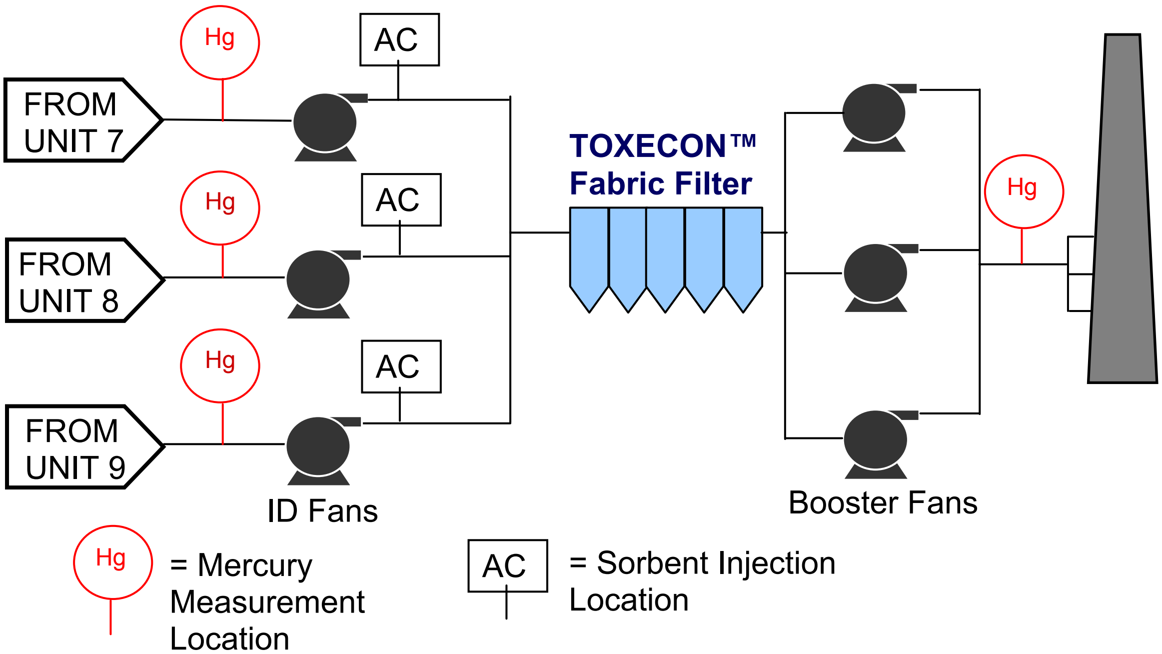


Figure 5 - Basic Schematic of PIPP TOXECON™ Process

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.

Other challenges for the installation was the limited electrical system capability to add additional loads, a constrained site for placement of equipment, and the construction impacts associated with weather conditions for a plant located in Northern Michigan on Lake Superior. The new equipment that needed to be installed consisted of:

- Supply and return ductwork from each of the three Units
- Diverter Dampers to isolate each unit from the combined flue gas ductwork
- Baghouse
- ID Booster Fans with guillotine isolation dampers
- PAC storage and injection systems
- Ash/spent carbon conveying and storage silo for the baghouse hoppers along with an unloading system
- Compressed air system for the pulse jet baghouse cleaning
- Control system cabinets and system programming
- Mercury CEMS
- Electrical switchgear and motor control centers
- Fan Enclosure Building

The available land at the PIPP site was very limited to place new equipment. The land behind the Unit 7-9 chimney was dedicated to coal storage and was not available (see picture at right). This removed the most logical spot to place the new baghouse and supporting structures. The final location chosen was adjacent to the last Unit built on the site (No. 9) in the employee parking lot. This location was further constrained by Unit 9 to the south and the Engineering Building and emergency coal silo dump to the West. The main access road to the East side of the Units also constrained the building site to the

Figure 6 - East Side of Units 7, 8, and 9

North and East. Because of these constraints the only way to fit the equipment in the land available was to elevate the baghouse to be able to run the common return duct underneath the baghouse, and to rotate the baghouse at an angle of 53 degrees. The installation also required a variance with the city of Marquette due to the height of the structure and the close proximity of the property line to the North.

Figure 7 - Baghouse and Fan enclosure (Looking South at Unit 9)The ash silo is beside the baghouse with the carbon storage silo closer to the boiler building. This picture was taken from adjacent property.

FABRIC FILTER BAGHOUSE:

Pressure Drop:

Several important parameters went into the selection of the baghouse for the TOXECON™ project. The first major difference was the function of the baghouse to maintain a layer of carbon on the bags to remove the mercury from the flue gas stream. In order to obtain the highest utilization of the PAC, it is desirable to keep the PAC on the bag as long as possible before cleaning. This necessitated that the baghouse was optimized to run at higher differential pressures than a standard baghouse that was designed to remove particulate. The TOXECON™

Baghouse was specified to be capable of operating with differential pressure up to 12 inches of water gage.

Type of Baghouse

A pulse jet style baghouse was selected. This style reflects a more typical industry standard and also would require less footprint area for the congested Presque Isle site compared to other style baghouses. The baghouse is also appropriate for the Presque Isle Toxexon 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 then the conditions at Presque Isle. Based on a competitive bid process, Wheelabrator Air Pollution Control (WAPC) was selected to supply the TOXECON™ Baghouse.

Figure 8 - TOXECON Baghouse under construction (ash silo is in the foreground)

Air-to-Cloth Ratios:

A gross air-to-cloth ratio of 5.5 ft/min was selected. The air-to-cloth ratio used was based on the project team's analysis of other installations where carbon injection had been applied and the level of mercury removal those installations had been able to achieve. Based on the historical experience, the projects stated goals and compartment configurations, the 5.5 ratio was selected. The net (one compartment out of service) and net-net (two compartments out of service) air-to-cloth ratios are 6.1 and 6.8 ft/min, respectively.
Determining the volumetric flow that the baghouse will be designed to is a key variable. The importance of this variable will affect all other equipment functions and will determine the overall success of the project. For the PIPP TOXECON™ Project the total volumetric flow of 1,200,000 acfm of flue gas was calculated using heat balance software and compared to test data that was taken for air heater performance tests and stack emissions tests. The final selection of flow was chosen at 350°F, which was determined to be an achievable flue gas temperature considering the historical operational flue gas temperatures. The reader is cautioned that in determining the volumetric design flow, avoid using only published data from the original plant design. Secure data from the plants actual operating data to account for design modifications, fuel changes, and actual in-leakages of the system.

Bag Material and Length:

The fabric filter bag material was selected to be a polyphenylene sulfide (PPS) based on the flue gas temperature, flue gas analysis and PAC properties. The bag material selected was a felted 2.7 denier fabric, nominal 18 ounces/square yard. The finish was heat set, calendared, and singed on one side. The bag dimensions are typical for most baghouse supplier's standard size of 26-foot long. The bags also had a nominal 5 inch diameter.

Cleaning Method:

Baghouses typically clean the filter bags in one of two methods, off-line and on-line cleaning. Off-line cleaning is accomplished by isolating an individual compartment in the baghouse from the flue gas flow prior to cleaning the bags. The bags are then cleaned in the stagnant compartment and the dust allowed to settle into the ash hopper before opening the compartment to the flue gas flow. Off-line cleaning is an efficient method for cleaning the bag thoroughly; however, a disadvantage to this method is the increased velocities in the other compartments in service when isolating a compartment for cleaning. The increased velocities create additional pressure drop. On-line cleaning is accomplished without isolating the compartment from the flue gas flow. As the bags are cleaned, the normal flue gas flow through the compartment would occur as the bags are cleaned. Although the on-line cleaning method would cause some re-entrainment of the dust on the bags, an advantage of the on-line cleaning method is that it can be accomplished in a shorter duration since compartment isolation is not required. Both cleaning methods clean the filter bags using pressurized air to blow down the filter bags. The burst of compressed air that travels down the filter bag snaps the bag outward causing the agglomerated ash and carbon on the bag to fall off the bag into the collection hopper at the bottom of the compartment.

On-line and off-line cleaning capabilities were considered and on-line cleaning was chosen, with the objectives of maintaining a consistent pressure drop across the baghouse and dust cake on the bags. With off-line cleaning, all of the bags in a compartment are cleaned at once, dislodging the fly ash/PAC dust cake and potentially creating an area with lower pressure drop and higher flow that does not have adequate sorbent to maintain a high mercury removal. Testing will be conducted to confirm or disprove this approach.

If a compartment was cleaned completely the flue gas flow would increase through that compartment, without the PAC on the bags the concern was that mercury emissions may spike temporarily until the carbon layer was reestablished on the bags. Initially, the baghouse will be configured to clean a couple of rows of filter bags in a compartment before advancing to another compartment. By not cleaning all of the filter bags in a compartment, this will evenly distribute the flow through the baghouse and prevent short circuit issues.

Compartments:

The available area to set the baghouse and the desire to isolate compartments to simulate higher air-to-cloth ratio operation influenced the selection of 10 compartments for the baghouse final design. Each compartment has 648 bags. In this configuration, isolating one or two compartments will allow evaluation of TOXECON™ performance at air-to-cloth ratios of 6.1 and 6.8 ft/min. For a TOXECON™ installation that is not being used as a test platform the number of compartments may be reduced to match a more economic design.

Penthouse:

The PIPP TOXECON™ Baghouse was a roof hatch access design. The top of the baghouse compartments was enclosed with a penthouse to protect maintenance work in inclement weather which is typical for roof hatch design. Because of the proximity of the TOXECON™ Baghouse to the parking lot and the main plant, and the height of the penthouse roof (90+ feet) there was a concern for falling ice from the building landing on plant personnel. To mitigate this issue the penthouse roof was designed with a reverse slope a few feet from the edge of the roof to keep ice buildup on the roof from falling of the structure.

Figure 9 - Baghouse penthouse roof

FLUE GAS SYSTEM:

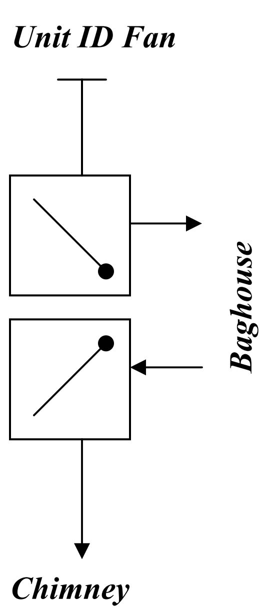
Simulated Stack Design Concept:

The main design concept used by Cummins & Barnard in designing the new flue gas system was to achieve a simulated stack operating condition for the existing ID fans. The new ductwork, baghouse, and Booster fans would be sized to provide a backpressure on the existing ID fans that was as near to the current operating pressures as possible. This would allow the existing ID Fan (and the whole Unit) to operate as if the new equipment was not there. By achieving this design goal the operation of each Unit was not impacted as greatly.

Flue Gas Ductwork:

The Flue Gas systems for Units 7, 8, and 9 have been combined in the TOXECON™ Retrofit Project. Therefore, the Flue Gas system of each Unit consists of a section that services that individual Unit, and a section that is shared with the other two Units. Refer to Figure 5 for a diagrammatic depiction of the system.

Flue gas exiting each Unit's Boiler Furnace is directed by steel ductwork to an electrostatic Precipitator. Ash particles (fly ash) entrained in the flue gas are removed by the Precipitator and collected in the Precipitator's hoppers for collection and disposal. The cleaned flue gas is then directed by ductwork to an Air Heater. The Air Heater is a rotating heat exchanger that cools the flue gas and transfers the heat to the Combustion Air system while maintaining separation of the two gas streams. The cooled flue gas then is directed by ductwork from the Air heater to the Induced Draft (ID) Fan. Prior to the TOXECON™ Project modifications, the flue gas would then be directed by ductwork from the ID fan discharge to the Units Stack located in the Chimney outside of the Boiler Building.



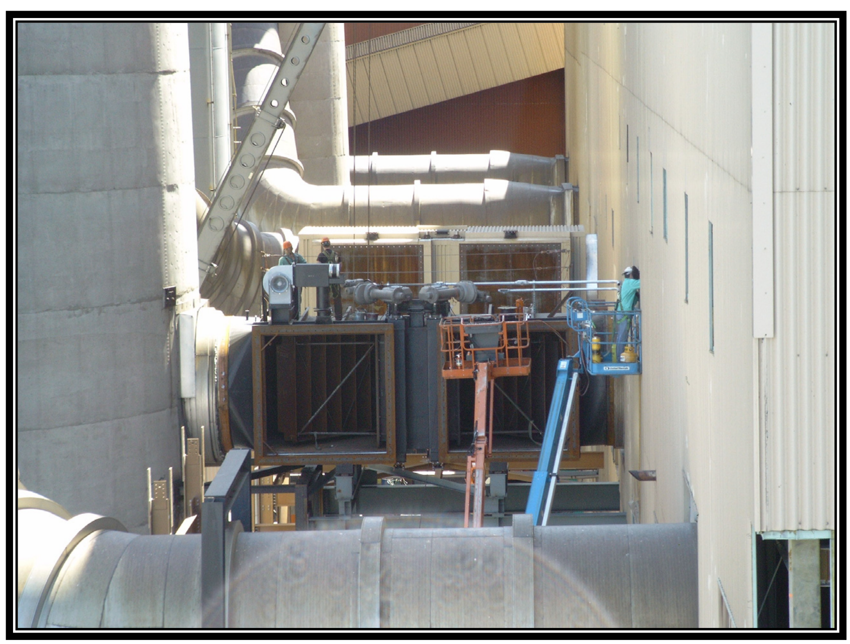


Figure 10 - New diverter dampers installed

After the TOXECON™ Retrofit, each Unit's flue gas ductwork between the ID Fan and the stack was modified to install two diverter dampers in series forming a four-port arrangement. The first port is connected to each Unit's ID Fan discharge ductwork, the second port is connected to ductwork that combines the flue gas flows from all three Units into a common header directed to the fabric filter baghouse, the third port connects to the common return ductwork from the baghouse, and the fourth port connects to each Units Stack. When flue gas is to be directed to the baghouse the diverter dampers will be aligned to block the direct flow of flue gas to the Stack. If required, the diverter dampers can close the supply and return ductwork to the baghouse and bypass the flue gas directly to the stack. Normally, the combined flows of all three Unit's flue gas will be directed by the common ductwork to the fabric filter baghouse. Since this was a test project for the TOXECON™ system, the ability to align the flue gas to the baghouse or the stack was a design criterion. The need for diverter dampers in a commercial application would most likely not be required.

The supply and return ductwork to the baghouse had to be located between the boiler building and the chimney to be economically installed and to minimize the land East of the chimney. The limited space for the ductwork required the cross sections to be square or rectangular in lieu of round ductwork that would have provided a lower pressure drop. The use of rectangular ductwork did simplify the support structure. The supply and return ductwork were designed identically and installed next to each other.

Figure 11 - Ductwork for Units 7, 8 and 9. The baghouse supply ductwork is near building and the return ductwork near the Chimney. The Toxecon™ Baghouse is around the corner to the right of the building. The ductwork increases in size from left to right as additional Units discharge to the common duct. The round ductwork to the chimney is original.

As part of the TOXECON™ retrofit a mercury sample probe was installed downstream of each Unit's air heater. The probes were then routed to a common CEMS shelter located in the boiler building. A separate CEMS shelter was installed under the baghouse to support the mercury CEMS probe located after the baghouse.

Powder Activated Carbon will be injected into the ductwork to react with vapor phase mercury in the flue gas and adsorb onto the surface of the PAC particles. The injection location of the PAC has been designed for two places, at the discharge of each Unit's ID fan, and at the entrance to the baghouse in the common duct.

The common ductwork also has a static mixer installed prior to the baghouse to reduce or eliminate potential thermal stratification from occurring due to the operating temperature of the flue gas being near the maximum temperature of the fabric filter bags. The static mixer will also ensure complete mixing of the PAC in the flue gas stream. A two-stage static mixer was selected and consisted of opposed inclined plates and were supplied by KOMAX Systems.

The PAC loaded flue gas will enter the baghouse where the fabric bags will filter the PAC and any fly ash not captured in the electrostatic precipitators from the flue gas. The fly ash and PAC will collect in the baghouse hoppers for collection and disposal (see Ash Handling for further detail).

The cleaned flue gas will then exit the baghouse and the common ductwork will split to three Booster Fans. Each Fan is sized for one Unit's flue gas flow. The Booster Fans control the draft on the discharge side of the ID fans by modulating variable inlet vane control dampers at the fan inlet. The Booster Fan control scheme is to mimic the existing pressure conditions at the ID Fans discharge prior to the TOXECON™ Retrofit by measuring the pressure at the common flue gas ductwork and modulating the Booster Fan's dampers. Each Booster Fan has an isolating Guillotine Gate on the inlet and outlet to allow maintenance of the Fan.

The flue gas discharged from each Booster Fan is combined into a common return duct. A particulate and mercury Continuous Emission Monitoring System (CEMS) was installed in this duct as part of the TOXECON™ Retrofit. The Particulate and Mercury CEMS are located beneath the baghouse on a horizontal run of ductwork. The common return ductwork then runs back to each Unit's return Diverter Damper where the flow is split into the three unit Stacks.

ID Booster Fans:

With the additional pressure drop associated with the installation of the TOXECON™ Baghouse and associated ductwork, new induced draft (ID) Booster Fans were required to be installed. A study was prepared outlining the advantages and disadvantages of 2 vs. 3 Booster Fans. The final decision to select 3 Booster Fans was influenced by the following issues:

- Three fans would allow designating a single fan for each of the three Boiler Units thereby maintaining the established practice at the plant of individual components for the three Units.

- The three fan arrangement had a smaller impact on the plant's electrical systems.
- Turndown of the three fan arrangement would be greater and would ensure compliance with NFPA boiler purge flow requirements.

The Booster Fans were sized for a single Unit's full load flue gas flow and the calculated pressure drop of the new ductwork and baghouse. A margin was then applied to these values based on typical power industry practice of 15% margin on flow, 32% margin on head, and 25ºF margin on temperature. The conditions of the fan with margin are referred to as "Test Block" conditions. The expected operating condition is referred to as "Net" Conditions. Test Block conditions are specified to account for system losses in the actual fan installation as compared to the ideal test setup installation that the fans have when shop tested to determine their capacity.

The Booster Fans need to have sufficient turndown capability to meet the requirements to purge the boiler during a Unit startup. During the procurement phase of the Booster Fans, the purge flow requirements were calculated, and it was found necessary to have the fan manufacturer install sealing strips on the fan control damper to limit leakage and achieve the turndown on the fan performance that meet the purge flow requirements.

A variable inlet vane (VIV) control damper was selected for the booster fans. The VIV has an advantage over inlet dampers in efficiency. A 13–15% increase in power consumption was projected when an inlet damper configuration was evaluated. The VIV had a larger first cost; however, the savings in electricity offset this.

Figure 12 - Booster Fan lower housing and rotor

Fan Data:

Manufacturer:	FlaktWoods
Quantity:	3
Test Block Rating:	460,000 acfm @ 375°F with 18.5"w.c.
Net Rating:	400,000 acfm @ 350°F with 14"w.c.

Total Efficiency	87.7% (test block) 87.6% (net)
Operating Speed:	893 rpm
Fan Configuration:	Double inlet
Fan Blade Style:	Airfoil
Fan Bearings:	Pressure lubricated
Control Damper:	Radial Variable-Inlet-Vane (VIV)
Damper Actuator:	Jordan Controls SM-60000
Motor Size:	1,700 HP
Motor Voltage:	2,300 Volts
Lube Oil Console Mfr.:	Howard Martin
Lube Oil Console Capacity:	3.5 gal/min

Flow Model Study:

NELS Consulting Services modeled the baghouse and inlet and outlet ductwork at a 1/12 linear scale. The objectives of the flow model study were to determine the configuration of flow distribution devices and to achieve the following:

- Uniformity of baghouse gas flow and dust distribution
- Confirm design velocities and flow distribution in compartments
- Temperature mixing at the baghouse inlet
- Determination of pressure drop of system
- Confirmation of minimal dust deposits in the ductwork
- Location of powder activated carbon injection and uniformity of flow at injection point
- Uniform velocity distribution and gas flow angle at proposed CEMS duct location
- Balanced flow in the three stacks

The findings indicated that the design goals had been achieved. Additionally, the locations and configurations of the flow control vanes were provided by NELS.

The pressure drop measured in the model study ductwork and baghouse from the I.D. fan discharges to the stack was 10.72 inches of water column ("w.c.) excluding the filter bags and ash cake on the bags and buoyancy effects of the hot flue gas in the stack. The pressure drop across the ash cake and filter bags was not predicted by the model study. It was necessary to simulate the fabric and ash cake pressure drop in the model so that gas flow distributions between baghouse compartments and within each compartment of the model were accurate. The pressure drop across the fabric and ash cake was expected to be between 4" w. c. and 6" w. c.

over the range of boiler operating conditions. The value selected for the model was based on test data taken from existing baghouse installations and factored to the TOXECON™ operating conditions.

Design velocities within each baghouse compartment were chosen based upon the design for other baghouses that operate within the limits of the performance goals of pressure drop and outlet emissions established for the TOXECON™ process. Low gas velocity at the bottom of the filter bags enables on-line bag cleaning. Providing low gas velocity is accomplished by gas distribution baffles that direct a portion of the gas flow away from the bottom of the compartment toward the top of the filter bags. The distribution baffles were included in the baghouse model study and confirmed their performance.

In regard to single particle re-entrainment, the individual particles collected on filter bags agglomerate with other particles making them larger and heavier and therefore easier to clean. WAPC's experience is that a portion of the filter ash cake falls into the hopper after bags are pulsed and a portion of the dust returns to the filter bags. The pulse causes all of the filter cake to break and when a portion of the dust is re-deposited on the filter bag the structure of the filter cake is altered in a manner that further reduces resistance to gas flow.

Two activated carbon injection concepts were evaluated. The first was to inject the PAC at the inlet to the baghouse through an injection grid of lances and nozzles. The second was to place a single injection lance and nozzle in individual unit ducts just downstream of the ID FAns. Because the results from the flow model study showed a widely varying flow velocity profile at the inlet to the baghouse, the individual unit, single point concept at the ID fan outlets was chosen. With three feeder trains, each generating unit will have a dedicated injection train, transport line, and injection nozzle. This injection location also provided a greater residence time for having the PAC mixing with the flue gas.

ACTIVATED CARBON INJECTION:

Activated Carbon Properties:

The form of the activated carbon chosen for the TOXECON™ process was powdered. Powder Activated Carbon (PAC) is typically used in flue gas applications because the density of the carbon prevents it from dropping out of suspension in the flue gas stream. Powder Activated Carbon does have some properties that should be considered during the system design and operation, mainly: moisture, oxygen depletion, and combustion.

Water causes the powder activated carbon to clump up and to clog the flow of the material requiring maintenance personnel to open up the system and clean out the PAC. Moisture associated with atmospheric humidity has not been reported as a problem to PAC handling systems; however, excessive condensation or the introduction of water would cause the material to clump.

Oxygen depletion is also a hazard with PAC. Activated carbon (especially when wet) can deplete oxygen from air in enclosed spaces, and dangerously low levels of oxygen may result. When workers enter a vessel (storage silo) containing activated carbon, it is required that they follow procedures for potentially low oxygen.

Combustion of PAC is also a possibility. The MSDS for activated carbon for the PIPP project indicates a flammability hazard as 1 out of 4. Activated Carbon is difficult to ignite and tends to burn slowly (smolder) without producing smoke or flame. Toxic gases will form upon combustion. The ignition temperature indicated by the PAC supplier for PIPP was significantly above the 350-400°F flue gas temperature for this application. Properties of activated carbon vary depending on the method of manufacture and type, and the reader is cautioned to obtain a Material Safety Data Sheet for details on the activated carbon that they may use.

Figure 13 - Powder Activated Carbon Storage Silo (feeder trains are located in lower part of silo)

<u>Activated Carbon System:</u>

The PAC injection system consists of a bulk storage silo for PAC sorbent with three dilute-phase pneumatic injection trains (three operating with no standby) and three distribution piping systems that convey the PAC sorbent to the injection nozzles located at each unit's ID fan outlet. Based on unit load, variable-speed volumetric screw feeders meter the PAC into the suction ports of educators where the PAC is transported in air supplied by regenerative blowers to injection lances installed in the flue gas ductwork. Vapor phase mercury is adsorbed onto the surface of the PAC particles, which are collected along with fly ash in the fabric filter dust collector.

The storage and feeding system consists of a bulk storage silo with pneumatic truck unloading capability, three PAC feeder trains each consisting of a feed hopper and variable speed feeder, an educator, and a transport air blower. This system is complete with the necessary control provisions to operate and monitor the system equipment.

The duct injection system consists of the transport piping from the feeding system and the necessary injection lances. Because of the erosive nature of PAC, long radius elbows with a ceramic backer were used in the transport piping from the blowers to the lances. Straight lengths of piping used small bore schedule 80 carbon steel piping.

Injection rate is controlled based on several variables, including boiler load/flue gas flow and mercury removal. Two CEMs, one measuring mercury concentration prior to PAC injection and the other in the common booster fan discharge duct are used.

The design parameters for the TOXECON™ system using PAC alone at Presque Isle for Units 7, 8, and 9 are as follows:

- Design flue gas flow rate: 1,200,000 acfm at 350°F
- PAC design injection rate: 3.0 lb/MMacf
- PAC design injection rate: 216 lb/hr
- Number of PAC injection trains: 3
- Capacity of each train: 200 lb/hr
- Total injection capacity: 600 lb/hr
- Silo storage capacity: 4,290 cuft
- Silo storage capacity: 94,000 lbs
- Storage capacity of bulk storage silo at design injection rate: 18 days

The overall system design includes the capability to inject a recycled carbon-ash mix coming from the baghouse hoppers. Since this mix would include partially spent activated carbon along with ash, the volume of injected mix would increase substantially. Thus, the system capacity as stated above will accommodate the injection of the Carbon/ash mix with the design injection rate of sorbent (3.0 lb/MMacf) with a 50-50 mix with ash.

ASH HANDLING:

Handling Activated Carbon with Fly Ash:

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. It was possible that the extremes of the two components would be possible, 100% PAC or 100% fly ash, or any mixture in between. 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 the conveying of PAC/Ash to the storage silo, it was with unloading the silo to trucks for disposal.

Ash Handling System Description:

The conveying rate of the PAC/ash handling system was sized for 4 times the baghouse particulate loading rate. This equates to 1.3 tons per hour, which is, a very small quantity compared to most fly ash handling systems. United Conveyor Corporation, the supplier of the system, provided the smallest ash piping that the company manufactures.

The PAC/Ash Handling System was selected to be a dilute phase pneumatic conveying system. This type of system has proven experience in conveying both fly ash and PAC. NORIT Americas uses a dilute phase system in conveying PAC at their production facilities.

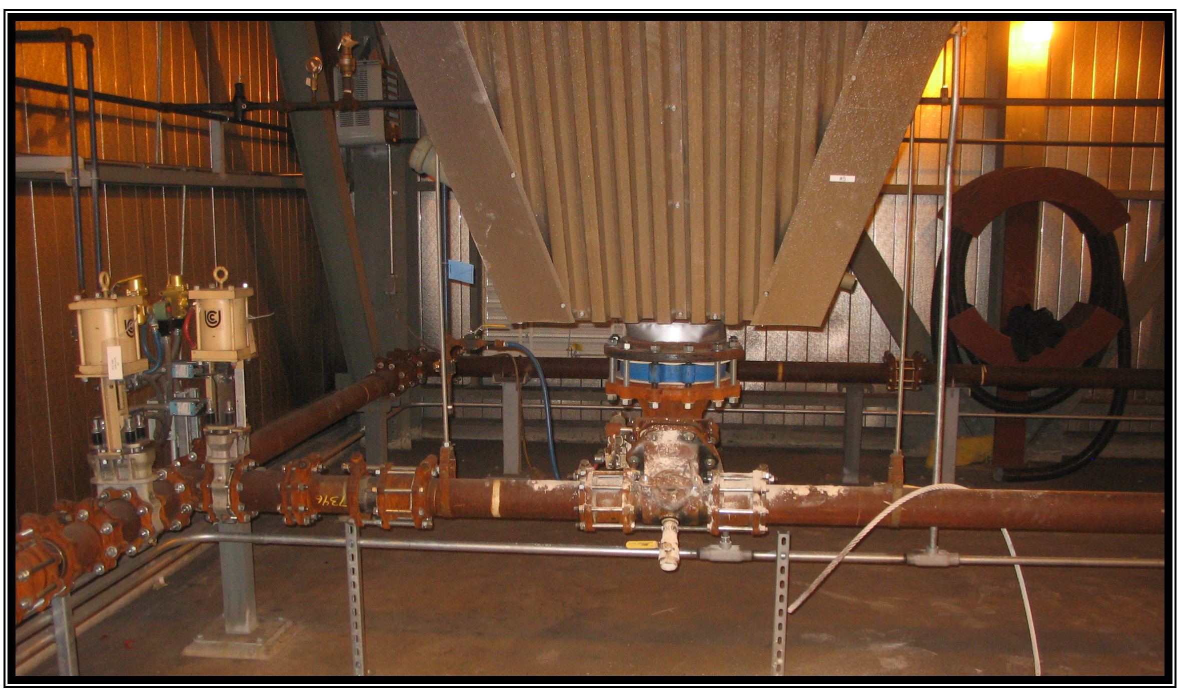


Figure 14 - Ash handling conveying piping below baghouse hopper

The dilute phase system would be used from the 10 baghouse hoppers to the ash storage silo. The ash enters a silo mounted filter/separator assembly for separation of ash from the air stream. A motor driven mechanical exhauster creates the induced vacuum, and discharges to the atmosphere.

The discharge of ash from the filter/separator storage hopper to the fly ash storage bin is accomplished by interrupting the conveying operation by breaking the vacuum in the conveying line. Upon activation of the level probe in the filter/separator, the exhauster and system relief valves open to break the conveyor line vacuum, at which time the filter separator bottom gate opens so PAC/ash material can discharge by gravity into the fly ash storage silo.

PAC/fly ash is removed from the conical bottom ash storage silo by two different means. The fly ash/PAC can be conditioned with water and unloaded through a pin paddle mixer. The second means is through a dry unloader with a telescopic spout.

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 PIPP did have 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 the hardware modifications to provide more fluidizing air to the silo bottom and discharge spout to help even out the flow variances. These modifications improved the unloading situation but demonstrated the need for further optimization and improvement in the design of this part of the system.

Disposal of Ash:

Used activated carbon at PIPP will be disposed of in a landfill. Previous research has determined that activated carbon used for mercury removal is not a leaching hazard and does not pose a threat of leaching into the landfill. The spent carbon/ash mixture is not considered a toxic substance and did not require a special landfill for disposal.

The TOXECON™ project test phase at PIPP will also investigate ways of recycling the used carbon/ash by re-injecting the used mixture back into the PAC injection system and or novel ways of disassociating the mercury from the used carbon and recovering the mercury.

UTILITIES:

Mechanical Systems:

Instrument Air, Service Water, Cooling Water and Fire Protection were additional systems that were affected by the TOXECON™ addition.

A new Compressed Air skid was installed under the baghouse hopper floor to supply dry air to the baghouse pulse jet cleaning system, the ash handling system, and the PAC injection system. The primary user was the baghouse pulse jet cleaning system which required 350 SCFM. The skid consisted of 2 air compressors, 2 air dryers and a single air receiver. The skid had redundant trains with each train capable of providing 475 SCFM dry air at -40°F and 100 psig. The Compressed Air Skid was fully assembled and tested at the suppliers shop to reduce field construction and commissioning activities.

Figure 15 - Compressed Air Skid located under baghouse

The Service Water system was extended to the Ash Silo to provide a water supply for the wet ash unloader. The Cooling Water system did not have any spare capacity at the plant so the Air Compressors and the Booster Fan lube oil system were purchased with forced air cooling systems. The Fire Protection loop required relocation of a small section to allow the ductwork foundation to be installed and the baghouse stair tower was installed with a dry standpipe. The fire detection and Alarm system was also extended to cover the new facilities installed.

<u>*Electrical Systems:*</u>

Presque Isle Power Plant is a mature power plant that has been expanded and developed over the course of many years. When installed, the plant electrical systems were designed for nominal load growth. Emissions controls and other upgrades have stretched some of the plant electrical systems past their design parameters.

For startup, the plant relies on Reserve System Transformers to provide power to the individual unit switchgear, until the time that the unit is up to operating speed and capable of powering the unit electrical loads via the Unit Auxiliary Transformer. During a unit trip, the unit electrical requirements are transferred from the Unit Auxiliary bus to the Reserve System to maintain boiler draft and safely shut down unit loads.

As the Booster Fan horsepower requirements increased during the project, the existing 2,400 VAC switchgear lineups in the plant that were to serve the Booster Fan loads capability was put in question. In short, Units 7, 8, and 9 switchgear required study to determine not only if the existing gear could adequately power the running load, but were they capable of starting the motors, and if the plant Reserve bus could provide enough power to satisfy the requirements of startup and multiple unit trips. An electrical study was performed to identify and examine these issues. The study verified the suitability of the switchgear to handle the new running loads, but pointed out deficiencies in the Reserve bus used during emergency situations. As a result of the study, upgrades to the plant Reserve Electrical system were identified and implemented to ensure the success of the TOXECON™ Project.

The Booster Fan Motors are each rated 1,700 horsepower, with one booster fan associated with each unit. These motors are controlled by dedicated medium voltage starters, which are fed from 2,400-volt switchgear located in each respective Unit. The motor starters receive commands from the plant distributed control system (DCS) for start/stop, and supply information to the DCS to allow operators in the control room to monitor Booster Fan motor performance. Based on the limitations of the existing plant electrical system and the reserve bus design, the motors were designed for a soft start utilizing an autotransformer. This allows the individual motors to start at reduced voltage and current draw.

Remaining baghouse systems comprise the balance-of-plant electrical system. These loads are powered from motor control centers (MCCs) operating at 480-volts. This system provides the operating power for all core baghouse functions, as well as the PAC injection system, ash handling, Booster Fan lube oil system, air compressors, the DCS system, lighting, HVAC, and damper operation for flue gas control.

Essential 480-volt loads are fed from MCCs, which receive power from existing plant equipment to ensure the most reliable source and functionality possible.

Control Systems:

The existing plant DCS system is based on the Emerson Ovation platform. The DCS system expansion required to support the Presque Isle Power Plant TOXECON™ project is based on this same platform.

The DCS expansion included three new cabinet groups. Each cabinet group will consist of redundant controllers, I/O modules, redundant power supplies, and communication modules.

One of the cabinet groups provided control and monitoring for the Wheelabrator Air Pollution Control (WAPC) baghouse. A second cabinet group consisted of unitized remote I/O cabinets dedicated to providing controls interfaces with the existing plant control system for, control of their respective unit booster fans, control of their respective unit baghouse supply and return diverter dampers, control of their respective baghouse supply and return diverter damper seal air blowers and valves. The third cabinet group is dedicated to control of the remaining balance-of-plant (BOP) equipment including booster fan draft control, fly ash system, powder activated carbon injection, compressed air system, baghouse outlet mercury CEMS.

CONSTRUCTION:

Weather Conditions on Lake Superior:

Figure 16 - Booster Fan Foundation Work Week of Nov. 29, 2004

Snow is to be expected in the Upper Peninsula of Michigan; in fact Marquette Michigan receives on average 200 inches of snow each year. The snow along with the exposed nature of plant on Lake Superior brought gusting winds and low wind chills as normal practice. The project release from the DOE in early February 2004 to begin design work created a schedule that would require foundation work to be done deep into winter. Concerns about concrete availability and increased installation costs required an early release of foundations to minimize the impacts. Luckily, the winter of 2004 in Marquette was mild enough to allow foundation work into December.

Concurrent Major Construction Projects:

During the construction of the TOXECON Baghouse, We Energies released another major construction project at the Presque Isle site in 2004. Units 5 and 6 were retrofitted with fabric filter baghouses also. These baghouses were placed into service in June-July of 2005. During this time frame the available laydown space at the plant was very limited. This also required coordinating the TOXECON™ Baghouse activities with the Unit 5 & 6 baghouse activities.

Commissioning and Startup of 3 Units:

Each Unit was commissioned and brought into the baghouse separately. Unit 7 was the first to exhaust into the baghouse on December 17, 2005. Unit 8 was switched over to the baghouse on January 5, 2006, and the final Unit 9 was switched over to the baghouse on January 27, 2006. Powder activated carbon was injected in all three Units flue gas streams on January 27, 2006.

RESULTS:

Construction activities were completed on schedule and within the project's budget.

During the construction phase and commissioning period Units 7, 8, and 9 were not impacted by the activities of installing the TOXECON™ equipment and balance of plant modifications. These Units were able to produce power without significant outages.

On January 27, 2006 all three Units were in service through the new TOXECON™ Baghouse. At this time ADA-ES began commissioning the PAC injection system. Initial mercury removal results of PAC injection indicated the mercury removal efficiencies were at the project's stated goals of 90% mercury removal rates.

REFERENCES:

The following publications were used in the preparation of this paper:

1. City of Marquette Website
2. NORIT Americas Website
3. DOE Public Design Report, "TOXECON™ Retrofit for Mercury and Multi-Pollutant Control on Three 90-MW Coal-Fired Boilers", DOE Cooperative Agreement No.: DE-FC26-04NT41766

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